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The Role of Contradictions in the Development of Technology-Supported Constructivist Classroom Practices: A Cultural-Historical Activity Theory Perspective

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The notion of contradiction from Cultural-Historical Activity Theory (CHAT) perspectives is known as an "engine" for the development of human practices because participants attempt to adjust their practices to resolve contractions. This study examines two middle school teachers' classroom practices from CHAT, focusing on the role of contradictions that emerged between their existing teaching practices and constructivist activities in the development of a student-centered technology-integrated learning environment. Findings indicated that teachers' awareness and resolution of contradictions played a large role in the development of a technology-supported student-centered learning environment, a culturally more advanced activity system: students displayed greater responsibilities for their learning and were guided to make effective decisions for their learning activity.

Keywords : cultural-historical activity theory(CHAT), technology-supported constructivist classroom

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Introduction

Recently there has been considerable research on K-12 teachers' adoption of information and communication technologies (ICTs) in their classrooms, and findings are not promising: Most teachers were overwhelmed by constructivist educational reforms and coped with this pressure by using ICTs in an incremental way to sustain their traditional teaching approaches (Cuban, 2001; Cuban, Kirkpatrick, & Peck, 2001; Ertmer, 2005). This is understandable given that constructivism in practice is more complex than teachers' mere enactment of instructional strategies or employment of technical skills. It involves the reorientation of classroom cultures to accommodate the nature of student-centeredness, such as new rules of interaction and new roles of teacher and students (Windschitl, 2002).

Bracewell, Sicilia, Park and Tung (2007) asserted that ICTs rather 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. As such, the challenges teachers face in ICT-supported classrooms are not just lack of technical skills and support but also the unfamiliarity of chaotic classroom situations that have resulted from the introduction of ICTs (Apple Computer of Tomorrow, 1998; Windschitl, 2002; Sicilia, 2005). For example, a participant teacher on our ongoing research claimed "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".

However, there has been little research attempt made to understand how teachers cope with such tensions or contradictions that the introduction of ICTs to their classroom teaching practice has created. Over the last five years our research team has been placing a great deal of the effort to understand how teachers cope with such tensions (Bracewell, Sicilia, & Tung, 2006; Bracewell, Sicilia, Park, &

Tung, 2007; Park & Bracewell, 2008; Park, 2009). As a part of the larger project, this present case study compares two Grade 7 mathematic teachers who coped with emerging contradictions differently: One teacher resolved contradictions while the other did not. This study illustrates (1) what kind of contradictions the teachers faced, and (2) how the teachers' resolution or negligence of contradictions affected the transformation of class activity system as a whole. Cultural-Historical Activity Theory (CHAT) framed the analysis of the classroom practices. We are hoping that by understanding causes and effects of classroom contradictions we can have a better direction for professional development for teachers to promote the effective use of ICTs. In what follows, an overview of CHAT will be presented.

Overview of CHAT: Mediation and Contradictions

CHAT is a cultural historical approach to understanding human development. It views human development as active transformations of existing environments through collective activities to select, adapt, and re-create cultural means and artifacts. Along with other cultural-historical theories, CHAT traces its origin to Vygotsky (1978), who asserted higher psychological behaviors are mediated by signs. According to Vygotsky, higher psychological processes develop through the dialectical process involving the internalization of extrinsic signs (e.g. learning languages and other signs) and the externalization of internalized signs through activity (e.g. modifying signs for better usability).

Vygotsky's perspective is originated in response to the stimulus-response (S-R) mechanism of behaviorism, which prevailed in the early 1900s. Figure 1 shows Vygotsky response to blackbox-like 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 are available and how to use them to solve everyday problems by communicating with and getting helped from more experienced individuals (i.e. adults).

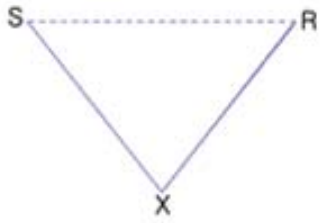

Figure 1. Structure of sign operation (Vygotsky, 1978, p.40)

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 (1978, 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 out there. By locating the ultimate motives of human activity in material object outside the mind, Leont'ev expanded the notion of mediation from individual actions to collective activities and stimulated further fundamental elaborations of CHAT.

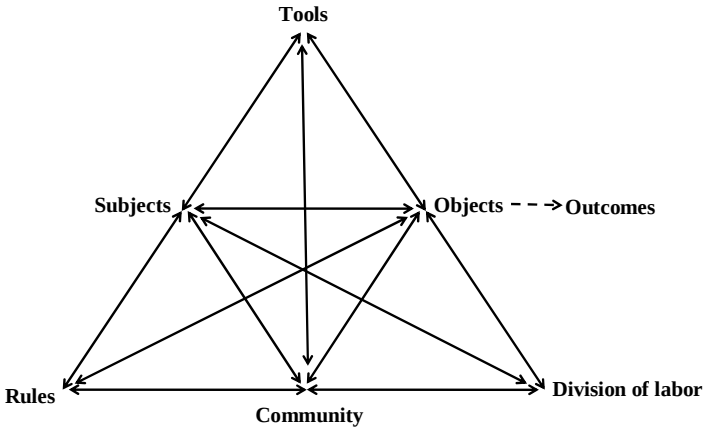

Figure 2. The structure of a human activity system (Engeström, 1987, p.78)

Meanwhile, this expansion called for a better account of the dynamics and movements of collective social activities and transactions. To this end, Engeström elaborated Leon'ev's concepts and graphically formulated Activity Systems Theory by adding such theoretical constructs as rules, communities, and a division of labor, in order to more fully represent dynamic mediations among collective activities, as shown Figure 2 (Engeström, 1987, p.78).

