Designing a Well-Formed Activity System for an ICT-Supported Constructivist Learning Environment: A CHAT Perspective

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ABSTRACT

Much educational research has suggested that information and communication technologies (ICTs) promote constructivist classroom. In contrast, most teachers in actual classrooms continue to struggle with the pedagogical and practical challenges in using ICTs to facilitate student knowledge construction and collaboration. This dissertation presents a new approach to overcome problems with ICT integration in K-12 school education. The study examined a Grade 7 teacher's constructivist instructional practices in a technology-rich mathematics classroom through a lens of cultural-historical activity theory (CHAT) and consisted of two phases: contradiction analysis and on-site intervention. Findings from the contradiction analysis indicated that it was not ICTs per-se that made contradictions in the ICT-supported constructivist activity; rather it was the changed nature of the class activity system due to the introduction of ICTs that called for systemic adjustment of classroom practices as a whole. Based on the identified contradictions, on-site intervention was designed and implemented. It focused on transforming an ill-formed activity system of the current instructional practices of the participant teacher into a well-formed one, where all the interwoven components and mediators, such as rules of interaction, division of labor, and the use of tools, adequately support activities that members carry out. Results indicated that the intervention and the modified unit played a large role in resolving the identified contradictions in the participant teacher's instructional practices and restructuring his existing pure-discovery mode of instruction into new practices, a guided discovery mode of instruction. The intervened instructional practices helped students establish a more effective division of labor, which led to more successful learning outcomes than those prior to the intervention. A new role of researchers is suggested to lessen a gap between theory and practice in the field of professional development for teachers. This dissertation is a manuscript-thesis. The three manuscripts address a literature review on constructivism in theory and practice, a case study to understand contradictions in the participant teacher's classroom practices, and an intervention study to resolve the identified contradictions.

RÉSUMÉ

Une grande part de la recherche en éducation semble indiquer que les technologies de la communication et de l'information (TIC) encouragent l'essor de la salle de classe constructiviste. En revanche, la plupart des professeurs sur le terrain font toujours face à des défis pédagogiques et pratiques lorsqu'ils utilisent les TIC pour faciliter la collaboration et la construction du savoir des étudiants. Cette dissertation présente une nouvelle approche visant à surmonter les problèmes d'intégration des TIC dans l'éducation scolaire de la maternelle à la 12ème année. De la perspective de la théorie culturelle-historique de l'activité, cette étude examine les méthodes d'enseignement constructivistes d'un professeur de 7ème année dans une classe de mathématiques riche en technologies. L'étude comporte deux phases : l'analyse des contradictions et l'intervention sur le terrain. Les résultats de l'analyse des contradictions ont indiqué que ce n'était pas les TIC en tant que telles qui généraient des contradictions dans une activité constructiviste soutenu par les TIC. Plutôt, c'est le changement de nature du système d'activité en classe dû à l'introduction des TIC qui exige des changements systémiques dans les pratiques d'enseignement. L'intervention sur le terrain a été conçue et mise en application à partir des contradictions identifiées. Elle visait à transformer un système d'activité mal conçu issu des méthodes d'enseignement habituelles du professeur participant en un système bien conçu, où tous les constituants et les médiateurs entrecroisés, comme les règles d'interaction, la division des tâches et l'utilisation des outils, appuyaient adéquatement les activités des membres. Les résultats ont indiqué que l'intervention et l'unité modifiée ont joué un rôle important dans la résolution des contradictions identifiées dans les méthodes d'enseignement du professeur participant et dans la restructuration de ses méthodes d'instruction axées sur la découverte pure vers de nouvelles méthodes axées sur la découverte guidée. Les nouvelles méthodes d'enseignement ont aidé les étudiants à établir une répartition des tâches plus efficace qui a mené à de meilleurs résultats d'apprentissage que ceux obtenus avant l'intervention. On suggère ainsi un nouveau rôle pour les chercheurs afin de réduire l'écart entre la théorie et la pratique dans le champ du développement professionnel des professeurs. Cette dissertation est une thèse manuscrite. Les trois manuscrits comportent une revue de la

littérature sur la théorie et la pratique du constructivisme, une étude de cas pour comprendre les contradictions dans les méthodes d’enseignement du professeur participant, et une étude d’intervention pour résoudre les contradictions identifiées.

DESIGNING A WELL-FORMED ACTIVITY SYSTEM FOR AN ICT-SUPPORTED CONSTRUCTIVIST LEARNING ENVIRONMENT: A CHAT PERSPECTIVE

CHAPTER I. INTRODUCTION

This dissertation is a series of three manuscripts that address an analysis and intervention of a Grade 7 teacher's classroom practices to promote effective constructivist technology-integrated instruction. More specifically, the three manuscripts address (1) a literature review of constructivism in theory and practice, (2) a case study identifying contradictions in a technology-rich constructivist classroom, and (3) a case study of designing and implementing interventions to resolve the identified contradictions.

Despite the increased access to and vast investment in information and communication technologies (ICTs) in K-12 school environments for the last decade, it is still not evident whether ICTs actually promote student-centered or constructivist learning. Reasons for this can be found in both *practice* and *theory*. In *practice*, despite the introduction of ICTs, current teaching practices in most schools remain largely traditional didactic approaches (Becker & Riel, 2000; Cuban, Kirkpatrick, & Peck, 2001; Ertmer, 2005). More seriously, such unchanged practices with the new tools appear to exacerbate the crisis between traditional and constructivist approaches (Bracewell, Sicilia, Park, & Tung, 2007). Regardless of the situations in classrooms and despite the fact that over 80% of teachers are interested in learning how to *integrate* ICTs in their teaching practices, current professional development programs for teachers still focus primarily on basic computer skills (Ertmer, 2005; U.S Department of Education, 2003). In *theory*, we still lack educational theories that account sufficiently for learning environments as "all the basic characteristics of the whole" (Vygotsky, 1986, p. 1-11). In other words, changing practices require a more comprehensive analysis of existing practices related to the use of ICTs (Chaney-Cullen & Duffy, 1999), as opposed to isolating and compartmentalizing ICTs from the instructional context. We need a theory that adequately frames the analysis of educational practices as a whole.

In this regard, cultural-historical activity theory (CHAT) is an alternative approach that provides researchers with a systemic view of school contexts as complex activity systems involving multiple participants (e.g., teachers, students, committees, etc.) who are working toward a common goal (e.g., ICT integration in constructivist learning). Their activities are mediated by multiple artifacts including physical/symbolic tools (e.g., computers, books, blackboards, etc.) and social/cultural practices (rules of interaction, division of labor, etc.). A large part of the current problem in analyzing ICT use for instruction rests on insufficient understanding of the incompatibilities between existing classroom practices and new practices afforded by the new tools, i.e., ICTs. Therefore, this dissertation aimed at expanding the development of teaching practices in a ICTs-rich grade 7 classroom by helping the teacher become aware of incompatibilities in his classroom practices and construct new practice models to integrate ICTs into his teaching practices.

This dissertation consists of a series of three manuscripts. It will be presented in the following manner. Chapter II is a manuscript of a literature review on constructivism, entitled "Reconsidering constructivism in theory and practice: Implications for the effective integration of technologies into constructivist classrooms[1]". It reviews key elements that contribute to the successful integration of technologies and constructivist pedagogical activities in K-12 settings. Chapter III presents a theoretical framework for this dissertation study, drawn from Cultural-Historical Activity Theory. It revisits and elaborates the constructs of mediations and contradictions of CHAT in order to frame the design of the intervention as well as the analysis of outcomes for two successive case studies. Chapter IV presents the second manuscript, a case study entitled "What makes contradictions in a technology-rich constructivist classroom: A case study[2]". It identifies contradictions in the exiting teaching practices in an ICTs-supported constructivist classroom. Chapter V is the third and last manuscript, entitled "On-site interventions of teaching practices for an ICT-supported constructivist classroom: Contradictions and resolutions[3]". It investigates the effectiveness of the designed intervention on

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1 Park, J. & Bracewell, R. J. (2006, October). Reconsidering constructivism in theory and practice: Implications for the effective integration of technologies into constructivist classrooms. Proceedings of Selected Research and Development Papers of the Association for Educational Communications and Technology Annual International Convention, Dallas, TX, October 10-14, 2006.

2 This manuscript is in final preparation. An earlier version was presented at AERA 2007 as "Park, J., Bracewell, R. J., Sicilia, C. & Tung, I. (2007). Understanding and Modeling Contradictions in a Technology-Rich Constructivist Classroom: A CHAT Perspective."

3 A shorter version of this manuscript was published as a book chapter as "Park, J. & Bracewell, R. J. (2008). Designing a well-formed activity system for an ICT-supported classroom: A CHAT perspective. In

transforming classroom practices. The second and third manuscripts are case studies that involve the same participant teacher. Between chapters or manuscripts, a transition text is provided in order to help readers understand how the previous and the successive manuscripts are related to each other.

J. Zumbach, N. H. Schwartz, L. Kestor, & T. Seufert. (Eds.). Beyond Knowledge: The Legacy of Competence (Meaningful learning in computer-based learning environments). Vienna, Austria: Springer Science Publishing.

Contributions of Authors

The first manuscript (Chapter II) was co-authored with Dr. Robert J. Bracewell, my academic supervisor. The manuscript was a part of my comprehensive examination. During the examination Bracewell helped me construe theoretical differences and similarities of various sects of constructivism. As well, he contributed to searching relevant literature for the preparation of the manuscript. After the examination, I, as the first author, constructed and submitted a proposal for publication. When the proposal was selected to be published, Bracewell and I collaborated to review and edit the draft of my comprehensive examination to turn it into an appropriate form for a manuscript.

The second manuscript (Chapter IV) was co-authored with Bracewell and Carmen Sicilia, one of my doctoral student colleagues. Bracewell and Sicilia contributed to the manuscript throughout the study including data collection, analysis, and reviewing the writing. Especially the researchers who were mentioned in the data analysis section of the manuscript are Bracewell and Sicilia. Writing, however, was largely done by myself as the first author. The co-authors agreed on the authorship order of the manuscript at the first time when the three of us decided to put the findings of the project into a manuscript format. The relative contributions of the authors were 75% myself, 15% Bracewell, and 10% Sicilia.

The last and third manuscript (Chapter V) was also co-authored with Bracewell. Bracewell contributed to coordinating the intervention experiment with the participant school. Bracewell also involved in designing the intervention, including a transparent ramp model and student worksheets. Like the first manuscript, I as the first author, wrote the proposals for publication. When one of them was accepted to be included as a book chapter, Bracewell helped me with editing and proofing. The relative contributions of the authors were 90% myself and Bracewell 10%.

Bridging Manuscript

The objective of this dissertation is to understand pedagogical problems in an ICT-rich constructivist classroom and to design and implement interventions to resolve these problems. Chapter II is a literature review of constructivism in theory and practice. The purpose of the review is to identify key elements that contribute to both the successful and unsuccessful integration of technologies and constructivist pedagogical activities in K-12 settings that have been reported in the literature. Based on the theoretical constructs that were identified from a theoretical review of constructivism, ten empirical studies on the use of technology in constructivist classrooms were reviewed. The manuscript was a part of my comprehensive examination in 2006. Thus there has been a concern about whether the list of the reviewed literature is comprehensive and up to date. To this end, I re-executed the same search in December 2008 that I did in February 2006 as described in p. 18. First, ERIC and PsychInfo databases were searched with the keywords "constructivis? and technology and (elementary or secondary)". The search was limited to peer-reviewed journal articles published in the period of 1999 to 2008. The search initially generated 87 articles, compared with 54 in February 2006. Second, abstracts of all the retrieved articles were reviewed in order to sort out classroom research on the technology use. Reviews and conceptual works were manually excluded. Articles on teacher education were more thoroughly reviewed to decide their in/exclusion. For example, if an article investigated how technology promoted pre-service teachers' learning to teach in their college class, it was excluded from the list; however, if an article surveyed teachers' belief on technology and/or constructivism and had something to do with their actual use of technology in classroom, it was included in the list. The final set of the literature consisted of 30 articles. The number of the articles published after the manuscript was written, which is between 2006 and 2008, is 17. The complete list of the articles is attached as Appendix A.

The new set of 17 articles might increase the currency of the review; however, it does not necessarily alter the comprehensiveness because the set still does not reflect studies by leading proponents of the field. Therefore, instead of reviewing these newly found articles, I carried out a manual search with the help of Dr. Bracewell, my academic supervisor, and through reference lists of relevant literature. This literature included those on constructivism and ICTs as well as teacher education for ICT-integration in classrooms. These reviews were included in the second and third manuscripts as in the literature review section.

Nevertheless, the manuscript follows in Chapter II did help me identify problems in current empirical studies on constructivism and ICTs and provided implications for the present dissertation study. The major implications were (1) learning tasks should be designed in a way to constantly challenge students pre-existing knowledge with the help of teachers and other peers; and (2) a more thorough theoretical framework; such as the cultural-historical approach, is needed to more adequately characterize technology-supported classrooms.

CHAPTER II: MANUSCRIPT 1

Reconsidering Constructivism in Theory and Practice: A Literature Review

From:

Park, J. & Bracewell, R. J. (2006, October). Reconsidering constructivism in theory and practice: Implications for the effective integration of technologies into constructivist classrooms. *Proceedings of Selected Research and Development Papers of the Association for Educational Communications and Technology Annual International Convention*, Dallas, TX, October 10-14, 2006.

Abstract

This review is to identify key elements that contribute to the successful integration of technologies and constructivist pedagogical activities in K-12 settings. To do so, differences and similarities between theoretical constructs of constructivism and empirical findings of recent K-12 classroom research were compared. Theoretical constructs of constructivism were reviewed based on literature about constructivist theories including individual (radical) and socio constructivism. Findings of the theoretical review indicated that (1) constructivist perspectives varied with respect to the nature of knowledge depending on the discipline under consideration, (2) individual and social constructivism addressed the common notion of crisis as a critical factor in learning, and (3) together with the previous two findings, different theoretical stances altered the methodologies to be employed. These theoretical findings in turn framed a review of ten selected empirical studies on the use of technology in classrooms that published for the period of 1999 to 2005. The main finding suggested that insufficient elaboration of constructivist theoretical constructs in empirical studies resulted in poor results or no significant effects on constructivist learning.

Introduction

I still feel like I'm teaching things the same way I used to.

(A secondary teacher, Interview, December 2004)

A great deal of research has examined teachers' adaptations of Information and Communication Technologies (ICT) into the classroom (e.g., Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000; Bracewell, Le Maistre, Lajoie, & Breuleux, in press; Bryson & de Castell, 1998; Windschitl & Sahl, 2002). This research suggests that ICT is a pedagogical mediator that promotes constructivist or student-centered classroom learning. However, in contrast to the theoretical findings of educational researchers, teachers in most classrooms continue to struggle with teaching practices that have barely changed since they began adopting technologies into their classrooms. As Windschitl (2002) argued, teachers face various pedagogical challenges in integrating ICT into instruction including facilitating student knowledge construction and collaboration, distributing knowledge and roles and evaluating learning.

This paper reviews key elements that contribute to both the successful and unsuccessful integration of ICT and constructivist pedagogical activities into K-12 settings that have been reported in the literature. Theoretical constructs of constructivism are identified based on literature about constructivist theories. These theoretical findings in turn frame a review of recent empirical studies of technology-supported learning environments. This review aims to identify key elements in the integration of ICT into constructivist classrooms based on differences and similarities between theoretical constructs and empirical findings. Finally, we will suggest some implications of the findings for designing teacher education programs.

Constructivism as a Theory

Human knowledge is constructed.

(Phillips, 1995, p. 5)

Although we do not believe anymore that human knowledge is simply absorbed through sensory experiences or is transmitted from one knower to another, it has been only two decades since we began seeing knowledge as by-and-large constructed. Despite the relative newness of this emerging view of knowledge, constructivism has become akin to a religion in the field of education. My intention in making an analogy between "religion" and constructivism, which was inspired by Phillips (1995), is not to exaggerate constructivism's impact on education. Rather, the analogy is entirely apt for two reasons; first, just as a religion has its own folk-tales explaining human origins, constructivism has its own account of the origins of knowledge; and second, as with many living religions, constructivism has many rival sects within it.

In this section, we will discuss first how constructivism has altered our view of the origin and nature of human knowledge. Second, we will illustrate the many faces of constructivism in education, laying stress on two prominent constructivist perspectives: individual constructivism and socio constructivism.

Nature of Knowledge

How can we come to know anything about our world? How can we approach knowledge that can contribute to its growth? Epistemology is the discipline that seeks answers to questions about the nature and justification of human knowledge (Hofer & Pintrich, 1997). Different paradigms in education often reflect different epistemological traditions. Each paradigm has its own beliefs about how one comes to know and what contributes to the growth of knowledge. When a paradigm shifts, its prevailing epistemological perspective often changes accordingly in a way to inform and justify knowledge gathering practices (Gergen, 1995).

The predominant paradigm in the field of education from the 1950's through the 1970's was behaviorism, where the perspectives on knowledge stemmed from a positivist epistemology. Positivism held knowledge to consist of "hard facts" that can be observed, empirically tested, and proved or disproved. Because positivists held that right answers must exist "out there", knowledge in behaviorism was seen as something that could be transmitted from one knower to another and reinforced by stimulus-and-response. Drawing on such an epistemology, Skinner (1974), the prominent behaviorist, saw learning as "an experimental analysis of behavior". In other words, learning outcomes are a series of repeated behaviors reinforced by external stimuli, and the internal causes of such behavioral changes are of no interest in this paradigm. Skinner's notion of a "black box" in learners was associated with an unexplained mechanism of how one comes to know. Because of this theoretical deficit, behaviorism failed to remain in a leading position in the field of education.

Unlike behaviorism, constructivism per se is more obviously a kind of epistemology. Constructivism's view of how learning occurs is based on an understanding of "how conceptual development should be approached and how it could be fostered" (von Glasersfeld, 1995a, p. 5). It was adapted by educational researchers to meet the growing awareness of a need for alternatives to the traditional theories of knowing in Western philosophy, which were unable to sufficiently explain how one becomes a knower.

Constructivism is philosophically influenced by interpretivism or postmodernism and views knowledge as theory-laden. This means that users interpret knowledge differently and that knowers construct new knowledge based on prior knowledge and experiences.

Since the replacement of behaviorism by constructivism, educational efforts have focused on understanding and enhancing the processes by which learners construct their knowledge. In doing so, some theorists, such as Piagetians and individual (radical) constructivists, attribute knowledge construction to the cognitive structures *within* individual learners; while others, such as Vygotskian or social constructivists, attribute knowledge construction to social interaction *between* learners or between learners and environments involving the sharing and negotiating of meaning and culture.

In the following section, we will illustrate and compare these two constructivist perspectives, the main sects of constructivism in education.

Individual (or Radical) Constructivism

Piaget (1968, 1970) was enormously influential in providing educational researchers and educators with a sophisticated theoretical perspective on learning as constructivism. For the past 40 years, it has been an unfalsifiable claim in education that students construct their own knowledge. Piagetian constructivism, also known as individual constructivism, argues that learning occurs through a process of disequilibrium, where learners constantly eliminate perturbations by accommodating new concepts or operations that prove incompatible with existing knowledge. That is, cognitive change or learning takes place when use of a scheme leads to perturbation, and then to an accommodation to the scheme in order to maintain or re-establish equilibrium (von Glasersfled, 1995a). To Piaget (1968), therefore, cognitive development is regarded as "expanding equilibration", an increase in the range of perturbations that the organism is able to eliminate in much the same way as organisms biologically adapt themselves to survive in ever-changing environments.

It is important to note that Piaget's notion of action schemes is radically different from the behaviorists' notion of stimulus-response. Although action schemes also underlie the feedback loops that cause changes in action, action schemes are explicitly goal-directed. This goal-directedness of action scheme enables learners to become increasingly self-regulated through the mechanisms of assimilation and accommodation.

The term, "radical" constructivism, which is associated with Piaget's genetic epistemology, was first introduced by Smock and von Glasersfled in 1974 in their research report, "The implications of radical constructivism for knowledge acquisition". As a researcher in the field of scientific reasoning, von Glasersfeld argues that "the virtually undisputed domination of a mindless behaviorism" (1995b, p. 4) for half of the 20th century confounded the distinctions between training (for performance) and teaching (for understanding). This was an unfortunate consequence of least two factors. First, science was seen as a way to absolute truth; and second, a drill-and-practice type of reinforcement training was believed to lead learners to the achievement of intelligent behavior. However, when von Glasersfeld found students in his school who became unable to solve problems that called for deeper understanding than mere rote-memorization, he began seeking a new perspective of learning that would be able to inform how conceptual development should be approached. Radical constructivism, in this regard, was an alternative approach that saw knowledge as "the internal mental construction of the individual" (Smith, 1995, p. 23).

Associated with cognitive psychology, research programs driven by individual constructivism have flourished in generating theories of teaching and learning. This is especially the case in the fields of science and math education where researchers have focused on understanding the knowledge structures that experts construct and on modeling efficient access to and retrieval of relevant knowledge for solving problems (e.g., Ericsson & Simon, 1993; Ericsson & Smith, 1991; Newell & Simon, 1972). While studying and externalizing these cognitive processes, researchers have become aware of how to scaffold or facilitate student construction of knowledge.

However, individual constructivism has also been criticized for its negligence of social interaction during the course of knowledge construction. Paour (1990) argues that this is because Piagetian constructivism "seeks to locate the psychological mechanism of adaptation in direct continuity with biological mechanisms" (p. 178). Phillips (1995) also criticizes the fact that von Glasersfeld's epistemology is developed in a way that is flawed in much the same way as positivist epistemology is flawed. To Phillips, radical constructivism is not a sufficient theory of knowledge construction or learning because it ignores social factors and it supports a standard set or structure of correct conceptions that all learners should have. Socio-constructivism has emerged to meet the demands for a more extended consideration of social and cultural influence on knowledge construction.

Socio-Constructivism

Unlike individual constructivism, socio-constructivism has many sects, which has perhaps contributed to complaints about theoretical illusion in constructivism. In their book, "*Construction in Education*", Steffe and Gale (1995) categorize socio-constructivism into three different paradigms: social constructionism, social constructivism, and socio-cultural approaches to mediated action.

The best representatives of social constructionism might be Thomas Kuhn (1962) and Imre Lakatos (1970). Although they have differing perspectives regarding how scientific knowledge grows, both stress the active role of scientific communities in knowledge construction. This is especially prominent in Kuhn's perspective with its emphasis on communities conducting research within a paradigm and then overthrowing a paradigm because of accumulated anomalies; but it is also significant for Lakatos with the emphasis on rival research programs and progressive or degenerating problem shifts (see p. 179). Since social constructionism places greater emphasis on theorizing the social dimensions of knowledge construction than on education, we will not deal with it any further in this paper.

Both social constructivism and the socio-cultural approach are rooted in Vygotsky's accounts of social aspects of learning. Differences between these two approaches reside in their focus of inquiry. That is, the former focuses on individual development through support or interaction with others whereas the latter focuses on collective efforts mediated by cultural means including material and immaterial artifacts in everyday activities.

Social constructivism employs Vygotsky's (1978) notion of the "zone of proximal development" (ZPD). To social constructivists, cognitive development is analogous to expanding one's ZPD. The distances between levels of actual and potential development are determined by proper guidance by experts (adults) or peers. Thus children can widen their ZPD infinitely in talking and sharing with others. "Cognitive apprenticeship" (Collins, Brown, & Newman, 1989) and "reciprocal teaching" (Brown & Campione, 1994) are two well-known instructional practices based on the notion of ZPD.

However, more radical socio-cultural perspectives criticize socio-constructivism for its insufficient account of what drives learning and human transformations in social and historical contexts. From socio-cultural perspectives, mental functioning cannot be understood without considering social contexts, including participation in social settings and the historical development of cultural artifacts and tools (Wertsch & Toma, 1995).

In fact, it was Leont'ev (1978), Vygotsky's student and colleague, who expanded the notion of mediation from individual to collective activities. This expansion called for a better account for collective nature of activities; and to this end, Engeström later elaborated Leon'ev's concepts into his Activity Systems Theory (AST) by adding such theoretical constructs as rules, communities, and divisions of labor, in order to better represent dynamic mediations in collective activities (Engeström, 1987).

Another major contribution of Engeström's Activity System Theory is his endeavor to illustrate transformation cycles in activity systems in order to account for the historicity of activity systems, which has been crucial in CHAT but had not been really touched before. Engeström (1999a) calls the historical cycle of activity systems the "Expansive Cycle of Learning". In this cycle learning occurs in crisis situations when members of an organization share common goals of overcoming the crises. When existing routines become problematic, members of an organization begin to externalize problems and to seek and test new models to replace existing ones (by either creating new cultural means or artifacts or by adjusting existing ones, such as rules, documents, technology, etc). Later on, a new model is chosen and becomes internalized and routinized by members, and finally the crisis is resolved. During the course of these collective activities, members learn and these learning processes are again historically accumulated in their organization.

However, socio-constructivism cannot avoid the criticism of overemphasizing external activities in social setting and underemphasizing individual knowledge structures and cognitive processes, which cannot be isolated from external actions. Individual constructivists find the notion of artifacts that are believed in socio-constructivism to historically mediate activities especially unacceptable. Von Glasersfeld (1989) argues that one can never know what is in the mind of another person by reading a book or looking at other artifacts because the meaning conveyed by words and other linguistic vehicles are inescapably subjective for both producers and receivers.

Summary

In the above section, we examined theoretical origins and constructs of constructivism and their relevance to the nature of knowledge. A summary of the examination is provided in Table 2-1. Based on a review of constructivist theories, with particular emphasis on how the nature of knowledge has been considered in individual constructivism and socio constructivism, three major framing considerations were identified: (1) preferred theoretical perspective, (2) the constructs that initiate learning (disequilibrium, differences, or crisis) and (3) methodological concerns.

Table 2-1. A Summary of Theoretical Constructs in Constructivism

		Sects	Representing Authors	Learning Principles	Methodology	Domains
Constructivism	Individual	-	Piaget; Von Glasersfeld	Equilibrium between existing and new knowledge through iterative process of accommodation and assimilation	Modeling knowledge structure (i.e., Expertise approaches)	Mathematics; Medical education (reasoning processes)
	Socio	Social constructi-vism	Brown, A.; Brown, J.; Lave	Social interaction; Shared cognition; Cognitive apprenticeship; Legitimate Peripheral Participation	Discourse analysis; Conversation analysis	Science education (project-based learning) Literacy education
		Socio-cultural approaches	Vygotsky; Leont'ev; Engeström	Mediated learning; Expansive learning cycle in crisis	Experimental treatment; Discourse analysis; Phenomenol-ogical studies	Cognitive/ social development; Workplace learning

First, constructivist perspectives differ with respect to the nature of knowledge depending on the discipline under consideration (Bereiter, 1994; Cobb, 1994). Thus, the process of formulating research questions place researchers within particular perspectives because perspectives on knowledge construction in literacy education often differ from those in science education. For example, on the one hand, researchers in the fields of mathematics (e.g., Schoenfeld, 2002) and medical education (e.g., Kaufman & Patel, 1991; Patel & Groen, 1986) prefer individual constructivism since they tend to focus on learners' reasoning processes. On the other hand, in science education where project-based learning is commonly used, researchers prefer socio-constructivism as they tend to focus on social influences on collaborative knowledge construction.

Second, as a learning principle, the constructs of expanding equilibrium in Piagetian (radical) constructivism (Piaget, 1970; von Glasersfeld, 1995a) and the construct of expansive learning cycles (Engeström, 1999a) in Vygotskian (socio) constructivism (Vygotsky, 1978) are basically alike with respect to the importance of "crisis" in order for learning to happen. The only difference between the two perspectives is that the former sees crisis as "internal occurrence within an individual" whereas the latter sees crisis as "organizational and cultural occurrences in a community". Both perspectives require learning tasks to be designed so as to enable students to critically appraise their existing knowledge and to externalize and reconcile latent discrepancies in their knowledge.

Third, together with the previous two findings, different theoretical stances alter the methodologies to be employed. For example, on the one hand, if one wants to investigate the knowledge structure and reasoning processes of an expert mathematician, drawing on radical constructivism, cognitive protocol analysis with the provision of well-designed tasks is more appropriate. On the other hand, in order to systematically examine social and individual phenomena associated with the adaptation of new practices such as constructivist activities by teachers, it is more appropriate for researchers to adopt a socio cultural approach such as the activity-theoretical framework.

These theoretical findings frame a review of empirical studies on technology-supported constructivist classrooms, which will be presented in the following section.

Constructivism in practice: A review of empirical studies

The socio-constructivist environment in which students were confronted might have been too complex to be handled constructively

(Clarebout & Elen, 2001, p. 462)

So far, we have examined the theoretical constructs of constructivism in terms of the similarities and differences between individual and socio constructivist perspectives. Based on the preceding theoretical review, we will review recent empirical studies on technology-supported constructivist learning environments. The purpose of this review is to find out how well the theoretical constructs have been reflected on in those studies. The goal is to examine our hypothesis that current problems in the unsuccessful use of ICT reside in insufficient reflection of the theories of constructivism, and thus in the inadequate design of methodologies.

To select articles to be reviewed, ERIC and PsychInfo databases were searched with the keywords "constructivis? and technology and (elementary or secondary)". The search was limited to journal articles published in the period of 1999 to 2006. Articles on higher education were removed from the search. The database generated totaled 54 articles. Then, articles dealing with distance education and problems caused by poor access to technology, as well as opinion papers rather than empirical studies, were removed. The final set consisted of 10 articles. A thumbnail of the selected articles is presented in Table 2-2.

