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Reflective Adaptation of a Technology Artifact: A Case Study of Classroom Change

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This case study examines the changes that took place in a 5th-grade mathematics classroom in Hong Kong when an American-made technological artifact was introduced. Using classroom observation, videotaping, and daily interviews with the teacher and students, the study documents the changes that occurred in the classroom and the factors shaping those changes. Using the artifact prompted the teacher to make changes by altering the content, the sequence of instruction, and the social arrangements for class participation. In addition, the class engaged in extensive discussions about the social implications of solving complex mathematics problems. Most of these changes, however, were made after the attempts to maintain routine instruction broke down. The study suggests that new technologies that are not compatible with the existing practice may lead to intense and sometimes profound reflections about which aspects of the individuals, their environment, and the new artifact to adapt into a new classroom structure. A significant challenge is how to support participants' role shifting and their subsequent psychological changes when new technology is introduced.

This article is about a fifth-grade mathematics teacher in Hong Kong who agreed to try out a new, American-made technological artifact—a video-based story involving mathematics problem solving from the Jasper Woodbury series (referred to as Jasper) developed at Vanderbilt University. My goal was to examine how the teacher responded to the new artifact by observing the changes she made in her classroom and the factors shaping those changes. As the data portray, the Jasper artifact prompted the teacher and her students to reflect on and change some of their

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practices but not others. Notably, in the process of adapting the artifact and the classroom to one another, both teacher and students became reflective about their current practices.

This study was motivated by an interest in how to change classroom practice. One approach that has drawn a great deal of attention in recent years is to look to the practices of other groups and cultures to uncover alternative models of education. For example, researchers have looked to learning in nontraditional educational settings, such as workplaces or households (Lave & Wenger, 1991; Moll, Amanti, Neff, & Gonzalez, 1992). In other cases, teachers from one culture have watched videotapes of teachers from another culture to notice useful techniques and practices (Stigler & Hiebert, 1999). Ideally, exposure to different educational practices can inform and even change the prevailing methods of instruction in one's own culture. However, as Hatano and Inagaki (1998) pointed out, transplanting practices from one culture to another can lead to a sense of restriction, threat, and defensiveness by the recipient culture when such practices offer prescriptions that are perceived as an imposition of foreign cultural values.

An alternative approach, explored in this study, comes from the history of sociocultural change. This body of research has suggested that cultures can influence one another through the material artifacts they exchange and develop. Anthropologists (Bernard & Pelto, 1987; Pelto & Muller-Wille, 1987), social philosophers (Garfinkel, Lynch, & Livingston, 1981; Marx, 1939/1973), and cultural historians (McClintock, 1988) are some of the many who have documented the power of material artifacts in precipitating cultural change. Artifacts can cause changes not only within a culture but also across cultures. For example, the printing press brought about dramatic changes within Western religion and politics (Eisenstein, 1983). The export of silk products from China to Rome reached across cultures to completely change the Roman fashion industry (Yang, 1993). The introduction of snowmobiles from America into Northern Arctic communities changed the local culture in a profound way (Pelto & Muller-Wille, 1987). The snowmobile enabled native people to reach their hunting grounds in one sixth the time it had previously taken. As a result, people started to live in centralized communities, and the culture became less nomadic.

Although numerous anthropological studies have demonstrated the significant role of an artifact broker in fostering cultural change and interaction, few studies have examined this process in classrooms. This issue is becoming increasingly important as more and more technology is introduced into schools. Recently, there has been a growing interest in using electronic material artifacts such as computer systems and software to change classroom practices. The few documented cases have suggested that such artifacts can be powerful sources for classroom change. Research by Schofield (1995) provided an example of classroom change within a culture. Her studies showed that the use of the Geometry Tutor, developed by Anderson, Boyle, and Yost (1985), resulted in unanticipated changes in classroom

culture. The roles and power relations between the teacher and the students shifted. The teachers lectured less, creating more opportunities for students to teach each other.

An example more relevant to cross-cultural settings showed that exposure to the Japanese Suzuki music instruction motivated American educators to change certain aspects of their approach to music education (Peak, 1998). Now American teachers try to improve student performance by having them spend more time in repetition and perfection of previously learned material. Another example is a software program, Computer-Supported Intentional Learning Environment (CSILE), which was imported from Canada to Japan (Oshima & Oshima, in press). The use of CSILE was influenced by Japanese learning styles, but the program also changed local students' face-to-face communication styles. It seems that when a new artifact is introduced into classrooms, there is a process of dual adaptation whereby the affordances of the artifact and the teachers' beliefs and practices interact to create changes. Although exporting material artifacts implies exporting a particular set of cultural values and practices, material artifacts are usually less restrictive and prescriptive than practices and can be used in different and unintended ways (Lin & Hatano, 2001; Suchman & Trigg, 1991). In this sense, exporting artifacts tends to be less imposing than exporting educational practices as prescriptions of action sequences. Material artifacts offer affordances for many different kinds of functions and uses (Lin & Hatano, 2001).

Sometimes new artifacts are assimilated into the existing culture without causing much change. Previous research on Jasper has shown that in some classrooms, teachers assimilate Jasper into their conventional ways of teaching by lecturing on problems and deciding for students what they should do (Cognition and Technology Group at Vanderbilt, 1997). At other times, a culture can be overwhelmed by the artifacts, as in the snowmobile example (Pelto & Muller-Wille, 1987). In most cases, however, people adapt some aspects of the cultural practices that the artifacts support, but not others. We know little about how people select adaptations or about the factors that influence the selection. Understanding how individual teachers handle new technologies is important because teachers are responsible for mediating the interactions between the artifacts and the classroom culture (Darling-Hammond & Bullmaster, 1997; Putnam & Borko, 1997, 2000).

The case study reported here contributes to the literature on artifacts and adaptation by looking at *reflective adaptation*—a process by which individuals within a community explicitly choose aspects of an artifact for adaptation and evaluate their choices. Reflective adaptation often includes the questioning of one's existing practice and goals. This article includes a description of how mathematical learning and teaching practice embedded in an American-made artifact changed and was changed by a Hong Kong classroom as well as what mediated the change. Studying cultural change in a classroom context allows a focus on individuals within a culture—a benefit that is rather difficult to achieve in studies of a larger

society. Such understanding may be valuable for supporting teachers' efforts to change the classroom and teaching practices that the technological artifacts invite.

I conducted a case study because the specific research questions required detailed and intensive classroom observation, making it impractical to study more than one class. As pointed out by Steffe and Thompson (2000), the theory derived from case studies is generalizable, even though the experiments are grounded in analyses of a small number of classrooms. The insights and understanding developed from detailed studies can inform the interpretation of events and instruction in a wide range of classrooms (Cobb, 2001).

Although the study reported here involves introducing an artifact from one culture into another, it was not a classic cross-cultural study. In studies such as those carried out by Stevenson and Stigler (1992), researchers have made cross-cultural comparisons of typical learning and teaching practices. In contrast, the aim of this study is to introduce novelty and observe how the teacher responds to the new situation. This approach is adapted from the breaching experiment methodology developed by Garfinkel (1963). Garfinkel studied social structures by introducing new rules into a well-established society (Heritage, 1984). In this case, however, rather than new rules or procedures, a new artifact is introduced. Artifacts tend to induce active participation and interaction; thus, leaving people with greater leeway to respond. For example, the teacher in this study had the option of adopting the artifact blindly, in the way the designers propose or in the way she had always taught, or of using it in new ways to take fuller advantage of the learning potential offered by the artifact.

DESCRIPTION OF THE RESEARCH DESIGN

The central questions for the study were as follows:

1. How did the teacher prepare for the new artifact?
2. To the extent that the artifact affected classroom routine practice, what changed and what remained the same?
3. What shaped that change, as revealed through the issues that the teacher and the students chose to reflect on, and what were their perceived personal gains and losses?

School Selection

The study was conducted in a morning elementary school in the Shatin district in Hong Kong. Students come to school at 7:00 a.m. and leave at noon. The one-building school is on a narrow street surrounded by government-subsidized housing where most of the students live. I chose this school because, compared to

other schools, the principal and the parents offered the strongest support for the use of the Jasper video. This support was important for the case study because a prerequisite for studies of this kind is the acceptance of the artifact by the local culture.

I sent the Jasper video with a letter explaining the research plan to 12 local elementary schools. Four schools responded enthusiastically that they were willing to try Jasper in their classrooms because it would help their students learn to deal with complex mathematics problems. None of these is a prestigious school; annual test scores are ranked average among the schools in Hong Kong. Among the 4 schools that responded, 3 schools were able to commit only 2 to 3 days to Jasper due to time constraints. The school chosen was able to devote 1 whole week to the project because of the strong support provided by the principal.

According to local colleagues, the average and lower ranked schools usually are more willing to try innovations because use of new technologies improves the status and popularity of the school in the community. More prestigious schools usually have heavier course loads and therefore less time for trying new things. In addition, parents at top schools see less need for change. Clearly, technological artifacts need to be accepted to be successfully adopted.

Teacher Selection

The teacher, Mrs. Lam, was chosen by the principal as a representative mathematics teacher in the school. She had a 3-year college degree in elementary education and 5 years of teaching experience. Similar to most of the mathematics teachers in the school, Mrs. Lam teaches two additional subjects, Chinese language and arts and craft classes.

When we presented the Jasper video to Mrs. Lam, she said, "Using a story for mathematics problem solving will help my students learn not only how to calculate, but also the concepts behind the calculations. I feel that the story will also provide a richer environment for moral and spiritual learning."

Mrs. Lam had never seen or used video materials such as Jasper in Hong Kong. Although Mrs. Lam liked Jasper, she voiced concern about using such materials as part of the existing Hong Kong curriculum because it did not fit into the current Hong Kong examination systems.

Mrs. Lam's Class

There were 40 students (22 girls and 18 boys), ranging from 10 to 11 years of age, in Mrs. Lam's class. Seventy-five percent of the students came from lower and lower middle-class families, and 25% were from upper middle-class families (e.g., parents have college degree or above). Students spent an average of 80% of their time after school (about 6 hr daily) doing homework, and 20% of the time (1–2 hr

daily) watching television (especially the evening news), helping parents cook dinner, or playing with friends.