The central theme of CHAT is that *individuals (subjects)* pursue *goals (objects)* within certain *communities of practice* and such goal-oriented activities are mediated by various material tools like *instruments (tools)* as well as immaterial tools like *rules* of interaction and *divisions of labor*. In other words, rules direct, promote, or confine the actions of subjects in their community. For example, from a CHAT perspective classroom contexts are complex activity systems involving multiple participants (e.g. teachers, students, administrative, parents, etc.), mediated by multiple artifacts including physical (e.g. books, blackboards, worksheets, computers, etc.) and social/cultural ones (rules of interaction, division of labor, etc.). More importantly, these mediators are not separable as they are in a system. When one of the constituents of the activity system gains a new quality, say, a new tool like a school intranet, it challenges the existing system and calls for consistent changes in other constituents of the system, like new staffs for technical support, new rules for using the intranet, and so forth.

This effect, which is called a "contradiction" in CHAT, is an important force or motive for the activity system to move forward (Engeström, 1987, pp. 82-91; Leont'ev, 1978). 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 such anomaly becomes norms that their community accepts. In doing so, the community is culturally transformed and developed. However, if the mediators remain unchanged despite emerging contradictions, the development of the activity system stagnates. This development cycle is depicted in Figure 3, adapted from Engeström's (1999) Expansive Cycle of

Learning, where collective participants externalize problems, institute new solutions, and reflect and consolidate (internalize) new practices. This development is dialectical because an attempt to resolve contradictions can be only successful when the participants internalize new societal mediations of the activity system (Roth & Tobin, 2002).

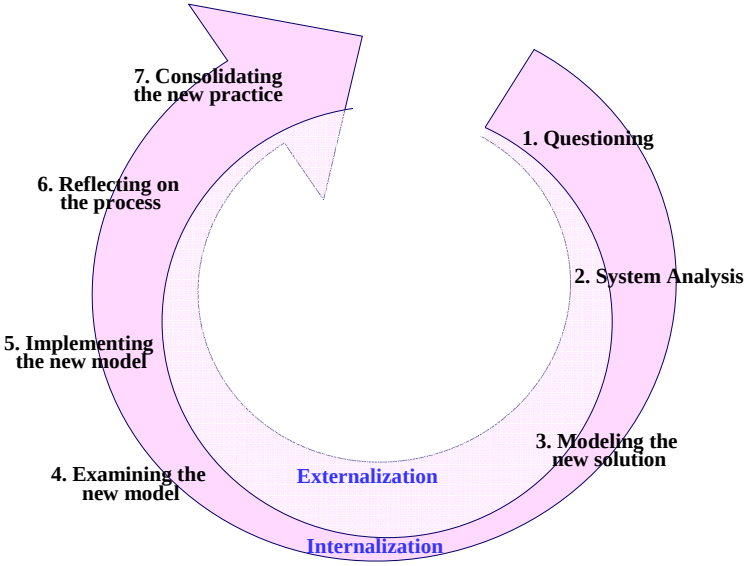

Figure 3. Expansive Cycle of Learning (Adapted from Engeström, 1999)

By revealing contradictions in the activity system of classroom practices, we can thoroughly track its development process triggered by contradictions. As such, the constructs of mediations and contradictions in CHAT provide researchers with a comprehensive means to systemically understand how participants develop their practices through various contradictions and problems by adapting, changing, and re-creating multiple mediations.

Informed by such premise of CHAT, this study is an attempt to understand contradictions in two Grade 7 teachers' ICT-rich classroom practices and impacts of resolved or remaining contradictions in the development of effective ICT-supported constructivist classroom practices.

Research Context

This study reports a part of a larger project that has investigated teachers' adaptation of ICTs in their instruction in one of the most technology rich schools in Canada for the last five years. The selected school is a private school with 600 students from kindergarten to high school. Most of students are from upper social economic status and their academic performance is average and above average. All of the students from Grade 7 on are provided with a laptop with a wireless access to the Internet. All classrooms are equipped with a Smartboard, a printer, and a projector. The class size is 15 to 20.