Table 2-2. *Outline of Reviewed Articles*

References	Discipline	Technolo-gy used	Participan-ts	Theoretical framework/ constructs	Methodology	Identified factors for success (if any)
Churach, D., & Fisher, D. (2001). Science students surf the web: Effects on constructivist classroom environments. *Journal of Computers in Mathematics and Science Teaching, 20*(2), 221-247.	Science	Internet and email	431 secondary students in Hawaii	Individual constructive-sm (explicit)	CLES survey (by Taylor and Fraser, 1991) and classroom observation	Active internet usage and teachers' supportive attitude
Clarebout, G., & Elen, J. (2001). The parleunet-project: Problems with the validation of socio-constructivist design principles in ecological settings. *Computers in Human Behavior, 17*(5-6), 453-464.	Multidiscipl-inary	Intranet between six schools	124 secondary students in Europe	Socio-constructivi-sm (explicit)	Pre-post test	Proper and controlled implementation of the designed environment Difficulties of tasks

References	Discipline	Technolo-gy used	Participan-ts	Theoretical framework/ constructs	Methodology	Identified factors for success (if any)
Ioannidou, A., Repenning, A., Lewis, C., Cherry, G., & Rader, C. (2003). Making constructionism work in the classroom. *International Journal of Computers for Mathematical Learning, 8*(1), 63-108.	Science	Computer Simulatio-ns	4^{th} and 5^{th} graders	Social constructive-sm (project-based simulations)	Case study (Protocol analysis of audiotaped classroom discourse)	Redefined curriculum in accordance with constructivist learning principles
Lavonen, J., Meisalo, V., & Lattu, M. (2002). Collaborative problem solving in a control technology learning environment, a pilot study. *International Journal of Technology and Design Education, 12*(2), 139-160.	Science	Computer (programming tool)	Thirty four 8^{th} graders	Socio constructive-sm (explicit; collaborate-ve problem solving)	Case study (Videotaped protocol, critical incident analysis)	Teacher support

References	Discipline	Technolo-gy used	Participan-ts	Theoretical framework/ constructs	Methodology	Identified factors for success (if any)
Rakes, G. C., Flowers, B. F., Casey, H. B., & Santana, R. (1999). An analysis of instructional technology use and constructivist behaviors in k-12 teachers. *International Journal of Educational Technology, 1*(2), 1-18.	Not particular	Not particular	435 randomly sampled K12 teachers	Individual constructivi-sm	Survey	Professional development
Rice, M. L., Wilson, E. K., & Bagley, W. (2001). Transforming learning with technology: Lessons from the field. *Journal of Technology and Teacher Education, 9*(2), 211-230.	Social studies	All available technolog-ies at the school	A secondary teacher	Unclear	Case study	Belief of administrators and parents

References	Discipline	Technolo-gy used	Participan-ts	Theoretical framework/ constructs	Methodology	Identified factors for success (if any)
Roberts, A. (2004). Analyzing patterns and relationships around a bond of common text: Purposes, dilemmas, and possibilities of a virtual community. *Journal of Research on Technology in Education, 37*(1), 1-27.	Literacy	Virtual communit-ies	35 students in Wyoming and 15 in Costa Rica	Socio constructivi-sm (Project-based learning in a virtual community)	Case study	Common language for students to use
Vincent, J. (2001). The role of visually rich technology in facilitating children's writing. *Journal of Computer Assisted Learning, 17*(3), 242-250.	Writing	Computer (MicroWo-rld)	Five 5th graders in Melbourne	Individual constructivis m (Papert's LOGO. but unclear)	Case study	-

References	Discipline	Technolo-gy used	Participan-ts	Theoretical framework/ constructs	Methodology	Identified factors for success (if any)
Wallace, R. M., Kupperman, J., Krajcik, J. & Soloway, E. (2000). Science on the Web: Students Online in a Sixth-Grade Classroom. *Journal of the Learning Sciences 9*(1): 75-104.	Science	Internet	Eight 6th graders in a middle school in US	Socio constructive-sm	Case study	-
Windschitl, M. & Sahl, K. (2002). Tracing Teachers' Use of Technology in a Laptop Computer School: The Interplay of Teacher Beliefs, Social Dynamics, and Institutional Culture. *American Educational Research Journal, 39*(1), 165-205.	Multi domains (social studies and math)	Laptop	Three teachers at a middle school in US	Hybrid (explicitly stated in five elements of constructive-st classrooms)	Case study using an ethnographic perspective	-

The review was carried out based on the theoretical findings in the previous section, such as preferred theoretical perspective with respect to discipline under consideration, the common notion of crisis in learning, and methodological concerns. Findings suggested that there are three critical discrepancies between theoretical constructs and their actual application in empirical studies: (1) ambiguous theoretical stances of most of the reviewed studies, (2) as a result, inappropriate study design for the nature of domains, and (3) insufficient reflection on theoretical constructs of constructivism in the design of the learning tasks under investigation. In what follows, we will present these three findings in more detail.

Ambiguous Theoretical Stances and Constructs

Among the ten articles, only three (Churach et al., 2001; Clarebout et al., 2001; Lavonen et al., 2002) explicitly claim their theoretical stances to be either individual or socio constructivism. For the rest of the articles, we inferred their theoretical tendencies based on a close review. For example, although Ioannidou et al. (2004) and Vincent (2001) commonly employed Papert's (1993) LOGO program, the former used it for group projects whereas the latter for individual learning. Therefore, we inferred the former to have adopted a socio-constructivist perspective the latter to have adopted a individual constructivist perspective.

This is not to say that educational researchers must explicitly choose a constructivist perspective for their inquiry. In fact, the need for balanced considerations between the two perspectives has been widely recognized by both camps of constructivism (Bereiter, 1994; Cobb, 1994; Longino, 1993; Phillips, 1995). Phillips (1995) in particular criticizes the continued existence of a persistent distrust between the two camps because such a one-sided view is unhelpful in pursuing the growth of theories of learning. We cannot ignore individual cognitive changes while actively engaging in learning activities nor can we neglect the surrounding natural contexts that place considerable constraints on knowledge construction and allow us to detect our errors.

In this regard, Windschitl and Sahl's (2002) article presents a nicely balanced constructivist theoretical perspective. The authors used the five characteristics of constructivist classrooms originally developed by Becker and Ravitz (1999) in order to frame their inquiry. These elements included (1) having students engage in collaborative work, (2) designing activities around teacher and student interests, (3) focusing on student understanding of complex problems and ideas, (4) assessing their understanding, and (5) (teachers') engaging in learning. These characteristics provided the authors with a trajectory that adequately blends the two constructive perspectives and with a lens to trace how technology transforms teaching and learning practices.

It is important to distinguish between balanced theoretical considerations and ambiguous theoretical stances. For example, one article (Rice et al., 2001) had such unclear perspectives on constructivism that it was impossible to infer a clear constructivist theoretical framework. More seriously, a few studies in the set did explicitly present their theoretical stance either as individual or socio constructivism; however, their actual focus of inquiry did not reflect on the theoretical framework they claimed to have adopted. For example, Clarebout et al (2001) explicitly claimed socio constructivism as their theoretical framework; however, in the study the actual constructs that they measured were the development of meta-cognitive strategies. This is not to say that what they looked at was totally inappropriate. Indeed, social interaction supported by network technologies can promote the development of student meta-cognitive strategies. However, unclear explanation on how authors get from networked technologies to meta-cognitive strategies is problematic.

A clear theoretical stance might not be so critical for practitioners such as teachers when promoting constructivist activities in their classroom; however, researchers have a responsibility to provide practitioners with rigorous theoretical bases in promoting such activities.

Inappropriate or Defective Methodology

As a result of their ambiguous theoretical stances, some study designs were deemed as inappropriate. These included inadequate methodologies for the nature of the domain that studies looked at and the failure to position technologies as a construct in the studies.

In this set of articles, the case study method was observed in seven studies out of ten. Quantitative methods using surveys and paper and pencil pre-post tests were employed in two of the studies and the remaining one used both survey and follow-up observations and interviews.

The case study methodology is accepted as an appropriate methodology for investigating questions concerning the how and why of contemporary phenomenon in real life contexts (Yin, 2003). Because there are countless factors and incidences to consider in real life settings, a salient framework and thorough analysis informed by a suitable theoretical framework is mandatory for supporting the findings of case-study research. However, this was hardly observed in the ways that the reviewed case studies were carried out. For example, Roberts (2004) addressed so many issues in her literature review (e.g., technology in education, constructivism, technology accessibility, foreign language learning and multiculturalism, etc.) that it is unclear as to what theoretical framework informed her study. Consequently, it is difficult to determine what constructs she used to examine the pedagogical activities in this learning environment and what framework she used to analyze her data. Not surprisingly, the unit of analysis was also unclear. Although Roberts (2004) mentioned “case data” (Stenhouse, 1978) as a unit of analysis, she analyzed, or more accurately described, interview data instead of cases that students produced.

Another problem with the case studies is that only one article (Lavonen et al., 2002) reported inter-rater reliability with respect to the data coding and none of them conducted a member check. Consequently, it is questionable whether interview or observation data were properly and faithfully analyzed or the author(s) simply counted on data that seemed to support their hypotheses. For example, Rice et al. (2001) analyzed a massive amount of data that they had collected for over a five-year period including e-mail interviews, participants’ course assignments, classroom observations, course plans, and so on and generated four categories using constant comparative analysis. In doing so, they reported no more than the following, “To produce an accurate presentation of the research findings, as well as to control for researcher bias, data were triangulated across the research team and data sources” (p. 215). It is necessary to describe *how* they triangulated the data, rather than simply to say “data were triangulated”, in order to increase the trustworthiness of the research.

The quantitative studies in this set also have methodological problems. For example, Clarebout et al. (2001) did a factor analysis to identify constructs to include in each of the four scales: epistemological beliefs, instructional belief, meta-cognitive strategies, and task-related knowledge. However, it is unknown from which theoretical framework these scales drew on. Moreover, the reliability of the scales (Cronbach α) for assessing epistemological beliefs and meta-cognitive strategies were only .56 and .62 respectively, which are quite low. Not surprisingly, this study produced poor results. That is, after participating in the project, students' epistemological and instructional beliefs, meta-cognitive strategies, and task-related knowledge declined. Although the authors blamed the poor results on the implementation stage rather than the design stage, they also could be a consequence of scales that did not measure what they were supposed to measure.

Designed Learning Environments

Some of the "constructivist" learning environments that the studies investigated were designed for the purpose of the studies, ranging from innovative curricula to computer simulation design programs and huge networks between schools. However, some of the design principles that they applied appeared to be inappropriate. Constructivist learning tasks do not imply that students are allowed to construct everything for their learning. Rather, they imply that learning tasks be more carefully designed to appraise learners' pre-existing knowledge, and more importantly, to model and scaffold activity in order to help students construct their own learning path.

In this regard, Ioannidou et al. (2004) provided one of the few good examples of well-designed learning tasks in this set. The authors investigated how 5th and 6th graders model and understand the ecosystem using a computer simulation program. The authors asked students to:

> design imaginary animals which do not actually exist but which *could* live in their environment. The animal design must include adaptations for the animal to survive the temperatures common to its environment as well as to mate and to acquire food. Within each group, students collaboratively work out the predator-prey relationships for their ecosystems. (p. 70)

With clear guidance for creating their own "eco-world", students were so engaged in the task that they referred to their creature in the first person, e.g., "I can eat you" rather than "my animal can eat yours". Because their assumptions about their creatures were constantly tested in the simulation and resulted in a living or dead ecosystem, this learning activity helped students to establish constant re-equilibrium through processes of accommodation and assimilation.

Unfortunately, such well-designed tasks were not always provided in the studies reviewed. For example, Vincent (2001) stated:

> A constructionist environment had been fostered by the participant researcher in the term prior to the study, in particular an environment in which children were encouraged to investigate all possibilities for use of computers in the learning environment, and in which it was acceptable to set problems beyond the minimum tasks proposed by the teacher. (p. 244)

This principle of a constructivist learning environment proposed by the author is somewhat misleading. Constructivist learning does not mean that students try to find their way in using learning tools or materials or in performing little tasks proposed by teachers. Rather, teachers must provide students with well-designed tasks that enable them to challenge their existing knowledge and eventually "expand equilibration" in Piaget's term.

Wallace et al. (2000) designed learning tasks that did not sufficiently reflect constructivist learning theories. The authors investigated how students look for and approach science information on the web. To do so, the authors had students generate three questions that they wanted to investigate on the web, which turned out to be problematic with regard to learning processes as well as research itself. Because students did not fully recognize the goals of such activity, they stuck to the original questions and got lost rather than constantly refining their questions so as to become more relevant with respect to constructing their own knowledge around what they were interested in. As a result, students focused on the searching phase instead of on all the stages (e.g., question asking, information gathering and evaluating, and information synthesizing and using). In the discussion, the authors correctly asserted that "it confirms research on task that tells us that a complex task in and of itself does not cause complex thinking….It matters what students are asked to do and how tools and techniques to accomplish these tasks are provided" (p. 97).

In sum, few of the studies reviewed investigated learning environments that were designed based on the theoretical constructs of constructivism, which are to enable students to critically appraise their existing knowledge and to externalize and reconcile latent discrepancies in their knowledge with crises either in "internal occurrence within an individual" or in "organizational and cultural occurrences in a community". Together with ambiguous theoretical stances, insufficient reflection on theories for designing learning environments appears to be a critical factor in explaining the outcomes of studies. Without such theory-based principles of design, constructivist learning environments can easily become merely trendy mumble jumble fads having no effects on student knowledge construction.

Implications for the Effective Integration of ICT into Constructivist Classrooms

In the previous sections, we examined the theoretical constructs of constructivism in terms of individual and socio constructivism. Also, we reviewed ten empirical studies to understand the current trends in the use of ICT to promote constructivist classrooms. Based on differences and similarities between theoretical constructs and empirical findings, we will suggest some key elements in the successful integration of ICT into constructivist classrooms.

Task Design and Motivation

According to Piaget's notion of equilibrium, it is important to provide students with tasks that challenge their prior knowledge scheme. The tasks should be neither too easy nor too difficult. However, in technology-supported learning environments, there can be two different challenges: new technology environments and new types of learning experience or tasks. As pointed out by one of the reviewed studies (Clarebout et al., 2001), it might be too challenging for students to become motivated if they find both the tasks and the environments to be unfamiliar. Therefore, it is necessary for teachers to be aware of the importance of balance between degrees of task difficulty and student motivation in designing ICT supported constructivism activities.

Teachers' Attitude and Professional Development

Related to the first element, teachers' active engagement in student constructivist learning is essential, ranging from the careful plan and design of curriculum and activities to supportive and flexible attitudes toward student self-directed learning. This adds credibility to Bracewell et al.'s (2007) findings that a successful teacher attitude was detected as appropriate "release of agency". The research indicates that one of the critical requirements for successful ICT integration into a constructivist classroom is that teachers must be comfortable with relinquishing authority and with distributing responsibilities for learning.

Meanwhile, cultural-historical approaches provide an adequate methodology for investigating teachers' instructional activities associated with their attitudes and beliefs. In fact, there has been an increasing number of studies employing Activity Systems Theory, one of cultural-historical approaches to understand how teachers use ICT to adapt, abandon, and reinvent new practices (e.g., Bracewell, Tung, & Sicilia, 2005; Windschitl & Sahl, 2002). Such research contributes to the effective use of ICT in constructivist classrooms by phenomenologically analyzing how members of such organizations including teachers, students, parents, staffs and administrators collectively overcome classroom crises arising from new instructional practices.

Along the same line, such research contributes to more systematic instructional design in professional development. As a participant teacher of one study in the reviewed set stated, it is challenging for teachers to conceive of "the intersection between the technology, the curriculum, and classroom management without knowing what a laptop-equipped classroom looked like" (Windschitl & Sahl, 2002, p. 178). A cultural-historical approach can help instructional designers model and design activity systems in classrooms and take into consideration multiple goals and participants, the nature of tasks, the uptake of tasks, shifts in roles, etc., which are socially, culturally, and pedagogically more complex than in traditional classrooms. Such modeled activity systems in turn make teachers aware of the socio-cultural contradictions between their current assumptions and new practices needed for the effective use of ICT to promote constructivist pedagogical activities.

Administrative Support

Finally, the data or findings from the field also speak to the need for theoretical development. Although it is not mentioned in any of the theories, administrative support is a critical factor in successfully putting constructivism into practice. This is an obvious example for showing gaps between theory and practice. In other words, without full understanding of nature of administrative work and situations, researchers' enormous efforts to design and implement constructivist classrooms with a solid theoretical background will often fail to get off the ground (Windschitl, 2002). Cultural-historical approaches provide possible solutions to the problem by investigating existing historical divisions of labor and cultural rules among members of communities including administrators and teachers in order to understand and model activity systems and to prevent the occurrence of possible problems.

Conclusions

The purpose of this paper was to review key elements that contribute to the successful and unsuccessful integration of ICT and constructivist pedagogical activities into K-12 settings that have been reported in literature. Constructivist theoretical constructs were identified based on the literature about constructivist theories. These theoretical findings in turn framed a review of recent empirical studies on technology-supported learning environments to identify key elements in the successful and unsuccessful integration of ICT in constructivist classrooms.

Based on a review of constructivist theories, with particular emphasis on how the nature of knowledge has been conceived in individual constructivism and socio constructivism, three major framing considerations were identified. First, researchers' perspectives on constructivism differ from one discipline to another (Bereiter, 1994; Cobb, 1994). Second, as a learning principle, the construct of expanding equilibrium in Piagetian (individual) constructivism (Piaget, 1970; von Glasersfeld, 1995) and that of the expansive learning cycle (Engeström, 1999) in Vygotskian (socio) constructivism

(Vygotsky, 1978) are basically alike. Both imply that learning tasks should be designed to enable students to critically appraise their existing knowledge and to externalize latent discrepancies. Third, together with the previous two findings, different theoretical stances were found to alter methodologies to be employed.

Given these theoretical findings, a set of empirical studies on technology-supported constructivist classrooms was reviewed. The articles were selected based on keyword searches of relevant databases and consisted of ten journal articles from the period of 1999 to 2006. Findings suggested that there were three critical discrepancies between theoretical constructs in theory and practice: first, most of the reviewed studies exhibited ambiguous theoretical stances. Second, as a result of the first discrepancy most of reviewed studies employed inappropriate designs for the nature of domains investigated. Third, most of the studies failed to adequately reflect constructivist theoretical constructs in the tasks used for their investigation. Insufficient elaboration of constructivist theoretical constructs in empirical studies resulted in poor results or no significant effects on constructivist learning. It is suggested that more thorough methodological concerns are needed to produce trustworthy studies.

The findings presented three implications for the successful integration of ICT for promoting constructivist pedagogical activities: (1) learning tasks should be designed in a way to constantly challenge students' pre-existing knowledge with the help of teachers and other peers; (2) teachers need to be more active in planning and enacting classroom activities. It can be possible with appropriate professional development programs that draw on a more thorough theoretical framework to reveal what technology-supported classrooms look like. Both principles of design for constructivist learning experiences and awareness of possible problems likely to occur in constructivist classrooms are important findings in terms of implications for what to include and how to design professional development programs. Finally, (3) administrative support is a critical factor in the successful integration of ICT into constructivist classrooms.

Research must inform practice and at the same time, must be inspired by practice. It is our responsibility as researchers to assist and guide such a teacher who "still feels like s/he is teaching things the same way s/he used to" to do their job better in such new and innovative learning environments.

Bridging Manuscript

Chapter II reviewed theoretical constructs of constructivism and compared them with those in ICT-related constructivist classroom research at K-12 levels. The findings implied that a more thorough theoretical framework was needed in order to fully account for complexity of ICT-supported constructivist classroom activity. The following section, Chapter III, presents a theoretical framework for this study through a theoretical review of CHAT. Originating from Vygotsky's socio-cultural constructivism, CHAT regards learning as cultural and historical development. It provides a systematic lens to address how people change, adapt, re-create, and abandon new practices through the constructs of mediation and contradiction.

Findings from the theoretical analysis of CHAT framed the two subsequent manuscripts, which are case studies that analyze and intervene on a Grade 7 mathematics teacher's instructional practices and student learning activities.

CHAPTER III. THEORETICAL FRAMEWORK

The purpose of this chapter is to present an overview of CHAT and to establish a theoretical framework for the present dissertation study. To do so, I will first describe the emergence of CHAT and discuss problems in the current applications of the theory. Second, I will delineate the evolution of CHAT along with the notion of mediation, a critical theoretical construct of CHAT in order to render the theory a more fully operationalized version of the theory for educational practices. Finally, based on the review, I will propose three principles for understanding and designing classroom practices from CHAT perspectives.

Unsolved Dichotomy: Internalization vs. Externalization

Traditional cognitive science is founded on the study of the symbolic representations and structures processed within individuals. Researchers adopting this perspective claim that human cognition can be characterized as physical symbol systems, or "cognitive architectures", consisting of memory and a set of information processes, which in turn cause motor actions (e.g., Ericsson & Simon, 1993; Ericsson & Smith, 1991; Glaser & Chi, 1988; Kintsch, 1998; Newell & Simon, 1972; Vera & Simon, 1993). Studies from this perspective have contributed to advanced understanding of learning mechanisms by revealing experts' problem solving processes, including how they decompose problems into sub problems and sub goals, how they structure the storage of conceptual and procedural knowledge efficiently enough for effective problem solving, and so on.

In the mean time, researchers in cognitive science have also come to recognize the importance of social contexts for learning. A main claim of this approach is that cognitive activities cannot be studied as processes isolated from contexts but as more complex processes associated with dynamic interactions between agents and environments (Cole, 1991; Greeno & Moore, 1993). In other words, every cognitive act can be viewed as a response to a set of circumstances and can be validly interpreted by examining circumstances and how participants understand situations. Studies informed by this theoretical perspective primarily employ ethnographic methods to understand relationships between human activities and contexts, and focus on distributed and social cognition (Hutchins & Klausen, 1998), knowledge construction in communities of practice (Lave, 1991), and cultural-historical forces affecting individual and collective activities (Engeström, 1987; Laboratory of Comparative Human Cognition, 1983).

Engeström's work, among these, has been a significant force to spread CHAT into the western educational research world. It views human development as active transformations of existing environments through internal processes of individual self-knowledge construction and external processes of collective adaptations or re-creation of cultural artifacts. In short, CHAT is a theory of human development focusing on relationships between individuals and environments, and how they affect and change each other through various kinds of mediations. A key contribution of the theory to learning science is that it removes the mystery of motives or intentions from the internal and biological systems of individuals to the external and more accessible nature of objects that are produced, modified, and transformed by culturally and historically organized collective activities (Miettinen, 2001, p. 305). What this means to educational research, especially designing learning activities, is that we can refer to more overt and visible artifacts that learners collaboratively produce and change, instead of conjecturing on the effectiveness of learning based primarily on what individuals recall from their minds. Because of this distinctive nature of the theory, a great number of attempts have been recently made to understand organizational changes and social development patterns from the CHAT perspective, such as work transformation in a merged hospital (Engeström, 1999b), distributed expertise in an intensive care unit (Patel, Kaufman, & Magder, 1996), joint writing tasks of city engineers (Bracewell & Witte, 2003), and the near-miss airspace incidents in an Air Traffic Center (Owen, 2001).

Cultural-historical researchers intended to solve a long-held dichotomy on the locus of cognition and learning such as individual vs. social and internal vs. external by looking at object-related changes. However, most of the CHAT related research employed phenomenological methods, focusing on describing overt social transitions. This has given rise to criticism of its one-sided emphasis on external environments and explicated social changes in human activities (Garrison, 2001; Patel et al, 1996; Stetsenko &

Arievitch, 2004). This is at best a reverse form of what CHAT researchers criticized about the internalization-focused of previous psychological research on learning.

Arievitch (2003) argues that although the trend in recent cognitive science has been to move beyond the individual to social interaction as the unit of analysis, the dichotomy still exists. One approach to solve the dichotomy is to "dissolve" the individual into socio-cultural context; the other way, which Arievitch advocated, is "to understand individual mental development as the gradual internalization and transformation of socially constructed shared activities." (p. 284). By internalization he means that humans gradually develop an "internal plane of action" which enables them to act by substituting symbols for objects. He argues that the notion of "internalization" realizes the mechanism of integration by which the "external" becomes "internal". However, the current use of CHAT has hardly been used to account for such a dialectical mechanism of human development and has inclined to its explanatory use for explicated activities and environments. For this reason, Stetsenko et al. (2004) criticized the current use of CHAT as "a reductionism upward" that dissolves individuals into external environments.

When Vygotsky (1978), an originator of CHAT, initially asserted "a dialectical materialist approach to analysis of human history" (p. 60) as an essential construct of the theory, he emphasized the importance of balanced consideration of internalization and externalization. In other words, the true transformation of individuals requires both externalization of their current problematic mediations (e.g., tools, communication means, rules, practices, etc.) *and* their internalization of newly adapted practices. Then, they re-create artifacts as reflecting on their newly internalized practices. This is a key aspect of CHAT that addresses the culture and history part of human development, as Vygotsky (1978) argued:

> [sign mediation] transfers the psychological operation to higher and qualitatively new forms and permits humans, by the aid of extrinsic stimuli, to control their behavior from the outside. The use of signs leads humans to a specific structure of behavior that breaks away from biological development and creates new forms of a culturally-based psychological process. (p. 40)

Engeström (1999a) asserted that CHAT research was still dominated by the paradigm of internalization, and argued for more concrete research on "creation of artifacts, production of novel social patterns, and expansive transformation of activity contexts" (p. 27). However, this can hardly be done without ample understanding of how changed practices transform individuals internally and of how the internalized practices, in turn, are associated with new artifact creation. Along the same line, Minnis and John-Steiner (2001) pointed out in their review on *Perspectives on Activity Theory* that Engeström considered "individuals genetically, in terms of their roles in the system, rather than personally, in terms of each one's experience as a participant" (p. 300).

A reason for such one-sided use of CHAT might be its insufficient methodological adjustments to the extension of its theoretical constructs. In other words, although the theory has been considerably extended by its followers from Vygotsky's single semiotic mediation to Leont'ev's object-related mediation to Engeström's multiple mediation in order to encompass complexities and dynamics of collective human activities, the idea of mediation, a core mechanism of the theory, has barely been elaborated accordingly (Bracewell et al., 2003; Engeström, 1999a). Such extension of the theory without redefining its core has blurred the dialectical nature of the theory and left a long-held dichotomy between internalization and externalization unsolved.

It is worthwhile to delineate the evolution of mediation, an essential construct of CHAT, in order to re-equip the theory with a better dialectical approach to understand human transformation. Revealing the ways in which this construct has developed from its origin may provide clues as to why CHAT has not been able to develop beyond a descriptive theory (e.g., a failure analysis tool) into a more productive one (e.g., a learning activity design framework). A further elaboration of the construct of mediation could lead to a more fully operationalized version of the theory for educational practices in which a myriad of mediations occur in teaching and learning (Lim & Ching, 2004).

Mediation and CHAT

In CHAT, human actions are viewed as ends shaped by means. Thus, relationships between actions and mediating means are so fundamental that it is impossible to understand individuals independently of the concrete situations in which they act (Wertsch, 1991, p. 12). Indeed, it is the construct of mediation that distinguishes CHAT from other psychological paradigms; it is also mediation that unifies the theory throughout various versions, from Vygotsky's semiotic mediation to Leont'ev's object-related mediation to Engeström's multiple mediations in activity systems. In this section, I will review the constructs of mediations and contradictions by the three most important authors in the development of CHAT: Vygotsky, Leont'ev, and Engeström.

Vygotsky's Semiotic Mediation

Vygotsky's notion of semiotic mediation departed from the notion of associative S-R chains of behavior, which prevailed in the early 1900s. Figure 3-1 shows Vygotsky's elaboration of S-R chains. With respect to human behavior Vygotsky posited the existence of signs (X) between stimulus and response and asserted that these psychological tools mediate behavior and activities by interrupting immediate responses to stimuli. More precisely, children develop as they learn what psychological tools (X) are available and how to use them to solve everyday problems by communicating with and getting help from more experienced individuals (e.g., adults).

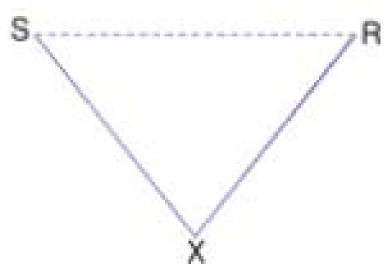
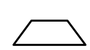
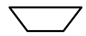


Figure 3-1. Structure of sign operation (Vygotsky, 1978, p. 40)

This is not to say that mediation for Vygotsky was a simple addition of a theoretical construct, mediator X, to a previously accepted psychological perspective. By mediated behaviors Vygotsky meant active engagement in higher psychological behaviors where individuals deliberately modify the stimulus as they attempt to respond to it. This appeared clearly in a mnemonic experiment with children in which Vygotsky exemplified his notion of mediated behaviors:

> For example, the figure  presented as a reminder of the word "bucket," was turned upside down by the children and served to remind them of the word only

when the figure  really began to resemble a bucket…. In all these cases, children linked the figures to the word stimuli by changing the meaning of the sign instead of using the mediating link offered by the experimenter. The introduction of these meaningless figures encouraged the children to engage in active mnemonic activity. (Vygotsky, 1978, p. 47-48)

In this experiment, which uses the method called "double stimulation", Vygotsky intentionally provided children with a contradictory aid, the up-side-down bucket shape, and observed if this aid facilitated them to actively engage in the process and to modify the aid for a better use to solve the given problem. These psychological experiments play an important role in making habitual and hidden processes visible. As such, what Vygotsky intended to reveal by the idea of mediated behavior was that higher psychological processes develop through the dialectical process involving the entire structure of activity, including the internalization of extrinsic signs (e.g., learning languages and other signs) and the externalization of internalized (intra-personalized) signs through activity (e.g., modifying signs for better usability). The latter, that is reversed behaviors, cannot be explained without mediation and, because of that, Vygotsky's idea is distinguished from other prevalent perspectives on human behavior research in those days. According to Vygotsky (1978), such a dialectical approach enables admitting the influence of environments on human developments and at the same time, tracing the transformation of environments driven by human developments.

In sum, although Vygotsky employed an experimental methodology, his focus of inquiry and the units of analysis are noticeably different: he focused on process, not performance. For instance, he was not interested in the number of words that children memorized but in activities, strategies, and external aids that children used to memorize words such as the help of peers, flash cards, and symbols.

Leont'ev's Object-Related Mediation

Vygotsky's initial notion of human development in the 1920s and 1930s was elaborated and expanded by A. N. Leont'ev and A. R. Luria. The crux of Leont'ev's (1981) account of human development is that every human activity is driven by certain motives which do not originate from inside individuals but originate in and evolve along with *objects* in the material world. By locating the ultimate motives of human activity in material objects outside the mind, Leont'ev expanded the notion of mediation from individual actions to collective activities and stimulated further fundamental elaborations of CHAT.

A key difference between Vygotsky and Leont'ev is that Vygotsky focuses on the internalization and externalization of psychological processes by means of cultural artifacts (mainly, language) whereas Leont'ev focuses more on how collective material production activity develops and transforms individual psychological processes. This is why Leont'ev (1981) calls human psychological processes "psychic reflections".

Leont'ev's well-known three-level structure of practical activity (activity/motive, action/goal, and operation/condition) was the first attempt to specify "activity", which at the time referred to any form of human behavior. According to his specification, activity is driven by an object-related motive, which endures over extended periods of time, whereas action is driven by short-term goals. The bottom level of operation is driven by and becomes automatized by conditions, e.g., tools at hand. These three levels can be best understood by his famous example of hunting activity: "the beater's activity is the hunt, and the frightening of the game his action (Leont'ev, 1981, p. 210)".