Similar to most of the classrooms in the school, Mrs. Lam's classroom had a blackboard and a desk and chair for the teacher and each student. Students regulated their own behavior well. For example, before and during class breaks when Mrs. Lam was not present, the students chased each other in the classroom, laughing and shouting. However, the students assumed calm, attentive attitudes with remarkable speed when the teacher entered. Students did not talk unless called on by the teacher. Mrs. Lam could concentrate on instruction without worrying about reinforcing classroom discipline.

The Instructional Materials

The technology artifact used in the study was a video-based story that invites students to solve mathematics problems involving time, distance, and speed. *The Adventures of Jasper Woodbury* (Cognition and Technology Group at Vanderbilt, 1997; National Council of Teachers of Mathematics, 1989) was designed to support understanding of mathematical concepts of distance, time, and speed through learning activities involving collaborative problem-solving skills, negotiation about multiple possible solutions, and effective communication. The 15-min video story was presented in English with Chinese subtitles. The story describes how Jasper Woodbury bought an old cabin cruiser with a small, temporary gas tank and broken headlights. The story ends by asking whether Jasper can get his newly bought cruiser home down the river before sunset. The students need to generate a plan that considers a number of factors, including whether Jasper has enough money to buy gas to get home, whether he can arrive home before sunset, and so forth.

The only additional material Mrs. Lam received was a design document for the Jasper video. The document elaborates the design rationale and principles for the Jasper adventure series as well as the instructional goals embedded in the video. No lesson plans or any forms of professional development were provided. The research team did not suggest specific instructional strategies or classroom structures for using Jasper. However, team members made themselves available for questioning about the material.

Data Sources and Analysis

This study drew on three sources of data: (a) coding of the videotaped lessons, (b) narrative descriptions of the videotaped lessons, and (c) daily interviews with the teacher and a sample of 12 students. The videotaped lessons are coded to capture and compare systematically what went on in routine and Jasper lessons and how the teacher's practice changed. The narrative descriptions of the videotaped les-

sons provide a rich sense of the flow of classroom events that was not captured in the coding. Formal interviews with the teacher and students provide the participants' perspectives on what was shaping the changes. Together, these data sources connect changes in the lessons with the beliefs embedded in the local culture that were influencing the change.

Videotaping Lessons

The research team consisted of the author of this article and two research assistants from Hong Kong. As participant observers, the team went to Mrs. Lam's class 2 days per week for 2 months before the study to get to know the students and the classroom setting. During the Jasper lessons, the teacher and students could share concerns and ideas with us. We responded to questions about the content of the video, the process of its development, and its design rationale. We also participated in parent–teacher meetings as well as students' after-class activities. This helped the researchers develop a sense of how the teacher and students engage in routine classroom practice. In addition, it minimized the disturbance caused by the researchers' presence. By the time videotaping began, trust between the researchers and the school administrators, teacher, and students had developed. The videotaping of the class did not seem to make students and the teacher act differently.

Five routine classroom lessons and five Jasper lessons were videotaped. The routine (non-Jasper) lessons consisted of three lessons on developing mathematical concepts of time (e.g., hours, weeks, days, years, and their conversions, etc.) using word problems, and two lessons on interpreting basic statistical bar charts. Each lesson was 40-min long. Selecting lessons that covered two different topics allowed us to see whether the instructional patterns changed when the topic switched. As with the Jasper lessons, the activities for each routine unit were spread out over several days. Therefore, the changes observed in Jasper lessons were not due simply to the duration of the Jasper unit.

Developing the coding system. Analysis of lessons began by transcribing videotapes of each lesson as completely and accurately as possible. The researchers watched each tape, paying special attention to similarities and differences in instructional patterns and classroom interactions across the lessons. Three major dimensions of the lessons emerged from the initial analysis of all the lessons. These dimensions formed the basis for further coding and provided objective procedures that could be used to describe the videotapes quantitatively (cf. Stigler & Hiebert, 1999). Interrater reliability for the initial coding was 91%.

The three dimensions were as follows:

1. Sequence of lesson activities: What went on in a lesson, and what goal was the teacher trying to achieve (e.g., reviewing previous lessons, explaining and clar-

ifying, analyzing, reflecting and revising, etc.)? How did the teacher sequence the activities, and how much time was devoted to each activity?

2. Social arrangements: What basic methods did the teacher use to engage students in a lesson? How did the teacher and students interact with each other? How did students interact with one another? How much time was spent in each type of arrangement?

3. Lesson content: What was the content of each lesson? How much time was devoted to different topics (e.g., problem identification, mathematical concepts and procedures, etc.)?

Coding of videotaped lessons. Once we developed general guidelines for what to code, we began creating specific coding systems for each of the three dimensions in a lesson. The three coders first worked on transcripts of a subset of the videos (i.e., three routine lessons and three Jasper lessons) to develop the detailed coding system for each dimension and to get a reliability estimate. We then coded the remaining lessons using the detailed coding system developed during the initial coding of the subset of the videos. All disagreements were resolved by discussions and consensus after the independent coding.

For each dimension, we coded for shifts in events. For example, we considered each change in the content of instruction to be a new event for the dimension of content knowledge and skills. However, a change in content was not a new event for the dimension of sequence of lesson activities if there was no change in the goals of the lesson (e.g., reviewing previous lessons, introducing a new lesson, and concluding a lesson). One advantage the video offers is that it can be coded multiple times, allowing data to be parsed at different levels depending on the dimension of the lesson being analyzed. We made passes through the transcripts of each lesson, focusing on a particular dimension in each pass. This ensured a correspondence between the level of analysis and the question we posed for each pass, thereby increasing the validity of our analysis (Chi, 1997). In addition, dividing coding tasks into several passes according to the goals of each pass or the lesson dimension reduced the cognitive load on coders and increased reliability and coding speed (Chi, 1997; Stigler & Hiebert, 1999).

Sequence of lesson activities. For this dimension, we coded sequence and length of different activities for a lesson. Often, there are at least three major instructional phases in each lesson: beginning a lesson, developing it, and ending the lesson (Erickson, 1992). We examined goals in each of these phases. For example, in different activities the teacher introduced the lesson, explained specific concepts and procedures through lectures, or assessed students' work (see Table 1). These activities represent what the teacher wanted to accomplish in a lesson.

We used the activities in Table 1 to parse transcripts into instructional events, with each shift in activity during a lesson considered a new event. The teacher gen-

TABLE 1
Codings For Sequence of Lesson Activities and Their Working Definitions

Category	*Definition*	*Example Quote*
Beginning a lesson		
Review	Teacher reviewing previous lessons with the students	Teacher started a lesson by asking, "Yesterday we learned how to convert weeks, days and hours. What were some of the key principles we have learned?"
Lesson introduction	Introducing the goals for a new lesson	"Today we are going to study …"
Developing a lesson		
Lecture–explain	Lecturing or explaining concepts, or problem-solving strategies	"This is how I convert 5 days and 5 hours into hours … OK, it is125 hours … how did I know if 125 hours was correct? I divided 125 by 24. Look at what I got …"
Class work	Students working on problems or other kinds of assignments	The teacher was working with all of the students in a whole-class situation, solving a particular problem.
Assessment	Checking students' understanding, work progress, and outcomes of their performance	"I would like to have four people come to the blackboard to show me whether they can solve these problems. The rest of you take out your workbooks and do the problems in your books …"
Homework	Teacher assigning homework and students working on it	Not applicable
Ending a lesson		
Conclude	Summarizing the main points of the lesson, and the class's progress	"Today, we learned how to prove our own solutions… the main point for today is …, but we did not finish what we had planned today. We'll finish tomorrow." "Let's compare what Group 1 did with Group 5. What have you noticed?…"

erally marked such shifts between lesson activities with explicit words and actions. For example, the teacher may have said, "Let's review what we learned yesterday," or, "Please take out the workbook that we did in class yesterday and review what we did." This review segment may include both lecture and seat work but was coded as one event for the dimension of instructional sequence because both activities served one goal—reviewing what was learned previously. A new instructional event was coded when the teacher said, "Today we will learn a new unit: how to

convert hours, days, weeks, and years. For this unit, we especially need to specify the unit of measures," indicating the shift to the instructional goal of introducing a new lesson.

For every lesson, we coded for the sequence of lesson activities and calculated the amount of time devoted to each activity. The interrater reliability was 82%.

Social arrangements. For the dimension of social arrangements, we analyzed the amount of time Mrs. Lam engaged her students in each form of arrangement: lecture, seat work, small-group, or whole-class discussions. See Table 2 for the descriptions of each category. The interrater reliability for this dimension was 84%.

Lesson content. For the dimension of lesson content, we analyzed the content that was taught in both routine and Jasper lessons. Mathematical procedures, mathematical concepts, problem identification, explaining processes, and social implications were the categories most frequently taken up in both routine and Jasper lessons. Each category, described in Table 3 with examples, was coded for the amount of time spent on different contents. The interrater reliability was 88%.

TABLE 2
Codings For Social Arrangement and Their Working Definitions

Category	*Definition*	*Links to Lesson Activities in Table 1*
Lecture	Teacher presenting or explaining a procedure, a new concept, a new problem, or guidelines for working on tasks in a lecture format	Review lesson introduction, explaining and clarifying, work on homework, conclude a lesson
Seat work	Students working independently on assigned tasks. The discussions were usually private between the teacher and one student. During the seat work, the teacher circulated the class to check students' work	Work on problems, work on homework
Small group	Students working with peers on assigned tasks. The discussions were usually between the teacher and the group rather than the whole class	Work on problems
Whole class	The teacher and students discussing or working as a whole group on various tasks. The discussions were usually public for the whole class to hear or to participate	Review, explaining and clarifying, in-class assessment, conclude

TABLE 3
Codings For Content Learning and Their Working Definitions

Category	*Definition*	*Examples*
Explaining processes	Providing verification or proof to the answers obtained. Explaining why and how specific strategies and formulas are used. Identifying what one does not understand	"How do you know that you got a correct answer?" "Okay, Jasper needs to start his journey to home at 2:35 pm. How did you know that? What information did you use?"
Mathematical procedures	Learning about the steps involved in doing various kinds of calculations; solving a specific problem	"Okay, how should we calculate this one: 2 weeks, 6 days, 19 hours + 18 weeks, 3 days = ( ) weeks, ( ) days …"
Mathematical concepts	Presenting general mathematical principles, properties, definitions (e.g., formulas or theorems), or methods for solving a class of math problems	"What's the formula that we can use?" "How many hours are there in a day?" "How to find out the distance between … and" "How many days are there in a year?" "How many days are there in 19 weeks?"
Problem identification	Analyzing the nature of problems, identifying what is given and what needs to be figured out, defining relations among various factors, and drawing inferences from what is said	"What was given in the video? What information do we still need to find out?"
Social–moral implications	Identifying the social–moral lessons learned from mathematics problem solving (e.g., attitudes, confidence, being neat and logical, etc.)	"What did Jasper problems tell us about the kinds of habits that we should develop in our daily life in order to avoid the problems that he had encountered?" "What did we learn about the importance of being organized from our Jasper experience?"