The participant teachers were Jorge and Martha. Jorge was a male teacher who taught mathematics and science at the school more than 15 years. Martha was a new female teacher who also taught mathematics and science for three years. Both teachers were strong advocates of constructivism and used various ICTs more frequently and effortlessly than any other teachers in the school. They collaboratively came up with an idea of a project-based mathematics unit, called "The Neighborhood Skate Ramp Project", where students were asked to build a skateboard ramp as a group using the Pythagorean theorem. Jorge explained the teachers' intention of designing and implementing this project-based math unit as following:

> Jorge: We [Martha and Jorge] were 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 [trusses] here.
>
> Researcher: So this ramp project is to give them concrete experiences with the Pythagorean Theorem.
>
> Jorge: Yes.

This excerpt from the post-interview with Jorge well illustrated the participant teachers' well-established tactics with constructivist instruction. The four-week project-based unit was implemented in two Grade 7 classes in 2007. The unit consisted of four sub activities including (a) designing a ramp with dimension calculations of each part, (b) verifying dimensions using Geometer's Sketchpad™, (c) crafting the ramp model using cardboard, balsa wood, glue, and tape, and (d) making PowerPoint presentations of their product. The number of participant students is 15 in Jorge's class and 17 in Martha's class.

Methodology

This study employed a qualitative case study methodology (Merriam, 1988; Stake, 1995; Yin, 2003). 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). Particularly, this study is an embedded multi-case study (Yin, 2003) where two and more cases embedded multiple units of analysis. In other words, this study investigated and compared two teacher cases of the ramp project and these cases embedded different levels of subunits of analysis, such as the class activity system, interactions between constituents of the activity system, and participants' individual understanding of the activities.

Data collection

The main data sources for this case study are video-taped classroom observation, researchers' field notes, student products, and interviews with teachers and students.

Jorge's and Martha's four-week ramp-project units were 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 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.

A one-hour pre-interview and a 45-minute post-interview with two teachers were conducted independently. As well, post-interviews with all the student groups from both teachers' class were conducted. The main purpose of the post interviews in the study was to serve methodological triangulation (Stake, 1995, p. 114). That is, 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

To identify contradictions and track their effects, Engeström's "ethnography of trouble" (2000) was employed. 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 such methodology, the researchers analyzed data to first look for disturbances or conflicts that occurred during the observed units of both teachers, and mapped these disturbances with six constructs of each class activity system. In other words, we attempted to provide explanations of the disturbances in the light of contradictory interactions among constituents of the class activity system. To identify patterns of disturbances and categorize them, techniques derived from open and axial coding (Strauss & Corbin, 1990) were used. To elaborate, we broke down and labelled the data to identify observable disturbances 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.

Results

The ramp project was a collaborative construction activity using mathematical concepts. With the one-on-one laptop program and ubiquitous technology of the classrooms, this project-based unit brought about various tensions or contradictions in the teachers' instructional practices. For example, students exhibited different needs, questions and working paces from group to group during the project-based activity that the teachers needed to accommodate. Students made unexpected errors and mistakes in the course of the project, ranging from calculating dimensions, to cutting cardboards and wood, and to fabricating the

ramp model. The use of laptops distracted students easily from main tasks into rather peripheral things. Altogether, the nature of the project-based activity exacerbated chaotic circumstances with the use of ICTs in both Jorge's and Martha's classes. As the observation went on, we realized that differences between chaos and dynamics resulted from teachers' resolution of the contradictions. In what follows, the two teachers' resolutions of those emerging contradictions and their impacts on the development of ICT-supported constructivist classroom practices will be presented.

Case 1: Jorge's class

An activity system analysis of Jorge's ramp project revealed that he set up innovative and unique mediators for his class activity system, i.e., well-accommodated artifacts, new rules of interaction, division of labor.

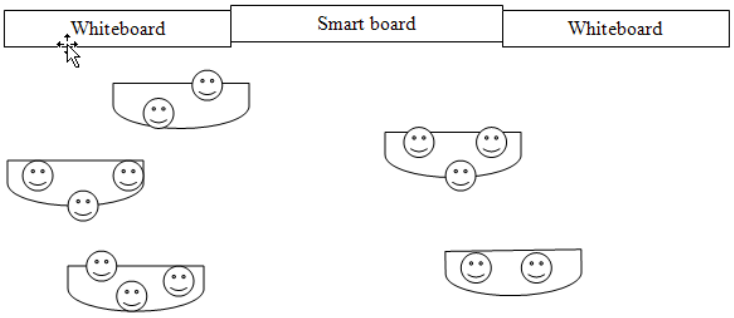

Figure 4. A typical setting of Jorge's class
(From the researcher's fieldnote on February 13, 2007)

Jorge used a science lab, where groups of two to three students sat around round tables. Figure 4 depicted a typical setting of Jorge's classroom during the project period. Students sat with their group partner(s) at the very beginning of the each class. At the beginning of the observation, Jorge's classroom appeared to be quite distracting and chaotic because students were free to walk around and talk to peers

in other groups. In contrast to the researchers' initial concerns, the further observations revealed that this new rule of interaction, which allowed students to exchange their knowledge with peers, fitted well with the project-based activity because it in turn set up a new division of labor, such as teacher as facilitator and student as active participants. This well-mediated activity system of Jorge's classroom led to the resolution of the contradictions, as follows.