Although his three-level specification of activity was beneficial in a way that made transformations between the three levels more visible (Engeström, 1999a), it has been criticized by different scholars, including followers of CHAT (Bracewell & Witte, 2003; Davydov, 1999; Engeström, 1999a; Lektorsky, 1999; Stetsenko, 2005). One of the most frequently raised criticisms is that Leont'ev neglected communication and semiotic mediation, which was initially the basis of Vygotsky's theory, and treated semiotics as mere tools like any other artifacts for tool-mediated production. In other words, he emphasized object-related mediation so exclusively that the human mind was viewed as something produced by collective production activities rather than as something involved in the reproduction, recreation, and transformation of productive activities. Because of this drawback, Leont'ev's version of CHAT has been criticized as "representing humans not as creative beings but as simple executors of plans, orders, and standards imposed from outside" (Lektorsky, 1999, p. 65).

Engeström's Multiple Mediations

Due to the considerable level of abstraction of Leont'ev's version of CHAT, a great deal of effort has been devoted by its successors to making it concrete enough to account for the dynamic nature of collective human activity. Engeström's elaboration of Activity Systems Theory is perhaps one of the most widely used models in CHAT-based research. Engeström's elaboration of Activity Systems Theory is an attempt to develop a more inclusive and unified model of the dynamic nature of collective human activity and transformations where qualitatively and quantitatively more complex mediations are going on than mere sign- or object-related mediation.

Engeström's Activity System could be easily interpreted as an extension of Vygotsky's subject-artifact-object triangle, as many researchers have assumed. However, a more careful look at his dissertation (Engeström, 1987) reveals that this is not correct. He reached his multi-mediational triangular model as follows: First, he drew on the general mode of biological adaptation in the form of animal activity as depicted in Figure 3-2. He then quoted Lewontin to support his argument for the existence of dialectic modes in activity systems (p. 59):

> The importance of these various forms of dialectical interaction between organism and environment is that we cannot regard evolution as the 'solution' by species of some predetermined environmental 'problems' because it is the life activities of the species themselves that determine both the problems and the solutions simultaneously… Organisms within their individual lifetimes and in the course of their evolution as species do not *adapt* to environments; they *construct* them. (Lewontin 1982, p. 162-163.)

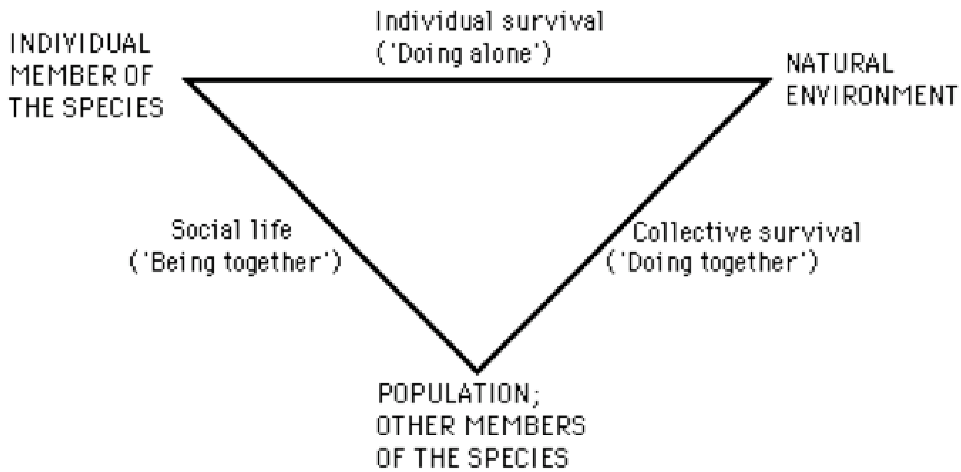


Figure 3-2. The general structure of the animal form of activity (Engeström, 1987)

Engeström inferred multiple mediations from this up-side-down triangle. He argued that on higher levels of animal activity among apes, dolphins, and human beings, we can witness "ruptures" (in his words) in the direct link between constructs and the emergence of mediations between the original constructs. First, individual survival (the upper side of the triangle) is mediated by emerging tools. Second, social life or being together (the left side of the triangle) is mediated by rules and rituals in order to get along with other members of a community. Finally, collective survival or working together (the right side of the triangle) is mediated by the division of labor. This elaboration is captured in Figure 3-3.

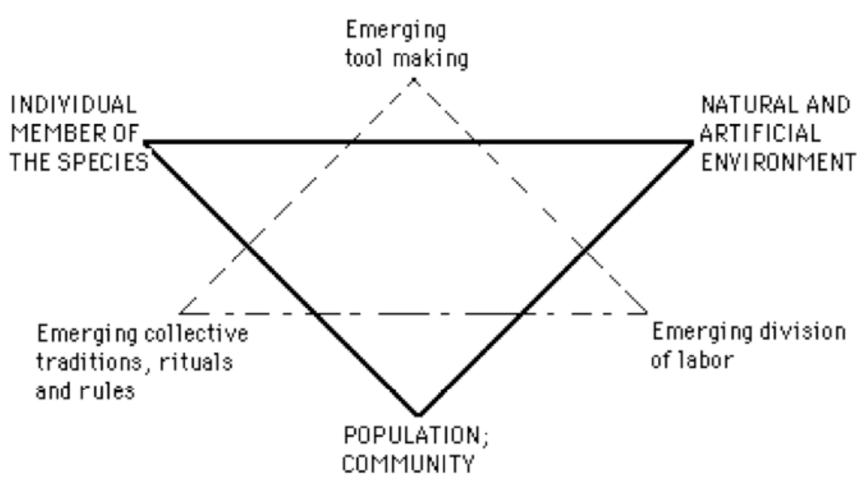


Figure 3-3. Structure of activity in transition from animal to man

As a logical continuation of the model in Figure 3-3, Engeström finally reconstructed the triangular structure of human activity, which is now commonly known as the Activity Systems Theory (Figure 3-4). By expanding the nature of mediation from semiotic or object-related mediation to a multitude of relations within the praxis of activity system, Engeström's model can account for a much greater variability in practical human activity (Bracewell & Witte, 2003).

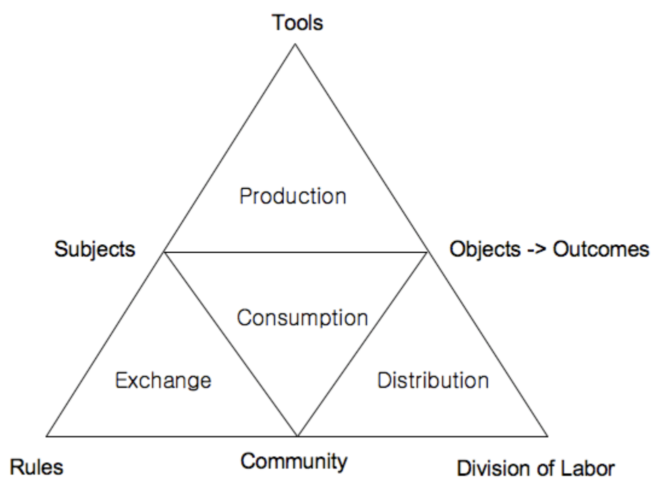


Figure 3-4. The structure of a human activity system (Engeström, 1987, p. 78)

Probably because of the graphical and practical tangibility of his model, Engeström's Activity Systems Theory is one of the most frequently applied models in CHAT-based empirical research, ranging from human-computer interaction (e.g., Nardi, 1996), to K-12 classroom research (e.g., Lim & Barnes, 2005; Postholm, Pettersson, Gudmundsdottir, & Flem, 2004), to higher education (e.g., Barab, Barnett , Yamagata-Lynch, Squire, & Keating, 2002), and to workplace transformation research (e.g., Engeström, 1999b; Roth & Tobin, 2002).

As analyzed so far, although it is mediation that holds the different versions of CHAT together, it is also mediation that differentiates one version from the other. Table 3-1 presents an analysis summary of mediation by the three symbolic authors in CHAT history: Vygotsky, Leont'ev, and Engeström.

Table 3-1. *A Comparison of the Construct of Mediations*

	Nature of Human Development	Unit of Analysis/ Methodology	Contributions	Criticisms
Vygotsky	Sign-mediated	S-R processes mediated by extrinsic aids (not performance)/ Experimental	Including extrinsic aids in the unit of analysis	
Leont'ev	Object-mediated	Object-related action/ Unclear methodology	Extending focus from individual actions to collective activity	Overemphasis on objects and insufficient empirical investigations
Engeström	Multiple mediations (Artifacts including rules and division of labor)	Activity system/ Phenomenologi-cal, discourse analysis	Extending coverage of the theory by adding multiple mediations	Increased abstraction and neglect of internal psychological processes

As the characteristics of mediating artifacts are broadened from sign to material objects to multiple relationships within activity systems including immaterial mediations, CHAT becomes more capable of accounting for dynamics of human development activity. At the same time, such theoretical extension has increased the level of abstraction with respect to the nature of multiple mediations (e.g., Bracewell et al., 2003; Cole, 1999; Park & Bracewell, 2005) and thus, has called for more thorough methodological considerations to investigate critical and dialectical processes of human development. For example, Vygotsky employed a relatively simple and straightforward (but appropriate) methodology to understand children's psychological development by providing tasks embedding certain obstacles to overcome as well as extrinsic aids such as mnemonic devices. He was interested in and investigated how the children used the extrinsic aids to solve the problem, rather than merely what they solved. How can we then accurately understand and investigate from a CHAT perspective a more complex and collective human activity such as classroom teaching and learning?

Another Construct for Dialectical Mechanism: Contradictions

A possible answer to the question above can be drawn from the construct of contradiction. As a matter of fact, contradiction has been commonly addressed as a motive for human development in the above three mediations. The construct of contradictions in CHAT is, in fact, seen as the "engine" of transformation (Engeström, 1987, p. 82-91; Kornilov, 1924, as cited in van der Veer & Valsiner, 1991, p. 118-124). When individuals encounter something that deviates from their norms, they attempt to solve the anomaly by changing or adapting their current practices or creating new practices, until the anomaly becomes a norm that the community accepts. In doing so, the community is culturally transformed and developed. According to Engeström (2000), contradictions do not manifest themselves directly; rather, they manifest themselves through disturbances or small innovations. For example, when a new rule is introduced to a school, such as a newly reformed curriculum by the Ministry of Education, it can create contradictory interactions between existing constituents of the activity system, and thus necessitate changes in the school as a whole, including new division of labor (e.g., curriculum consultant, teachers as facilitators, etc.) and new tools (e.g., advanced communication technology to promote collaborative learning, etc.). Without this adjustment, the reformed curriculum would cause an ongoing crisis between various actors and mediators in the school, instead of promoting student learning as intended.

Identifying and analyzing contradictions enable researchers to *visiblize* (in Engeström's (1999b) term) underlying problems and tensions when organizational change occurs. Thus, an analysis of contradictions makes local participants or actors in an activity system both aware of these tensions and allows them to concentrate their energy on resolving them.

Engeström (1987, p. 77-85) classified contradictions of human activity into four levels. The primary level is an inner and inherent contradiction within each construct of the central activity (for example, the classic Marxist contradiction inherent in a tool that one makes, in that one can either use it to make something or exchange it for something else). The secondary level is contradictions between the constructs of a given activity system (for example, those outlined above between tools on one hand and rules of interaction and division of labor on the other). The third level is contradictions between the object/motive of a dominant form of the central activity and the object/motive of a culturally more advanced form of activity (for example, play as the central activity of children and education as the more advanced activity). Finally, the fourth level is contradictions between one major activity system and its neighboring ones (for example, family activities and work activities). Engeström (1999b) asserted that transformation of an activity system can be seen as "attempts to reorganize, or re-mediate, the activity system in order to resolve its pressing inner contradictions" (p. 67).

By revealing contradictions in an activity system, we can more accurately track the development process triggered by the contradictions. More precisely, various levels of identified contradictions point to adjustments or changes of mediations in which the contradictions occur. For example, the introduction of new tools often runs into conflict with exiting practices such as rules of interaction and division of labor. Without adjusting such mediating components, that is, rules of interaction and division of labor, the contradictions remain unresolved, and thus the development of the activity system is stalled.

As such, the constructs of mediations and contradictions provide a comprehensive means for understanding how participants resolve contradictions between their existing and new practices -- by adapting, changing, and re-creating multiple mediations. Moreover, it provides insight into how such evolved mediations that resolve contradictions affect their psychological processes. What is most attractive about the idea of contradiction is that, as educators or researchers, we can embed or design contradictions within learning activities in order to cultivate desired culture and practices in the activity system.

Three Principles for CHAT-Based Designs

Based on the review of theoretical accounts for mediation and contradictions, I will propose three principles that enable us to take full advantage of CHAT as a theoretical framework for understanding and designing classroom practices: (1) Learning environments should be designed based on an activity system analysis; (2) Designed constructivist tasks should evoke a dialectical cycle of learning between internalization vs. externalization and individual vs. collective; and (3) Designed learning environments should be evaluated by tracking reflected practice of the activity system in question. The unit of analysis, therefore, should be the history of changes in the activity system encompassing all the mediations as well as its impact on outcomes that members produce as a result of the activity.

Design Based on Activity System Analysis

Designing learning environments from a CHAT perspective means designing interventions to facilitate the development of an activity system as a whole on the basis of an ample understanding of the activity system in question. It is often suggested that researchers actively engage in undergoing transformation processes of the actual activity system and construct new models of activity with local participants (Engeström, 1999a; Engeström, 2004; Kuutti, 1991). Engeström (1999a) asserted that “such construction can be successful only when based on careful historical and empirical analysis of the activity in question” (Engeström, 1999a, p. 35-36). In short, designing learning environments from a CHAT perspective should be activity-system specific and thus requires Activity System Analysis (ASA).

ASA focuses on understanding and identifying the layers of social and cultural contradictions historically accumulated in the organization. Not only does it enable explication of the mediating constructs such as artifacts in use, rules of interaction, and division of labor among participants, but it also reveals contradictions within or between the activity system(s). In other words, the constructs of mediations and contradictions in an activity system provide a comprehensive means to understand as well as to cultivate the culture of an activity system in question.

Through ASA, one can better understand the dynamics of the activity system and thus, design interventions focusing on weak mediations caused by unresolved contradictions. This can be better understood by considering a contrast between a well-formed activity system (Figure 3-5) and an ill-formed activity system (Figure 3-6). In an activity system, multiple mediations such as tools, rules of interaction, and division of labor are not discrete but reinforce each other; that is, contradictions within one mediation or between mediations affect the whole activity system. And, the growth of one mediation calls for adjustment of the other mediations to balance activities of the activity system.

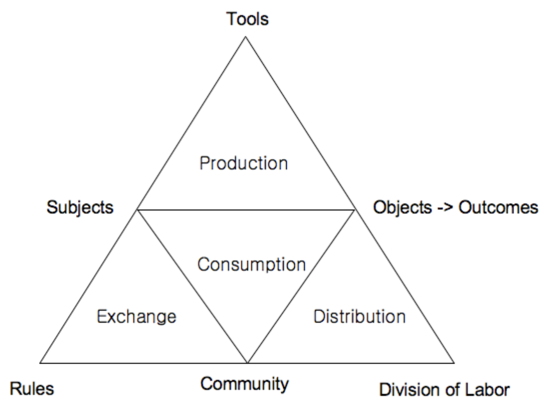


Figure 3-5. A representation of a well-formed activity system

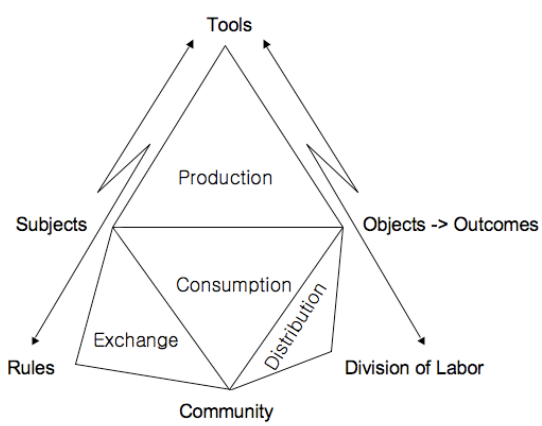


Figure 3-6. A representation of an ill-formed activity system

For example, when a school begins to run a one-on-one laptop program the school might experience numerous disturbances such as when to allow students open their laptop during the class, who to fix laptops if broken, how to promote teachers to use them for instruction, and so forth. In other words, the presence of laptops in class generates tensions with the other existing components of the school activity system, such as rules, division of labor, and tools. To overcome these tensions and realize the laptop program as an effective ICT-supported learning environment, the other components must change appropriately. When this occurs, the activity system can be referred to as a well-formed activity system, where individuals as a collective proactively modify and produce artifacts to achieve common goals (Figure 3-5). In contrast, if the other components are not adjusted, the motive of the laptop program cannot be fulfilled; and thus the development of the school activity system towards an ICT-integrated learning environment is stalled. Such activity systems can be referred to as an ill-formed activity system where the rules of interaction and divisions of labor are not sufficient to support the effective use of tools (i.e., laptops) for instruction and learning (Figure 3-6). Comparing the two representing figures, one can easily see which triangle forms a well-formed pyramid whereby the three mediations are equally developed and hence capable of acting in synergy.

Through ASA, one can better understand the dynamics of the activity system, and thus design interventions focusing on weak mediations caused by unsolved contradictions. Thus, ASA should be a basis of the macro design of interventions where the existing contradictions causing the ill-formed activity system is dealt with to make it well formed.

Evoking Learning Activity

After understanding and explicating the layers of contradictions occurring or existing in the activity system in question as a macro design, learning activities are to be designed as a micro design. The activities should embrace authentic contradictions revealed by ASA in order to facilitate a dialectical process of learning.

This principle, indeed, is consistent with how Vygotsky designed his experiment with double stimuli (Vygotsky, 1978, p. 74): providing children with tasks usually embedding obstacles or difficulties and providing “external aids” that enabled children to alternate problem solving processes. What is different about the ASA-based design of learning tasks from a conventional learning activity design is twofold. It assess learners’ pre-existing knowledge and guides learners throughout the activity in order for them to associate the tasks with better practices suggested by the characteristics of the activity system revealed by ASA. An example might be providing external aids such as detailed worksheets for learners to track and explicate the change of their internal knowledge (e.g., daily log) as well as the changes of their external practices (e.g., uptakes of the task, rules of interaction in class, and so forth.) in carrying out the given tasks.

Evaluation of the Intervention

In CHAT, human development is understood as two ongoing processes of internalization and externalization (Engeström & Miettinen, 1999). Internalization is a reproduction process of culture and practices whereas externalization is the creation of new artifacts to transform existing practices. These two processes are intertwined and dialectically support each other during a transformation process.

The transformation process is triggered by contradictions in an activity system, where contradictions manifest themselves through disturbances. Therefore, to accurately evaluate whether a designed intervention changes participant practices as intended (i.e., whether it helps resolve the identified contradictions) a new approach to make contradictions explicit and visible is necessary. Three phases of analysis appear to be needed. The first phase is to identify patterns of observable disturbances. The second phase is to find relationships between the patterns of the disturbances and the six constructs of an activity system; subjects, objects, artifacts, community, rules, and division of labor. This is to find whether the patterns of disturbances are produced by any contradictory interaction between the constructs of the activity system. Close attention should be given to whether the identified contradictions affect the subjects (participants) in achieving a desirable outcome of the activity. These two phases should be done before and after the intervention respectively. The third and last phase is to compare patterns of disturbances and contradictions that are identified before and after the intervention. This phase reveals resolved contradictions as well as remaining and newly emerging contradictions.

In sum, the analysis for an effective development cycle of an activity system is not the activity system itself, but the historicity of changed practices of the activity system in question through contradictions. That is, the analysis should account for the extent of the designed activities to help the members become aware of the hidden contradictions, to construct new artifacts or models, and finally to consolidate new practices to realize their activity system from an ill-formed into a well-formed one.

Conclusions

The progress of CHAT has, on the one hand, broadened the theoretical coverage of the nature of human collective activity and development; on the other hand, it has increased the level of abstraction on the construct of mediation (Bracewell et al., 2003; Cole, 1999; Park & Bracewell, 2005) and resulted in the negligence of the dialectical nature of human development. Such insufficient elaboration of the core construct of the theory, in my view, has prevented the theory from extensive use in educational practices and has limited it to a descriptive framework for analyzing organizational crisis. As an attempt to find the roots of such theoretical limitations, in this chapter I reviewed the constructs of mediation and contradictions as depicted throughout the history of CHAT. By revealing contradictions in an organization or an activity system, it is possible to thoroughly track what triggers its development process. More precisely, changes in one construct of the activity system call for adjustment in the other constructs of the activity system, such as rules of interaction and division of labor. If they are not sufficiently adjusted to support subjects to carry out the activity, the contradictions remain unresolved, and thus the development of the activity system stalls. Such an activity system could be regarded as an ill-formed activity system, as opposed to a well-formed activity system where the other mediators are adapted, adjusted, or recreated to support the activity. As such, the constructs of mediations and contradictions give a comprehensive means to understand how participants resolve contradictions between their existing and new practices and how such evolved mediations that resolve contradictions in turn affect participants' psychological processes.

Based on the theoretical review, three principles were proposed in order for the theory to be used more productively as a framework for understanding and designing classroom practices. The principles were the following : (1) Learning environments should be designed based on an activity system analysis; (2) Designed learning tasks should evoke a dialectical cycle of learning; and (3) Designed learning environments should be evaluated by tracking reflected practice of the activity system in question.

A new role of researchers is then suggested: to identify hidden contradictions in an activity system in question with active involvement in the participants' everyday practices, make the participants aware of contradictions, and help them concentrate their energy on resolving contradictions and consolidate new practices.

Bridging Manuscript

The following manuscript is a case study of a Grade 7 teacher's instructional practices in a technology-rich mathematics classroom through a lens of CHAT. Our focus was on identifying contradictions and tensions that the presence of ICTs generated and on tracking impacts of these contradictions on student understanding.

Findings from the previous manuscript and the theoretical review informed the following manuscript in two ways: first, partial applications of constructivist approaches that were addressed in the first manuscript guided the analysis of the participant teacher's constructivist teaching practices. Second, two important constructs of CHAT, namely, mediation and contradictions framed the analysis of disturbances that occurred in the participant teacher's classroom, largely due to contradictory interaction between existing mediations and newly introduced mediations of the class activity system. This manuscript in Chapter 4 was prepared based on "Park, J., Bracewell, R. J., Sicilia, C., & Tung, I. (2007). Understanding and modeling contradictions in ICT-rich classrooms: A CHAT perspective. Paper presented at Annual Meeting of AERA 2007, Chicago, IL, April 9-13, 2007".

CHAPTER IV. MANUSCRIPT 2

What Makes Contradictions in a Technology-Rich Constructivist Classroom? : A Case Study

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Abstract

Much educational research has suggested that information and communication technologies (ICTs) promote constructivist or student-centered classroom learning (e.g., Churach & Fisher, 2001; Vincent, 2001; Windschitl & Sahl, 2002). In contrast, most teachers in actual classrooms continue to struggle with the pedagogical and practical challenges in using ICTs to facilitate student knowledge construction and collaboration (U.S Department of Education, 2003). Therefore, we need a more thorough understanding of challenges that teachers face in ICT-supported constructivist classrooms, including social and cultural aspect of the classroom practices. This case study examined constructivist classroom practices in a Grade 7 technology-rich mathematics classroom through a lens of cultural-historical activity theory (CHAT). We focused our attention on identifying contradictions and tensions that the presence of ICTs generated and on tracking impacts of these contradictions on student understanding. Findings indicated that it was not ICTs per-se that made contradictions in the ICT-supported constructivist activity; rather it was the changed nature of the class activity system due to the introduction of ICTs that called for systemic adjustment of classroom practices as a whole. Implications for professional development for teachers are presented.

Introduction

A great deal of research on the integration of Information and Communication Technologies (ICTs) into the classroom suggests that ICT is a pedagogical mediator that promotes constructivist classroom learning. (e.g., Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000; Bracewell, Le Maistre, Lajoie, & Breuleux, 2008; Bryson & de Castell, 1998; Windschitl & Sahl, 2002). However, in contrast to the findings of educational researchers, teachers in most classrooms continue to struggle with the pedagogical and practical challenges in using ICTs to facilitate student knowledge construction and collaboration (U.S. Department of Education, 2003). The challenges teachers face in ICTs classroom are not just a lack of technical skills and support but also the unfamiliarity with chaotic classroom situations that can result from the introduction of ICTs (Bracewell, Tung, & Sicilia, 2005; Sicilia, 2005; Windschitl, 2002). For example, a participant teacher of our on-going research claimed that "You can guarantee that out of the fifteen kids in class (with laptops), four of them are off somewhere else and I find that very frustrating".

Despite struggles that teachers face in ICT-supported constructivist classrooms, current professional development for teachers continues to focus primarily on basic computer skills (Ertmer, 2005; U.S Department of Education, 2003). The successful realization of ICT-supported constructivist classroom practices calls for a more thorough understanding of these practices, with particular attention on the sources of instructional challenges as well as their impacts on student learning.

This case study was motivated by our observation of a Grade 7 mathematics classroom in which ICT –supported constructivist instruction did not lead to effective student learning. The participant teacher, Jorge, designed and implemented a two-week mathematics project, called "The neighborhood skate ramp project". The project was to teach the Pythagorean Theorem in part through a skateboard ramp building activity. In the event, only one of five student groups built a ramp in a way that was consistent with their calculations using the Pythagorean Theorem. This case study is an attempt to find the reasons for these disappointing results by investigating the social and cultural aspects of this ICT-supported collaborative classroom activity. Cultural-historical activity theory (CHAT) framed the analysis of the case and enabled us to gain a better understanding of challenges facing this ICT-rich constructivist classroom activity. Our expectation is that such an understanding will provide directions for more effective professional development initiatives for teachers, an area that has been flagged as "underdeveloped" in educational research (Berry et al., 2003; Lawless & Pellegrino, 2007; Wilson & Berne, 1999).

ICTs and Constructivism

In educational research and practice that is guided by constructivist assumptions, learners are seen as important agents who are actively engaged in constructing their own knowledge. Recent and rapid developments in technology promote the learners' access to resources that facilitate such construction (Duffy & Jonassen, 1992; Hannafin & Land, 1997). Indeed, such technologies have been so rapidly developed that the percentage of classrooms with Internet access in U.S public schools has jumped from 3% in 1994 to 94% in 2005 (Wells & Lewis, 2006). This means teachers in K-12 classrooms have been forced to deal with a wide spread of technology integration in their curriculum to promote constructivist learning.

The findings of recent research on teachers' adoption of ICTs into their classrooms are not very promising. Teachers in most classrooms continue to struggle with the pedagogical and practical challenges in using ICTs to facilitate student knowledge construction and collaboration (U.S Department of Education, 2003). Because teachers are overwhelmed by constructivist-oriented educational reforms they often employ ICTs in an incremental way to sustain their traditional teaching practices (Cuban, 2001; Cuban, Kirkpatrick, & Peck, 2001; Ertmer, 2005). Indeed, changing traditional teaching practices to constructivist ones requires more of teachers than simply acquiring new instructional strategies and technical skills. Teachers need to *make sense of constructivism* on their own and *reorient classroom cultures* to accommodate the nature of student-centeredness of constructivist practices by specifying new rules of interaction and new roles for teachers as well as students (Windschitl, 2002, p. 131).

Making sense of constructivism, however, is not easy because views on how learning is achieved and promoted vary widely (Phillips, 1995). Some theorists, primarily Piagetians and radical constructivists, attribute knowledge construction to the cognitive structures that are associated with constant assimilation and accommodation based on learners' prior knowledge (Piaget, 1970; von Glasersfeld, 1995a). Others, such as Vygotskian or social constructivists, regard learning as a cultural product generated *between* learners as a result of social interaction (Vygotsky, 1978). There has also been sustained disagreement on just how "constructivist" one ought to be. For example, Perkins (1992) drew a contrast between BIG (beyond information given) constructivism and WIG (without information given) constructivism. BIG referred to a *guided* constructivist approach where students were provided with basic information about the learning contents to help them reach beyond the information given whereas WIG referred to a *pure* or extreme constructivist approach where students were not provided any information related to either learning contents or procedures. Despite these differences within the theory, the literature for practitioners barely informs them of these variations and often ends up making them misunderstand constructivism (Park & Bracewell, 2006; Windschitl, 2002). In a review of recent empirical studies on ICTs and constructivism Park and Bracewell (2006) found that most of studies in the review misused constructivism because they designed the learning tasks of the investigation so as to let students discover everything for themselves. Such pure-discovery mode of instruction, or WIG in Perkin's term, often results in poor learning outcomes as students tend to experience cognitive overload due to inadequate directions or absence of core conceptual learning (Brown & Campione, 1994; Kirschner, Sweller, & Clark, 2006; Mayer, 2004).

Reorienting classroom culture is equally challenging. Bracewell, Sicilia, Park, and Tung (2007) asserted that ubiquitous ICTs bring to the forefront a looming crisis over the implementation of constructivist instruction in the classroom because of "the tension between traditional instructional approaches that assume a receptive role by students and the productive capabilities of ICTs that invite a much more initiating and participatory role by students" (p. 1). A large part of the problem resides in a prevailing perspective on ICTs in the field of education as a decontextualized and separated element from classrooms rather than as tools that generate social, cultural, and pedagogical contradictions motivating individuals to change or inhibiting them from carrying out their daily practices (Engeström, 1999a; Park & Bracewell, 2006; van der Veer & Valsiner, 1991). As Vygotsky (1986, p. 1-11) asserted, we need a theoretical perspective that allows us to account for educational environments as “all the basic characteristics of the whole” rather than seeing them as the sum of decomposed and decontextualized elements. Equipped with such theory, we will be able to generate more systematic understanding of classroom activities involving ICTs.

In this regard, we selected CHAT as a theoretical lens to understand Jorge’s project-based ICT-supported classroom practice as a complex activity system. The following section briefly reviews CHAT and specifies how it can inform the analysis of classroom practices.

An Overview of CHAT

CHAT is a cultural historical approach to understanding human development through activity. It assumes that human development is intrinsically embedded in and woven into everyday activities in cultural and historical contexts. A core premise of CHAT is a dialectical transformation between individuals and environments, i.e., how individuals change environments and how changed environments affect individuals. Studies informed by this theoretical perspective primarily employ ethnographic methods to understand relationships between human activities and environmental contexts. These studies include distributed and social cognition (Hutchins & Klausen, 1998), knowledge construction in communities of practice (Lave, 1991), mediated action (Wertsch, 1991, 1998), and cultural-historical forces affecting individual and collective activities (Engeström, 1987; Laboratory of Comparative Human Cognition, 1983).