Narrative Descriptions of the Videotaped Lessons

Narrative descriptions provided a summary of interesting events that emerged from the videotaped lessons (cf. Stigler & Hiebert, 1999). Using this technique, we characterized what took place in the routine and Jasper lessons (Marshall & Rossman, 1995). Rather than describing entire lessons, this source of data provided detailed accounts of interesting events within individual lessons, in contrast to the video coding, which identified general patterns across all the lessons. For example, to examine assessment in routine lessons, we went back to specific seg-

ments and described what was going on with assessment. The narrative descriptions of the video thus added richness to the quantitative coding of the video lessons.

Interviews

The researchers interviewed Mrs. Lam and 12 students for 20 to 30 min at the end of the lesson each day. The teacher selected the sample of participating students, which represented low, medium, and high academic achievement in the class (4 students from each level). Focus group interviews were conducted with the 4 students each time. The interviews of the teacher and students were conducted in separate, private settings, such as a small conference room or an instructional material room in the school. All the interviews were audiotaped and transcribed, and the participants were assured that their comments would be treated confidentially and used only for research purposes.

The interviews included questions such as: "What went well or did not go well in today's lesson?" "Did you encounter any challenges or problems in today's lesson? If so, what were they?" and "How did you deal with these challenges?" These interviews provided us with the participants' viewpoints about what needed to be changed or preserved and why such changes were important. The interviewers probed the participants' responses extensively and followed up on topics suggested by the teacher and the students as important even if they were not part of the prepared questions. With respect to the Jasper artifact, we also asked the teacher and students what they liked and disliked about the Jasper experience and the perceived benefits and losses in using Jasper.

Three coders worked from the written transcripts of the interviews, with each coder individually reading and rereading all the transcripts. The constant comparative method of data analysis was used to construct and capture categories of the recurring issues that emerged from the data (Glaser & Strauss, 1967). The coders then compared notes to reach agreement on the most important issues that the teacher and students chose to reflect on for routine and Jasper lessons. The interrater reliability was 82% for the coding of teacher interviews and 84% for the students' interviews. Finally, we also presented our analysis of the interview data to the participants to increase the trustworthiness of the findings (Lincoln & Guba, 1985).

RESULTS

This section presents three main areas of findings. First, Mrs. Lam's preparations for the routine and Jasper lessons are described and compared. Discussion then focuses on how the instruction and interactions were organized in the routine and

Jasper lessons. Finally, the interviews of the teacher and students are summarized, including how they felt about the Jasper experiences.

Preparation for the Routine and Jasper Lessons

In Hong Kong, textbook publishers often provide teachers with standard lesson plans that have the following components: (a) specific learning goals and outcomes for each lesson, (b) content knowledge and skills that students should learn, (c) activities that teachers are encouraged to use, (d) learning habits the unit should promote (e.g., explaining the process of getting to the answer, independent reasoning, mental calculations, etc.), (e) supplementary materials and activities that the teacher might consider, and (f) homework assignments.

Because we did not provide Mrs. Lam with lesson plans for teaching with the Jasper video, she had to create her own. Her plan had three major components: (a) her general instructional objectives for the unit, (b) learning habits that she would like students to develop, and (c) predictions about the difficulties that students may have with Jasper problem solving. Table 4 contains an outline of her lesson plans.

Mrs. Lam also shared with us her feelings about preparing to use Jasper: "I have not been able to sleep well for many days, because there are too many things that I do not feel very certain about … I can't decide exactly what I want the students to do."

TABLE 4
An Outline of Mrs. Lam's Plans for Jasper Lessons

1. Objectives for the unit
   - Solving Jasper's problems: Can Jasper get home before sunset? Does he have enough gas to get home?
   - Understanding the story and the connections among subproblems and the main problem
   - Understanding what they are doing without guessing or copying others' ideas
2. Learning habits for the unit
   - Mental calculation
   - Displaying processes
   - Explaining what they do so that they understand what they do
   - Being logical
3. Predictions of difficulties and questions
   - Making sense of the American culture embedded in the story, including units of measure, accent of the characters, use of the boat, and so forth.
   - Maintaining efficiency in problem solving: How many problems should be solved each lesson? What should I do if they are behind schedule?
   - Evaluating the quality of problem-solving strategies: What count as good or poor strategies?
   - Homework: What kinds of homework should I give them each day?

She made predictions about difficulties students would encounter:

> Well, some of these concerns were generated from my own experience while watching the video and trying to solve the problem myself. Others were from my knowledge about my students, since I have taught them for 2½ years. I know their families … I know them quite well … know that my students will like the Jasper problem because they love difficult tasks and challenges. I also know that they will work hard and will also listen to me. These are the things I feel certain about

In discussing how she planned to address these difficulties, Mrs. Lam said that she could prepare for some difficulties ahead of time but would have to deal with others as they arose:

> I do not have specific plans for each of the areas that I am concerned about, but I do have some general plans. To help students understand the American culture, I need to learn about the culture embedded in the video myself first … I need to know how much is the gas in the U.S.? Does a gas station provide repair services or only gas? In the U.S., does it cost the same if you pay with cash or a credit card? I think I may give more instruction and guidance in Jasper lessons than I would in my normal classes

Comparing Routine and Jasper Lessons: What Was Changing?

In this section, I present the results from the coding and narratives of the videotaped lessons for three dimensions: sequence of lesson activities, social arrangements, and lesson content.

Similarities and differences between routine and Jasper classrooms for each of these dimensions are discussed in turn. Although five routine lessons and Jasper lessons were taped, one routine lesson video was not usable due to a technical failure during the taping. I present the findings from the four routine lessons and five Jasper lessons.

Sequence of Lesson Activities

The sequence and amount of time Mrs. Lam spent on each of the lesson activities during the routine and Jasper classes are displayed in Figure 1 (see Table 1 for activity definitions).

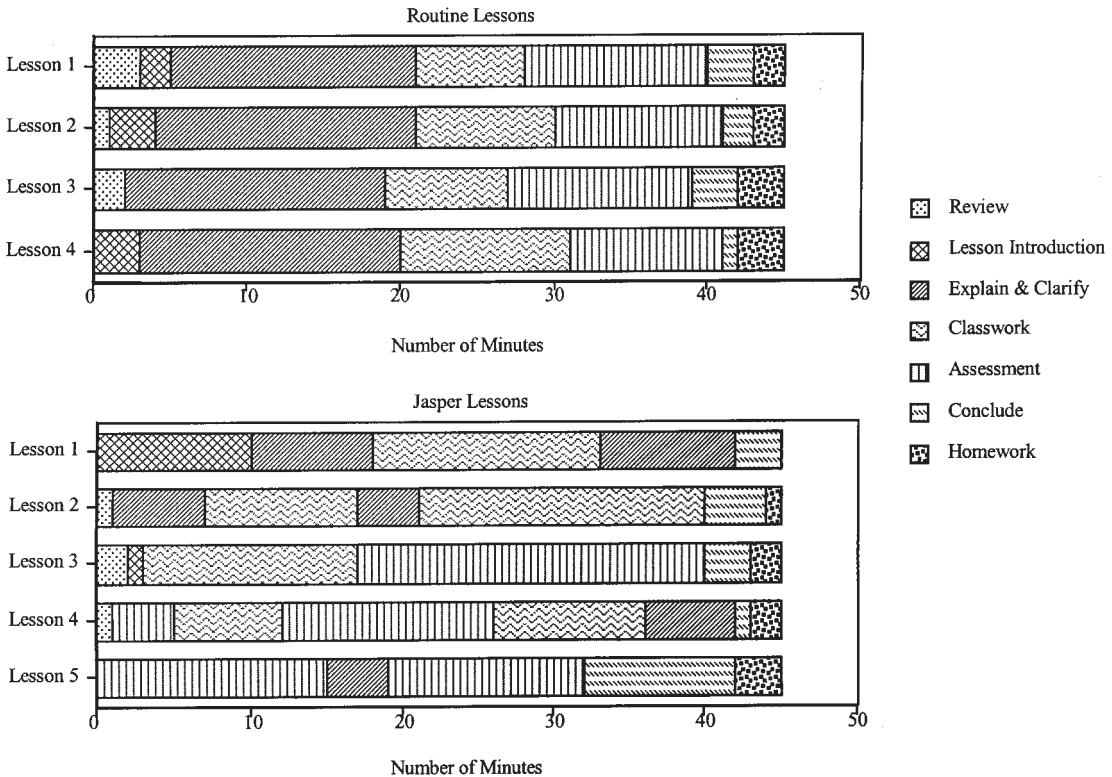


FIGURE 1 Sequence of lesson activities in routine and Jasper lessons.

Routine Lessons

Several important themes about the routine lessons are noticeable in Figure 1. The sequence of instruction remained quite stable and consistent for all the routine lessons, although different content topics were taught. Each lesson began with reviewing and introduction of the lesson, continued with the teacher's explanations or lectures on the content, followed by student class work and assessment activities, and concluded with the homework assignment.

Narrative descriptions of the videotaped lessons. Mrs. Lam began the routine lessons by relating the new concepts to previous lessons or daily life experiences. For example, Lessons 1 and 2 were about conversion of time, such as weeks, days, and hours. Before studying the mathematical concept of time, Mrs. Lam asked students to give examples from daily life of cases in which they had to convert weeks into days or hours, or vice versa. Once the teacher generated involvement in this manner, she lectured or explained how to solve a set of model problems. After the teacher finished lecturing, the whole class began working on problems individually. The teacher explained and clarified concepts to students by lecturing. She rarely held discussions, and students rarely asked questions or exchanged ideas with one another.