Student diverse needs in the project-based activity. During the project-based activity, students displayed different needs, questions, and working paces. Jorge cultivated dynamics of the activity by setting up new rules of interaction and establishing new roles for students and teacher. To encourage students to engage in activities and exchange learning experiences with peers, Jorge allowed students to walk around the classroom to seek help from their peers. Moreover, he was often observed to redirect students, who asked him questions, to their peers whom he recognized as knowledgeable about a particular question. Jorge referred to these students as "Class Experts". This rule freed him from answering all the questions that students asked and thus he was able to spend more time facilitating individual group work. For example, he walked around from group to group, mediated arguments among students, asked students to make sure everyone got a turn to cut frames or cardboard. Once students checked their work with Jorge, they were allowed to advance to the next step of the project so that students could work on their pace.

The effectiveness of Jorge's new role was evident in our observation of Jorge's intervention with one particular group. This group of two was problematic because either one of the students was absent for three consecutive days (Day 5, 6, and 7). Jorge went up to the group, where Antonio was working alone, and encourage him by saying, "You had an exceptional decision yesterday to stay working alone, but if you need help, I can put you with a group to work with." When Antonio refused to work with other groups and decided to work on his own, Jorge respected his decision and offered help to him by holding the parts while Antonio was trying to

glue them together. Jorge also provided him with an individual advantage for working alone, such as a half-done Geometer's Sketchpad file for homework, in order for him to ease the workload.

Dealing with unexpected errors. The project-based ramp activity is not the kind of curriculum that could be commonly seen in traditional secondary math classrooms. Due to its unstructured nature, the project-based activity resulted in students making a diverse range of errors, including incorrect calculations, cutting the wood sticks inconsistently with calculated dimensions, gluing wrong pieces together, and so forth. The teachers' role is then to help students deal with challenges and overcome obstacles that they run into during the project (Blumenfeld, Fishman, Krajcik, Marx, & Soloway, 2000; Krajcik, Czerniak, & Berger, 1999; Postholm, Pettersson, Gudmundsdottir, & Flem, 2004). When Jorge' discovered calculation mistakes made by a student group on Day 4, which was the first observed student mistake, Jorge asked the students to cross out their incorrect calculations, instead of erasing them, so that they could track what they did wrong and how they went about it. As well, he eased student frustration about the mistakes that they made by saying that "it is OK to make a mistake because you're learning from mistakes". On Day 6, Jorge stressed the importance of reflecting mistakes as following:

> 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.

With such a well-elaborated role of the teacher as facilitator and students as primary actor, Jorge created a supportive learning environment that enabled students to cope with and overcome the obstacles that they encountered during the

project. A stunning outcome from these role changes can be seen in the following episode. On Day 7, Group 1 discovered an error on their back view where cardboard was a bit shorter than the wood sticks. The two students discussed whether they would redo the part and decided to move on. Then, they asked the teacher for a digital camera, took pictures of their ramp inside and out, and added to their daily project log, in order for them to thoroughly report what went wrong and why it happened. After seeing them doing so, other groups wanted to take pictures of their models too. One student even pulled out his cellphone (after asking the teacher because of the school's no cell phone policy) and took pictures with it, showing a voluntary integration of technology for their learning. Later in the project, all of the student groups included the inside views of their ramp in their PowerPoint presentations, which would have been hidden under the sealed cardboard construction otherwise.

From math to hands-on practice. In the project, a core activity was to calculate the lengths of x-trusses of the ramp, cut balsa wood according to the dimensions, and build a ramp with the support of the x-trusses. This is where students were asked to show their situated mathematical understanding as well as hands-on applications of the Pythagorean theorem. However, because of the thickness of the balsa wood (.7cm) it was not an easy task to construct an x-truss with the intersection being overlapped and required quality collaboration. In Jorge's class, students were aware of the importance of the x-truss and thus seeking a way to make the truss stable. Jorge, again as a facilitator, helped students resolve this problem by suggesting using heavy books to press down and bend wood sticks. One of the groups had an argument over this activity because one of the students wanted to cut a piece of truss in half and put them together with the other piece in a butt-joint in order to make the task simpler. The other two students of the group disagreed, explaining that it would not give enough support if cut in half. After all, all of the groups did manage to complete this challenging requirement of the project, except one group

whose ramp was too small to put an overlapped x-truss, according to their own analysis in this group's PowerPoint presentation.

Case 2: Martha's class

An activity system analysis of Martha's ramp activity revealed that, despite the nature of the project-based class activity, she remained a rather traditional teacher-as-the-authorized instructional approach throughout the project period. The physical setting of her classroom was a typical traditional arrangement, where a pair of students sat in a desk and viewed the teacher, as depicted in Figure 5. Martha spent the first three days of the nine-day-project in solely lecturing about the concepts of the Pythagorean theorem and the project. Even after these three days of lecturing, she always spent the first 20 minutes of the 75-minute class in lecturing on math, mainly problems on the Pythagorean theorem for the rest of the entire project period. While the teacher was lecturing, students sat on their desk viewing front with different partners from whom they worked with for the ramp project. Such unchanged traditional instructional approach of Martha's appeared not to effectively resolve contradictions in the ICT-supported constructivist activity. Detailed analysis follows.