Along with the above mentioned cultural-historical theories, CHAT traces its origin to Vygotsky (1978), who claimed that mediation between individuals and environments is the central aspect to the higher mental development and that it fundamentally shapes the activities in learning environments. The mediators can be a tool, sign, or language. Leont’ev (1978), a student and colleague of Vygotsky, expanded the notion of mediation from individuals’ actions to collective activities. Leont’ev’s expansion called for a more comprehensive account of the dynamics of collective social activities and transactions. To this end, Engeström (1987, 1999a) elaborated Leon’ev’s concepts and graphically formulated Activity Systems Theory. In that, he expanded the nature of mediators from supporting individual actions (e.g., symbols) to facilitating interaction between people (e.g., cultural norms of rules of interaction and division of labor).

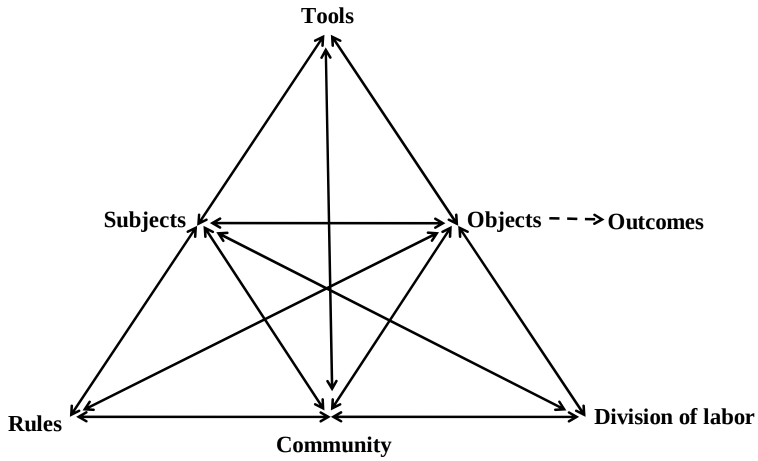

Figure 4-1. The structure of a human activity system (Engeström, 1987, p. 78)

Engeström's (1987) formulation comprises a minimal context in which collective subjects carry out designated activities to transform their objects into outcomes (Barab et al., 2002). The central theme of CHAT is that an individual (*subject*) pursues goals (*object*) in a certain community. Such object-oriented activities are mediated by various material and symbolic means (*tools*) as well as more social means (*rules* and *divisions of labor*). When these means or mediators sufficiently support participants in carrying out the activities, the object is transformed into a specific result (*outcome*). This transformation leads the activity system to progress.

The dotted arrow between objects and outcomes in Figure 4-1 represents the importance of the transformation process. Without this process, activities that subjects carry out cannot be considered "activity" from a CHAT perspective because in CHAT activity does not just refer to "doing" but "doing in order to transform something" (Barab et al., 2002; Engeström, 1987; Kuutti, 1991).

CHAT as a Framework to Analyze Classroom Practices

From a CHAT perspective school contexts can be seen as complex activity systems involving multiple participants (e.g., teachers, students, committees, etc.). Their activities are mediated by multiple artifacts including physical means (e.g., computers, blackboards, texts, etc.) as well as social/cultural ones such as rules of interaction (e.g., behavior codes, collaboration rules, etc.) and division of labor (e.g., roles, technical support, etc.). More importantly, these mediators do not act independently, but dynamically reinforce each other in order to resolve various resultant incompatibilities occurring in everyday practices. For example, when a new tool such as a school intranet is introduced to teachers and students in order to extend the mutual interaction (object) of the class community, it calls for systemic adjustments of existing mediators to resolve incompatibilities with other mediators. These adjustments may include a set of new rules for communicating on the intranet and new roles (division of labor) for students. If all these mediators are adjusted well enough for students and teachers to actively and effectively use the intranet, the class activity system advances towards a more participatory or student-centered learning environment (outcomes). However, if rules and division of labor remain unchanged, disturbances may appear (e.g., cyber-bullying) and the effective use of the intranet becomes limited and thus it plays at best a partial role in the development of constructivist and student-centered class practices.

Such incompatibilities, or contradictions[4] in CHAT terminology, between existing and new practices are essential to the development of any type of human practices. Indeed, the construct of contradictions in CHAT is seen as an important force or "engine" for the activity system to move forward (Engeström, 1987, p. 82-91; Kornilov, 1924, as cited in van der Veer & Valsiner, 1991, p. 118-124). That is, the activity system becomes more culturally advanced (outcome) by constantly adjusting various mediators so as to resolve contradictions. We regard such activity systems as being well-formed or fully-developed. In contrast, if the mediators remain unchanged in spite of emerging contradictions, the development of the activity system stagnates. We regard the latter type of activity systems in the classroom context as being ill-formed or underdeveloped in that

[4] The construct of "contradiction" is a major one in activity theory and is derived from Hegel and Marx (a summary can be found in Emmanuel, 2001). It is commonly illustrated by the distinction between use value and exchange value of an object that is produced with some tool. The prototypical example is borrowed from Marxist economics, where the produced object has both use value and exchange value, hence the dilemma of the producer of whether to use (e.g., consume) it oneself or to exchange (e.g., sell) it for another product. This construct of contradiction is related to Piaget's construct of disequilibrium and, in principle, provides a dynamic capability to activity systems.

the rules of interaction and divisions of labor are not sufficiently modified to support new teaching practices with new tools (i.e., ICTs) as shown in Figure 4-2 (Park, Bracewell, Sicilia, and Tung, 2007; Park & Bracewell, 2008).

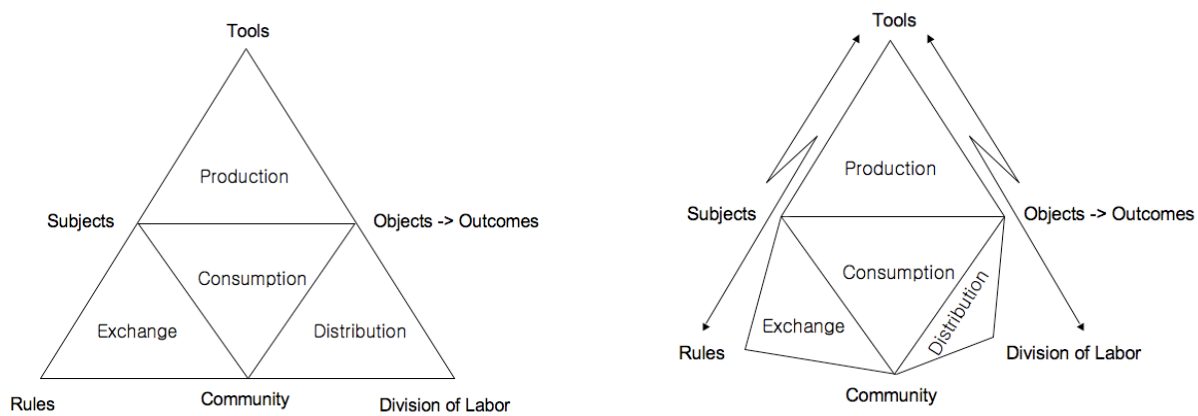

Figure 4-2. A contrast of well-formed and ill-formed activity systems[5]

The aim of this case study is to understand the activity system of a Grade 7 ICT-supported constructivist classroom. More specifically, we focused our attention on analyzing Jorge's instructional practices and how contradictions in his instructional practices affected student understanding of the Pythagorean Theorem, a desired outcome of the class activity system. Our hypothesis, framed by CHAT, was that the nature of the ill-formed activity system of Jorge's project-based classroom practice could have inhibited meaningful student understanding of the Pythagorean Theorem. This case study addressed the following research question:

Why did the participant teacher's instructional practices not lead student understanding of the Pythagorean Theorem and the successful completion of the project activity? What were the characteristics of the teacher's instructional practices that

[5] This representation of an ill-formed activity system has been somewhat oversimplified to give readers a better sense of the relationship between contradictions and activity system. According to Engeström (1987, p.77-85), contradictions of human activity consist of four levels: The primary level is an inner and inherent contradiction within each construct of the central activity (for example, the classic Marxist contradiction inherent in a tool that one makes, in that one can either use it to make something or exchange it for something else, see Footnote 4). The secondary level is contradictions between the constructs of a given activity system (for example, those outlined above between tools on one hand and rules of interaction and division of labor on the other). The third level is contradictions between the object/motive of a dominant form of the central activity and the object/motive of a culturally more advanced form of activity (for example, play as the central activity of children and education as the

hindered student understanding of the Pythagorean Theorem and the successful completion of the project activity?

Research Context

The selected school is one of the most technology-rich in Canada. It is an all-boys private school with 600 students from kindergarten to high school in an urban area. The majority of students are from middle to upper social economic status and their academic performance is average and above average. All students from grade 7 on are provided with a laptop computer with wireless access to the internet as well as the school intranet. Every classroom is equipped with a Smart Board, a printer, and a projector. There are three full time technicians and a pedagogical consultant available. The class sizes range from 15 to 20.

Attracted by such ICT-readiness of this school, our research team approached the school and proposed a project documenting how ICTs could improve constructivist teaching practices and student learning. Upon approval of the project by the headmaster of the school, the research team advertised to teachers that the team sought to exemplify the best practices of ICT-supported constructivist instructional practices. Four teachers volunteered. These teachers perceived their teaching practices as ICT-supported constructivist instruction. After observing one lesson unit per each of the four volunteer teachers' classrooms, which lasted two to four weeks, the research team found distracting classroom situations or disturbances rather than best practices across the classrooms. In line with what Parlett and Hamilton (1976) and Stake (1995) called *progressive focusing* in case study, the researchers refined research focus from exemplifying *best* practices to understanding *real* practices involving ICTs and constructivist instruction. To obtain a deeper understanding of the nature of ICT-supported constructivist teaching practices and their impact on student learning, the researchers selected Jorge's two-week project-based mathematics unit for the study. This case satisfied two criteria. First, this case represented patterns of what the other volunteer teachers' classroom practices looked like. Second,

more advanced activity). Finally, the fourth level is contradictions between one major activity system and its neighboring ones (for example, family activities and work activities).

this case entailed a project-based instruction which generated more social dynamics than the other teachers' classes.

The participant teacher, Jorge, was a male teacher and has taught science and mathematics in the school for more than 20 years. He was well known in the school for a strong advocate of constructivist as well as a technology savvy teacher. He conceived of constructivist instruction as "letting students discover" as he stated in a conversation with the researchers. The participant students were 15 Grade 7 male students.

The observed unit was called "The neighborhood skate ramp project". The project was to consolidate student understanding of the Pythagorean Theorem through a project-based collaborative activity. In this unit students were asked to collaboratively build a skateboard ramp model using the Pythagorean Theorem. The unit consisted of four sub-activities such as (1) calculating the lengths of each part using the theorem, (2) drawing plans on papers, (3) calculating the cost of their ramp if it were built in a real size using the given prices of plywood, (4) crafting a 1:10-scaled ramp model using cardboard, wood sticks, and glue. A core mathematical concept of this activity was calculating the three x-trusses that were required for base, ramp, and back views of the ramp, using the Pythagorean Theorem (Figure 4-3). Students were also asked to make informal presentations of their product to peers describing the characteristics of their ramp and what they learned from this project. Each class lasted 75 minutes.

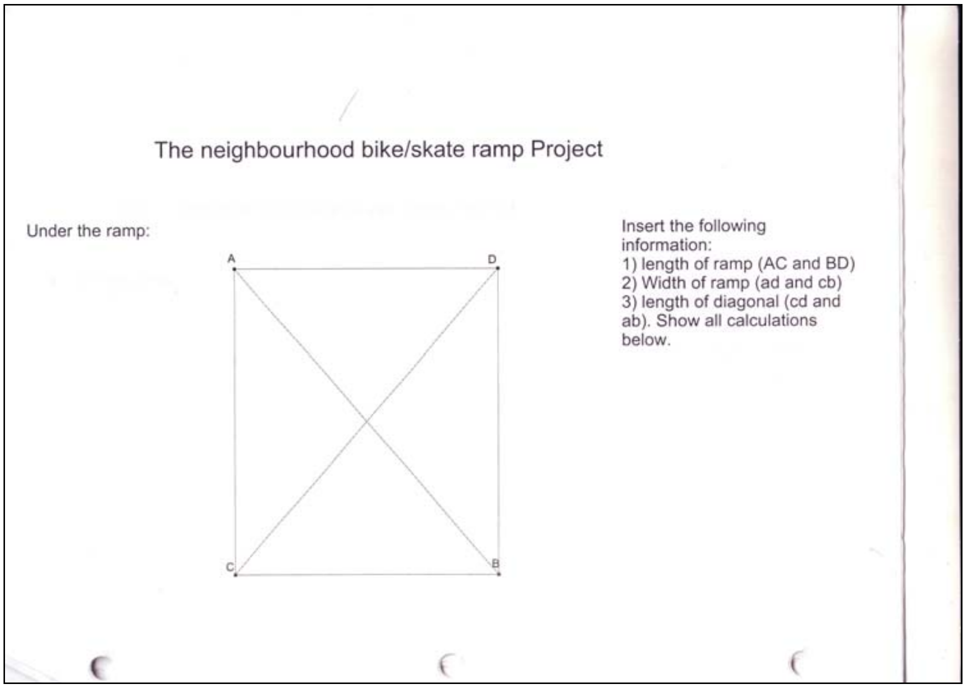

Figure 4-3. The plan of a ramp part with X-trusses (from student worksheets)

Throughout the project activity, students were constantly encouraged to use various kinds of ICTs, including electronic class materials which were downloaded from the school server, in-class notes that the teacher wrote on Smart Board during classes and that were available on the server for the later use, as well as various pieces of educational software. In addition to using Microsoft Word, Excel, and PowerPoint to organize work students were introduced to Geometer's Sketchpad™, a geometric educational software, which they used to draw plans and calculate lengths and angles.

Methodology

This study adapted two major methodologies: Case study (Stake, 1995; Yin, 2003) and "ethnography of trouble" (Engeström, 2000, p. 153). According to Yin (2003), a case study strategy has distinct advantages compared with other strategies when "a "how" or "why" question is being asked about a contemporary set of events, over which the investigator has little or no control" (p. 9). This study had those conditions because it attempted to find reasons for the contradictory results ("why" question) of an ICT-supported constructivist classroom activity (a contemporary set of event) over which the researchers had no control. This study employed an embedded single-case study (Yin, 2003) where a single case embedded multiple units of analysis, as opposed to a holistic case study that examines “the global nature of an organization or a program” (p. 43). In other words, this study investigated one single case of the ramp project which embedded different levels of subunits of analysis, such as the class activity system, interactions between constituents of the activity system, and participants’ understanding of the activities.

Ethnography of trouble[6] is a methodology introduced by Engeström (2000) to identify contradictions in workplace practices. Identifying contradictions allows researchers to explore critical aspects of activity in terms of learning, changing, or developing, rather than in terms of describing “the status quo” of the activity (Hasu, 2001). According to Engeström (2000), “contradictions do not manifest themselves directly. They manifest themselves through disturbances, ruptures, and small innovations in practitioners’ everyday work actions.” (p. 153). The role of the researchers is then to make disturbances visible, and to connect and interpret “these seemingly random incidents” as contradictions in the activity system. Informed by this methodology, the researchers attempted to first identify disturbances in Jorge’s classroom practices and then to provide explanations of the disturbances in the light of contradictory interactions among constituents of the class activity system.

Data collection

This case study embedded multiple levels of units of analysis as shown in Table 4-1. The very top level unit of analysis was the activity system of Jorge’s class for describing the actors, the objects that the actors carried the activity toward, the artifacts, rules, and division of labor used or created to achieve the objects, members of the broader community, and the outcomes of the activity. The main data sources for this unit of analysis were classroom observation, class hand-outs for students, and detailed field notes.

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[6] Although the ethnography of trouble is originally developed to conduct intervention studies, it is still reasonable to adapt this methodology in this present study because contradiction identification is a sub step of the whole methodology.

Table 4-1. *Multi-levels of Units of Analysis and Data Sources*

	Top	Intermediate	Individual
Unit of analysis	Activity system	Contradictions in the activity system	Individual knowledge and action Teacher understanding of instructional activity Student understanding of the theorem and project
Data sources	Class observation Class hand-outs Field notes	Class observation Video-recorded class discourse Field notes Post-interviews	Transcripts of classroom interaction Student products (worksheets, ramp models) Post-interviews

The intermediate level unit of analysis was contradictions that appeared during the course of the ramp project. This unit of analysis was to find patterns of disturbance, an indicator of contradictions underlying the ramp activity. The main data sources for this phase were classroom observation, video-recorded classroom activity, field notes, and post-interviews with the teacher and student groups.

The individual level unit of analysis was individual action and knowledge, including teacher understanding of the activity and student performance in the project. The main data sources for this level were transcripts of classroom discourses, student products including class worksheets and ramp models, and post-interviews. Details of the data collection follow.

Classroom Observation

Jorge's two-week unit was both videotaped and observed by at least two researchers. The researchers recorded their observations in a standardized field-note form which included the layout of the classroom, lesson objectives, minute-by-minute sequences of lesson events, the number of participants, researchers' reflection, and further questions for the teacher and students.

Student Products

Student products were collected at the end of the unit. They included ramp models, worksheets, quiz grades, and self-evaluation sheets for students to assess quality of their group collaboration. These products were mainly used to investigate whether students gained meaningful understanding of the mathematical concepts and were able to appropriately apply that knowledge to the project. For example, the researchers measured student ramp models and compared the measurements with calculated measurements that were written in student worksheets.

Post-Interviews with the Participants

The main purpose of the post interviews in the study was to serve methodological triangulation (Stake, 1995, p. 114). To increase validity of the interpretation, the researchers developed post-interview questions for the teacher and students during the observation. For example, when the researchers observed students struggling with a certain issue, such as a function of software or new class rules, we asked the teacher and students independently how they perceived the incident and determined if it was seen in the similar way. The post-interviews were conducted immediately after the unit with the teacher and student groups independently. All interviews were audio-recorded and transcribed.

Data Analysis

The first step of the data analysis was to identify observable disturbances in the classroom practices using techniques derived from open coding (Strauss & Corbin, 1990). These techniques were used because, although we are assuming that disturbances in the activity would be found, a priori we did not know specifically what they would be. Immediately after each observation, the researchers had lengthy discussions about what they observed, referencing their fieldnotes and student products of the day until reaching agreement on their interpretation of the characteristics of the observed lesson. These debriefing sessions helped the researchers develop initial codes to identify observable disturbances. Identified disturbances were labelled for further pattern matching in the successive classes. The timelines of the observed disturbances were recorded in the research log. When similar incidents were observed in the successive classes, they were classified as a disturbance and the class discourse during the incidents were transcribed.

The second step of the data analysis was to identify patterns of disturbances, using techniques derived from axial coding (Strauss & Corbin, 1990). In other words, whereas we broke down and labelled the data at the open coding stage, we tried to put those labelled disturbances back together at the axial coding stage by making *connections* between labels and looking for categories of the patterns. For example, disturbances initially labeled "student working alone", "no help from peers", and "no partner" by open coding were categorized as "lack of collaboration" through axial coding.

The third step of the data analysis was to try to find relationships between the patterns of the disturbances and the six constructs of an activity system; subjects, objects, artifacts, community, rules, and division of labor. This coding corresponds to a second level of axial coding methodology. Referencing activity system diagrams, the researchers connected the disturbances with possible contradictions between constituents of the activity system. For example, teacher's questions to distracted students who were off-task and wandering around such as "Who are you working with? Who's your partner?" were coded as contradictions in rules and division of labor in that students were unaware at least of what the teacher's expectation was for the rules of interaction and division of labor in this ramp building project. The identified contradictions were tracked and matched up with student products to explain to what extent the contradictions affected student outcomes of the ramp project activity.

Interview data were to serve methodological triangulation (Stake, 1995). That is, when we observed an incident we asked the participants what they saw for the same incident. Through interview data we examined the consistency of the responses to the questions between three parties, the teacher, the students, and the researchers as well as sought additional observation from the participants. For example, when the teacher did not agree with what the researchers observed about tensions in a group, but if the students from the group agreed, we classified this as a contradiction between the teacher as a subject and students as a community. When the teacher and students equally disagreed with the issue that the researchers raised, we discarded the identified incidents. When the teacher or students stated incidents or meanings behind incidents that the researchers did not capture, these data were used as additional interpretation of the incidents.

To validate the interpretation of the data, a first draft of the findings which included three major identified contradictions was member checked by the participant teacher (Lincoln & Guba, 1985).

Results

This case study had three levels of units of analysis: (1) characteristics of activity system, (2) disturbances and contradictions between constituents of the activity system, and (3) individual student understanding and performance. The results of the analysis will be presented accordingly, first describing the activity system of Jorge's ramp project, second, patterns of observable disturbances and their contradictory relationships with the six constructs of the activity system, and third, impacts of the contradictions on student understanding of and performance in the unit. In each section, we will provide representative vignettes of the findings as well as interview excerpts to support our findings.

Characteristics of the activity system of Jorge's ramp project

The activity system of Jorge's ramp project practices is depicted in Figure 4-4. In this activity system, Jorge was a *subject* who had an *object* of student understanding of the Pythagorean Theorem through the project-based activity. Participant students were comprised of the class community. The object of the activity system for Jorge was student ramp models based on the appropriate use of the theorem. The desired outcome through this object was to achieve student meaningful understanding of the mathematical concepts that enabled students to apply the theorem to a real-life problem. Jorge stated his intention in the post interview as:

Researcher: How did you come up with the ramp project?

Jorge: [I was] looking for hands-on real problem solving…I included building materials and cost of the materials and started to make it something more practical…it also brought connection to integrated science with trusses and adding strength to something when putting in x here.

Researcher: So this ramp project is to give them concrete experiences with the Pythagorean Theorem.

Jorge: Yes.

For Jorge to achieve this object and outcomes, multiple mediators were placed to support the activity such as artifacts, rules, and division of labor.

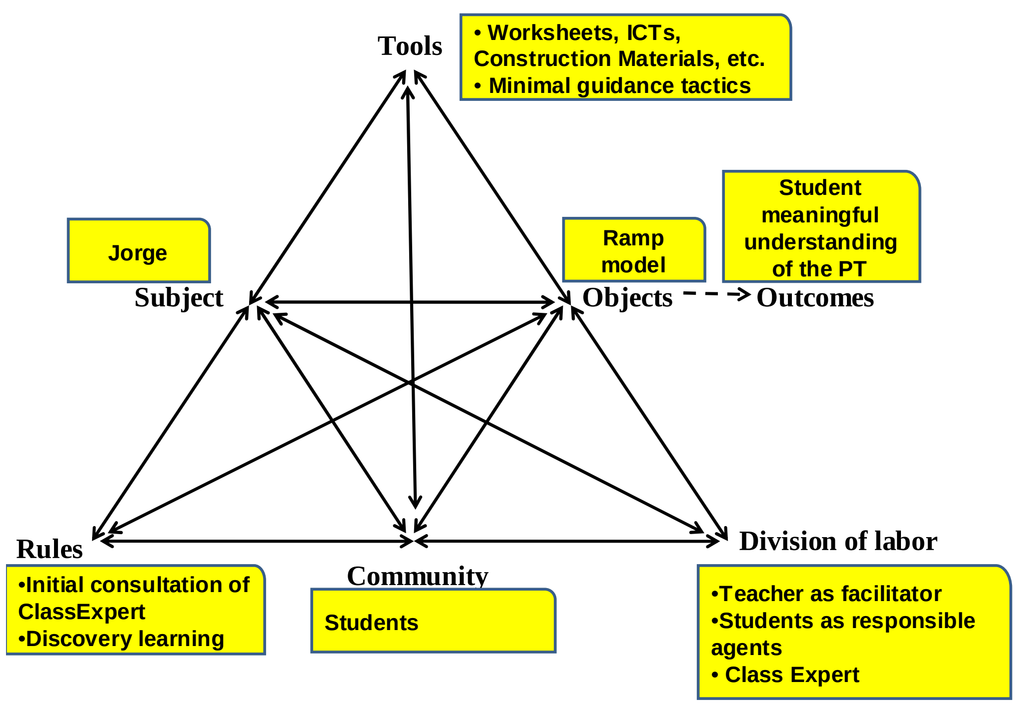

Figure 4-4. An activity system of Jorge's classroom practices of the ramp project

Artifacts that were being used in this activity included class worksheets, project instruction sheets, construction materials (cardboard, popsicle sticks, glue, wire cutters, etc.), as well as various forms of ICTs (laptops, Smart Board, printers, educational software, etc.). In this school, every student from Grade 7 on was provided with a laptop. That is, the participant students were having the first year of experiencing laptops in class. Jorge did use a variety of ICTs more frequently than any other teachers in the school. Most of the class notes were written on the Smart Board so that students did not have to divide their attention to write down their notes during lecture. These notes were saved on the school server and student could download and refer to them after class.

In Jorge's classroom practices, general norms were student-centered constructivist approaches. The following classroom discourse represented Jorge's instructional practices that promoted student engagement and thinking. It took place on the first day of the project where Jorge explained to students where and why the Pythagorean Theorem would be needed for the project.

Jorge: The top piece I want to look at the more detail.

Ss: (Chatting)

Jorge: Just a minute! (To stop student talking) You're gonna decide how big [the top piece is] with two diagonal pieces. If you want to make this one meter (vertical) and three meter (horizontal), how long would one diagonal be? How are we gonna calculate that?

S12: I think you do the length times 1.45.

Jorge: Ok.. any other suggestion?

S6: No, 1.44.

Jorge: Ok, why 1.44 instead of 1.45?

S6: That's how much… how much the diagonal is..

Jorge: Ok, interesting. Any other suggestion?

S12: Or 1.46!

Jorge: Ok, one more. I like that. That's called confusion. Let's just take out that side [top half triangle] (erasing the part). We are looking at only this diagonal. How would you describe this triangle?

Ss: Right angle triangle

Jorge: It's a right angle triangle. It has how many arms?

Ss: Two

Jorge: At the end of the arms are?

Ss: Hypotenuse.

Jorge: Is hypotenuse. Did you learn anything about hypotenuse?

Ss: Draw square on it.

Jorge: Draw square on it. Remember we had a formula $a^2+b^2=c^2$?

Ss: Ahha….

Jorge: You may be able to [use this formula]. I am not going to teach this [how to calculate x-trusses using the Pythagorean Theorem] today. This formula, this lesson gives you this diagonal [x-truss]. I don't want to spend more time on it but this is a lot more sophisticate than you think… So you need to do a little bit more thinking... I'm going to stop and want you to get back to your own thinking.

This classroom discourse well illustrated Jorge's instructional approach. In this lecture, although Jorge employed a didactic instruction, it did not show a traditional informant-receiver relationship between teacher and students. He did not tend to give direct answers for the problem. Rather, he constantly formulated provocative questions to encourage students to engage in the lecture. These questions in fact served to promote a constant dual process of, what Piaget (1970) called, assimilation and accommodation. That is, when Jorge first attempted to bring out the ramp project to the students, he did not directly show students where they needed to use the theorem which they learned previously and how the theorem related to the project. Instead, he asked questions to intentionally cause student disequilibrium on the calculation of the diagonal, and help students gradually realize how the theorem could be used to solve a real life problem such as ramp building. At the end of the conversation, upon detecting that students came to the stage where they recalled the theorem formula ("Ahha" moment), he decided to withdraw and let students work through the rest of the part as they proceeded the project. We have included Jorge's minimal guidance tactic as part of the tools of the activity system in Figure 4-4 – an unusual placement given the tactic's minimal material basis. However, it is clear from the above that minimal guidance was a deliberate tactic on Jorge's part, a condition that he felt would promote discovery learning by the groups. As such then, it is comparable to the tactic f using Geometer's Sketchpad as a tool for determining lengths of trusses.

Being consistent with this constructivist approach, his role (division of labor) throughout the project activity appeared as a facilitator of student learning and collaborator to make students more participatory and responsible agents for their learning and project activity. A unique role for this student-centered division of labor was observed, namely, "Class (or Table) Expert". At times, he called a student from each group, trained them on a certain topic (e.g., how to use functions of a software), and sent them back to their group to teach the rest of the group members. For example, on Day 1 when he distributed worksheets he announced to the class that:

Jorge: I'm gonna pass this [worksheet] out. I don't want to give you too much instruction. I want to leave you alone. As you progess, I'm gonna hold a little mini lesson. You send one person up each table to take notes. They're gonna come back and teach the lesson. So you're not allowed to be a *class*.. um.. *table expert* twice in a row.

When the researchers asked students about the rules of interaction for this role they clearly understood how it worked as the following:

Researcher: I noticed that when you guys have some questions about the work you always call someone to ask the question, I mean, your peers. How do you know who's better on what?

S6: Well, I mean, you don't always know, but usually we have…if there's a problem one person will go up and will sort of help the group out. So, usually if you go up, before you go up to ask a question, you'll usually ask the person who is sitting next to you. And if he doesn't know, you'll go up and ask on behalf of both of you.

S7: And then when you find it out, Mr. Jorge says you're like the person who's the expert in that.

Researcher: Hmm hmm.

S7: And then you teach everyone else how to do it if they don't understand.

As such, Jorge's classroom discourses in the ramp project generally represented a constructivist and student-centered practice. From a CHAT perspective, the constituents of the activity system, especially artifacts in use, rules, and division of labor, displayed multiple aspects of Jorge's constructivist student-centered classroom practices. In the following section, we will present how these constituents of the class activity system interacted with one another and why these interactions caused contradictions in the classroom practices, based on four patterns of disturbances that we observed during the project.

Disturbances and Contradictions

Four major disturbances were revealed: Student off-task behaviors, a lack of student collaboration, confusing artifacts, and rejecting Class Experts.

Student off-task behaviors

The researchers observed considerable off-task disturbances during the project-based collaborative activity. The students got off task and attempted to access the Internet or flash games; they walked around from one group to another for no purpose; they constantly flipped their laptops on and off without actually using them; the teacher frequently had to ask students to go back to work. For example, in the middle of the group work on Day 1, a student exclaimed "I know how to get The Podium of Dynamite video right now!" Such off-task and distracting behaviors prevailed on Day 1 and 2 (which was a half way through the project). They caused an enormous amount of downtime and delay in the project and consequently, three of the five groups were not able to begin the ramp construction task by the end of Day 3, which was originally set as the project due date. In the end, Jorge had to extend another day for students to complete the project.