Toward the end of the class the teacher assessed student progress. During these assessments, she circulated through the aisles identifying students' mistakes or probing for more complete answers. Mrs. Lam usually kept these conversations private, instead of letting the whole class hear them. Some assessments involved having students come to the blackboard to show the steps for solving particular problems. The teacher graded students' work on the blackboard according to the correctness of their answers and how well they explained their solution processes.

Jasper Lessons

In the Jasper lessons, the sequence of lesson activities varied considerably from day to day (see Figure 1). However, the changes evolved over the course of the week. For example, the sequence of instruction for the first two Jasper lessons was similar to that of the routine lessons. The first two Jasper lessons started with lectures as the routine lessons did, even though the lectures occurred in two places (e.g., the beginning and toward the middle or the end of the lessons) instead of only at the beginning as in the routine lessons. Our interviews with Mrs. Lam at the end of the first two lessons showed that she made a conscious effort to maintain the routine lesson sequence at the beginning of the Jasper lessons. She later made changes in response to the problems her class encountered—breakdowns in the routine structure:

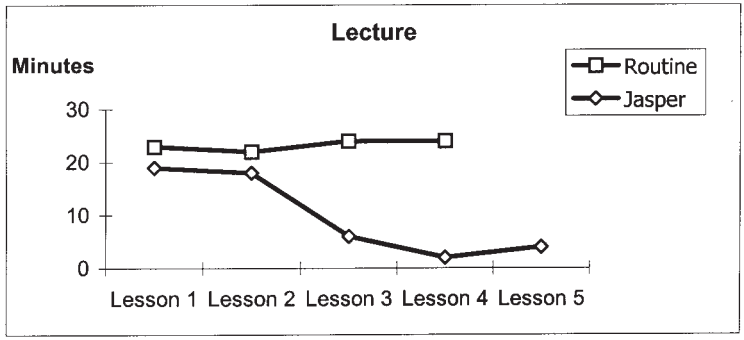
> When I first started Jasper, I tried to lecture to the class on what to look for in the story, what notes to take when the video was shown, and what problems

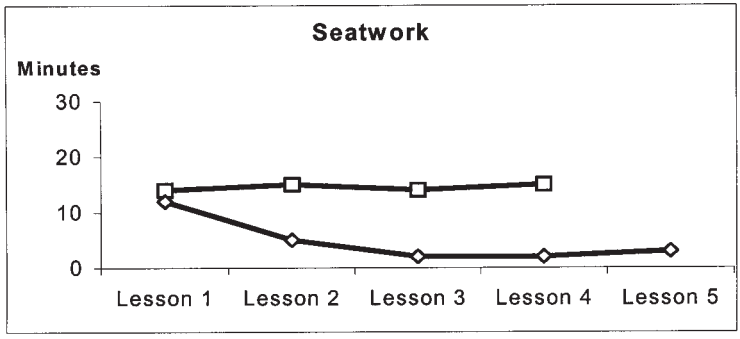
> the class needed to solve. I wanted to keep the same class structure … However, the complex nature of the Jasper problem caused a lot of disagreements among the students as to what was important to look for in the story, and how to approach the problems … It was almost impossible to give the kinds of lectures I used to give in the class.

By Lessons 3 through 5, the routine sequence of instruction was totally broken down, and a new sequence structure had developed. Figure 1 shows that instead of giving lectures or explanations at the beginning, the teacher started Lessons 3 through 5 by first letting students work on problems (class work) or assessment. The teacher lectured toward the end of the class. The total amount of time spent on lectures decreased greatly in Lessons 3 through 5 (see Figure 2), and more time was spent on assessment compared to routine lessons. Our interviews suggest that the teacher did not anticipate the changes in the sequence of instruction and lecture time ahead of time. For instance, during the preparation for Jasper, she said, "I do not have specific plans for each of the areas that I am concerned about … I think I may give more instruction and guidance in Jasper lessons than I would in my normal classes …"

Narrative descriptions of the videotaped lessons. A close look at Lessons 3 through 5 shows that Mrs. Lam started these lessons by first having students work on problems, ask questions, or present their work, followed by her instruction or whole-class discussions. (Participation arrangements are presented in more detail in a subsequent section.)

To assess students during the Jasper lessons, Mrs. Lam also developed new instructional activities that she had never used before in her mathematics class. As she said, "I have never used student presentations in my math class, although I have used them a few times in my Chinese language class." She asked the students to present and reflect on their work to the whole class instead of to her alone. During the presentations, instead of having students merely talk about their accomplishments, Mrs. Lam asked them to reflect on the issues the students did not understand and the difficulties they encountered in the group. The presentations ended by suggesting how the group would proceed with the problem solving more effectively on the next day. Because eight groups needed to present their work, Mrs. Lam also emphasized the need for the presentation and reflection to be highly focused and precise. In addition, Mrs. Lam told the class, "If your group experienced personal conflicts, let's not mention anybody's names, because that would only hurt the friendship, and might slow down your pace of problem solving." Thus, the students identified only the nature of the group problem, not the individuals who may have caused the problem. In the final Jasper lesson, most of the class time was spent in assessment, during which students explained and reflected on the problem-solving process and compared strategies used by each group. Mrs. Lam then





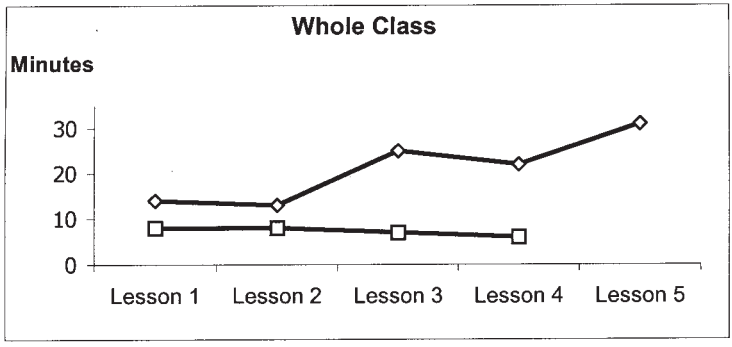


FIGURE 2 Number of minutes devoted to lectures, individual seat work, and whole-class discussions (each lesson is 45-min long).

assigned grades to each group according to whether the presenters clearly explained where they were in the process, what they did not understand, and the issues on which the group members could not reach an agreement.

In summary, the following changes were noticeable in the Jasper lessons when compared to routine lessons: (a) When Jasper was first used, Mrs. Lam made conscious efforts to maintain her routine lesson sequence, but she encountered difficulties—breakdowns in which routine practices were no longer effective; (b) after reflecting on the first two Jasper lessons, she made shifts in the sequence of instruction (e.g., Jasper Lessons 3–5 began with students solving problems or presenting their work followed by lectures from the teacher); and (c) she developed new instructional activities (e.g., the assessment was made more public, presentations were used, etc.). One common element shared by both routine and Jasper lessons was that the teacher always carefully guided and monitored students' progress. There was not one lesson in which the students were left alone to explore.

Social Arrangements

The use of the Jasper artifact also prompted Mrs. Lam to alter the forms of classroom interaction. Table 5 displays the average minutes spent on each kind of lesson interaction structure. In the routine lessons, most of the time Mrs. Lam chose to teach by lecturing and having students do seat work. No group work was involved. However, during the Jasper lessons, the majority of class time was spent on small-group work and whole-class discussions.

The large standard deviations for the Jasper lessons in Table 5 indicate that the time spent in lecture, small-group work, and whole-class discussions varied greatly across the five lessons. Figure 2 presents the distribution of class time over the five Jasper lessons. It shows that Mrs. Lam began the first two Jasper lessons trying to lecture (19 and 18 min each lesson) as she did in the routine lessons. As the lessons progressed, she lectured less, and the time spent on whole-class discussions increased (an average of 15 min for first two Jasper lessons vs. 26 min for

TABLE 5
Average Minutes Spent On Each Kind of Social Arrangement
(Total 45 min)

	Routine Lessons		*Jasper Lessons*	
Types of Social Arrangement	*M*	*SD*	*M*	*SD*
Lecture	23.25	0.95	9.8	8.07
Seat work	14.50	0.57	4.8	4.20
Small group	0.00	0.00	9.4	6.94
Whole class	7.25	0.95	21.00	7.58

Lessons 3–5). Her effort to maintain routine classroom social interaction was consistent with the findings in the sequence of instruction section.

Narrative descriptions of the videotaped lessons. The videos show that Mrs. Lam initiated most of the questions and conversations in class. In addition, the social-arrangement structures chosen by Mrs. Lam linked closely with the particular kinds of learning activities that she wanted her students to engage in (see the third column of Table 2). For example, small groups were never used in routine classes (see Table 5). During the Jasper lessons, however, she assigned students to small groups when there were many disagreements in the class as to the best way to solve the problem. When whole-class discussion was used, it was usually for lesson review and introduction, explaining or clarifying issues, or assessment. That is, the teacher's decisions about how to involve students in a lesson were influenced by the goals of instruction and the nature of the learning activities. Again, the changes in classroom social interaction were made with conscious effort and occurred after difficulties were encountered. For example, during our interviews, Mrs. Lam said:

> Students had a lot of disagreements on how to approach Jasper problems … I felt that dividing the students into small groups might be a wise thing to do because small groups come to agreements more easily and quickly than a whole class.

In summary, two key changes occurred in Jasper lessons: Time spent on lectures and individual seat work decreased over the course of Jasper lessons, and whole-class discussions and small-group work were the major forms of class participation in Jasper lessons. In both routine and Jasper lessons, the teacher initiated most of the questions and discussions.

Lesson Content

Due to the complex nature of Jasper problems, the content knowledge and skills required of students in Jasper lessons differed from those in routine lessons (see Table 3 for explanations of the content-knowledge categories). Table 6 displays average minutes spent in each kind of content learning for both routine and Jasper lessons.