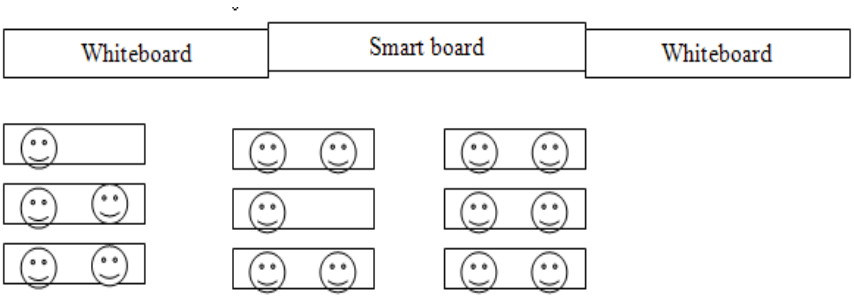

Figure 5. A typical setting of Martha's class
(From the researcher's fieldnote on February 20, 2007)

Student diverse needs in the project-based activity. Like Jorge's class, students displayed different needs during the project. However, the traditional role of Martha as a principal actor and that of students as rather passive recipients generated conflicts in their classroom practices. Because of her maintaining authority in class, whenever students had questions, they only came to Martha and not their peers, which heavily occupied her. Martha, moreover, was observed to stop students from talking to other groups because she said it was distracting. Students in Martha's class did not exhibit active exchange of knowledge between peers because students were only familiar with rules of interaction between the teacher and themselves, not between peers.

This traditional rule of interaction in the project-based activity created chaotic situations because while she "taught" a group many other groups had to line up to get their turn to ask. Moreover, it made difficult for Martha to identify and accommodate varied needs from group to group. For example, on Day 5, a student, Tom, had to work alone because his partner was absent. Tom was observed off-task and playing around with his laptop, e.g., surfing the Internet, reading and writing emails, for the first entire 40 minutes. When the researcher asked why he was not working he said because his partner had all the calculations and thus he could not do anything. Unlike Jorge, Martha never offered him to work with another group nor sit with him to help him with the task. Martha was not aware of this conflict that Tom encountered, mainly because her role as a principal and authorized person heavily occupied her time and thus she was not able to effectively intervene or accommodate individual needs of student groups to help them carry on the project.

Martha was often observed to try to have a control over student work, such as stopping an advanced group from progressing further in order to keep every group at the same progress level, whereas Jorge allowed students to move on once they got confirmed about the tasks with Jorge. This approach of Martha's generated conflicts because those who were done with designated work for the day started to

chat and play around with their laptop. It also influenced the other groups who still worked on the task because they joined in the conversations or web surfing instead of focusing on their remaining work. Such unchanged division of labor in the project-based unit caused students to be passive and receptive, which is far from what characterizes a well-formed student-centered learning environment (Park & Bracewell, 2008).

Hiding errors from the authorized. Students in Martha class also experienced various types of unexpected errors in the course of the ramp project, just like students in Jorge's class. However, ways that students dealt with the errors appeared to be dramatically different from those of Jorge's students. Students were mostly observed to attempt to hide their errors from the teacher as opposed to reporting and reflecting on their mistakes. For example, when Group 1 found calculation errors in their back view of the ramp, Joe in the group suggested to build the ramp first and adjust the calculation later (which should be the other way around) because "she [the teacher] won't know". This group did not report these errors at the final PowerPoint presentation.

It was more evident in the following episode with Group3 that students did not appreciate the opportunities to reflect on the mistakes that they made and wanted to hide their mistakes from the teacher. On Day 8, the researcher found that students in Group 3 were about to seal the ramp without an x-truss, which was one of the essential requirements of the activity. It was when the researcher asked one of the students where their trusses were that they realized the mistake. After the researcher left the group, they decided to seal the ramp model without putting x-trusses because they said that the teacher would not know after it was sealed. As students anticipated, Martha stated in the post-interview that "Most of them discovered before their ramp was complete that they were making… either they discovered or they're pointed out to them, that they're making mistakes. So, they managed…I think all groups managed to fix it", showing her unawareness of

students' hidden errors.