These student off-task behaviors are in fact phenomena that considerable laptop-related research has reported as one of the greatest challenges that teachers face in an ICTs-supported constructivist classroom (Windschitl & Sahl, 2002; Wallace, Kupperman, Krajcik, & Soloway, 2000). This off-task problem in the ICT-rich classroom can be characterized from a CHAT perspective as a contradiction between the use of tools (e.g., laptops) and a lack of rules of interaction (e.g., when and how to use laptops in class), as indicated with a broken arrow in Figure 4-5. That is, rules of interaction about when and how to use laptops in Jorge's class did not sufficient mediate or support students to use laptops more effectively than could.

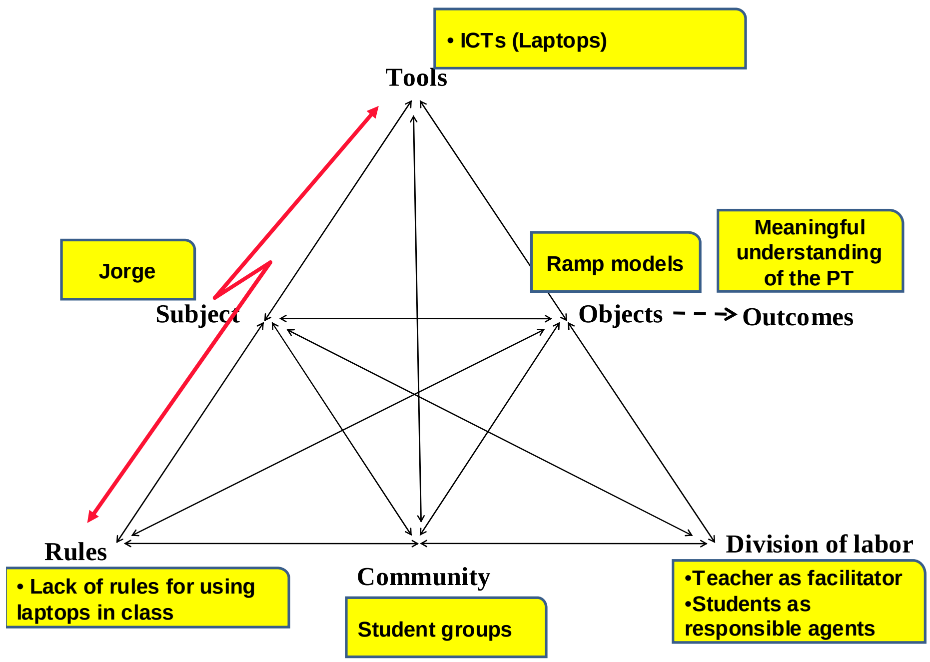

Figure 4-5. Off-task behavior disturbance characterized from a CHAT perspective

For example, it was not until Day 2 that most of the groups divided up the project into subtasks because the task where students had to use their laptops were not clearly defined and divided up – little guidance for students in carrying out the task. Not knowing what to do with laptops students were just looking at their laptop screens purposelessly and chatting with their partners. A need of new rules for using laptops was evident in the following student response to the researcher's question on whether he preferred working in group or independently with laptops:

> I like working independently with the laptop because there's nobody like distracting you. When you're working in a group, everyone's like opening their own laptops and everyone's like doing their own thing, so I feel it's easier when you're doing something independent. And also when you're in a group, I find it's easier using just one laptop and not like everyone else's laptop because everyone's more

concentrated. And also independently you're more concentrated with uh just your computer open.

A lack of shared rules between the teacher and students on when and how they could use laptops during the project activity caused unnecessary downtime in the project. Jorge's classroom practices necessitated new rules of communication for the teacher and students to avoid or to resolve tensions that the introduction of the laptop program might have created in the whole class activity system.

Lack of Collaboration

The off-task behaviors that were previously presented were significantly reduced on the third day of the project, the initial due date, because students realized there was no time to lose. As students got to work, another type of disturbance in group collaboration emerged. For example, Student 3, one of the top students, was observed not to collaborate well with his partners. He had been working alone on his laptop and the other two students were sitting beside Student 3 and chatting together for the first two days. On Day 3 Student 3 was told by Jorge several times to divide up the tasks among three of them as following:

Jorge: Ok, are you ready where you can divide labours, some people can do cutting and building or somebody else can do the other part of it (calculation)?

S3: Yes I think so.

Jorge: Ok, good.

S3: (still working alone without dividing tasks)

(2 minutes later)

S3: Mr. Jorge, what happens if we don't finish this today?

Jorge: Could you stop being so negative? We're gonna figure that out when you don't. In the mean time get to work and get the job done. But you can have some people doing... You know all these lengths. You know all these pieces. Maybe somebody in your group starts cutting and gluing or somebody else could do the other part of the paper work. It divides you more efficient.

S3, S4: Ok.

(The other students fetched glue and popsicle sticks and looked for tasks)

When the other two students realized the looming deadline they began to construct a ramp model on their own without referring to Student 3's calculation at all, and argued:

S5: (after finishing gluing one part) Rick, what else do we have to do on the ramp?

S3: (carrying out calculation tasks and did not recognize his partner asking)

S5: Rick! Ramp! Think about ramp! What else do we have to do now?

S3: (Still looking at the screen without answering S5)

S5: Rick? (angrily)

S3: (as raising his head) I don't know.

Another group also appeared to have a problematic collaboration. Because Jorge asked students form a group and divide up the tasks on their own, some of the students did not find their partners until Day 2. Finally this group of six students banded together on Day 3. This group was observed to have a hard time working through the project because of delayed formation and too many members, some of whom found themselves with nothing to do; two students calculated dimensions and costs while the remaining four students went on and off to the building task. As the project due date was approaching, this group looked frustrated with being behind and often had arguments between members on the tasks. For example, this argument between students in this group was observed on the last day of the project:

S8: I don't know how to build this [ramp]. What am I supposed to do this?

S10: Luc (S12) has to give us dimensions. We don't have dimensions. We're waiting for dimensions.

S12: That's my job.

S13: Well, I'll help you but there's nothing else to do.

S12: (to S13) You have to do Task 2. Look at Task 2.

S13: (looking at the instruction) Task 2, Pythagorean Theorem, right? That's easy. Fine. (He got a sheet of paper from the class printer and opened his laptop. Looking at the screen where the problems were displayed. Opening and looking at class note). Task 2 isn't the Pythagorean theorem.

S12: Yes it is!

S13: Alright. (5 seconds looking at his note) How am I supposed to do that?

S12: (without looking at S13 and angrily) I don't know right now! I have so many things to do now!

S13: Mr. Jorge! I don't understand what's needed right now.

Jorge: What? (as exhaling) Show me your diagram, your GSP.

Although it was the last day of the project Student 13 did not know the nature of the task and no one in the group really helped him figure it out. Also, Student 12 shouted to S 11 that "John, I need you! What are you doing there? There're four people over there (as pointing out where other members were building the ramp)!"

Such disturbances associated with student collaboration can be interpreted from CHAT perspective as a contradiction between Jorge's instructional tactic of the minimal guidance to promote pure-discovery learning (Mayer, 2004, p. 15) and unstructured division of labor, as indicated with a broken arrow in Figure 4-6. The pure-discovery mode refers to an instructional method where students were provided maximal freedom to explore, as opposed to the guided discovery mode where students were provided systematic guidance on the learning objectives. The pure-discovery teaching method has been criticized for its biased emphasis on having students experience the process or procedures of a discipline, rather than teaching the body of knowledge of a discipline (Kirschner, Sweller, & Clark, 2006; Mayer, 2004). Students need to spend more time in learning the body of knowledge of a discipline rather than the process or procedures of a discipline. In Jorge's class, students were overwhelmed by both new roles as a responsible learning agent and unfamiliar procedures that they needed to find and follow to carry out the project on their own. Although Jorge advised student groups at times to distribute their work among members, students still needed more structured division of labor to guide the collaborative learning activity, such as what to do until when with whom.

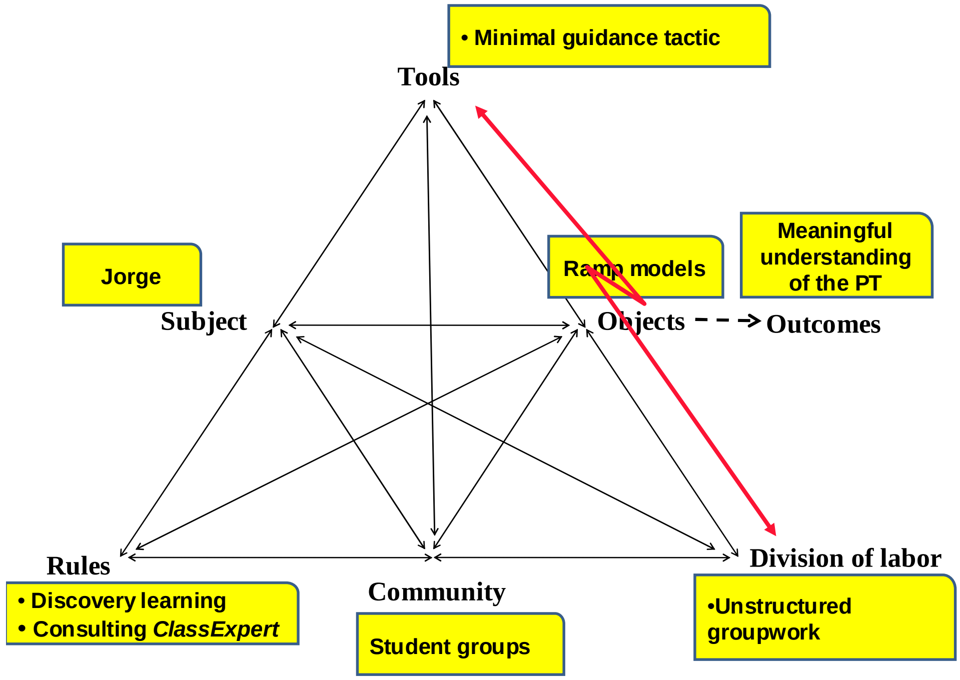

Figure 4-6. Lack of collaboration disturbance characterized from a CHAT perspective

This disturbance associated with unspecified division of labor was evident in the following interview excerpt with the group of six:

Researcher: So, how did you find the work with six people?

S11: It was very… I think it could have been easier if we were four people.

Researcher: Four?

S11: Yeah, because… when we were building the thing everyone wanted to build it and it kept on breaking apart when everyone wanted to touch it.

S13: And… and then there wasn't enough people working on the actual calculations, like the truss and everything.

Also, when researchers asked if they generally liked working in a group, Student 11 from the group responded:

S 11: I agree with Student 9 and 10 [who just said to prefer working alone] because it takes so much time to select them…it takes like a whole class or like an hour or so dividing up the work, well, why don't you just get it done yourself much quicker.

This group apparently had negative experience from the project which in turn affected their opinion about collaborative learning.

Confusing Artifacts

As described earlier, a variety of artifacts was used to support instruction and student learning, including ICTs, worksheets, construction materials, and so forth. Among them, we particularly observed disturbances in using the worksheets that Jorge designed for students to record calculations of the each part of the ramp. Jorge provided four worksheets each of which included a pre-drawn plan for each part of the ramp, such as base view, front view, side view, and under the ramp view. Students were observed to struggle with identifying which drawing represented which part of the actual ramp. For example:

S12: (looking at the screen) we have both lengths equal. Base view is the same thing as under the ramp? Or no?

S9: No, no they're not same thing.

(2 min later)

S9: I sent it.

S12: you sent it? (as opening the file from his laptop) Did you put under ramp too, or no?

S9: (no answer)

S12: what's under ramp? I don't get under ramp. Is it same thing as base view? (S8 tried to explain)

S12: Oh, under ramp is like this? (pretend to lie back)

S8: Base view is like top.... (making a ramp shape with his laptop) this is a ramp, ok? This is..

S9: No, base is back. Front is like this, top (making slope with hand) and side is side. Base is back.

S8: Guys guys, looking at the ramp like this (making a slope with his laptop).

S12: Then what's under ramp? I think this is…

S8: Under ramp is underneath.

(Argument went on for the next three minutes but the students did not come to a solid solution)

Indeed, the provided worksheets did not help students clearly match the two dimensional drawings to the three dimensional ramp. Students often became disoriented about where they were between four sheets during the design and calculation tasks, and put unnecessary effort to figure out which drawing went with which part of the ramp. From CHAT perspectives, this disturbance can be interpreted as a result of contradictions between an artefact (worksheets) and the object of the activity, as depicted in Figure 4-7. That is, confusing representation contained in the student worksheets (artifacts) were not well-enough designed for students to use as a tool to realize the object of the activity.

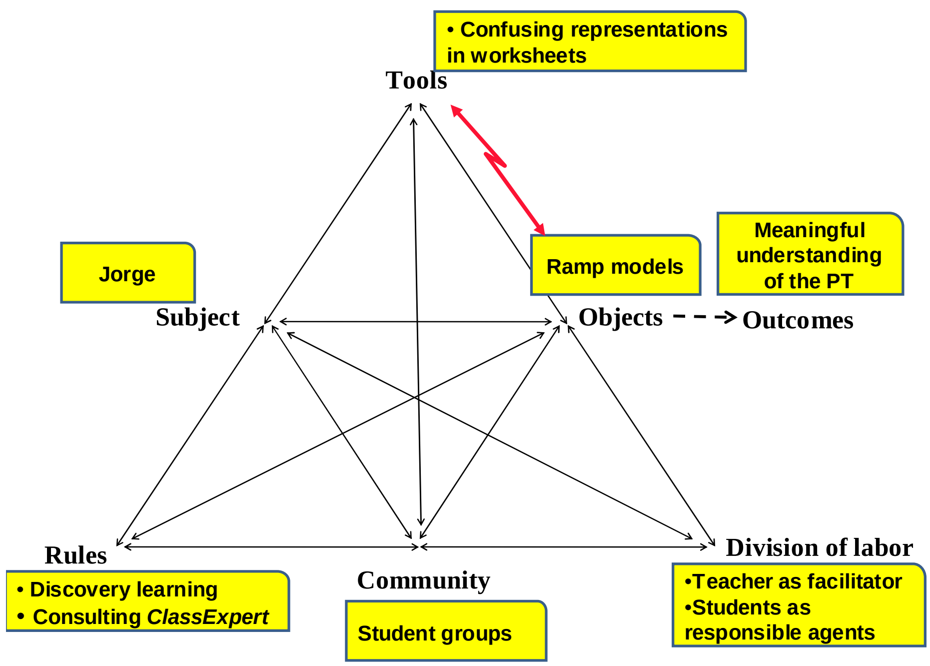

Figure 4-7. Confusing artifact disturbance characterized from a CHAT perspective

Rejecting Class Experts

The Class Expert, as presented earlier, was a unique division of labor and rule of interaction that Jorge established in order to promote student active knowledge exchange in the class community. Jorge was frequently observed to redirect questioning students to their peers who he had trained or were recognized as knowledgeable about a particular topic. However, disturbances associated with this Class Expert practice emerged as students desperately sought help from Day 3 in order to complete tasks in time. Questioning students were tossed back and forth from Jorge to Class Experts without getting an answer or help. For example, there was a group which was performing well and thus got called on a lot by their peers on the last day of the project. The group began to refuse to help at one point. This group later in the interview stated:

Researcher: I noticed that you're…you guys are doing very well so your group was asked many times by other students.

S6: …At times it got a little bit annoying because some kids, it's not so much that they're not capable. It's just they don't want to do the work or they're too lazy, so…that became a bit of a problem later and they relied on us.

This disturbance can be characterized from CHAT perspectives as a contradiction between tools (e.g., minimal guidance tactic) and rules of interaction (e.g., consulting Class Experts when having questions). It is not a contradiction in the division of labor because it was obvious to every member of the class who the Class Experts were for a topic. As illustrated earlier, Jorge used the minimal guidance tactic to promote discovery learning. He did not want to give much information about the content knowledge as well as the procedures of the project, providing the opportunity to let students think and discover how they could use the Pythagorean Theorem to build the ramp. However, this minimal guidance on content knowledge generated student confusion and thus some of the students did not find this peer-consultation rule helpful and comfortable. For example, when the researcher asked students:

Researcher: Do you prefer to ask your peers than the teacher when you have questions?

S12: Yes, peers.

Researcher: Why?

S13: Sometimes the teacher, he doesn't…

Researcher: What?

S12: It's because like sometimes he just doesn't…like *he doesn't answer our questions so, it's hard to learn…*

S11: And when he explains it, and some people don't understand, he takes like the smarter people and he says, Oh they understand, so…

S13: Yeah, he makes examples of people.

S11: And when you go ask them, they say, "Oh just ask Mr. Jorge".

Researcher: Okay.

S13: It gets mixed up.

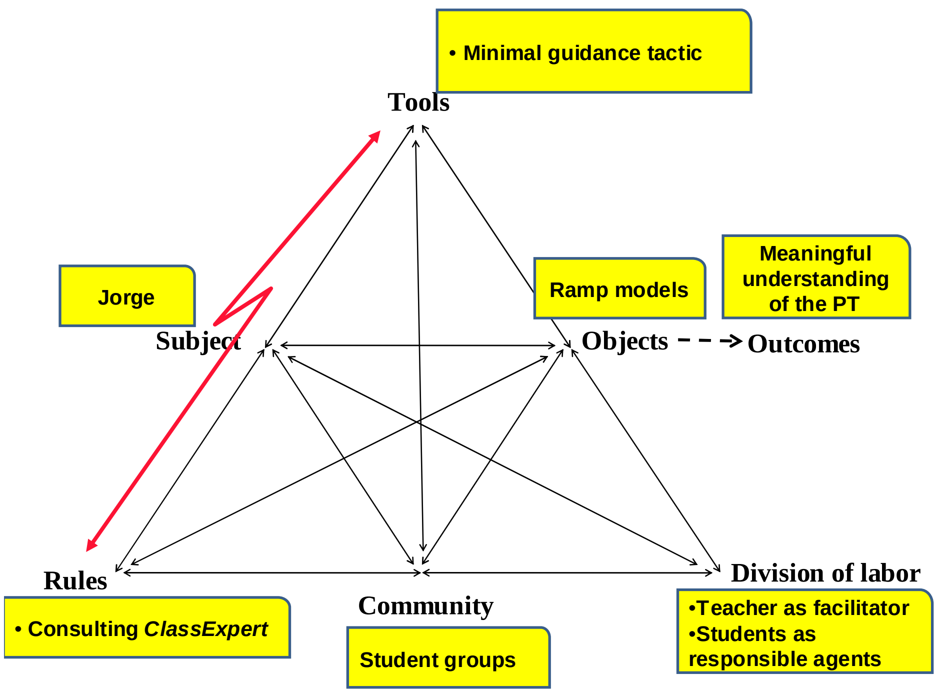

Figure 4-8. Rejecting Class Expert disturbance characterized from a CHAT perspective

This seemingly innovative rule played only a partial role in promoting active knowledge exchange in the class community because of contradictory interaction between Jorge's minimal guidance tactic and disrespected rules of consulting Class Experts among students. As a result, students ended up getting lost between Class Experts and the teacher when they really needed help.

Impacts of Contradictions on Student Understanding and Performance

Jorge's instructional tactic of minimal guidance, superficially shared rules of interaction between teacher and students, and unspecified division of labor for the group work altogether delayed the project work. As a result, students did not have sufficient time to fully integrate their mathematical knowledge of the Pythagorean Theorem with the ramp project. A close analysis of student products including worksheets and ramp models revealed that actual dimensions of all five ramps were not consistent with their designed and calculated dimensions. In other words, students somehow managed to calculate dimensions but they were not able to build their ramp in accordance with the dimensions that they had designed and calculated. Moreover, two groups, whose members constituted half of the class (8 out of 15 students), did not calculate the x-trusses at all, where the Pythagorean Theorem was required. This means more than half the students failed to find links between the theorem and the building project. Two groups were observed to build the ramp without referencing calculated measurements, as illustrated in the following group conversation:

S4: (just about to cut the stick without measuring)

S5: No you have to cut the exact..!! No no!!

Jorge: (coming to the group at hearing their argument) You don't have a pencil mark on it, do you?

S4: No, we don't have this one (measurement).

Jorge: Then how do you know how long you make it?

S4: (silent)

Jorge: Oops! (Jokingly) Take a pencil and mark it.

(A min later after Jorge was gone)

S4 & 5: (still looking for the measurement from what the other student (S3) had done alone, but not finding them)

S4: (whispering to S5) Just mark it anywhere and cut it up.

Contradictions between the constituents of Jorge's class activity system, which caused the ill-formed nature of the activity system, appeared to hinder the teacher from realizing the desired outcome, which were the student ramp models that were built on student solid mathematical understanding of the Pythagorean Theorem. Table 4-2 presents discrepancies between student calculations on the worksheets and the actual dimensions of their ramp. Students in each group are indicated in parentheses under the group name. Group E was excluded from the table because this group did not submit any of their products and they did not calculate any dimensions as they stated in the group presentation. It was only Group D that built a ramp model consistent with their calculations; however, they also failed to recognize and complete the core activity of the project, the calculation of the x-trusses that required the Pythagorean Theorem.

Table 4-2. *Discrepancies in Student Products (cm)*

	Calculated Height	Actual Height	Calculated Length	Actual Length	Calculated X-truss	Actual X-truss
Group A (S 1,2)	6.24	5	19	14.7	20.95	15.7
Group B (S 3,4,5)	4.6	1.8	12.65	10	15.02	10.5
Group C (S 6,7)	5.5	3.5	20	19.8	22.5	22
Group D (S 8-13)	4.2	4	12	12	Not calculated	12.5

All in all, only Groups A and C, who managed an appropriate division of labor during the project, were able to finish all the required activities and hand in the products on time. Groups B, D, and E spent most class time dealing with problems in their division of labor. Not surprisingly, the two groups that completed all the four sub activities were those who stated the project as enjoyable in the post interview, whereas the other groups stated it was not a fun project to work on. However, these two completing groups still failed to allow sufficient time for the construction task and ended up building ramp models without fully referring to their design and calculations.

Discussion

This study traced and analyzed classroom practices of an ICT-rich classroom from CHAT perspectives in order to understand the causes and effects of the contradictions that hindered the participants from achieving the desired outcomes. More specifically, we identified problematic incidents, namely disturbances, that occurred during the participant teacher's instructional practice of the ramp project, and interpreted the disturbances along with six constituents of the activity system in order to identify contradictions. This approach allowed researchers to more systemically understand challenges or problems that participants encountered in carrying out the activity. Findings indicated that it was not ICTs per-se that led to contradictions in the project-based ICT-supported activity; rather it was interactions between the constructivist teaching practices and the changed nature of the class activity system due to the introduction of ICTs that called for systemic adjustment of classroom practices as a whole. During the project, students were asked to organize their project work, including selecting their own group members, dividing the tasks among the members, scheduling timelines for the project, and evaluating their outcomes. However, the students appeared to be overwhelmed by too much responsibility and too little guidance on content knowledge. The responsibility of learning new content knowledge as well as organizing project work by themselves led to students becoming lost and produced enormous downtimes figuring out what to do with whom until when. Hence Jorge did not succeed in transforming the object, the ramp models, into the desired outcome, student meaningful understanding of the Pythagorean Theorem. This outcome suggests that students need more structured guidance for an ICT-supported project-based activity, such as clear rules of interaction and specified division of labor, rather than just a let-them-do mode. Such guidance would enable teachers to keep students from being off task and from focusing on peripheral or procedural tasks, which in turn could result in a lack of time to reflect on their learning and thus misconception of the learning contents (Brown & Campione, 1994; Postholm et al., 2004). As Wallace et al. (2000) showed in their research on the use of the Internet by 6th Graders, a complex task and minimal guidance does not cause complex thinking and constructive learning. They also suggested that it matters what students are asked to do and how tools and techniques to accomplish these tasks are provided.

The presented case illustrates the importance of systemic changes in promoting successful ICT-supported constructivist classroom practices, rather than a current emphasis on ICT skill training in teacher education programs (U.S Department of Education, 2003). From a CHAT perspective, ICTs are not an agent or direct cause of change but one of many other situated mediators that either support or hinder people from transforming their practices. Therefore, other multiple mediators in classroom practices such as rules of interaction and roles of teacher and students should be taken into consideration. An activity system analysis to identify contradictions allows researchers to effectively locate weak mediators that make the activity system ill-formed. More importantly, by locating weak mediators, researchers can more accurately inform local actors where to concentrate their energy on in order to make the activity system well-formed and progress.

This implies a new approach to professional development for teachers. To cultivate best practices of using ICTs in a constructivist way, researchers should pursue what the actual mediating processes in the activity systems are, uncover hidden contradictions, and construct new models of activity with the local participants, i.e., teachers and students in this case (Engeström, 1999a; Engeström, 2004; Kuutti, 1991). Engeström (1999a) asserted, "such construction can be successful only when based on careful historical and empirical analysis of the activity in question" (p. 35-36). Unfortunately, most current professional development programs are designed in a one-size-fits-all manner, which segregates ICTs from classroom contexts and mainly focuses on how to use ICTs. This might change teacher knowledge but does not necessarily help the teacher to change classroom practices, a lack of follow through that probably plays a major part in the ongoing skepticism about the current use of ICTs in school contexts. Best practices come from a well-formed activity system where all the interwoven components adequately support activities that members carry out. Therefore, a new approach to professional development for teachers should address more multifaceted activities based on contradictions faced by the teachers in their everyday practices, from making them aware of the hidden contradictions, to constructing new artifacts or models, and to consolidating new practices to realize their activity system as a well-formed one.

A key tactic would be when introducing new ICTs into instruction to carry out an analysis of what new practices with respect to the division of labor among students and teachers and the rules of interaction among students and teachers. (An example of this will be presented in the next manuscript where student worksheets were designed in order to scaffold a more effective division of labor on student ramp building project.)

Bridging Manuscript

The following manuscript presents the final part of this dissertation study, designing a well-formed activity system for an ICT-supported constructivist learning environment. It is also a case study that follows from Manuscript 2. Based on the identified contradictions in the previous study, on-site intervention for the Grade 7 mathematics classroom practices were designed and implemented in order to help the participant teacher construct and consolidate new practices.

Because this study was built on the previous manuscripts, particularly Manuscript 3, parts of Chapter V might be found somewhat redundant. To avoid this issue, the following manuscript focuses more on presenting a new approach to professional development for teachers to promote the effective ICT integration for constructivist instruction. However, the redundancy in the methodologies for the data analysis is unavoidable because the units of analysis are identical. Due to the limited space as a manuscript, I presented a summarized version of the data analysis procedures and put a footnote referring Chapter IV, instead of repeating the detailed data analysis methodologies that I already presented in Chapter IV.

All the class materials that were designed for the intervention were attached in Appendix B (Teachers' Guide), C (In-class Worksheets), and D (PowerPoint Templates). A short version of the manuscript (3,500 words) was selected and published as a book chapter in 2008. The following manuscript is a full paper that has been developed based on the book chapter.

CHAPTER V. MANUSCRIPT 3

On-site Interventions of Teaching Practices for an ICT-Supported Constructivist Classroom: Contradictions and Resolutions

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Based on:

Park, J. & Bracewell, R. J. (2008). Designing a well-formed activity system for an ICT-supported classroom: A CHAT perspective (p. 101-109). In J. Zumbach, N. H. Schwartz, L. Kestor, & T. Seufert. (Eds.). *Beyond Knowledge: The Legacy of Competence (Meaningful learning in computer-based learning environments).* Vienna, Austria: Springer Science Publishing.

Abstract

This case study presents an approach to overcome problems with information and communication technology (ICT) integration in K-12 school education. We analyzed contradictions that a Grade 7 mathematics teacher faced in his teaching practices and helped the teacher design and construct new models of teaching. Cultural-Historical Activity Theory (CHAT) framed the analysis of existing teaching practices as well as the design of interventions. Identified contradictions were (1) contradictions between the use of ICTs and rules of interaction; (2) contradictions between the teacher's instructional tactics and division of labor, and (3) contradictions between the use of worksheets and the object of the activity. To help the teacher resolve the contradiction, the observed unit was modified and implemented in the following year. Major features of the modified unit were (1) appropriate use of ICTs, (2) structured division of labor and rules of interaction for the project, and (3) enhanced reflection activity. Results indicated that the intervention and the modified unit played a large role in resolving the identified contradictions in Jorge's instructional practices and transforming his existing pure-

discovery mode of instruction into a guided-discovery mode of instruction. A new role of researchers to lessen a gap between theory and practices in the field of professional development for teachers is suggested.

Introduction

Research has shown that simply placing computers in classrooms does not necessarily change instructional practices into more constructivist ones (Cuban, 2001; Ertmer, 2005; Windschitl, 2002). The conditions for the successful integration of ICTs to promote constructivist classroom practices included teachers' belief (Ertmer, 2005; Judson, 2006; Becker & Ravitz, 1999; Windschitl & Sahl, 2002; Zhao & Cziko, 2001), professional development (Rake et al., 1999, Fishman & Krajcik, 2003), and supportive administrators and parents (Lavonen et al., 2002; Rice et al., 2001).

This study was motivated by a particular teacher, Jorge, who met all the requirements for the successful ICT integration that were indicated by the above research. He is a strong advocate of constructivism and teaches at one of the most technology-rich schools in Canada. On-site technical support is always available. He has unlimited professional development opportunities as well as a myriad selection of resources and software. However, what we found from a year-long observation was that Jorge's ICT-supported constructivist classroom activities did *not* result in meaningful student learning, largely because of student off-task behaviors and downtimes. Challenges that Jorge faced corresponded to what most teachers struggle with in ICT-rich constructivist classrooms. For example, a participant teacher in Windschitl and Sahl's study (2002) stated that it was challenging to conceive of "the intersection between the technology, the curriculum, and classroom management without knowing what a laptop-equipped classroom looked like" (p. 178). Wallace and his colleagues (2000) also stated in their study of a science inquiry learning using the Internet that students often focused more on peripheral tasks rather than the main learning activity. ICTs, then, should be seen as a catalyst that brings to the forefront a looming crisis over the implementation of constructivist instruction in the classroom (Bracewell, Sicilia, Park, & Tung, 2007). This crisis is a developing yet understudied tension between constructivist instructional approaches that expect students to be more responsible and participatory agents for their learning and history of traditional instruction that has not equipped students with the rules of interaction and division of labor to achieve effective constructivist instructional practices.