As shown in Table 6, the amount of attention devoted to explaining processes was quite high for both kinds of lessons (13 min for routine lessons and 16 min for Jasper lessons). Explaining mathematical processes appeared to be a fundamental habit and skill that the teacher encouraged students to develop regardless of the nature of the lesson. However, compared to Jasper lessons, the routine lessons included much more time on teaching mathematical procedures (M =17 min in rou-

TABLE 6
Average Minutes Spent On Different Kinds of Content (Total 45 min)

	Routine Lessons		*Jasper Lessons*	
Nature of Topics	*M*	*SD*	*M*	*SD*
Explaining processes	13.75	0.96	16.80	3.90
Mathematical procedures	17.25	0.96	3.00	1.73
Mathematical concepts	11.25	0.96	5.80	2.59
Problem identification	0.00	0.00	12.00	9.08
Social implications	2.75	0.96	7.40	2.88

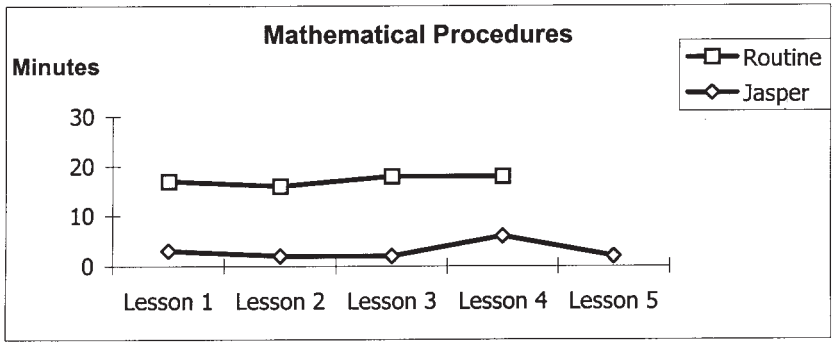
tine lessons vs. 3 min in Jasper lessons). Interestingly, in routine lessons, the teacher spent almost twice as much time addressing mathematical concepts as in the Jasper lessons (M = 11 min vs. 6 min). In solving Jasper problems, the teacher invested more time on mathematical problem identification and discussions of social implications than in the routine lessons (see Figure 3).

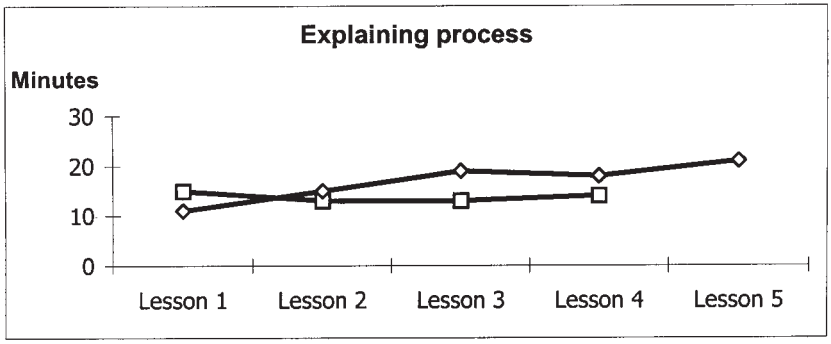
As shown in Figure 3, the teacher spent much more time at the beginning of the Jasper unit helping students identify problems (21 min and 20 min for the first two lessons, respectively). As the Jasper unit progressed, she spent less time on problem identification (10, 6, and 4 min for Lessons 3–5, respectively).

Narrative descriptions of the videotaped lessons. To get a realistic feel for the classroom flow, we examined video segments from the first two Jasper lessons. Mrs. Lam focused the first lesson on students' understanding of the story by asking students the following questions: "What was the relationship between Jasper and other characters in the story?" "What were the features of the boat that Jasper bought?" and "What was the moral of the story?" In the second lesson, she allocated more class time to analyzing what constituted the major problem and its subproblems. They talked about which information from the video was useful for solving Jasper's problems or for understanding American culture and which information should be ignored. The effort spent on identifying important information in the beginning made it unnecessary to allocate additional time to identifying problems as they progressed with the problem solving.

We also examined the nature of explanations because they were important components of both routine and Jasper lessons. In both kinds of lessons, the teacher usually asked students to explain what they did and why certain procedures were taken. For example, in Jasper lessons, the teacher frequently asked the groups who presented their work to explain how they came up with their solutions and what information led to the solution.

The coding of the videos showed that the time spent on social implications increased both from the routine to the Jasper lessons (M = 2.7 min in routine lessons vs.





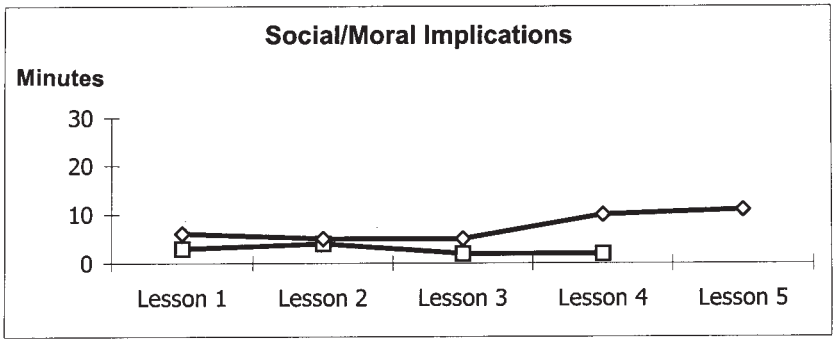


FIGURE 3 Time spent on different kinds of contents for routine and Jasper lessons (each lesson was 45-min long).

7.4 min in Jasper lessons; see Table 6) and across the 5 days of Jasper lessons (see Figure 3). To understand what was going on in those segments of the lessons, we went back to the video and saw that the teacher engaged students in talking about how the problems encountered by Jasper taught them about the kinds of habits they should develop as students, such as planning ahead, paying attention to details, being specific, using logic, and so forth. Mrs. Lam asked the students, "One of the social implications of working on Jasper problem solving involved the need for all of you to learn to work together as you coped with complex problem-solving issues. What lessons did you learn from the group work?" The class replied, "It is very important to honor patience and hard work because it takes a long time to get to the answers …"

In summary, we observed the following changes when the Jasper lessons were compared to the routine lessons: (a) More time was devoted to understanding and identifying problems rather than on mathematical procedures and concepts, (b) the class did not proceed until the story and the Jasper problems were fully analyzed and understood, and (c) the class spent an increased amount of time on the discussions of the social implications involved in Jasper problems. One common element of the routine and Jasper lessons was an emphasis on explaining and verifying solution processes for problem solving.

Issues Revealed From the Interviews

The interviews with the teacher and students provided additional data to help understand the various changes described previously. During our interviews, the teacher and students reflected on the kinds of challenges and dilemmas they encountered in Jasper lessons and how these challenges influenced the decisions for classroom change. Most issues the teacher and the students chose to reflect on were quite compatible with the values and expectations of the local culture.

The Teacher

The challenges for routine lessons centered on the students being too quiet and passive. In Jasper lessons, the kinds of challenges the teacher and students chose to reflect on were quite different. As shown in Table 7, the teacher's reflection over the course of Jasper experiences centered on six challenges, each discussed in turn.

Attention focusing. When Jasper first started, Mrs. Lam wanted to teach the same way as she did in routine lessons:

> When I first started Jasper, I tried to lecture to the class on what to look for in the story, what notes to take when the video was shown, and what problems the class needed to solve. I wanted to keep the class structure as consistent as possible, so that students could predict what was coming up in a lesson …

TABLE 7
Summary of the Teacher and Student Reflection

Categories	*Example Quotes*
Routine lessons	
Teacher	
Students too passive and agreeable	"I wish my students were not so quiet and so passive. They agree too easily with what I say. I wish they were more active."
Students	
Lectures too fast paced to follow	"The teacher gives us interesting math problems. But the lectures go too fast."
Jasper lessons	
Teacher	
Focusing attention on learning goals	"The students were distracted by the American culture embedded in the story. They can't focus on the instructional goals that I have in mind."
Dealing with disagreements	"...there were too many different opinions. They could not agree with one another. We will be far behind the schedule."
Dealing with competition	"Many of the students, especially those who are quiet, felt left out by the group. It is hard to let them feel that we are not competing, but working together as a good and big team."
Assessing students' understanding	"Usually, when I walk around and see what they write, I will be able to tell if they understand. In Jasper, I can't tell if they get it or not by looking at what they draw or write."
Maintaining an identity as a good teacher	"Am I doing a good job? Do my students still think of me as a good teacher?"
Students	
Maintaining independence in thinking	"Too many people talk about their answers. You can't think on your own any more."
Making contributions to the group and being appreciated by the peers	"The challenge is how to get the group members to listen to me and accept my ideas."
Maintaining an identity as a good student	"Who am I? Will Mrs. Lam still think of me as a good student?"

Clearly, Mrs. Lam made conscious efforts to assimilate the Jasper mathematics problems into routine practice because making lessons coherent and consistent was important to her and was expected by the students as well:

> Coherent and consistent instruction frees students from guessing what the next activity is so that their energy can be directed to learning and understanding the new Jasper problem solving. Being coherent also increases lesson efficiency, as everyone in the class knows what to expect and do next.

> Also, a coherent sequence helps students develop stable minds even with the introduction of new tasks. I believe that having a stable and calm mind is crucial for learning mathematics.

However, Mrs. Lam had to give up some of the routine structures in the Jasper lessons because she soon noted that the students had a hard time following her lectures and doing exactly what she asked them to do. Mrs. Lam experienced a breakdown of routine practices.

The interviewer asked, "What might have caused these difficulties?" and Mrs. Lam responded:

> The complex nature of the Jasper problem invited multiple interpretations from the students. Some students felt that the story was about how to fix the boat and others said that it was about helping Jasper find clean drinking water, since his boat was in the ocean like in Hong Kong. Another reason might be the American culture embedded in the video … because the students showed a great interest in the T-shirt Jasper wore, the American houses in the video, and the food Jasper ate, instead of focusing on the goal of identifying problems and relevant information … the video introduced more distractions to the class than I predicted. On one hand, it was so good to see that they loved the story and went wild with their imagination, because I worried that they could not relate to the story since it was from a foreign country. They were all very engaged and creative … they really surprised me. On the other hand, they did not follow my directions. I was struggling to get them to focus on the problem solving rather than America.