Gap between theory and practice. Putting thick x-trusses in the ramp also appeared to be challenging for students in Martha's class. In contrast with how Jorge's students deliberated to deal with this problem, Martha's students did not think twice: they started to cut one of the wood pieces in half. In this way, they would not have to bend one piece over onto the other; however, not only would it not give the ramp much strength and support once it was cut, but it also was inconsistent with the purpose of this project, building a ramp based on the calculations of the wood lengths using the Pythagorean theorem. After all, five out of six groups in Martha's class cut their trusses in half to make it an easier task whereas none of the groups in Jorge's class did so. This incident showed the project based-activity in Martha's class hardly accomplished its main purpose, helping students construct knowledge by bridging gaps between mathematical theories and hands-on practices (Blumenfeld et al., 2000). That is, gaps remained between the calculations of the Pythagorean theorem for the x-trusses and student understanding of why the x-trusses were required for the construction. A traditional division of labor in Martha's classroom practices (i.e., teacher as authority and student as passive learner) affected student performance--not to go beyond what the teacher asked them to do and avoid any extra work, resulting in less creativity and flexible thinking than what Jorge's active students displayed during the project.

Consequences of a lack of teacher's facilitation for student reflection were more evident in the student PowerPoint presentations at the end of the project, as Martha expressed herself disappointment about the student presentation in the post-interview. None of the students took a picture of inside of their ramp models to report how the inside of the ramp construction looked like and all the groups sealed the ramp with stickers before the PowerPoint presentations. The students in Martha's class paid little attention to their errors and how they went about them because Martha, unlike Jorge, had never stressed on keeping track on their errors

and solutions. In the post-interview with one of the student groups who made errors, they responded as follows:

Researcher: I remember that you didn't talk about the errors that you've made at the PowerPoint presentation.

Tom: Yes, that's true

Jack: We forgot that.

Tom: We forgot to add that. We just forgot. But we had errors. We had a lot of errors. We just forgot to put them in.

The post-interviews with the students revealed that none of the students took a note about their mistakes or errors to keep track on their project, whereas Jorge's students were fully aware of the importance of keeping notes on errors. In the end, Martha's students ended up losing an opportunity to reflect on what they had learned from the mistakes. The following student responses to a researcher's question about the presentation indicated how differently theses students from Martha's and Jorge's classes conceived of benefits of the presentation session.

Researcher: Did you learn anything from others' presentation?

Mat (from Martha's class): Not much. It was just about presenting what they did.

Alex (from Jorge's class): [I learned that] there's no good or bad design you can say. Either way, you always have to find and correct problems.

Discussion

According to Blumenfeld et al. (2000), project-based activities provide students with opportunities to construct knowledge by solving real and authentic problems through "asking and refining questions, designing and conducting investigations,

gathering, analyzing, and interpreting information and data, drawing conclusions, and reporting findings" (pp. 150). The effective use of ICTs could elevate potentials of such project-based constructivist learning activities in classrooms in many ways, ranging from widening information resources through the Internet, to promoting interaction between teacher and students through email and knowledge forum, and to easing complicated tasks through automatized software. However, findings from this study indicated that it was not ICTs per se that played a key role in the effective development of the student-centered project-based learning activity; rather it was teachers' awareness, efforts, and resolutions of the problems and conflicts that the project-based ICT-supported activities generated in classroom activities.

Jorge adjusted other mediators than simply the use of ICTs, such as introducing new rules of interaction (e.g., consulting Class Experts) and establishing new divisions of labor. Students were encouraged to interact and exchange their knowledge with their peers and the teacher acted as a facilitator for the project, advising and intervening on problems that the students ran into during the project. These revised mediators with the use of ICTs helped the students develop ownership of the project and make more effective choices for the project. For instance, although it was the student's idea to pull out the cell phone and take pictures of their trusses, the opportunity was created by Jorge's encouragement that it is okay to make mistakes. Jorge created a safe environment for students to admit, show and explain errors without the traditional negative consequences of receiving a grader reduction.

In contrast, Martha tended to remain with traditional instructional approaches, where rules of interaction were not well established to encourage students to actively exchange their knowledge and perspectives with peers. This underdeveloped rule of interaction in turn defined the division of labor in her class in terms of teacher as an authority and students as followers, resulting in student passive participation and less reflections on the project. We regarded Jorge's class activity system as a well-formed activity system where other components had been

changed to resolve emerging contradictions whereas Martha's as an ill-formed activity system in that the rules of interaction and divisions of labor had not been sufficient to support the effective ramp project. The contrast between Jorge's and Martha's class activity system for the ramp unit were depicted in Figure 6 and 7, respectively. Broken arrows in Figure 7 represent contradictions between constituents of the activity system.

Change in one part of an activity system often creates problems in another part of the system. In other words, classroom practices requires a more comprehensive analysis of the context under study, particular when related to the use of ICTs. Often ICT is studied in isolated rather than in relation with other factors such as teachers, students, lesson plan, and more (Chaney-Cullen & Duffy, 1999). Like in the present cases, a teacher's enactment of new instructional strategies associated with ICTs can at first cause disturbances in existing classroom practices such as student off-task behaviors or unexpected errors. 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. However, contradictions are not necessarily bad because they are the "engine" for the activity system to move forward. Development is seen as an attempt to adjust, abandon, or re-create mediators in the activity system in order to resolve contradictions (Engeström, 1987; 1999b; Kornilov, 1924, as cited in van der Veer & Valsiner, 1991). A key in the development from this perspective is how much actors are aware of the contradictions and react to them effectively, as shown earlier in Figure 3, the Expansive Cycle of Learning (Engeström, 1999). Applying the two teachers' cases into the Cycle, Jorge's development of his ICT-supported constructivist classroom practices can be marked at the sixth stage where Jorge and students together sufficiently reflected on their ramp building project whereas Martha's can be interpreted as being stalled at the first stage where Martha was questioning herself about student disappointing performance.