Despite these tensions and challenges in issues around the integration of ICTs to promote constructivist instructional approaches, most current teacher education programs still focus on showing teachers how to operate equipment or software (Ertmer, 2005; McCannon & Crews, 2000; U.S Department of Education, 2003). This calls for a new approach to professional development for teachers. In order to design professional development to help teachers effectively use ICTs to promote constructivist pedagogical activities, we need to address systematically the issues that teachers face when adopting and integrating ICTs in their teaching practices through a comprehensive understanding of social dynamics and cultural complexities of local conditions of constructivist classroom practices.

This study intervenes on a Grade 7 teacher's constructivist teaching practices supported by various forms of ICTs. We first observed the participant teacher's instructional practices over the course of a year, analyzed tensions and contradictions that emerged in his classroom practices, selected and modified a unit focusing on resolving identified contradictions, and implemented the unit in the following year. Cultural-historical activity theory (CHAT) framed the analysis of the teaching practices and the design of the learning activities. We were hoping to illustrate through this study that an ICT-integrated constructivist classroom does not result from a teacher's individual action, but requires the transformation of "societal" aspects of collective classroom practice incorporating various factors that mediate students and teacher to carry out the activities.

Constructivism and ICTs in Classrooms: Happily Married?

Nearly two decades ago, Perkins (1992) wrote an chapter "Technology meets constructivism: Do they make a marriage?" in a book *Constructivism and the Technology of Instruction: Conversation*, in which proponents in the field of educational technology eagerly put their efforts together to envisage the forthcoming era of a massive educational reform due to the new practices in education and the rapid development of technology. In his chapter, Perkins claimed that information technology could help overcome the existing impediments to constructivist classroom learning by enhancing five facets of a learning environment, such as information banks, symbol pads, construction kits, phenomenaria (simulations), and task managers. Indeed, technology has advanced enough to enhance those facets that he classified: Students have an access to the insurmountable amount of information via the Internet; symbol pads can be easily produced as in professional-looking text and graphics; automatic construction kits are available such as Geometer's Sketchpad and robotics applications; simulated phenomena from microworld to SimCity that students can manipulate are no longer new; and computerized task managers are beyond imagination. Now, with all those advanced ICTs, have our K-12 classrooms effectively promoted constructivist classroom practices?

Findings of recent research on teachers' adoption of information and communication technologies (ICTs) in their classrooms are not as promising as Perkins predicted two decades ago. Most teachers have been overwhelmed by reforms that call for implementation of constructivist instructional practices and coped with this demand by using ICTs in an incremental way to sustain their traditional teaching approaches (Cuban, 2001; Cuban, Kirkpatrick, & Peck, 2001; Ertmer, 2005). Given that ICTs did their duty by advancing enough to allow multiple facets of a learning environment, a large problem with this not-so-happy marriage between technology and constructivism can be found in the latter, and more specifically, with constructivist practices in classroom.

Confusions and disjuncture between theory and practice in constructivism are not new. Windschitl (2002) attributed this confusion to teachers' partial understanding of a constructivist approach where teachers let students structure their own learning and rely on hands-on activity on its own sake without careful thinking on its intellectual implications. Park, Bracewell, Sicilia, and Tung (2007) revealed teachers' misunderstanding of constructivist instruction led students to unsuccessful learning. Kirschner, Sweller, and Clark (2006) also criticized the current educational application of constructivism for its somewhat biased emphasis on having students experience the process or procedures of a discipline, rather than teaching the body of knowledge of a discipline.

The challenge, then, is how much of a constructivist one should be (Mayer, 2004; Perkins, 1994). This challenge evolves into the questions: how much and what kind of guidance should be provided to promote student learning without collapsing the potential zone of proximal development?

Understanding Practices from a CHAT Perspective

Teaching is complex practice, no matter whether it involves constructivist or traditional approaches with/without technologies. It encompasses numerous factors inside and outside of a classroom, including various stakeholders with possibly different goals for schooling (e.g., students, teachers, administration, parents, etc.), many artefacts to use (e.g., textbooks, whiteboard, worksheets, computers, etc.), various rules for the effective communication and interaction (e.g., behaviour codes, assignment due, school policy, etc.), and many more. Furthermore, these multiple constructs that constitute school practices are not stable but constantly adapted, abandoned, or re-created through everyday activity. Given the complexity of the school context it is reasonable to say that we cannot place technology in classrooms and expect teachers to transform their traditional teaching practices into a constructivist one. Along the same line, the matter of how much and what kind of guidance needs to be in place for successful constructivist instruction is heavily dependent upon the pedagogical, cultural, and societal aspect of teachers' teaching practices.

In this regard, CHAT is a promising approach that allows researchers to systemically account for educational practices as all the basic characteristics of the whole (Vygotsky, 1986). A core premise of CHAT is a dialectical transformation between individuals and environments. They affect and are affected by each other through various kinds of material/symbolic *mediations*.

The construct of mediation distinguishes CHAT from other psychological theories because it removes the mystery of motives or intentions from the internal and biological systems of individuals to the external and more accessible nature of object that is produced, modified, and transformed by collective activities (Miettinen, 2001, p. 305). For example, Vygotsky (1978, 1986), the originator of CHAT, investigated children's development of higher psychological processes by tracing children's use of external aids (mediators) and explained:

> … a neutral object is placed near the child, and frequently we are able to observe how the neutral stimulus is drawn into the situation and takes on the function of a sign. Thus, the child actively incorporates these neutral objects into the task of

> problem solving. We might say that when difficulties arise, neutral stimuli take on the function of a sign and from that point on the operation's structure assumes an essentially different character. (Vygotsky, 1978, p. 74)

In such experiments Vygotsky presented a potential mediator or external aid for students to reach beyond their ability. He traced the process wherein such achievement took place by looking at student use and manipulation of the external mediator.

Leont'ev (1978) expanded the construct of mediation from sign to object in order to address a broader context of collective activity, rather than individual action. Engeström's (1987) diagram of activity system triangle expanded the notion of mediations even further to fully account for dynamics of human activity. The multiple mediations included material (tools) as well as more abstract ones (rules and division of labor). The six components of the activity system triangle are subjects, objects, tools, rules, community, and division of labor, as shown in Figure 5-1. The central theme of CHAT is that individuals (subjects) pursue goals (objects) in a certain community. These goal-oriented activities are mediated by various material mediators like instruments (tools) as well as less material mediators like rules of communication and divisions of labor. When these mediators sufficiently support subjects to carry out the activities, the objects can be transformed into outcomes.

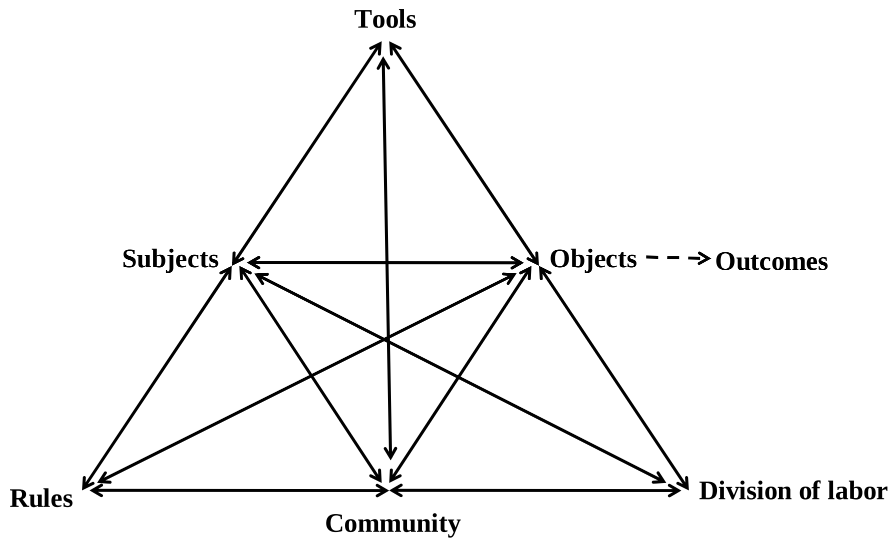

Figure 5-1. The general structure of a human activity system (Engeström, 1987, p.78)

The dotted arrow between objects and outcomes represents the importance of the transformation process. Without this process, activities that subjects carry out cannot be said to be "activity" from a CHAT perspective because in CHAT activity does not just refer to "doing" but "doing in order to transform something" (Barab, Barnett , Yamagata-Lynch, Squire, & Keating, 2002; Engeström, 1987; Kuutti, 1991). In CHAT, differentiating action from activity is vital. Action is temporal, individual, and goal-oriented whereas activity is long-term, historical, collective, and motive-driven (Engeström, 1999a; Leont'ev, 1978). Here, a goal is not to be confused with a motive; rather, a goal is different from and is subordinated to a motive. This specification can be best understood by Leont'ev's famous comment on activity versus actions in hunting: "the beater's activity is the hunt, and the frightening of the game his action" (Leont'ev, 1981, p. 210).

A more pertinent example is that a teacher's one-time enactment of a project-based strategy or use of ICTs in his/her classroom is a goal-oriented individual action, which can be depicted by the uppermost triangle of the activity system. When other mediators such as rules and division of labor support the teacher's action or the enactment of constructivist instruction, this action can lead a collective classroom activity where objects of the activity can be transformed into a desirable outcome. However, if other mediators do not change to support the activity despite the teacher's new action, the teacher's project-based instruction is stalled at the teacher's individual action level.

Intervention as Expansive Visibilization of Distance between Action and Activity

Change in one part of an activity system often creates problems in another part of the system. For example, a teacher's enactment of new instructional strategies or introduction of new software to students can at first cause disturbances in existing classroom practices such as student off-task behaviors or a lack of resources to use the software. In CHAT these disturbances are results of contradictory interaction between a mediator that has obtained new potential and the other mediators that have not changed. Such problems are seen as "contradictions[7]" in CHAT. Contradictions are not all bad because they are the "engine" for the activity system to move forward in CHAT. Development is seen as an attempt to adjust, abandon, or re-create mediators in the activity system in order to resolve contradictions (Engeström, 1987; 1999; Kornilov, 1924, as cited in van der Veer & Valsiner, 1991). In other words, to realize the goal of the teacher's action for the new software s/he must adjust or create new rules of interaction or division of labor. When they are not sufficiently adjusted the goal of this action cannot be reached and thus the integration of the software in his/her instructional practices is stalled at the teacher's individual action level. We regard such activity systems as being ill-formed in that the rules of interaction and divisions of labor are not sufficient to support the effective use of tools (i.e., software) for instruction and learning, as opposed to being well-formed where other components are changed to resolve emerging

[7] According to Engeström (1987), contradictions of human activity consist of four levels: The primary level is an inner and inherent contradiction within each construct of the central activity (for example, the classic Marxist contradiction inherent in a tool that one makes, in that one can either use it to make something or exchange it for something else). The secondary level is contradictions between the constructs of a given activity system (for example, those outlined above between tools on one hand and rules of interaction and division of labor on the other). The third level is contradictions between the object/motive of a dominant form of the central activity and the object/motive of a culturally more advanced form of activity (for example, play as the central activity of children and education as the more advanced activity). Finally, the fourth level is contradictions between one major activity system and its neighboring ones (for example, family activities and work activities).

contradictions (Figure 5-2). Comparing the two representing figures, one can easily see which triangle forms a well-formed pyramid whereby the three mediations are equally developed and hence capable of acting in synergy.

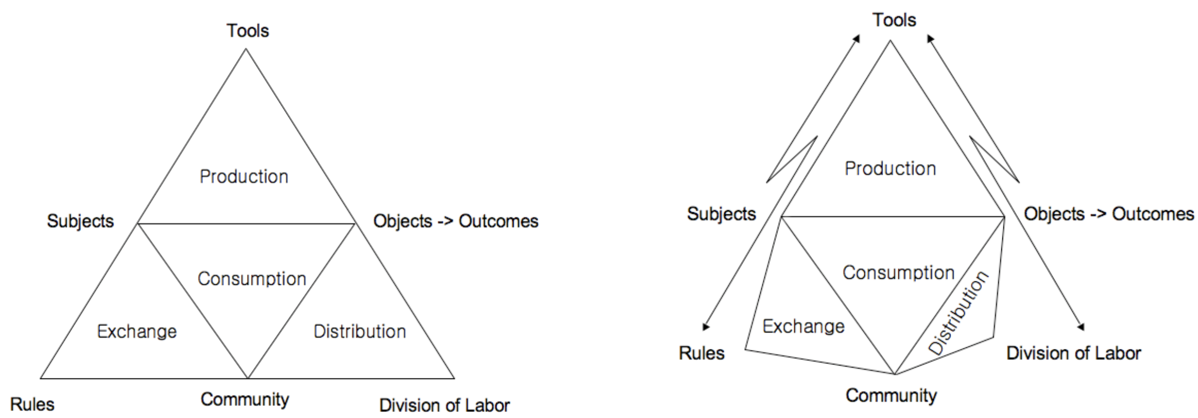

Figure 5-2. A contrast of well-formed and ill-formed activity systems

An intervention from a CHAT perspective then means facilitating the development of an activity system as a whole in a way that leads individual action into collective activity to resolve emerging contradictions. A role of researchers is in turn to make these disturbances visible to the participants and connect these seemingly random incidents with contradictions in the whole activity system (Engeström, 2000).

Engeström (1999a, 2000) illustrated the expansive cycle of learning as shown in Figure 5-3, where participants collectively question and externalize problems, seek and institute new solutions, and reflect and consolidate (internalize) new practices. Intervention, in this schematic cycle, is to facilitate participants to progress as far as possible—otherwise participants often halt at the initial stage and only question the stagnant development of their practice.

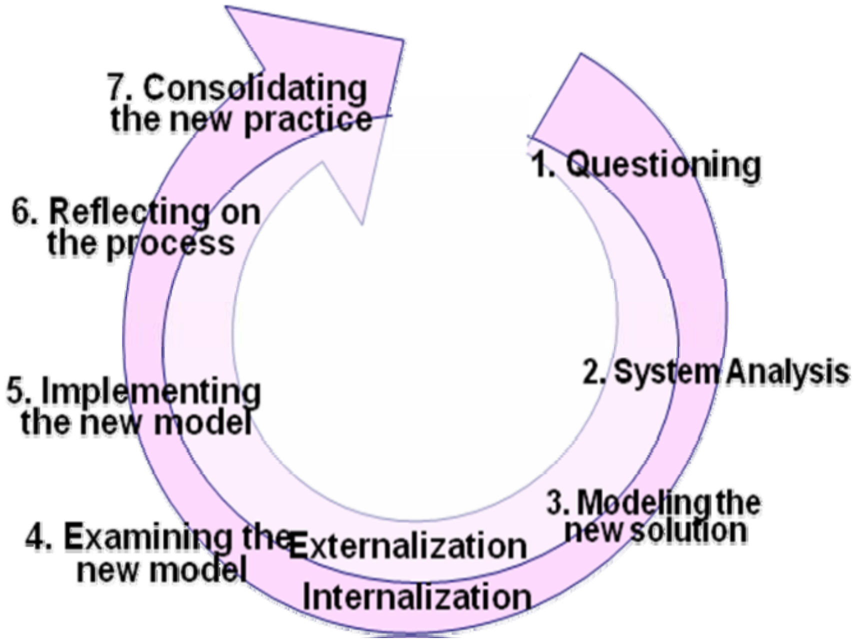

Figure 5-3. The expansive cycle of learning (adopted from Engeström 1999a, 1999b, 2000)

There have been a large number of intervention studies from CHAT perspectives in the field of workplace transformation. Engeström (1999b) facilitated the transformation of a children's hospital in Finland, where two hospitals merged together. He identified four steps of intervention: (1) videotaping practices and making contradictions visible to practitioners; (2) modeling activity systems using the triangular template and examining patterns of contradictions; (3) designing and implementing interventions; and (4) following and revising expected/unexpected consequences. He concluded that an innovative solution to contradictions may cause new unexpected contradictions and open up a possibility to the new expansive cycle of development. Roth and Tobin (2006) examined contradictions in the process of initial teacher education and attempted to redesign a teacher education program by providing new teachers with co-teaching approaches with in-service teachers. Findings indicated that their redesign process formed more participatory relations between new teachers and cooperating in-service teachers than had been seen in the past.

Although an increasing number of studies investigated from a CHAT perspective tensions and contradictions in class activity system at various school levels, few studies have attempted to intervene on actual classroom activity based on identified contradictions (e.g., Barab et al., 2002; McDonald, Le, Higgins, & Podmore 2002). This study aimed at helping the teacher realize a more structured way of constructivist instruction by making him aware of dynamics of classroom contradictions. Therefore this study addresses the following questions.

Research Questions

(1) From a CHAT perspective, what contradictions occur in the activity system of an ICT-supported constructivist classroom?

(2) What conditions have to be in place in order to reduce the identified contradictions?

(3) Does reducing contradictions on the existing mediators (division of labor, rules of interactions, and the use of tools) realize a well-formed activity system that promotes more substantive objects/outcomes of the activity?

Research Context

The selected school is an all-boys private school with about 600 students from kindergarten through secondary school. It is one of the most technology-rich schools in Canada where students from Grade 7 on are provided with a laptop and wireless access to the Internet. Every classroom is equipped with a Smart Board, projector, and printer. There are three full time technicians and a pedagogical consultant at their disposal. The majority of students are from middle to upper social economic status and their academic performance is average and above average. The class sizes are 15 to 20.

Our research team has looked at teachers' adaptation of ICTs in their classroom for the last three years in this school (Bracewell, Sicilia, Park, & Tung, 2007). The present intervention study was motivated by a particular teacher in the school, Jorge, a 20+ year experienced mathematics and science teacher, who is a strong advocate of constructivist inquiry-based instruction and used various ICTs more frequently than any other teachers in the school. Despite his good intention, his actual classes were often observed to be quite chaotic and off-task. For example, Jorge designed and implemented "The neighborhood skate ramp project" in his grade 7 classes to teach the Pythagorean

Theorem, which he stated his intention as "[I was] looking for hands-on real problem solving…to start to make it something more practical". However, the project ended up failing to promote student mathematical understanding: only one out of five groups was able to use the Pythagorean Theorem appropriately to build their ramp. To this end, we decided to identify contradictions of this unit that hindered the successful integration of ICTs in Jorge's constructivist practices and design interventions to help him to resolve the contradictions in the following year. The number of students in Jorge's class was 15 in 2006 and 14 in 2007.

Procedure

Adapted from Engeström's (2000) "ethnography of trouble", the intervention procedure of this study consisted of four phases (Figure 5-4). Ethnography of trouble is a methodology to identify contradictions in everyday practices and make them visible to the local actors of the activity.

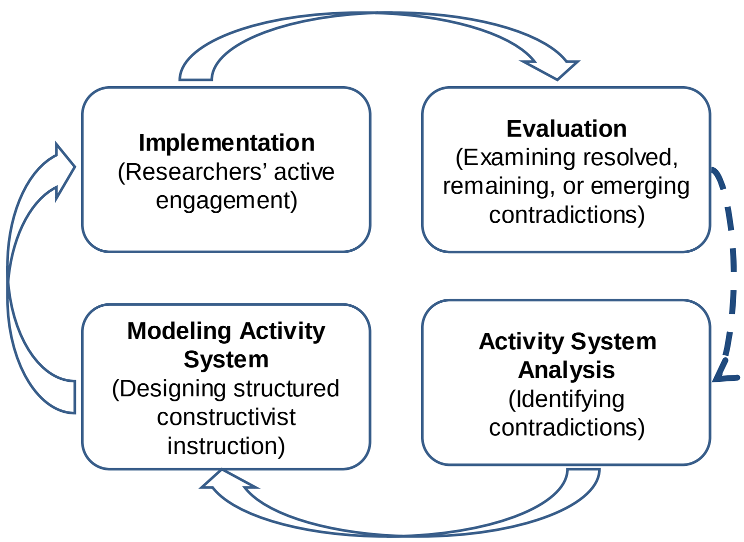

Figure 5-4. Intervention procedure

The first phase was an activity system analysis to identify contradictions. This phase allows researchers to explore critical aspects of activity in terms of learning, changing, or development, rather than to describe "the status quo" of the activity (Hasu, 2001). The unit of analysis to identify contradictions is patterns of disturbances because according to Engeström (2000) contradictions manifest themselves through disturbances, rupture, or small innovations. The researchers attempted to first identify disturbances in Jorge's classroom practices and second provide explanations of the disturbances in the light of contradictory interactions between constituents of the class activity system[8].

The second phase is to model a potential well-formed activity system where the identified contradictions could be resolved. Identified contradictions were debriefed to the participant teacher as a part of intervention. The researchers held three debriefing meetings for this purpose. This researcher-teacher engagement is an important process in intervening practices from CHAT perspectives because it helps to "connect seemingly random incidents with contradictions in the activity system" (Engeström, 1999a, p. 68). By recognizing recurring patterns of disturbances and contradictions, both researchers and practitioners become able to conceptualize a tentative "troubled" scenario as well as a possible future where contradictions are resolved. In other words, this process was to make the teacher become aware of hidden contradictions and concentrate his energy on resolving the contradictions, and to help him consolidate new practices. Particularly in Jorge's case, we attempted to make him aware of hidden tensions between mediating constructs of his class activity system and suggested where, what kind of, and how much structure or guide Jorge would need to solve the tensions, that is, a more guided approach to constructivist instruction with ICTs.

The third phase was the implementation of the intervention. With a close collaboration with the participant teacher, the ramp unit was modified and implemented in the following year. Park, the first author of this study, participated in every class of the four-week project and facilitated the teacher to effectively reflect on daily changes in his instructional practices.

The fourth phase was the evaluation of the intervention. Because the intervention was designed based on the identified contradictions in Jorge's class activity system, the effectiveness of the intervention was examined by tracking whether the contradictions prior to the intervention were resolved or remained. More specifically, as an evidence of the resolution of the contradiction, patterns of disturbances in the ramp project activity

8 For detailed methodology to identify contradictions, please see Park, Bracewell, and Sicilia in Chapter 4.

prior to and after the intervention were compared. Classroom observation, videotaped classroom discourses, student products, and post-interviews with the teacher and students were main sources of data, as follows.

Data Collection

The main sources of data were classroom observation, videotaped classroom activities, minute-by-minute fieldnotes by at least two researchers, student products, and post-interviews with the participants in order to analyze the activity system of Jorge's class of before- and after-intervention.

Classroom activities of the unit in 2006 and 2007 were videotaped and observed by at least two researchers. The researchers recorded their observation in a standardized field note form, which included layouts of the room, lesson objectives, minute-by-minute sequences of the lesson, the number of participants, researchers' reflection, and further questions for the teacher and students.

Student products were also collected at the end of the unit, including worksheets, quiz, powerpoint presentations, and ramp models. This data were mainly used to investigate whether students gained meaningful understanding of the mathematical concepts and appropriately applied the knowledge to the project.

Post-interviews were conducted with the teacher and student groups independently. The main purpose of the post interviews in the study was to serve methodological triangulation (Stake, 1995, p. 114). To increase validity of the interpretation, the researchers developed post-interview questions for the teacher and students during the observation. For example, when the researchers observed students struggling with a certain issue, such as a function of software or new class rules, we asked the teacher and students independently how they perceived the incident and determined if it was seen in the similar way. The post-interviews were conducted immediately after the unit with the teacher and student groups independently. All interviews were audio-recorded and transcribed.

In the following sections, results of the activity system analysis prior to the intervention will be presented, focusing on identifying disturbances and contradictions.

Then, the major features of the intervention will be presented, followed by results of the intervention.

Activity System Analysis: The Ramp Project Prior to the Intervention[9]

The ramp unit, called "The neighborhood skate ramp project", was a four-day lesson. Jorge designed a lesson plan including worksheets, evaluation rubrics, and electronic representations of mathematical concepts to help students understand the activity. Subtasks in the unit included (1) calculation of the lengths of x-trusses of the ramp using the Pythagorean Theorem, (2) drawing plans on papers, (3) calculation of cost of their ramp if it were built in a real size using given prices of plywood, (4) crafting a 1:10-scaled ramp model using cardboards, wood sticks, and glue. Each class lasted 75 minutes.

From a CHAT perspective, Jorge's planning and implementation of the ramp project was his individual action driven by a more long-term motive, promoting student meaningful understanding through student-centered learning activities. In this particular unit, Jorge was a *subject* who had an *object* of student ramp model building through the project-based activity. Participant students were comprised of the class community. The desired outcome of the activity system for Jorge was to achieve student meaningful understanding of the mathematical concepts through hands-on practices as he stated in the interview. This activity was supported by multiple mediators such as various forms of tools (e.g., ICTs, worksheets, construction materials, instructional tactics, etc.), multiple rules of communication and/or division of labor.

The activity system analysis of the ramp project unit revealed four patterns of disturbances: a lack of collaboration in group work, student off-task behaviors, confusing learning artifacts, and rejecting rules for peer-consulting. These disturbances in turn were characterized from a CHAT perspective as contradictory interactions between constituents of the activity system.

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[9] The complete version of the activity system analysis of Jorge's ramp unit prior to the intervention is presented elsewhere (Park, Bracewell, Sicilia, & Tung, 2006; Park, Bracewell, & Sicilia, in final preparation).

First, a lack of collaboration was characterized as a contradiction between tools (e.g., Jorge's minimal guidance tactic) and division of labor (e.g., unspecified group work). Jorge employed minimal guidance tactic as an instructional tool to promote discovery learning, as he stated in an informal conversation with the researchers. This minimal guidance was not only for the content knowledge but also for the procedures of the project. For example, Jorge asked students to group themselves, divide up the task into subtasks, and plan the timeline of the project. Such minimal guidance exacerbated the chaotic circumstances associated with ubiquitous technology of the classroom and unspecified division of labor, and acted as an obstacle for students to complete their objects of the activity, i.e., the ramp building project. It was found that half of Jorge's students struggled with grouping and dividing the tasks throughout the activity. One particular group finally formed a group of six on the third day, which was planned as the last day of the project, and they clearly showed frustration to meet the project due date and often appeared to have argument on who would do what. A student from this group stated in the post interview that, "when we were building the thing everyone wanted to build it and it kept on breaking apart when everyone wanted to touch it.… and then there wasn't enough people working on the actual calculations." Students were overwhelmed by both new roles as a responsible learning agent and unfamiliar procedures that they needed to find and follow to carry out the project on their own. Students needed more structured division of labor to guide the collaborative learning activity, such as what to do until when with whom.

Second, student-off task behaviors were characterized as a result of a contradiction between a lack of rules of interaction (e.g., when and how to use laptops in class) and tools (e.g., one-on-one laptops and ubiquitous ICTs) in the class. Jorge used various forms of tools, such as one-on-one laptops, Geometer's Sketchpad, Smartboard, Internet, worksheets, construction materials, and so forth. The researchers observed considerable off-task disturbances during the ramp project activity, especially due to the presence of the laptops. This is, in fact, one of the most frequently reported challenges that teachers face in the laptop-based classrooms (Bracewell, Sicilia, Park, & Tung, 2007; Wallace et al., 2000, Windschitl & Sahl, 2002). Students got off task and attempted to access the Internet or flash games; they walked around from one group to another for no purpose;

they constantly flipped their laptops on and off without actually using them; the teacher frequently had to ask students to go back to work. This disturbance was interpreted as a contradiction between rules of interaction and tools because the task where students had to use their laptops was not clearly defined and divided up – there was little guidance for students in carrying out tasks, which was closely related to the unstructured division of labor addressed earlier. Because the division of labor for the group work was not sufficiently specified for students, they were barely able to set up rules of interaction within their group to carry out the tasks. Without knowing what to do with whom until when, students with laptops at their disposal got easily off task and attempted to access the Internet or flash games and walked around from one group to another for no purpose, which resulted in substantial downtimes and thus left them short of time to reflect and establish links between the ramp building activity and the Pythagorean theorem.

Third, confusing artifacts were characterized as a contradiction between tools (e.g., student worksheets) and the object of the project (e.g., ramp building). Jorge provided students with four worksheets of plan that each represented a required pattern to build a ramp. Students were asked to calculate the dimensions of each plan and write on the worksheets. However, the representation of each plan of the ramp model was not helpful for 7th graders to appreciate which piece goes where in the ramp. More importantly it was quite challenging for the students to conjecture what the ramp model would look like from the two dimensional plan, which in turn played a significant role in failing to indicate the necessity of the x-trusses where the Pythagorean theorem should come in. As a result, on many occasions students flipped back and forth between the worksheets spending extra time to figure out where they were and thus more than half the students (8 out of 15) did not put the trusses for the ramp, indicating that students could not find a link between the theorem and the ramp project.

Fourth, rejecting rules for peer-consulting was characterized as a second contradiction between tools (e.g., Jorge's minimal guidance tactic) and rules of interaction (e.g., peer-consulting). In Jorge's class there was a unique rule, called consulting "Class Experts". "Class Experts" referred to student resources who were recognized as knowledgeable on a particular topic and to whom Jorge redirected students who had questions on the topic to. At times, Jorge nurtured Class Experts by calling out one student each from the student groups and teaching new concepts or skills for the day. These students then went back to their group and were supposed to teach the other members of the group. These new rules appeared to help students exchange their knowledge with their peers and develop responsibility for their learning. However, his instructional tactics of minimal guidance, despite his intention of student-centered learning, appeared to overwhelm students at the end of the project. Jorge's minimal guidance on content knowledge as well as project procedures generated student frustration and confusion and thus some of the students did not find this peer-consultation rule helpful and comfortable. For example, some of the Class Experts appeared to get annoyed and refused to help peers because they were asked excessively by many frustrated peers as the project due date approached. As a result, students ended up getting tossed back and forth and lost between Class Experts and the teacher when they really needed help.

Altogether with these contradictions, the object of the Jorge's action of the enactment of the project-based class activity, which is "student ramp models", did not appear to be transformed into the desired outcome, which was "student meaningful understanding of the Pythagorean Theorem". At the beginning of the project, students were observed to be quite excited about the project; however, as time went by, and as students realized the project due date was fast approaching, the excitement turned largely to frustration. Jorge had to extend the project because none of the student groups completed by the end of the third day. So the project lasted four days in the end. A close analysis of student products, including worksheets and ramp models, revealed that none of five groups built ramp models for which actual dimensions were consistent with their design and calculations. In other words, students somehow managed to calculate the dimensions; but they were not able to build their ramp in conformity with the dimensions that they designed and calculated. Moreover, two student groups, whose members constituted a half of the class (8 out of 15 students), did not calculate the x-trusses at all, where the Pythagorean Theorem needed to be used. This means more than half the students failed to establish links between the theorem and the building project. In sum, Jorge's action of the enactment of constructivist activity was not fully transformed into collective class activity of student-centered learning because the other components of the class activity system, such as rules of interaction and division of labor, had not been adjusted to sufficiently mediate or support the activity.

Designing intervention: How constructivist should the ramp project be?