To move the class forward, Mrs. Lam said that she decided to do whole-class discussions focusing on whether the information obtained from the story was useful for understanding American culture, mathematics, or the Jasper problem.

What Mrs. Lam chose to reflect on (e.g., attention focusing and maintaining coherent lessons) reflected the values of the local culture. For instance, Mrs. Lam's school publishes parents' letters in the school newspaper every month. These letters show that the habits the parents would like the school to help their children develop include the ability to focus attention on relevant information in class. They also expect children to respect the teachers. The school expects its teachers to work hard, monitor students' understanding closely, and give clear and coherent lectures. These findings echoed those reported in the cross-cultural studies conducted by Stevenson and Lee (1995) and Stigler and Hiebert (1999). They found that, in general, Asian lessons were more coherent than American lessons. The Asian teachers believe that a coherent lesson structure reduces distraction and helps students focus attention on relevant information.

Dealing with disagreement. As noted in the previous sections, for the first two Jasper lessons, Mrs. Lam tried to retain her routine format of lecture-based classes. However, as the lessons progressed, she found lecturing increasingly difficult because students saw multiple ways to approach the Jasper problem. This gave rise to disagreements among the students regarding the order in which the problems should be solved. The class simply could not reach an agreement on the relevant information and the strategies to adopt for the problem solving.

Lecture depends on the students' paying attention to the teacher and following the directions defined by the teacher. Mrs. Lam made the following comment:

> It just occurred to me that the lecture format was best suited for topics about which there was agreement, or in which there was an accepted solution. Since that was hard to do for Jasper problems, I felt that dividing the students into small groups might be a wise thing to do because small groups come to agreements more easily and quickly than a whole-class lecture … They have all worked in small groups in my Chinese and craft classes, but I have never tried it in the math class.

Mrs. Lam also said that group work was not encouraged in most mathematics classes in her school, as well as many other schools in Hong Kong, because mathematics is used as a means to train students' ability to think and solve problems independently. According to Mrs. Lam, working in groups may not be considered appropriate if the goal is to develop independent thinking. Nonetheless, Mrs. Lam used group work in response to the breakdown of routine practices she confronted in Jasper lessons. The changes she made were in accord with the issues she chose to reflect on.

Because she did not lecture, she had more time to observe different groups and listen to the students. Through observing students working in groups, she became more aware of the students' capabilities and saw consequences for her role as a teacher. For example, she noticed that students possessed the ability to teach each other and that, given time, students gave quality explanations and presentations of their thinking:

> These days, I feel that I have learned more about how they think, as well as how they interact with one another. They were quite capable of explaining and specifying what help they need from me, which was really a surprise to me. They had so many good ideas. I could never have come up with all these ideas by myself. I feel that I began to like them more.

Dealing with competition. Another major challenge mentioned by Mrs. Lam was how to deal with students' competitiveness. For example, as she moved among the groups and listened to conversations, she realized that most of the groups had dif-

ficulty listening to each other, coming to agreement, and making every member feel included and appreciated. They were competing for time to air their ideas and for a chance to present for the group.

The interviewer asked, "Did you do anything about it or did you decide to let it go?" and Mrs. Lam said:

> No, I could not let it go. It really bothered me that they competed. I used whole-class discussions to ensure that everyone felt included. In whole-class sessions, I made special efforts to remind them of our togetherness as a whole class and the need to alleviate competition.

It seemed that Mrs. Lam was surprised by this challenge:

> I did not predict that students would look at Jasper as a competitive game rather than as an experience of solving a complex problem. So, I had to constantly remind them that we were not competing with one another, but working as a whole class.

Related to the issue of competition in problem solving was competition for the video players. It was rather difficult to share two video players with 40 students and eight small groups. This led to a quandary about how to best share the resources among students—all of whom needed to revisit the video as they worked to solve the Jasper problem. Mrs. Lam said:

> I also found that I needed to encourage groups to share their ideas and their understanding, instead of keeping information to themselves, because we only had two VCRs. I suggested that also because I wanted to reduce the number of video revisits by the students.

Mrs. Lam's concern over competition and students' feelings of being included was also shared by her principal and colleagues. When we first met with the principal, he said:

> Although our school is not ranked as top tier, it ranked second in the district as a favorite school by the parents. We put a great emphasis on creating a friendly family environment, where every child feels welcome and sees opportunities for success … We emphasize the need to create happy and friendly learning environments within which teachers, parents, and students build strong personal bonds. A lot of our school activities are organized to support these goals.

Assessing students' understanding. Giving students more opportunity to work with one another in small groups introduced another challenge. Mrs. Lam experienced difficulty keeping track of how the students were progressing and whether they understood what they were doing:

> With simple problems, I can tell whether they understand by looking at what they write or draw in their exercise book. I need no further explanation from them. However, with Jasper problem solving, it was too complex to tell … at the end of second day, I collected drawings and notes from each group trying to see whether they were on the right track, whether each group was working at the same pace, and whether they understood how they came up with the answers … but I really could not tell by merely looking at their drawings and notes. I started to be worried.

The interviewer asked, "What did you do then?" and Mrs. Lam responded:

> I decided to use presentations to help me get a sense of their understanding and participation, to provide individual and group feedback, and to help me decide in which direction the class should go next … Not an easy decision … They have never done presentations in math classes before even though they have done them in extracurricular activities, such as composing poems or songs.

Mrs. Lam proceeded with new methods cautiously and reflectively, and her reflections were aligned with the problems she encountered and the subsequent changes she made in the Jasper lessons.

On the last day of the Jasper lesson, every group presented their solutions. On that day, Mrs. Lam encountered another dilemma: What was the correct answer, given that there were variations in the final solutions? Mrs. Lam stated the following:

> Usually we do not have the problem of deciding who is right or wrong, since most of the math problems we do in class have one answer. In Jasper, the answers and procedures differed across groups. This surprised the students, and they started to worry whether they were all wrong. They were used to problems that had one or two correct answers. I decided to make an average out of the answers that each group got. This gave them one correct answer, because I did not want them to feel incomplete about solving the Jasper problem.

Questioning identity. Issues of identity as a competent teacher frequently came up in our interviews with Mrs. Lam. According to her, over the years, her students and their parents have developed perceptions of what a good teacher does

(e.g., lectures clearly, manages time well, encourages independent thinking, gives a lot of homework, etc.). There is a profound connection between a teacher's own identity and how he or she is perceived by the community. As noted in the video data, there were changes in almost every dimension of Mrs. Lam's instruction during Jasper. These deviations from her normal practice made her constantly reflect on her role as a teacher. For example, during our interviews, Mrs. Lam frequently raised the following questions: "Am I doing the right thing here?" "What is my goal here?" "Will students think that I am not a good teacher, since I have not lectured much these days?" "I do not know what I really did today. I feel that I have not done my job as a teacher since I did not talk much …" and "Will they [my students] still think of me as their teacher?" Mrs. Lam also expressed other concerns, such as the amount of learning perceived by the students:

> Will they [my students] think that they have not learned much these days, especially not much about mathematics, because I usually have them solve several different kinds of math problems in one class period. In Jasper, they only solved one problem in 5 days. They may think that I have not taught them enough, especially not enough about mathematics formulas and calculations.

Mrs. Lam also expressed concerns about the space for independent thinking and her role as a helpful teacher in small-group settings:

> They may feel that I do not encourage them to think independently since I asked them to work in small groups. Several students told me that it was difficult for them to think on their own in groups, and some group members came up with the answers too quickly to allow others time to think for themselves. They may think that I do not value independent thinking any more since I put them in groups … On one hand, I was happy to see that students were able to teach each other. On the other hand, I felt that I have not done my job as a teacher since they did most of the work.

In Hong Kong, many schools have both students and parents evaluate teachers' performance. Mrs. Lam had to be very mindful of the students' opinions and perceptions. As such, these concerns may have led her to reflect on her identity as a competent teacher.

Perceived gains and losses of using Jasper. When asked about her perceived gains and losses of this experience, Mrs. Lam stated that her confidence in dealing with surprises increased. She also commented that she learned as much about herself as she did about her students. For example, she realized she had previously been too controlling because she worried the students would make mis-

takes if left alone. She also found that she could actually enjoy the surprises. They opened her eyes to students' strengths that were invisible and underutilized in their routine classes.

In learning about her students, Mrs. Lam found her assumptions challenged:

> They came up with ideas that I have never even thought about before. They are all very creative and brave … They also dealt with complex information better than I ever imagined. I was especially impressed by their ability to present and explain their problems. They were a lot more independent than I thought. As teachers, we should not control their thoughts too much …

In addition, she explained that student anonymity decreased as she learned more about their unique abilities and personalities. Such interactions increased her enjoyment with the students. Mrs. Lam also began to establish relationships with them in new ways. She started having discussions with them as equals without worrying about losing their respect. Perhaps her most powerful comment was that she now considered that "The students are my mirrors from whom I can get feedback." When asked about the drawbacks of using Jasper, she said:

> The main drawback is that I am not sure if the students have learned what I want them to learn. They had their ideas about which strategies to use for Jasper problem solving, but some of these strategies were not efficient and may not be the kinds of strategies that I want them to learn. Another drawback is that I felt unsure about the decisions I made in class. There were a lot of activities going on and I was overwhelmed. It is really difficult when the instructional goals could not be set firmly ahead of time and I have to decide what to do as I go.

Mrs. Lam was also uncertain about whether she had covered all the issues that should be covered in Jasper. She felt a sense of incompleteness:

> I felt that we have done a lot these days. But I felt that I really did not have a clear sense of whether I have covered all that I was supposed to cover. What have I left out? The students solved the Jasper problems. But I was not sure if they really learned enough mathematics and practiced enough calculation skills.

Another drawback mentioned by Mrs. Lam was incompatibility between the mathematical learning in Jasper and the Hong Kong examination system:

> It is great that students learned to solve a complex mathematics problem, present their ideas to the class, and to work well in their groups. But none of

these skills will be tested in our curriculum. Unless we change our examination system, it will be difficult to use the Jasper kinds of problems to replace the standing curriculum. It could be used as an extra curricular activity though.

The Students

As shown in Table 7, the students' reflections about the Jasper experiences centered on four issues.