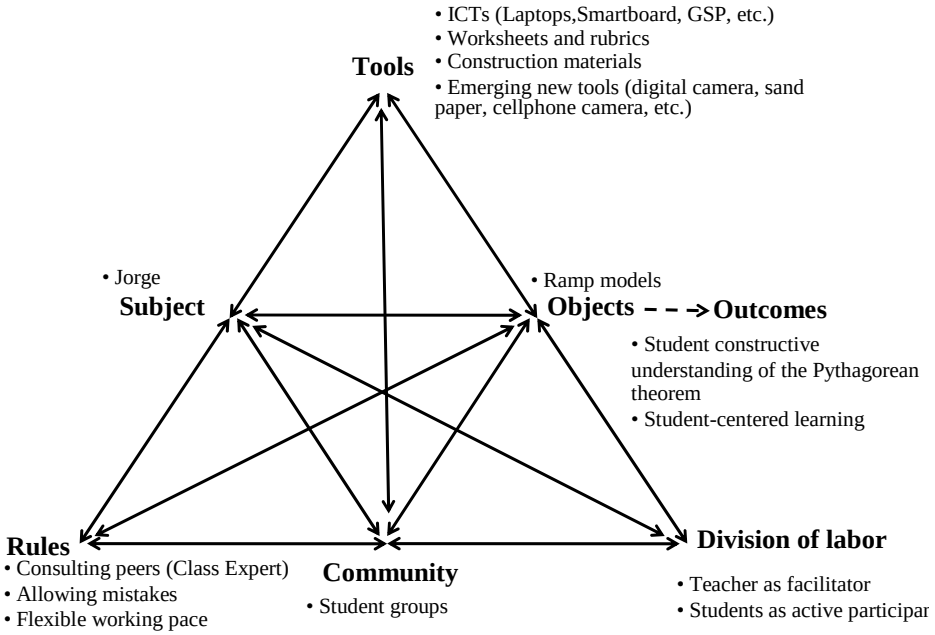

Figure 6. Jorge's Activity System in the Ramp Unit

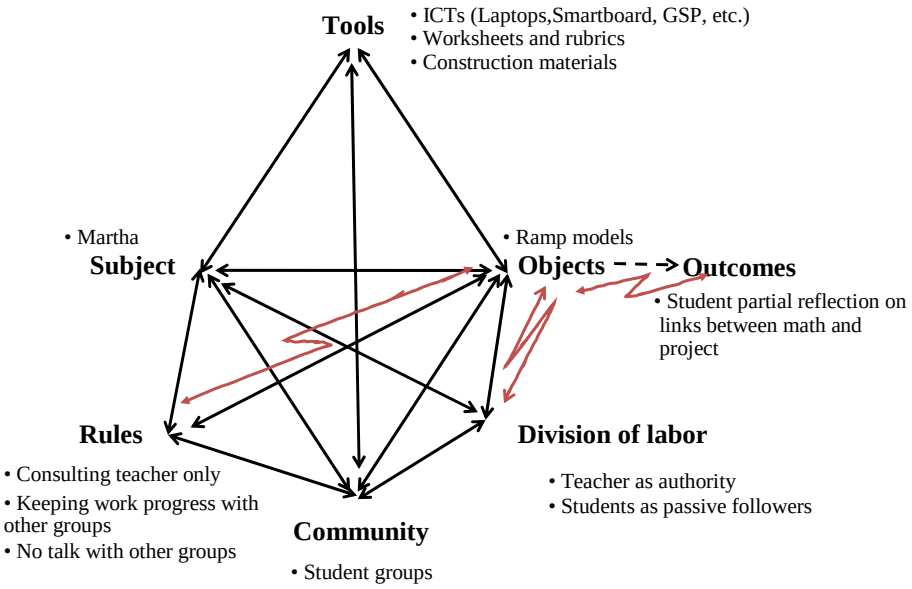

Figure 7. Martha's Activity System in the Ramp Unit

Overall, this study implied that the extent of teachers' awareness and resolutions of the classroom contradictions played a large role in the development of a student-centered learning environment or a culturally-advanced activity system, where students assumed greater responsibilities for their learning and were guided to make effective decisions for their learning (Hannafin & Land, 1997). A role of researchers is then to help teachers be aware of and visualize hidden tensions and contradictions through active engagement in the actual classroom activities. Along the same line, a new approach to professional development for teachers could be researchers' on-site active engagement in the local contexts and help teachers concentrate their energy on resolving contradictions.