The modification of the unit drew on the mutual agreement between the teacher and the researchers on three major contradictions to be resolved. The major features of the modified unit were (1) appropriate use of tools, (2) structured division of labor and rules of interaction, and (3) enhanced reflection opportunity.

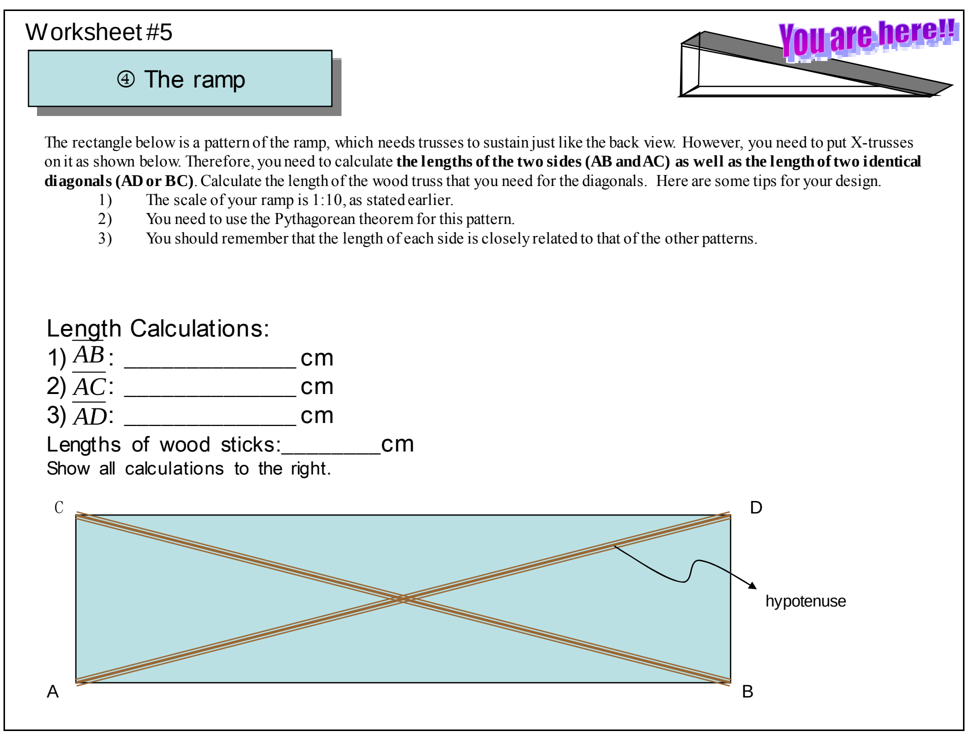
First, to realize appropriate tools that Jorge and students used in the project, various artifacts were designed and provided. Main artifacts included a transparent ramp model where all sides of the ramp were clear plastic so that students could see through the structures of the ramp (e.g., x-trusses, wood supports, etc.), ramp plan representations on the worksheets that could visually help students orient where they were (Figure 5-5, At the upper right corner it displays with a shadow area that which part in the ramp this plan goes to and where they are working at.), and a Geometer's Sketchpad task where students could verify their calculations by hand with the help of the software before they went into the building stage. These tools are in line with "cognitive tools" (Lajoie, 2000; Jonassen & Reeves, 1996) and "external aids" (Vygotsky, 1978) that scaffold student psychological processes and reduce cognitive overload by largely distributing mundane tasks to the tools.

Second, to help establish more structured division of labor and rules of interaction, a team-up activity was given a special emphasis. For example, a separate worksheet was provided where subtasks for the ramp project were explicitly presented and students were asked to divide up the tasks and write the names of the persons who were in charge of each task (Figure 5-6).

Third, to enhance student reflection, students were not only asked to track every change, mistake, challenges, and solutions (if solved) of their project, but also were provided a PowerPoint presentation template that encouraged students to reflect on and learn from mistakes that they made. This was mainly to help students find links between the ramp building (e.g., the object of the activity) and a mathematical understanding of the Pythagorean Theorem (e.g., the desired outcome of the activity), which could also be partly done by the previously described modifications. The guidelines included an introduction of team members in terms of their roles, justification of their ramp design, characteristics of their ramp models, where the Pythagorean Theorem were used, errors that they made during the project, and lessons learned from this unit.

The evidence of agreement by the teacher can be seen in the following excerpt from one of the collaborative meetings:

> Researcher: So, how did you find the course design?
>
> Jorge: very nice. I think it's great. It's really well put together.
>
> Researcher: Do you feel that we deviate from what you really want to do?
>
> Jorge: No not at all. It also solved some of the problem. It simplified things to very nice direction…. I think especially put the graphics that they actually can see and make it clear to them where is the actual Pythagorean Theorem coming in. Which is actually what we want them to do.


Worksheet #5

④ The ramp

You are here!!

The rectangle below is a pattern of the ramp, which needs trusses to sustain just like the back view. However, you need to put X-trusses on it as shown below. Therefore, you need to calculate **the lengths of the two sides (AB and AC) as well as the length of two identical diagonals (AD or BC)**. Calculate the length of the wood truss that you need for the diagonals. Here are some tips for your design.

1) The scale of your ramp is 1:10, as stated earlier.
2) You need to use the Pythagorean theorem for this pattern.
3) You should remember that the length of each side is closely related to that of the other patterns.

Length Calculations:

1) $\overline{AB}$: ______________ cm

2) $\overline{AC}$: ______________ cm

3) $\overline{AD}$: ______________ cm

Lengths of wood sticks:_________cm

Show all calculations to the right.

Figure 5-5. An example of the worksheet that helped students orient themselves.

Worksheet #1

Team-Up

You need to collaborate with your peers to do this activity. Therefore, the first task for you is to team up a group of three. Each person should take responsibility for a certain task to get it done in a given time. The below table will help you to divide up the tasks among the members of your group, as well as to schedule your work.

	Task1: Team-up	Task2: Design and Calculate Dimensions	Task3: Verification of Your Dimensions with GSP	Task4: Build Ramp	Task5: Presentation*
Name of person in charge	N/A			Supposed to be done by all of the team members	
Due	Day 1	Day 2	Day 3	Day 4-5	Day 6
Expected Outputs	This worksheet (WS #1)	Worksheets (WS #2,3,4,5,6)	GSP-generated plans, Worksheet(WS #7)	Ramp model, Worksheet (WS #8)	Powerpoint of your presentation
Evaluations		Rubric #1	Rubric #2	Rubric #3	Rubric #5
		← Self-Evaluation for Collaboration (Rubric #4) →			

*Note: Those who are in charge of presentation should keep taking reflection notes or daily journal throughout the project periods so as to present how your team has been going about the project. See the Powerpoint templates provided.

Figure 5-6. A separate worksheet that guided students to divide up the tasks evenly and to keep track on the tasks.

Based on the agreement on the contradictions and potential solutions, the former four-day unit was modified to a six-day unit, consisting of (1) a team-up activity to divide tasks, (2) designing a ramp including dimension calculations of each part, (3) verifying dimensions using Geometer's Sketchpad, (4) crafting the ramp model using cardboard, balsa wood, glue, and tape, and (5) making presentations of their product including challenges that they face and solve during the activity. Modified worksheets were a key artifact to guide the activity throughout the project. For example, they guided team-up and task distribution and included features to enhance student reflections on their learning by asking questions like "Is Geometer's Sketchpad able to draw the plan according to your calculations?", "Is the design realistic enough to play on? (angles, lengths, height, widths, etc.)", and "Is the model strong and sustainable enough to hold up under typical stresses?". In addition, a teachers' manual was provided to consult at his disposal. The overall differences between the units in the initial (Year 1) and following year (Year 2) are presented in Table 5-1. The newly designed and added activities are underlined.

Table 5-1. *Comparison of the Unit Features*

	Year 1	Year 2
Timeline	Six sessions/Two weeks	Nine sessions/Four weeks
Activity structures	Conceptual learning Dimension calculations Design/drawing Cost calculations Model constructions Mini presentation	Conceptual learning Team-up Dimension calculations Design/drawing Verifying with GSP[10] Model constructions Reflection presentation
Construction materials	Construction paper, popsicle sticks, scissors, tape, and glue	Cardboard, balsa wood, saw, stapler, tape, and glue
Course materials	Worksheets for dimension calculations	Worksheets for: (a) team-up, division of tasks (b) dimension calculations (c) GSP verification (d) Presentation guidelines
Participants	Jorge and 15 students	Jorge and 14 students

Effectiveness of the Intervention

The modified six-lesson unit of the ramp project was implemented in one of Jorge's seven grade class in the following year. At least two researchers including the instructional designer of the unit actively participated and engaged in the unit implementation. The analysis of classroom discourses revealed that observable disturbances that were identified in the previous year dramatically decreased, as presented in the following section.

Resolved Contradictions

Effective Group Collaboration

The structured division of labor and rules of interaction for the group work helped Jorge facilitate group collaboration more effectively. Fourteen students fell into five groups and divided up the tasks on the very first day with the help of the team-up worksheet (Figure 5-5). Jorge explained the activity in the first class of the unit using the worksheets:

> Jorge: from my perspective this [team-up activity] is one of the more important pages…so by Friday we are gonna be looking at the [task] 3, and we are gonna make it a little bit ahead or a little bit behind, not terribly worried about sticking really tightly to the schedule, what I want is to organize.. you got yourself figure out.

And on the second day Jorge said to students:

> Jorge: Now, let's take a look at today's work. Take your sheets out…. I'm looking at the task 2 on the schedule. .. The fact is that your name is in charge doesn't mean that you have to do all the work yourself. You have to make sure that the work gets done.

By referencing the worksheets, students were able to organize themselves for what to do with whom until when. As well, the clearly defined subtasks enabled students to track their work day by day, leading to more effective collaboration within a student group. It was evidenced in the following excerpt that students were benefited from the worksheets that guided the structured division of labor and rules of interaction in groups.

> Researchers: How did you divide up the tasks?
>
> Student 3: Well, [they were] already divided [on the worksheets]. We just put our names on to it. Like this and this, who's in charge of that…
>
> Researcher: Did it help? The worksheet?
>
> Student 4: Yes, it made us put every one of us in charge of one thing and divided up the work equally.

---

[10] Geometer's Sketchpad

Student 5: And in that way, we don't forget the steps because we had all the steps in front of us, so if we forget a measurement, while you're building then you said, oh what that measurement supposed to be?

As the project period went by, students appeared to improve collaborative practice. For example, when Group 3 got to the presentation preparation task, the final task of the ramp project, they tried to get mutual agreements on the roles within the group members before starting the task, as following:

Student 5: I'll do the first slide [Introduction].

Student 8: I want to do the mistakes.

Student 7: I want to do those calculations.

Student 9: We have to conclude… (referencing the worksheet and reading along) 'what things we've learned'. Things are we learned… is… the Pythagorean Theorem.

This stands in marked contrast to the lack of collaboration in the previous year where students constantly argued who were doing what even at the end of the project period and some required work had not done by anyone.

Active collaboration guided by the structured division of labor and rules of interaction led students to positive experiences on collaborative learning as Group 3 told in the post-interview:

Researcher: how did you find working in the team?

Student 6: It helped me understand more because the part that I didn't understand, I watch them doing and I understood that.

Student 8: We have a variety of people in our group and different people know different things and we put it together and you know more.

This is evidence that these students traversed the zone of proximal development as an effect of the intervention. In other words, the intervention provided sufficient support and guidance for the students to succeed themselves in solving the problems in a constructivist and collaborative way but did not provide so much support and guidance that they could solve it in a rote or algorithmic way (Perkins, 1992).

Reduced Off-Task and Downtimes

The structured worksheets had the effect of achieving a division of labor for various subtasks that allowed the effective use of ICTs in the ramp project. For example, the Geometer's Sketchpad software was used to verify the calculated dimensions of the ramps. In the previous year, although Jorge introduced Geometer's Sketchpad to students for the design task, students did not use the software effectively, generating downtimes and off-task behaviors. To deal with this, instead of setting up a rule to control student use of laptops, we included a task called "Verifying [your design] with GSP [Geometers' Sketchpad]" which asked students to verify their design and pencil and paper dimension calculations with the help of the geometry educational software before starting to construct the ramp model. At the same time this guided use of the software also resolved contradictions between use of the tools and rules of interaction. By specifying subtasks (division of labor), the rules of interaction also became more straightforward—that is, someone had to take on the subtask, carry it out, and then report on the outcome to the group.

During this activity, students were observed fully engaged in validating their calculations with software-generated numbers and oftentimes exclaimed that their calculations were accurate. Student off-task behaviors associated with the use of the laptops were considerably reduced in this Geometer's Sketchpad task, whereas in the previous year the use of the same software distracted students from the main activity.

Largely due to the guided use of ICTs in the intervention, downtimes associated with laptops were considerably reduced and students used the laptops more effectively than had in the previous year. A student response to the guided Geometer's Sketchpad task in the post-interview was "it helped us a lot…when we did it [Geometer's Sketchpad task], we noticed that they [pieces of the ramp design] wouldn't go together, so we fixed some changes on the paper before we built it." Another student stated that "if we hadn't had the GSP we would have made tons of mistakes".

Guiding Artifacts

The newly adapted tools such as a transparent ramp model and the ramp plans with better representations helped Jorge realize constructivist instruction that was more guided by providing a means of scaffolding. The transparent model especially enabled Jorge to maintain a discovery approach but with better guidance. For example, on the third day of the project, which was right before the construction stage, Jorge stopped the class and advised:

> Jorge: I want you to look at the [transparent] model and make sure there is a consistency between what you're planning to build and what [the model] is. I think there is something you missed structurally originally…. why is there a space [between ramp side and back wood]? Why are the corners of the X truss shaped like arrow?

The following conversation took place during the group work where Jorge helped a student group (Group 3) negotiate their argument with the model:

> Student 6: The wood should be 28.6 [cm].
>
> Student 7: No! We don't need a wood for that.
>
> Student 6: Mr. Jorge, we don't need a wood piece here?
>
> Jorge: You guessed, eh? The plastic [transparent] model is easier to take out the guess if you're wondering how you build this. This is why I asked to take time to look at the model (while bringing the model to the group).
>
> Student 6: (exclaimed after examining the model) Yes, we need this!

He did not give students direct information about what they missed but using the clear model facilitated students to figure out by themselves. During the construction stage, especially at the beginning of it, it was frequently observed that students consulted the transparent model and corrected their design. Together with the modified worksheets that helped students orient which piece they were working on (Figure 5-5), student arguments on confusing representations of the ramp were reduced and successfully negotiated. Jorge stated the benefits of the newly adapted artifacts in the post interview that:

> Researcher: How did you find the worksheets? What do you think is the advantage or disadvantage of it?
>
> Jorge: There're two things that came in my mind. One is, I liked to present an opportunity for kids to work ahead. And this is very much like, here is pile of work to do. Get busy. And you're able to say [with the worksheets],

you're here, let's work with this piece. I think there is a huge advantage of that. I like that idea of giving them here's what you have to do and where I have to go. And the other is, I think they had a better view of what the end product look like this year because of the worksheet and because of the [transparent] model…and I think that helped tremendously.

Voluntary Peer-Consulting

In the previous year, the rule of consulting peers when having questions appeared to get rejected by Class Expert students largely because they got annoyed by so many questions asked by a number of frustrated peers as the project due date approached. This rule rejecting disturbance was a result of contradictory interaction between rules of interaction (e.g., peer-consulting rules) and Jorge's minimal guidance tactics (tools) on content knowledge as well as the project procedure. In this year, student confusion on the project procedure was barely observed due to the structured division of labor and rules of interaction guided by the worksheets. As well, the provided transparent model appeared to help students figure out where to put x-trusses that were required the Pythagorean Theorem. Guided by such tools, rules of interaction, and division of labor, students appeared to be more comfortable with the peer-consulting rule (i.e., consulting Class Experts). For example, on Day 5 Group 2, one of the advanced groups voluntarily went up to Group 1, who appeared to be struggling with putting wood pieces together, and offered helps to figure out what went wrong although they had not been asked for help. In the following excerpt Student 3 is from Group 2 and Student 2 is from Group 1.

Student 3: (After trying to explain why some pieces were not fitting together) I'll just give you an example (as putting the wood pieces together that Group 1 had cut). How could this [piece] fit here?

Student 2: Oh! (realizing the error that they made) We'll have to cut it again. Thank you.

This shows that an innovative rule may be effective only when the rule is not supported by other mediators in the activity system. In other words, the innovative and unique rule of Class Expert in Jorge's instructional practice at last had an effect of promoting student active exchange of knowledge within and between groups in the intervened activity system where other mediators, such as tools and division of labor, sufficiently support the class activity.

Enhanced Student Reflection

The presentation task appeared to help enhance student reflection on their learning processes. A template for the presentation was distributed to the students before the project began so that they were aware of what they needed to track during the project. Jorge, largely due to his awareness of the importance of the reflection activity that was addressed in the researcher-teacher collaborative meeting, often gave an explicit emphasis on the presentation task to the students during the class, such as:

> Jorge: I'm concerned about two things. Number one, I don't think you're keeping good enough notes about how you change your plan as you go. Remember your powerpoint presentation that you're gonna be doing? You're gonna need to explain how things are and why things are different. … so I want you to take more notes… Guys, get your computers away but have a pencil and paper, the old fashion way of taking notes. And I do want you to criticize yourself and your changes.

The modified student presentation session was very different from the mini-presentation of the previous year that did not evidently lead to student reflection. Initially, Jorge and the researchers had been concerned about whether the PowerPoint template was so excessively structured that it might end up limiting student reflection and activity. However, this did not happen; rather, students came up with their own PowerPoint presentation instead of using the template provided and even went beyond what the teacher and the researchers asked for. They voluntarily took digital pictures of their ramp models and presented daily logs with those pictures (Figure 5-7 & 5-8), which shows a voluntary integration of various technologies into their learning. We construed that time was freed from arguing about rules and division of labor for groupwork with the help of the structured unit materials, and this gave students more opportunities to reflect on their work. In turn this increased student ownership of the activity, which is a important characteristic of student-centered learning (Hannafin & Land, 2005).

Figure 5-7. An example slide of student PowerPoint presentation that showed the inside of their ramp that cannot be seen after completing construction.

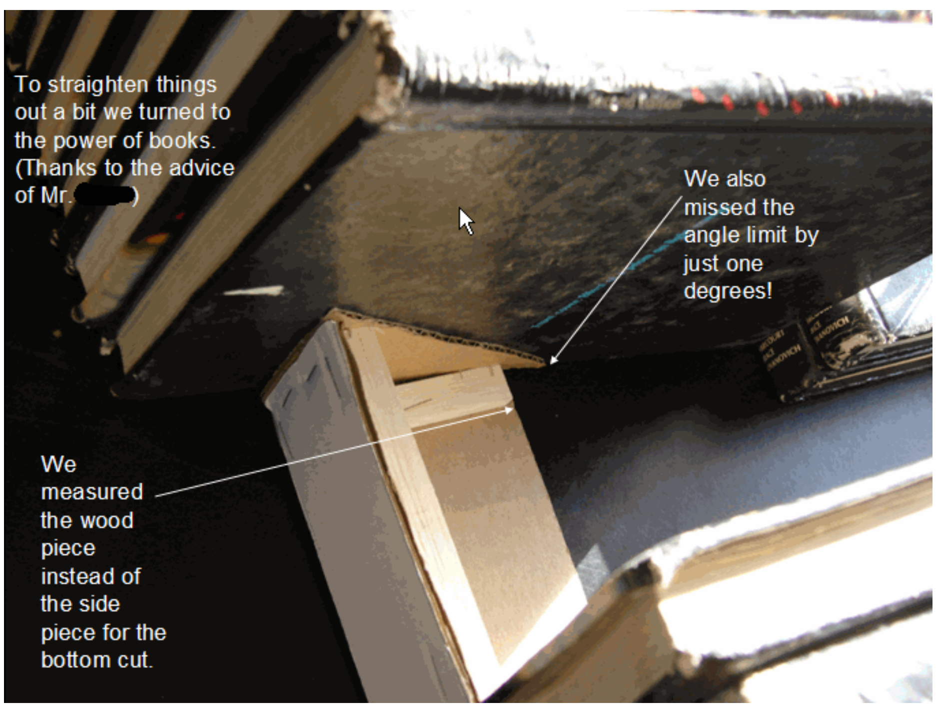


Figure 5-8. An example slide of student PowerPoint presentation that showed mistakes that they made during the project and how they solved the mistakes

Of course, not all the students built the perfect ramp in the end; two groups out of five (Group 1 and Group 4) built ramp models that were inconsistent with their design and calculations; whereas four of the five groups did so in the previous year. However, the difference between the previous year and the following year was not just the number of groups but how the students realized and reflected on their mistakes. In this intervention year, the two groups who made mistakes and built an incorrect model thoroughly analyzed their mistakes and reported the problems that they encountered in carrying out the project. For example, one of the groups (Group 4) that made mistakes stated:

> Student 10: We made a mistake and it slowed us down. It seemed that our measurement for cutting the wood for the back was wrong because we needed a little bit of space that the trusses would fit. On the fifth day we finished the back part and we solved our problem with the wood.
>
> Student 11: It is little bit different from our initial measurement due to the facts such as the cardboard width.

The other group (Group 1) that built an inconsistent model also stated:

> Student 2: We measured the wood piece instead of the side piece for the bottom cut.
>
> Student 1: The top of our ramp was too small for the cross braces to cross each other. If we did force them to cross, then they would snap. So to solve this problem we simply laid the first piece down, then cut the second brace in half and glued the two halves to the first piece.

It was evident from the post-interview that students found the presentation session significantly helpful for their learning. A student from Group 5 stated, "[Through presentation] we could conclude all of our mistakes, everything we've done. It was just like a refreshment of whole our processes of making around". Another student from Group 4 stated to a researcher's question about lessons learned from peers' presentation that, "[I learned from others' presentations that] there's no good or bad design you can say. Either way, you always have to find and correct problems."

Jorge's resolution of the contradictions in the class activity system by redesigning artifacts (e.g., structured worksheets, a transparent ramp model, and the Geometer's Sketchpad task) and specifying rules of interaction (e.g., guided discovery) and divisions of labor (e.g., structured group work) helped in turn to foster student constructive understanding of the task. This is an important achievement because it resulted in the transformation from the activity object (i.e., ramp building) into the desired outcome (i.e., constructive understanding of the Pythagorean Theorem) and from Jorge's action level of curriculum enactment to the collective activity level encompassing changes in student learning practices. In addition, a student from Group 4 stated in the post interview that, "When usually you learn things like say algebra… what is the use? But at least in this one, we could actually use it for our own purposes…we actually did use the Pythagorean Theorem to build the ramp."

Remaining Contradiction

The intervention could not solve all the contradictions that were identified the previous year. In Year 1, Jorge had to extend the project for an extra day for students to complete the project. In Year 2 with the intervention, the project also took the class extra two days to finish all the tasks so it lasted nine lessons instead of six. The reasons for the unexpected extensions, however, should be distinguished between Year 1 and Year 2. In Year 1, students had to spend a large amount of time in figuring out what to do with whom until when and then ended up hurriedly carrying out most of the task on the last day of the unit. In contrast, in the intervention year, students kept their work on schedule until Day 3, where they finished the calculation, design and Geometer's Sketchpad task. It was the construction and presentation task that students spent more time on than scheduled. We interpreted that this remaining time schedule contradiction was a result of the following: first, few students had done any building activity like this before; second and relatedly, they were heavily engaged in the construction tasks and in turn developed greater ownership on the ramp project; and third and consequently, their documentation of what they did for the PowerPoint presentation became a much bigger and more engaging task than we had foreseen. Jorge also agreed on our interpretation and did not even perceive this delay as a contradiction. In the post-interview, Jorge said:

> Researcher: Did you expect this unit lasted this long?
>
> Jorge: I didn't care. What's happening was being productive. The kids were working hard and learning.

Nonetheless, it should be classified as a remaining contradiction because delayed lessons cause various problems in general school settings where a designated amount of curriculum must be covered in a given school year.

Emerging Contradictions

There were also newly emerged contradictions due to the intervention. Although we reached agreement with Jorge on the re-designed classroom materials before the unit began, Jorge found some of them contradictory with his teaching style during the implementation. Especially, he claimed difficulties in managing rubrics that were provided for each of five tasks, such as design, Geometer's Sketchpad verification, construction, presentation and the overall quality of student collaboration:

Researcher: As a teacher, what was the biggest challenge of the unit?

Jorge: I think it was paper management. I just found there were too many pieces of papers around. And on the other hand, I look at every one of them and they valued individually but collectively it was, wait a second, I lost focus on where the sheet was actually looking at it now. And also it's my style. I'm not somebody who follows a sheet of paper well. I can't say I'm going this way now. Because of something that past in the class.. and it's always been my style, so, I'm kind of, yes, I like the sheets for the structure but I'm not gonna stay with structure alone. If I see something more important, what I perceived as more important elsewhere. I think one rubric of the total rather than pieces (would be better).

It is a norm rather than an exception in a CHAT perspective that an intervention brings about new contradictions in the activity system, because constructs of the activity system take on new qualities due to the intervention. This effect is rather consistent with the development cycle in CHAT as Engeström (1999b) asserted:

> [T]he seemingly successful implementation of an innovative solution may open up a new, unexpected contradiction which requires serious revision and possibly serves as impetus for a new cycle of expansive visibilization. Such negations are essential ingredients and energy sources in an expansive process, not mistakes or anomalies to be eliminated. (p. 91)

This is why development is referred to as a "cycle" rather than a "process". In the present case, the rubrics, a new entity of the tools, led to tensions between Jorge and his rules of instruction. By resolving this newly emerged contradiction Jorge's teaching practices will continuously evolve, which we are currently working on.

Discussion

Roth and Tobin (2002) claimed that both pre-service and in-service teachers found teacher training in their university and professional development programs did not help teachers adequately cope with their actual classroom teaching, indicating significant gaps between theory and practice in the field of teacher education. Zhao and his colleagues (2002) also argued that most current survey-based research on professional development that looked into correlations among factors around teachers' use of technology tended to neglect teachers' struggles "to negotiate a foreign and potentially disruptive innovation into their familiar environment"(p. 483). Lawless and Pellegrino (2007) concluded in their extensive literature review on technology professional development that we need a more systematic way to address the issues that teachers face when adopting and integrating ICTs in their teaching practices. A large part of the problem with current teacher education for the integration of ICTs with constructivist instruction is that it focuses on changing teachers' *action* or skill isolated from larger contexts where all the contradictions emerge during teaching *activity*.

The activity system triangular template provides a useful tool to examine and determine how much and what kind of support is needed for a classroom activity system to realize a learning goal. To transform one's action to the level of activity, which is an outcome of the activity system, the other components of his/her class activity system, such as tools in use, rules of interaction, and division of labor should be well established and adjusted. However, if the other components remain unchanged despite new actions, like Jorge's unspecified division of labor in the new project-based discovery approach, the development of the activity system stalls and often stops at the individual action level. This was a factor that in large part caused unsuccessful learning outcomes in the initial ramp project.

This study intervened on Jorge's instructional practices to help him construct new teaching practice models by enhancing and adjusting various mediators in his classroom such as artifacts in use, rules of communication, and division of labor, based on the understanding and analysis of contradictions that emerged in his classroom. In effect, we tried to transform an ill-formed activity system into a well-formed one, where all the interwoven components and mediators, such as rules of interaction, division of labor, and the use of tools, adequately support activities that members carry out (Park et al., 2006).

This on-site intervention study might have limitations for those who seek generalized principles for instructional design. However, we believe that to cultivate best practices of ICTs-supported learning environments, researchers should engage actively in transforming the actual activity system in question and should construct new models of activity with the local participants, i.e., teachers and students in this case (Engeström, 1999; Engeström, 2004; Kuutti, 1991). Engstrom (1999) asserted the importance of this on-site intervention because:

> If actors are able to identify and analyze the secondary contradictions of their activity system, they may focus their energy onto the crucial task of resolving those contradictions by means of expanding the object and reorganizing the activity accordingly, instead of being victimized by changes that roll over them as if forces of a natural catastrophe. (Engeström, 1999, p. 67-68)

A role of researchers should then be that of a "mediator" who proactively gets involved in changes and helps participants resolve struggles in everyday practices, as Rogers (1997) suggested:

> Rather than always take a backseat role, researchers need to become more proactive in their involvement with the people and objects of their study. This means engaging more in an ongoing dialogue with the various groups of people working or designing together (i.e., the users, the managers, and the designers). Researchers should stop shying away from being involved. On the contrary, they should be seeking ways of taking a more active role in the design and implementation process, even becoming 'change agents' (cf. Blomberg et al., 1993) where appropriate. In doing so, ideas can be fed back, discussed, and negotiated as part of the ongoing practice of research. (Rogers, 1997, p.69)

CHAPTER VI. SUMMARY, CONCLUSIONS, LIMITATIONS, AND CONTRIBUTIONS

This doctoral dissertation is a series of manuscripts that were intended to contribute to our knowledge about challenges that teachers face in ICT-supported constructivist classroom practices and to propose a new approach to professional development for teachers.

The first manuscript (Chapter II) was a literature review of constructivism in order to address a gap between constructivism as a theory and its application in research practices. The literature about the theory was reviewed with close attention given to differences and similarities between cognitive (radical) constructivism and socio cultural constructivism. Framed by this theoretical review, recent empirical studies on the use of ICTs to promote constructivist classroom practices at K-12 levels were reviewed. Three interrelated problems between theoretical constructs and their application in the studies were revealed: (1) ambiguous theoretical stance of most of the reviewed studies, (2) inappropriate study design for the nature of domains, and (3) insufficient reflection on theoretical constructs of constructivism with respect to the learning tasks under investigation. These findings implied that (1) learning tasks should be designed in a way to constantly challenge students pre-existing knowledge and scaffold their new knowledge construction, instead of letting them structure everything that they need for their own learning, and (2) a more thorough theoretical framework such as cultural-historical approaches is needed to guide design principles of constructivist learning task as well as to account for dynamics of ICTs-supported classrooms. To this end, CHAT was chosen and reviewed in Chapter III to establish a theoretical framework for this dissertation study because it provided a systemic lens to accurately understand human practices and development.