Maintaining independence in thinking. Students usually do not work in small groups in Mrs. Lam's math class but rather do more individual seat work. As a result of the small-group work used in the Jasper lessons, they felt the opportunity for independent thinking decreased. One student expressed the following concerns:

> The most difficult thing for me was that I was unable to think about the solutions by myself. Other people in my group could not wait to show the group how smart they were, so they told you their answers. I could not even concentrate or think for myself.

Another student said:

> It was wonderful that Mrs. Lam did not tell us solutions and made us think independently. It was sad that some of group members could not keep answers to themselves and wait for me to come up with my answers. I did not like to take their answers. I want my own …

Students had a strong desire to think independently throughout the solution process yet felt that small-group work in the Jasper lessons did not let them do that easily. Of the students we interviewed, 10 of 12 voiced such concerns. Their concerns echoed what Mrs. Lam said, in particular, that group work was not encouraged in mathematics class and mathematics was used as a means to train students' ability to think and solve problems independently.

Making contributions to the group. Related to the issue of maintaining independence in thinking were the challenges of making contributions to the group and being appreciated by the group members. Students wanted to be valued by their peers rather than to obtain solutions from other members. One key factor that determined if students were valued by the group seemed to be whether their ideas were accepted, appreciated, and viewed as helping the group reach a solution. For

example, one student expressed concern over the fact that his ideas seemed not to be heard and adopted by the group members:

> I was not happy that my group did not adopt my ideas. They gave me opportunities to express my ideas; then they voted on the ideas. The decision was based on the number of votes each idea got. I believe that my suggestions were great. However, I did not get enough votes. Therefore, mine did not get accepted. I really do not like that because I saw friends voting for friends. Most of my close friends were not in my group. We should find other ways to do this.

Another student said:

> I am extremely happy these days because my group members loved my ideas and suggestions. They saw me as a hero, who could help them find solutions faster. I like group work.

It was interesting to note that those who expressed concerns over acceptance were usually ranked as low or medium in academic achievement in the class (i.e., three low, three medium, and one from the high achievement level).

The concerns over group contributions invoked worries among the students about how they would be evaluated and perceived by their teacher and peers. As one student said:

> The biggest challenge for many of us is how to convince other members that our suggestions are the best. They will not accept my ideas if I do not convince them. I am very worried that none of my ideas have been accepted so far. I do not want my teacher to think that I did not work hard … I would be much happier if other members thought that I helped the group find answers, rather than thinking that I was just there waiting for them to find the solutions.

Research on characteristics of group learning in Hong Kong classrooms reveal that individual students are usually rewarded on the basis of their performance and contributions in comparison to other members in the group (e.g., Salili, 1996; Tang, 1996). It is possible that this reward system has produced students' concerns about their group participation.

Questioning one's own identity as a good student. When the Jasper artifact was first presented in the classroom, students felt out of place because the American characters, accents, and settings in the story were quite foreign to them. Students created their own versions of the Jasper story using local life experiences.

For example, many students said, "Jasper's boat got stuck in the Hong Kong bay. Trash in the Hong Kong bay may have caused damage to his boat. We need to help him figure out whether he could fix the boat and get home before sunset …" They would not proceed with the problem solving until they understood the expectations from the teacher. When the performance criteria or roles changed, the students worried about how they were perceived and interpreted by others. For instance, one student stated:

> My group decided that those who had good handwriting should write for the group and present for the group. I am not good at handwriting, but I am a top mathematics student in my class and I did most of the calculations for the group. I did not get to present. How would the teacher and students think of me? A lazy bones who stole other people's work? I do not like this rule at all. I wanted to write and present as well.

Another said:

> Am I still a good student? I really got confused. I knew that [another student's name] … is much worse than I am in math. But she appears to be active and talkative, as if she got all the answers for us. I am the kind of person who is quiet, but I think a lot. Who is a better student? Me or her?

The students also actively checked whether they were still on task and in line with other members in the group. For example, they exchanged drawings with each other as a way to check their alignment with the group:

> I showed my drawings to the other people in the group and I was really happy to see that we approached the problem similarly and progressed at the same pace … It's good to know that I am not too far off track.

> I really wanted to know if I got the same answers as others did.

> It was important that I was on the same track as others in my group.

Perceived personal gains and losses from the Jasper experience. As with Mrs. Lam, the students also perceived a change in their classroom. They reported a difference in their relationships with one another as well as with their teacher. Some typical student comments were as follows:

> The best thing about Jasper class was that we were given a lot more opportunities to talk and to do things freely. We could talk to one another, which was

> not usually allowed. We could also discuss and question each other. We felt that we were "little teachers." We actually had many good ideas.
>
> The Jasper lessons were a lot more interesting. We did not have to be the students all the time, but had opportunities to speak our own opinions just like Mrs. Lam does.

Students, as a result of the adaptation process, altered their view of the teacher. The students found Mrs. Lam warmer than they had previously known. Students saw her to be more caring and friendly than before. They also realized they could please their teacher and that she praised them more often than before.

Students learned not only about their teacher but also about themselves. Of the students we interviewed, 10 of 12 mentioned their own competitiveness. They said that they did not get along as well as they had initially thought they would. They commented on the realization of their own "selfishness," as they put it. Students talked about their surprise at how poorly they listened to one another. They also realized that they possessed greater abilities and talents than they had previously thought. Finally, all students we interviewed indicated that they learned to build the trust that was needed to work in groups and stated that they had deepened their friendships toward the end. In comparing interviews before and after the Jasper experience, students reported a much higher self-confidence in solving complex mathematics problems and in resolving group conflicts after experiencing Jasper. In addition, they also discovered that they enjoyed challenging and complex problems much more than they thought they would.

The major disadvantage of using Jasper, as identified by most students (9 of 12), was that they had a hard time hearing the teacher's instructions because there was a lot of noise in the class. One half of them also felt a sense of confusion in the process because of the wide variety of classroom activities that were going on.

In summary, the reflections by the teacher and students on Jasper experiences demonstrate the powerful impact of the sociocultural contexts in which they were embedded. For example, the issues Mrs. Lam and her students chose to reflect on were quite different from what we observed when Jasper was used in American classrooms (e.g., Cognition and Technology Group at Vanderbilt, 1997). The studies of Jasper in American classrooms have shown that American teachers tend to reflect on issues such as what they should do if students generated wrong solutions, how to prevent students from getting onto a wrong track, and how to manage the class so that students would not get involved in off-task activities. The most frequent concerns of American teachers in using Jasper were about content knowledge and whether they were able to solve the Jasper problems themselves and how to tell whether the students learned or not. The concerns most often voiced by the American students in using Jasper were about group and interpersonal conflicts (e.g., group members' off-task behaviors and disagreements among members in

the group). The researchers rarely heard American students' concerns about group contributions and their own identities as good students.

Summary of Results

This study examined how a fifth-grade mathematics teacher in Hong Kong responded to a technological artifact introduced into her classroom. The major findings are summarized as follows:

1. During the Jasper lessons, Mrs. Lam made noticeable changes by altering the sequence of instruction, doing less lecture and individual seat work, engaging students more in problem identification, small-group work, presentations, and whole-class discussions. Most changes were made after the conscious attempts to maintain routine instruction broke down or failed. For example, the instructional pattern for the first two Jasper lessons was quite similar to the routine lessons. Noticeable changes did not occur until the third Jasper lesson.
2. Constant across routine and Jasper lessons was an emphasis on explaining and verifying students' solution processes, teacher monitoring and guidance, and achieving unified solutions.
3. The factors shaping these changes centered on the teacher's deep concerns about the students and a particular set of problems she confronted in her effort to maintain routine lesson structures in Jasper lessons. She paid particular attention to the students' attention focusing, understanding of the problem, feelings of being included and appreciated, and judgments of her as a teacher (see Table 7).
4. The changes observed in the Jasper lessons were consistent with the issues the teacher, Mrs. Lam, chose to reflect on, and her reflection was influenced by the beliefs and expectations of her local culture.

Overall, we found that throughout the Jasper lessons, Mrs. Lam made conscious decisions about what to change and what to preserve. These decisions were made through careful reflection and analysis of the breakdowns that occurred when routine teaching practices were no longer effective and what was important to the students. This process of reflective adaptation occurred through several stages as shown in Figure 4.

When the Jasper artifact was first introduced, Mrs. Lam, her principal, and the parents embraced the new artifact. Compared to many schools that were invited, her school committed the most time to the project. However, it is one thing to embrace an artifact and quite another to weave it into one's existing practice. Any new instructional practice risks being assimilated into the old practice without much adaptation (Cohen, 1991). At first, Mrs. Lam tried to assimilate Jasper into her routine practice by lecturing on how to proceed with the problem. However, the disagreement and distractions provoked by the Jasper problem made lecturing an in-

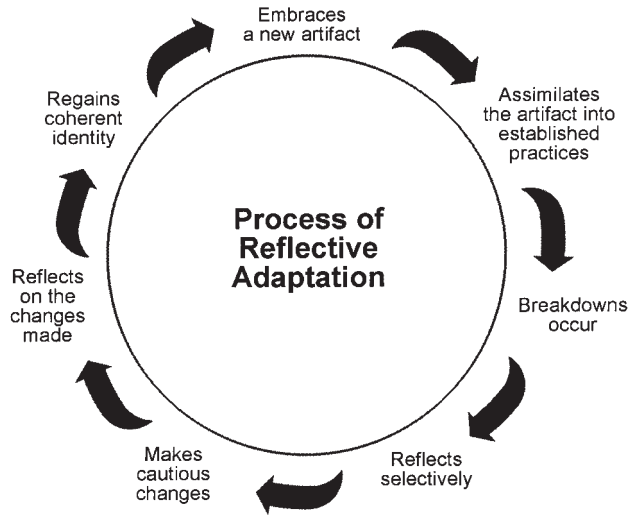


FIGURE 4 Inquiry cycle for reflective adaptation.

effective method for instruction. Such breakdowns occurred continuously throughout the course of the Jasper lessons. They ranged from the students' competition over ideas, recognition, and resources to the teacher's difficulties in assessing students' understanding and dealing with different solutions. These breakdowns caused both the teacher and students to reflect on their current practices and their roles in the new environment (e.g., identity questioning during the interviews, etc.). Subsequently, in responding to the breakdowns, Mrs. Lam invented a new sequence of instruction, content of learning, and forms of class participation. She continued to reflect on the changes because they often led to new challenges. For example, in dealing with disagreements, Mrs. Lam initiated small-group work. This led to new challenges, such as student competition and difficulties in assessment. The kinds of breakdowns Mrs. Lam and her students chose to focus on reflected their goal of achieving a sense of coherence or harmony in problem solutions (e.g., achieving agreement, obtaining one solution at the end, having a consistent sense of identity, etc.).