References

Apple Computer of Tomorrow (ACOT). (1998). *Changing the conversation about teaching, learning, and technology: A report on 10 years of ACOT research*. Retrieved on March 12, 2007 from: http://images.apple.com/education/k12/leadership/acot/pdf/10yr.pdf

Blumenfeld, P., Fishman, B. J., Krajcik, J., Marx, R. W., & Soloway, E. (2000). Creating usable innovations in systemic reform: Scaling up technology-embedded project-based science in urban schools. *Educational Psychology, 35*(3), 149-164.

Bracewell, R. J., Sicilia, C., Park, J. and Tung, I. (2007, April). The problem of wide-scale implementation of effective use of information and communication technologies for instruction: Actyvity theory perspectives. Paper presented at Annual Meeting of AERA 2007, Chicago, IL, April 9-13, 2007.

Bracewell, R. J., Tung, I. & Sicilia, C. (2005). Activity, tasks, and work ensembles: Constructs for understanding teachers' use of information technologies for instruction, paper to be presented in American Educational Research Association, April 11-15th, 2005, Montreal, Canada.

Chaney-Cullen, T., & Duffy, T. M. (1999) Strategic teaching framework: Multimedia to support teacher change. *Journal of the Learning Sciences, 8*(1), 1-40

Cuban, L. (2001). *Oversold and Underused: Computers in the Classroom*. Cambridge, MA: Harvard University Press.

Cuban, L., Kirkpatrick, H., & Peck, C. (2001). High access and low use of technologies in high school classrooms: Explaining an apparent paradox. *American Educational Research Journal*, 38(4), 813-834.

Engeström, Y. (1987). *Learning by expanding: An activity theoretical approach to developmental research*. Helsinki: Orienta-Kousultit.

Engeström, Y. (1999). Activity theory and individual and social transformation. In Y. Engstrom, R. Miettinen, and R. Punamaki (Eds.). (1999). *Perspectives on*

Activity Theory (pp.19-38). Cambridge University Press.

Engeström, Y. (2000). From individual action to collective activity and back: Developmental work research as an interventionist methodology. In P.Luff, J. Hindmarsh & C. Heath (Eds.), *Workplace Studies*, 150–168. Cambridge, UK: Cambridge University Press.

Ertmer, P.A. (2005). Teacher pedagogical beliefs: The final frontier in our quest for technology integration? *ETR&D*, 53 (4) 2005, 25-39.

Hannafin, M. J. & Land, S. M. (1997). The foundations and assumptions of technology-enhanced student-centered learning environments. *Instructional Science,* 25, 167–202.

Hasu, M. (2001). *Critical Transition from Developers to Users. Activity-Theoretical Studies of Interaction and Learning in the Innovation Process.* Academic Dissertation. University of Helsinki, Department of Education. Espoo: Otamedia Oy.

Kornilov, K. N. (1924). The dialectical method in psychology. *Pod Znamenem Marksizma*, 1, 107-13.

Krajcik, J., Czerniak, C., & Berger, C. (1999). *Teaching children science: A project-based approach.* Boston: McGraw-Hill.

Leont'ev, A. N. (1978). *Activity, consciousness, and personality.* Englewood Cliffs: Prentice-Hall.

Leont'ev, A. N. (1981). The problem of activity in psychology. In Wertsch, J. (Eds.), *The concept of activity in Soviet psychology.* Armonk, NY: Sharpe.

Merriam, S. (1988). *Case study research in education: A qualitative approach.* San Francisco: Jossey-Bass.

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

Park, J. (2009, April). On-site interventions of teaching practices for an ICT-

supported constructivist classroom: Contradictions and resolutions. Paper presented at the Annual Meeting of the American Educational Research Association, San Diego.

Postholm, M. B., Pettersson, T., Gudmundsdottir, S., & Flem, A. (2004). The need for structure and guidance when ICT is used in project work. *Mind, Culture, and Activity, 11*, 178-200.

Roth, W-M. & Tobin, K. (2002). Redesigning an "Urban" Teacher Education Program: An Activity Theory Perspective . *Mind, Culture, and Activity, 9*(2), 108–131.

Sicilia, C. (2005). *The challenges and benefits of teachers' practices in constructivist learning environments supported by technology*. Unpublished master thesis, McGill University, Montreal, Canada.

Stake, R. E. (1995). *The Art of Case Study Research*. CA: Sage Publications.

Strauss, A. & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. London: Sage.

van der Veer, R. & Valsiner, J. (1991). *Understanding Vygotsky: A quest for synthesis. Oxford, UK: Blackwell.*

Vygotsky, L. (1978). *Mind in Societi: the development of higher psychological processes.* Cambridge, MA: Harvard University Press

Windschtl, M. (2002). Framing constructivism in practice as the negotiation of dilemmas: An analysis of conceptual, pedagogical, cultural, and political challenges facing teachers. *Review of Educational Research, 72*(2), 131-175.

Yin, R. (2003). *Case Study Research: Design and Methods.* 3rd edition. CA: Sage Publications.

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