The second manuscript (Chapter IV) presented a case study that examined instructional practices of a Grade 7 mathematics teacher from CHAT perspectives, focusing on challenges and problems that he faced in an ICT-rich constructivist classroom. A two-week project-based classroom activity was investigated in order to find contradictions that hindered the participant teacher from realizing meaningful student learning through the project-based activity. The project was designed and implemented by the participant teacher to teach the Pythagorean Theorem through a skateboard ramp building activity. Findings indicated that it was not ICTs per-se that made contradictions in the ICT-supported constructivist activity; rather it was the contradictory interactions between constructs of the class activity system due to the introduction of ICTs. To elaborate, Jorge's minimal guidance instructional tactics to realize discovery learning (tools) resulted in the unstructured division of labor for student group work and such unstructured division of labor in turn lacked rules of interaction about how to take on the tasks among students. In other words, mediators in Jorge's class activity system appeared not to sufficiently support students to carry out the ramp project activity. Consequently student off-task behaviors on laptops increased and a lack of collaboration prevailed. As a result, students failed to find links between the project-based activity (i.e., ramp building project) and the learning content (i.e., the Pythagorean Theorem). Such contradictions called for systemic adjustment of classroom practices as a whole.

Based on the identified contradictions, the third manuscript (Chapter V) presented a new approach to professional development for teachers through on-site intervention to promote the effective ICT integration for constructivist instruction. Adapted from Engeström's (2000) "ethnography of trouble", a methodology to intervene on workplace development based on an activity system analysis, the researchers debriefed results of the activity system analysis to the teacher and discussed the identified contradictions. With a close collaboration with the teacher, the ramp unit was modified and implemented in the following year. In effect, the researcher(s) and the teacher designed an intervention intended to transform the existing ill-formed activity system into a well-formed one, where all the related components and mediators, such as rules of interaction, division of labor, and the use of tools, adequately supported activities that students carried out (Park, Bracewell, Sicilia & Tung, 2007). The major features of the modified unit were (1) appropriate use of artifacts (ICTs and worksheets), (2) structured division of labor and rules of interaction, and (3) enhanced reflection opportunity. The intervention was focused on restructuring the participant teacher's pure-discovery mode of instruction, largely stemming from his partial understanding of constructivist theories, into a more guided-discovery instruction (Brown & Campione, 1994; Mayer, 2004). Findings indicated that the on-site intervention played a large role in helping the participant teacher not only resolve contradictions that had occurred in the previous year but also implement new practices of the guided-discovery instruction that improved student learning.

This dissertation study implies that teacher professional development to promote effective ICT-supported constructivist classroom practices must pass beyond current one-size-fit-all and one-time workshop types of programs. Such one-size-fit-all programs may change teachers' individual actions (e.g., how to operate an equipment or software) but rarely lead to long-term changes in instructional practices where social, cultural, and pedagogical contradictions occur all the time. Therefore, professional development should be designed based on a thorough understanding of everyday classroom practices obtained through researchers' active engagement in the local contexts. A researchers' role then should be more proactive in identifying hidden tensions and contradictions, and helping teachers become aware of the contradictions and concentrate their energy on resolving them.

This case study has a limitation with regard to understanding a more long-term effect of the intervention. In light of Engeström's expansive cycle of learning (1999b), the researcher helped the teacher become aware of problems in his instructional practices through an activity system analysis, construct new models of teaching, and implement them in his classroom. However, the present study was not sufficient to understand whether the teacher consolidated the new practices. A further and longitudinal study is needed in order to examine whether the effects of the on-site intervention are transferred to other practices of the participant teacher under the different instructional contexts.

Along the same line, this study might not provide sufficient understanding of contradictions that lie behind the classroom practices. To understand the third and fourth orders of contradictions beyond what happened in the classroom, we need a deeper analysis of contradictions between what teachers believe they are supposed to act like as a teacher in class and what a broader school community including administrative and parents expect teachers to be.

The ideally individualized on-site intervention approach that was presented in this study might not be affordable for every teacher or school. Alternatives to this approach include mentor programs to help teachers construct new instructional models to resolve contradictions or case-based teacher education programs to help teachers become aware of and be prepared for possible challenges.

This dissertation study contributes to both theory and practice in education. Theoretically, this study elaborated CHAT by demonstrating an innovative and replicable methodology to analyze contradictions occurring in classroom practices. This is timely because CHAT has been criticized for its ambiguous and descriptive methodology (Garrison, 2001; Patel et al, 1996; Roschelle, 1998; Stetsenko & Arievitch, 2004). The elaboration of CHAT advanced the theory from a somewhat one-sided perspective on describing overt change to a more dialectical and productive theoretical framework to understand as well as intervene on classroom practices. Practically, this study presented a new approach to professional development for teachers. To cultivate best practices of using ICTs in a constructivist way, we need to take a whole picture of a classroom activity system into account and help transform an ill-formed activity system into a well-formed one, where artifacts in use, goals of activities, rules, and division of labor are defined and shared among the participants sufficiently to guide such activities.

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APPENDIX A

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APPENDIX B

The Ramp Project: Teachers' Guide

McGill

Contents

- README
- A Lesson Plan
- Student Evaluations
- Checklist
- Contact

README

The purpose of this unit is to facilitate student understanding of the Pythagorean theorem through hands-on experiences, namely the ramp project.

This Teachers' Guide contains lesson plan, timeline for each class, student evaluations, checklist, and contact information.

The participants of the ramp project are four classes of George Ladd and Maire Duffy; however, class video-taping will be conducted in only two classes, one from each teacher.

Please note that before the project begins you may spend a couple of periods to teach students basic conceptual understanding of the Pythagorean theorem in order for students to get ready for the project. In this way, you could spend Day 1 -as shown in the Lesson Plan- only to do quiz, introduce the project and team up groups of three. Also, please make sure that all the materials to be used during the unit such as worksheets and rubrics are uploaded and available to students before the unit begins.

Duration of the project is six periods between Feb 13 and 23, 2007. After the unit, the research team may need to interview the students as well as the teachers in the following week.

Lesson Plan

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Tasks	Concept Learning	Design Calculation		Construction		Presentation & Test
Activities	**Warm-up** • The Theorem • Project overview **Team-up**	• Design a model • Calculations	Verification of the design with GSP	Construct a model		• Presentation • Reflections
Materials	In-class worksheet package	• In-class worksheet package • GSP		Plans, Cardboards, Staple guns, Wood sticks		• Powerpoint templates
Outputs	WS #1	• WS #2,3,4,5, and 6	• GSP-generated plans • WS #7	• WS #8 • Models		• Powerpoint • Reflection notes
Evaluation*	Quiz for Conceptual Understanding	• Rubric for Design (R-1) • Rubric for GSP (R-2) • Rubric for Collaboration (R-4) - Self-evaluation		• Rubric for Construction (R-3)		• Rubric for Presentation (R-5) • Test

* In Evaluation, those in green represent what the McGill team developed whereas those in pink represent what the teachers developed last year.

Timeline for Each Class

Class A

Mon	Tue	Wed	Thu	Fri
12 School Closed	13 Day 1 (Period 1) Team up	14 Day 2 (Period 3) Design	15	16 Day 3 (Period 3) Design and Verification
19 Day 4 (Period 2) Construction	20 Day 5 (Period 3) Construction	21 Day 6 (Period 4) Presentation and Test	22	23

Class B

Mon	Tue	Wed	Thu	Fri
12 School Closed	13 Day 1 (Period 2) Team up	14	15 Day 2 (Period 2) Design	16
19 Day 3 (Period 4) Design and Verification	20 Day 4 (Period 1) Construction	21 Day 5 (Period 3) Construction	22 Day 6 (Period 4) Presentation and Test	23

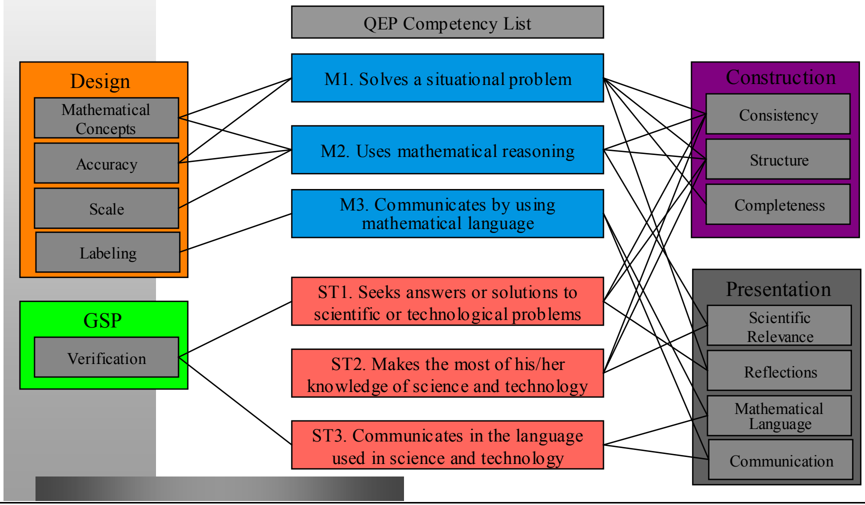
Student Evaluations

This unit consists of seven kinds of evaluations as shown below. You can put different values for each evaluation according to your goal and intention of the activity. For more effective use of evaluations, please make sure that students are aware of what is to be evaluated and how before the unit begins and keep reminding them to refer the rubrics throughout the activity.

	Evaluations	Weight	Example
1	Formative Quiz	TBA	10
2	Rubric for Design		20
3	Rubric for GSP		5
4	Rubric for Construction		20
5	Rubric for Presentation		10
6	Rubric for Collaboration		10
7	Test		25
	Total		100

FYI: Mapping with QEP

For your information, here's how the evaluations map to the QEP competency list. As well, you can find in the rubrics which competency(ies) will be covered with each item.



Checklist

	Items	Handouts	On Server
Project Overview	Overview.doc		
Worksheets	Worksheet.ppt		
Rubrics	Rubric for Design (rubric_design_student.doc)		
	Rubric for GSP Verification (rubric_GSP_student.doc)		
	Rubric for Construction (rubric_construction_student.doc)		
	Rubric for Collaboration (rubric_collaboration_student.doc		
	Rubric for Presentation (rubric_presentation_student.doc)		
	Have you valued each rubric?		
Templates	Student_presentation_template.ppt		
Materials	Cardboards (1mx1m for each group)		N/A
	Wood sticks (2m for each group)		N/A
	Rulers		N/A
	Staplers		N/A
	Taping (Labeling Stickers, tapes, etc)		N/A
	Scissors and saws		N/A
	Containers (boxes, bags, etc)		N/A
Prototypes	2 sets (actual one and clear one)		N/A

Contacts

You may contact the McGill team whenever you have questions during the unit. The contact list is provided below. The McGill team will greatly appreciate any of your comments and suggestions and be happy to reflect your opinions on the rest of the unit period.

Name	Roles	Email	Tel	Tel (for emergency)
Robert Bracewell (Dr.)	Project Manager	Robert.bracewell@mcgill.ca	514-398-3443	514-710-9050
Jonghwi Park	Instructional Designer (Lesson Plan)	Jonghwi.park@mcgill.ca Jongwhi@chol.com	514-398-4308	514-792-9895
Vicky Tung	Evaluation Designer	I-pei.tung@mail.mcgill.ca	514-398-4308	514-758-1221
Carmen Sicilia	Project Coordinator	Carmela.sicilia@mcgill.ca	514-398-4308	514-382-9696

APPENDIX C

Building a neighbourhood Bike/Skate Ramp

Ever dream of getting sweet air just like Pedro? Well now you can! Your group has been tasked with building a ramp for your neighbourhood. The parents have agreed to provide you with tools and hardware (saw, wood sticks, and such) but you have to design it yourselves and build it. Please read this overview through before you get to work!!

Task 1: Team-up

You need to collaborate with your peers to do this activity. Therefore, the first task for you is to team up a group of three. Each person should take responsibility for a certain task to get it done in a given time. The Worksheet (WS #1) will help you to divide up the tasks among the members of your group, as well as to schedule your work.

Task 2: Design and Calculations

You must design your ramp according to your purpose and calculate dimensions. You can take a grasp of what patterns you need for your ramp with ref-001 and ref-002. You must fill in all the dimensions in the designated worksheets such as WS #2, 3, 4, 5, and 6 and hand them in. While designing your ramp, please remember that you need to present and justify your design at the end of the project, which is Task 5.

Task 3: Verification of your design with Geometer Sketchpad (GSP)

After designing and calculation all the dimensions, you must verify your design and calculations using GSP (See WS #7). GSP will automatically calculate all the dimensions and prevent you from mathematical errors so that you won't have to go back to your calculations after cutting the cardboards.

Task 4: Construction

Now, it's fun time! Using cardboards, wood sticks, staples, and tapes, build a model of your ramp. **Remember you have two sides where needed truss(es) to sustain the ramp.** If you want to put more trusses on any other sides, which is optional, and if it holds up the ramp better, you will get some bonus points. You may also decorate your

ramp, e.g. painting, drawing, stickers, etc. Unlike other tasks, we will spend two periods on construction.
After completing the construction, fill out the worksheet (WS #8) and hand it in.

Task 5: Presentation

On the last day of this unit (Day 6), you need to present your ramp-building journey to your classmates. Those who are in charge of presentation should keep reflection notes or daily journal throughout the project periods so as to present how your team has been going about the project. To prepare the presentation, please see the powerpoint templates provided. Presentation for each team should take no more than 10 minutes including a Q&A session.

The Skate Ramp Project:

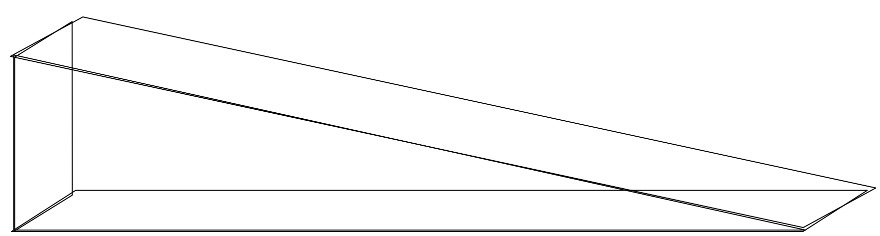
The Pythagorean Theorem

Your Name:________________

In-Class Worksheets

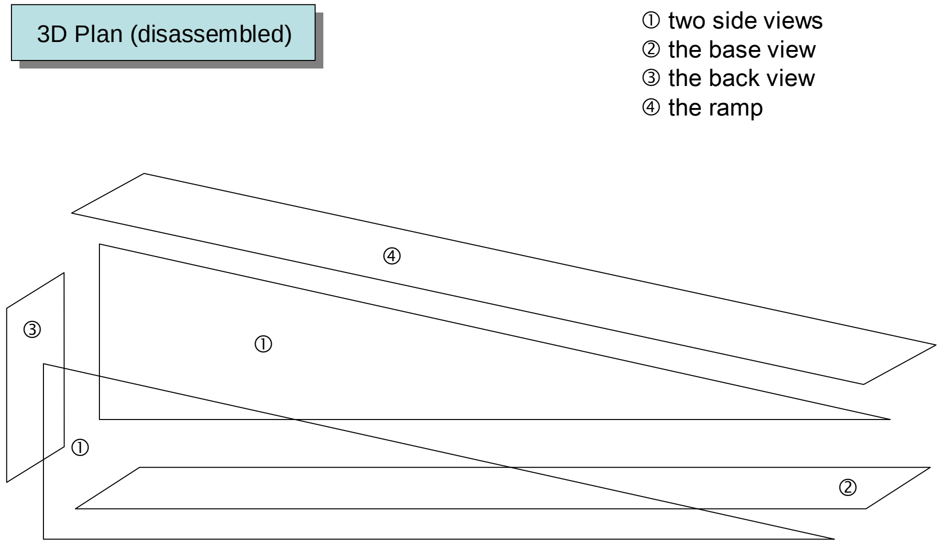
Ref #1

3D Plan



Ref #2

3D Plan (disassembled)



Worksheet #1

Team-Up

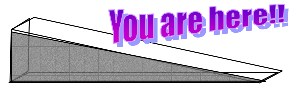
You need to collaborate with your peers to do this activity. Therefore, the first task for you is to team up a group of three. Each person should take responsibility for a certain task to get it done in a given time. The below table will help you to divide up the tasks among the members of your group, as well as to schedule your work.

	Task1: Team-up	Task2: Design and Calculate Dimensions	Task3: Verification of Your Dimensions with GSP	Task4: Build Ramp	Task5: Presentation*
Name of person in charge	N/A			Supposed to be done by all of the team members	
Due	Day 1	Day 2	Day 3	Day 4-5	Day 6
Expected Outputs	This worksheet (WS #1)	Worksheets (WS #2,3,4,5,6)	GSP-generated plans, Worksheet(WS #7)	Ramp model, Worksheet (WS #8)	Powerpoint of your presentation
Evaluations		Rubric #1	Rubric #2	Rubric #3	Rubric #5
		← Self-Evaluation for Collaboration (Rubric #4) →			

*Note: Those who are in charge of presentation should keep taking reflection notes or daily journal throughout the project periods so as to present how your team has been going about the project. See the Powerpoint templates provided.

Worksheet #2

① The side views



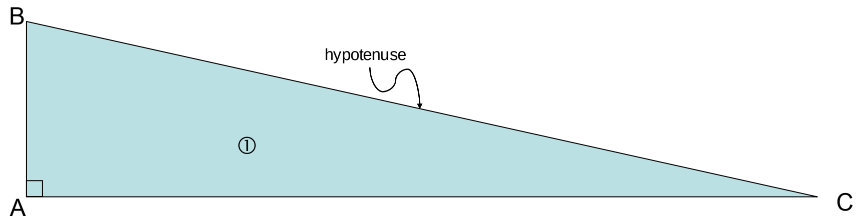
The triangle below is a side view for your ramp, where you need two of them. You need to calculate the lengths of three sides; AB, AC, and BC. This pattern plays an important role in the shape of your ramp as well as the function of it. Here are some tips for you design. **You must show your calculations for BC.**

1) **The scale of your ramp model is 1:10** throughout the design. That is, if you want to make a real ramp that is 1m high, your ramp model should be 0.1m (or 10cm) high.
2) The angle between A and C **should not exceed 30°**.
3) You need to use the Pythagorean theorem for this pattern. Identify the right angle and the hypotenuse on the triangle.

Length Calculations:

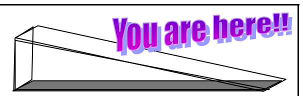
1) $\overline{AB}$: ______________ cm
2) $\overline{AC}$: ______________ cm
3) $\overline{BC}$: ______________ cm

Show all calculations to the right.



Worksheet #3

② The base view

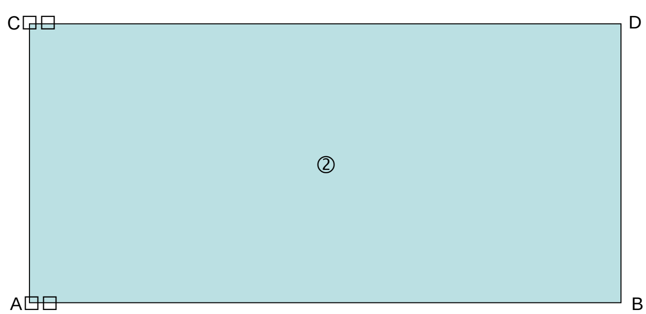


The rectangle below is the base view of your ramp. You need to calculate the length of two sides; AB and AC. Here are some tips for your design.

1) The scale of your ramp is 1:10, as stated earlier.
2) You should remember that the length of each side is closely related to that of the other patterns.

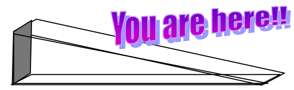
Lengths:

1) $\overline{AB}$: ______________ cm
2) $\overline{AC}$: ______________ cm



Worksheet #4

③ The back view



The rectangle below is the back view of your ramp, which **needs trusses all the way around** to hold up the ramp as indicated below with patterned lines. **The width of wood sticks is 13mm (1/2 inch).** Calculate the length of wood truss you need for this pattern. Here are some tips for your design.

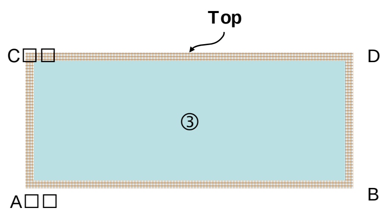
1) The scale of your ramp is 1:10, as stated earlier.
2) You should remember that the length of each side is closely related to that of the other patterns.

Lengths:

1) $\overline{AB}$ ______________ cm
2) $\overline{AC}$ ______________ cm

Lengths of wood sticks:________cm

Show all calculations to the right.



Worksheet #5

④ The ramp

The rectangle below is a pattern of the ramp, which needs trusses to sustain just like the back view. However, you need to put X-trusses on it as shown below. Therefore, you need to calculate **the lengths of the two sides (AB and AC) as well as the length of two identical diagonals (AD or BC)**. Calculate the length of the wood truss that you need for the diagonals. Here are some tips for your design.

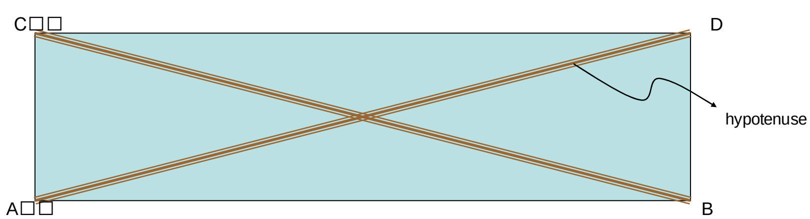
1) The scale of your ramp is 1:10, as stated earlier.
2) You need to use the Pythagorean theorem for this pattern.
3) You should remember that the length of each side is closely related to that of the other patterns.

Length Calculations:

1) $\overline{AB}$ ______________ cm
2) $\overline{AC}$ ______________ cm
3) $\overline{AD}$ ______________ cm

Lengths of wood sticks:________cm

Show all calculations to the right.



Worksheet #6

All Calculations

1. Fill in all the calculations for your ramp model.

① Side views:
1) $\overline{AB}$: ______________ cm
2) $\overline{AC}$: ______________ cm
3) $\overline{BC}$: ______________ cm

② Base:
1) $\overline{AB}$: ______________ cm
2) $\overline{AC}$: ______________ cm

③ Back view:
1) $\overline{AB}$: ______________ cm
2) $\overline{AC}$: ______________ cm

④ The ramp:
1) $\overline{AB}$: ______________ cm
2) $\overline{AC}$: ______________ cm
3) $\overline{AD}$: ______________ cm

2. Which lengths are consistent with which? And why?

____
____
____
____

Worksheet #7

Verifying Your Design with GSP

Now, you have all the dimensions needed for your ramp model at hand. However, it is better to verify your calculations before you cut the pieces of cardboards to build the model. In this activity, you are asked to verify your design and calculations by using Geometer Sketchpad(GSP). Draw five plans (2 side views, a base view, a back view, and a ramp) according to the calculations that you wrote in the worksheets (WS #2 through #6) and see if GSP is able to do so. If not, your design needs to be corrected. Fill out the table below and redo calculations where necessary. Remember you need to hand in GSP-generated plans as well as this worksheet by Day 3.

	Is GSP able to draw the plan according to your calculations? (Y/N)	If not, explain why.
The Side Views		
The Base View		
The Back View		
The Ramp		

Worksheet #8

Constructions

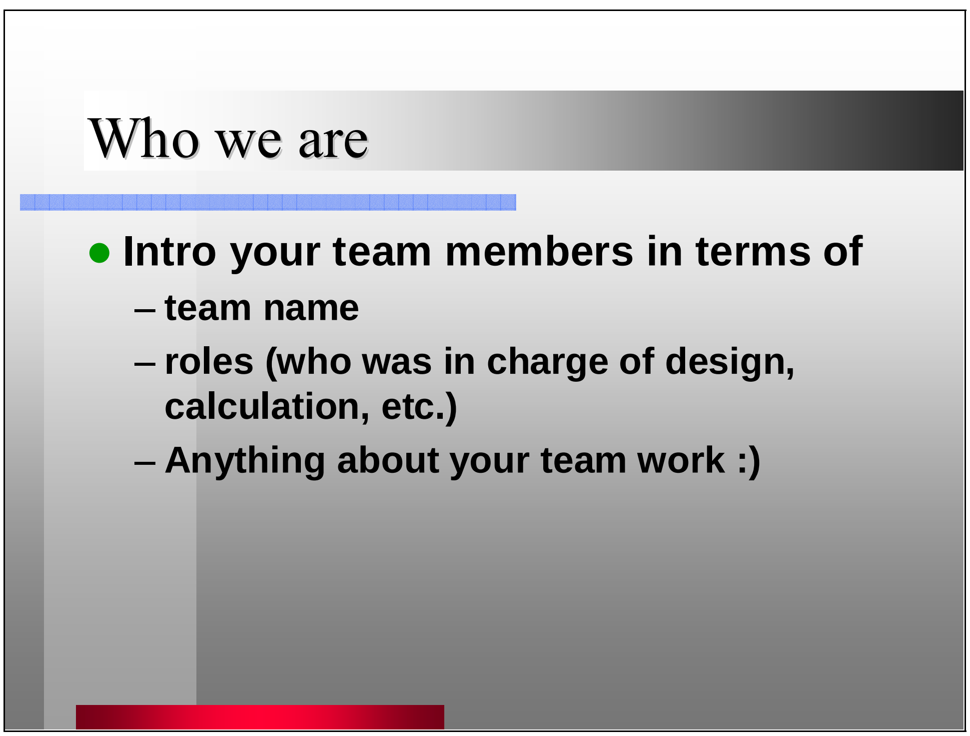
Now, it's fun time! All the members of your team need to participate in building a ramp model based on your design. You might need to go back and forth between your design and construction many times as you construct a model. Build a ramp model using tapes, staples, wood sticks, etc. **Remember you have two sides where needed truss(es) to sustain the ramp (See the transparent model that the teacher provided).** If you want to put more trusses on any other sides, which is optional, you will get some bonus points. You may also decorate your ramp to make it cool! Please take a look at the evaluation rubric for this activity (Rubric#5).

After construction, fill out the table provided below as reflection and hand it in.

	Y/N	If not, specify errors and reasons.
Are the calculations of dimensions accurate enough to build a ramp?		
Is the design realistic enough to play on? (angles, lengths, height, widths, etc.)		
Is your construction (cuttings, drawings, etc) consistent with your design?		
Is the model strong and sustainable enough to hold up under typical stresses?		

APPENDIX D


Your Project Title Here
Team Name (optional)
Names of Team Members Here

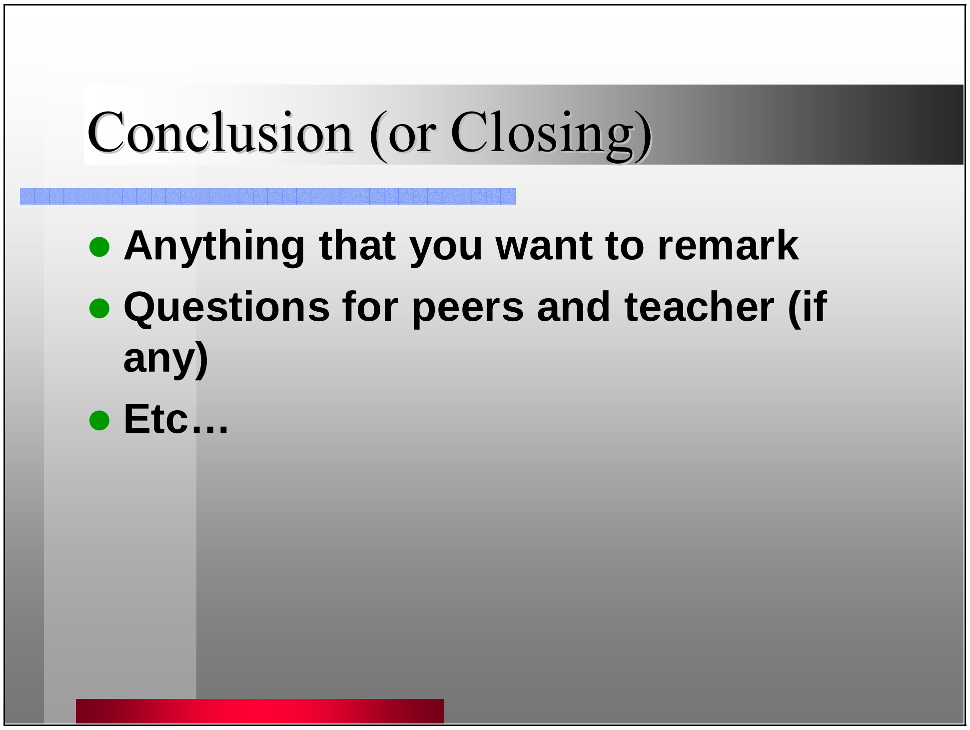

Who we are
Intro your team members in terms of
– team name
– roles (who was in charge of design, calculation, etc.)
– Anything about your team work :)

What we made

- Overall introduction of your ramp (e.g. Features, specialty, uniqueness of your ramp, justification of your design…)
- You can insert your worksheet or GSP design, anything you want to use to stand out your model. This slide can be more than one page.
- You can even demonstrate how your ramp works

What we learned

- Your reflection about:
  - The project (e.g. difficulties, what you liked or disliked, about teamwork, whether and how technology (e.g. GSP or Internet) help your project, etc.)
  - The Pythagorean theorem (e.g. how the project help you learn it, etc.)
  - Anything we learned from this activity


Conclusion (or Closing)
Anything that you want to remark
Questions for peers and teacher (if any)
Etc…

APPENDIX E

McGill

Research Ethics Board Office
McGill University
1555 Peel Street, 11th floor
Montreal, QC H3A 3L8

Tel: (514) 398-6831
Fax: (514) 398-4644
Ethics website: www.mcgill.ca/researchoffice/compliance/human/

Research Ethics Board III
Certificate of Ethical Acceptability of Research Involving Humans

REB File #: 109-0908

Project Title: Designing a well-formed activity system for an ICT-supported constructivist classroom: a CHAT perspective

Principal Investigator: Jonghwi Park **Department:** Education&Counselling Psychology

Status: Ph.D. student **Supervisor:** Prof. Robert Bracewell

Funding agency and title: FQRSC

This project was reviewed on Oct. 31, 2008 by

Expedited Review ✓
Full Review ____

Lynda McNeil, Research Ethics Office
for Blaine Ditto, Ph.D.
Chair, REB III

Approval Period: November 14, 2008 **to** November 13, 2009

This project was reviewed and approved in accordance with the requirements of the McGill University Policy on the Ethical Conduct of Research Involving Human Subjects and with the Tri-Council Policy Statement: Ethical Conduct For Research Involving Humans.

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* All research involving human subjects requires review on an annual basis. A Request for Renewal form should be submitted at least one month before the above expiry date.
* When a project has been completed or terminated a Final Report form must be submitted.
* Should any modification or other unanticipated development occur before the next required review, the REB must be informed and any modification can't be initiated until approval is received.