DISCUSSION

There has been a long history of debate over the question of whether technologies are autonomous in that people cannot have much control over them (Mehan, 1989; Mehlinger, 1996; Provenzo, 2000). For instance, the rapid spread of the Internet to-

day makes people believe that it has grown beyond our control (Kiesler, 1997). This study suggests that technology artifacts can indeed lead to classroom change. However, this was not a case of technological determinism. Rather, the participants made ongoing decisions about the use of technologies.

These decisions became explicit and concrete when they were seen in light of the values and practices embedded in the artifact and the local culture. For example, Mrs. Lam frequently asked herself, "How can I adapt this artifact?" "What is my goal here?" "How do I know if my students understand or not?" "How can I help students ease the competition?" "Which aspects of the artifact should I have my students experience?" and "What is my identity as a teacher?" She often felt out of control, especially when there was a breakdown in the effectiveness of her routine teaching practices. Throughout the process, however, Mrs. Lam was reflecting on whether and how to adapt the methods embedded in the artifact into her practice. Her decisions about what to change were influenced by the local culture. It is not simply a question of whether technology changes the classroom practice. Rather, the significant questions are whether certain changes are necessary and what the reflection and adaptation processes are by which teachers make decisions that produce those changes.

This study reveals three aspects of the adaptation process that occurred when the technological artifact entered the classroom. First, the artifact itself led to changes, and its pattern of use was adapted to the local culture. Second, the culture and practice changed in some ways but not others. Third, introducing a new artifact and the subsequent disruption to normal practices led to intense and sometimes profound reflections about which aspects of the participants themselves, their environments, and the new artifact to adapt into a new classroom structure.

Therefore, when looking at how technology, classroom culture, and individuals interact, it is important to consider three aspects simultaneously: (a) the affordances of the artifact, (b) support and constraints offered by the local culture, and (c) the kinds of reflection and decisions that influence the adaptation. Each is discussed in turn with a greater emphasis on the role reflection plays in the process of adaptation.

Concrete technologies or materials can turn abstract concepts and ideas into real experiences. Artifacts guide activities and mediate interactions between people and their environment, so they can do things either that they could not do or that would be more difficult to do without such artifacts (Cole, 1996; Lee, 1999). For example, Jasper provided support to change the way mathematics is routinely taught in this Hong Kong classroom, in part because it embodied and supported a set of instructional ideas. Without the technological support, it may be quite difficult to communicate in a detailed manner certain aspects of the practice that were intended by the designers.

Although a technological artifact is an important catalyst to change, the sociocultural context has a powerful effect on the degree to which the potential of the ar-

tifact is fully exploited. For example, there were several reasons why Jasper was accepted and implemented by Mrs. Lam and her school, albeit cautiously. First, in a fast-changing society like Hong Kong, the schools and parents are supportive of innovations that have potential to prepare students to adapt to changes (Ho, 1986; On, 1996). Second, Mrs. Lam's school is not a top-tier school, and there are constant incentives to try innovative instructional programs to improve the status of the school. These cultural needs were crucial in convincing Mrs. Lam to accept the challenge of implementing Jasper in her classroom. As a result, using Jasper was perceived as a positive opportunity rather than a risk by the teacher and parents.

In addition to cultural support, effective adaptation requires teachers who are able to integrate and organize technical and cultural resources to benefit students. The teachers' role becomes even more important when the culture does not have all the supports and resources its members need. For example, Hong Kong culture both enhanced and restricted the use of Jasper. Students of Mrs. Lam's class had developed habits of being reflective, persistent, and understanding at a deep level. These beliefs and habits facilitated the Jasper problem solving. On the other hand, in Hong Kong, mathematics achievement is regarded as a measure of intelligence and the ability to think independently. Students usually learn mathematics individually rather than collaboratively. Moreover, silent mental calculations, rather than discussion and public presentation skills, are emphasized in the local curriculum. When the local cultural beliefs and routine practices became constraints, the teacher had to modify and readjust classroom activities and suspend her previous beliefs about what makes good teaching. She also had to help students change their views about how mathematics should be learned (e.g., not through competition, etc.) so that the interactions between the students and the Jasper artifact were productive. Meanwhile, the teacher needed to invent new ways to assess students and their thinking so she could make instructional decisions sensibly and promptly. The quality of educational change, with or without technologies, depends on who the teachers are, what they do, and how they think (Darling-Hammond & Bullmaster, 1997; Shulman, 1987).

In most of the research on technology and classroom change, students are viewed as the recipients of the changes that occur. They play a rather passive role in the change process. However, in Mrs. Lam's class, students were key catalysts to change. For example, the students' reactions and needs influenced Mrs. Lam's decisions about what to change and how these changes should be made. The students also cared deeply about the teacher's reactions and her opinions about them. Without such an intertwined relationship between the teacher and students, the class may not have adapted as well to the Jasper artifact.

We have only begun to understand how artifacts, cultural contexts, and individual learners and their thinking processes interact to influence classroom change. The need to consider three variables simultaneously creates interesting challenges for research in education. Looking at adaptation to change in the context of artifacts and cultures calls for new ways of thinking about research on technology and

instructional design. It may be interesting to explore not only how specific features of technology artifacts affect classroom culture and individuals' growth and reflection but also how the classroom culture, particularly the kind of reflection engaged in by individual teachers and students, affects the uses of the artifacts.

I do not mean to suggest with this study that we should change traditional practice by simply importing educational technologies developed in another culture. On the contrary, introducing new technologies, domestic or foreign, that are not compatible with existing values and practices requires a considerable amount of reflection and careful adaptation by teachers to influence their practices. This study calls for special attention to the role reflection plays in adaptation; change in culture and practice brings with it a tremendous amount of questioning of who we are and what roles we should take on in the new environment. This is a special kind of metacognition rarely experienced in routine classroom practice, and it has not been studied much in the metacognitive research literature. I conclude this article by discussing metacognition as a mechanism for identity building and the implications it offers for future research.

Metacognitive Reflection as a Mechanism for Identity Building

Metacognition has been classically defined as knowledge about one's own cognition and activities that regulate that cognition (Brown, 1978; Flavell, 1987). For more than 30 years, most of the research on metacognition has concerned how individuals become aware of their own thinking, how they actively monitor their learning strategies and task performances, and what are the best ways to teach people these metacognitive strategies (Brown, Bransford, Ferrara, & Campione, 1983; Flavell, 1987; Hacker, Dunlosky, & Graesser, 1998; Pressley, Etten, Yokoi, Freebern, & Meter, 1998). Research has shown that metacognitive awareness helps students understand and remember subject matter as well as solve problems (e.g., Lin & Lehman, 1999). These findings are instrumental in helping us understand human reasoning, learning, and behaviors, as well as the development of adaptive learning expertise (e.g., Hatano, 1990; Wineburg, 1998). Nevertheless, most research has addressed the "internal conversations" of individuals, and not how individuals interact with cultural contexts (Donovan, Bransford, & Pellegrino, 1999).

In recent years, there has been an increased interest in how to create social environments to provide support for metacognitive activities, such as reflection, self-assessment, and revision (e.g., Lin, 2001; Lin, Hmelo, Kinzer, & Secules, 1999; Vye, Schwartz, Bransford, Barron, Zech, & The Cognition and Technology Group at Vanderbilt, 1998; White & Frederiksen, 1998). These research efforts are important because many of the strategies people use for metacognitive thinking reflect the norms and beliefs of the cultural context within which they are embedded (Lin, Schwartz, & Holms,1999). That is, metacognitive reflection is a social practice (Lin

& Schwartz, in press). However, few of these studies consider the role that changes in social participation play in metacognition and vice versa. Metacognitive research will be even more valuable if it focuses more explicitly on one of the increasingly frequent inevitabilities of life—change. This study provides a unique perspective on how metacognition can be used to help teachers deal with change when their identities are challenged rather than being fixed by their membership in a stable community. In this context, metacognition helps develop a sense of "productive agency" by building learner identities that are consistent with and in partial control of changes in the learning environment (Schwartz, 1999; Schwartz & Lin, 2001).

Our identity often comes from taking a role offered by a culture or social practice. We tend to think of our identity in terms of whom we are with and where we are in a situation. I am a teacher when I am with my students, but I am a parent when I am with my children. We tend to behave differently in these two different roles. Therefore, personal identities are often situational and culture bound. They should not be viewed as stable personal traits or labels but rather as a complex and dynamic system that consists of several selves (Neisser, 1988). According to Neisser, people usually experience these selves in a unified manner because it is the whole individual who interacts with the real environment. We develop a sense of coherence as our experiences in the environment become routinized. In cases in which coherence breaks down, the unity of the self is correspondingly weakened, leading one to question and reconstruct a sense of self. The drive to build a coherent self may be one of the key motivations for questioning one's identity. Consequently, a change in the structure of a situation as a result of the introduction of new technologies or other factors will change our sense and other people's sense of "us" and "them" (Meyrowitz, 1985, p. 55).

In the study reported here, the teacher's and students' coherent sense of self was disturbed when changes occurred in their learning environment and in their roles as contributing members in the classroom. Both the teacher and the students struggled to reconceptualize themselves in relation to the new expectations and their emerging roles. They were eager to regain a coherent sense of self and the environment, particularly when the situation seemed to be ambiguous and uncertain. Mrs. Lam and her students constantly reflected on how their own actions were perceived and interpreted by others. The students also actively identified the need to communicate their reflections to their group members to check whether they were still on task and in line with the progress of the class. They were concerned with whether their ideas made contributions to the group and how to adjust their own ideas so that the group members would accept and appreciate these ideas. Most interesting, they wanted their contributions to be fairly and publicly recognized. Not only did they change their attitudes and assumptions to better fit the new classroom norms and structures, they also changed their environment (e.g., the instruction, learning content, and participation structures) so that they could be more successful in their new roles and new memberships.

This study suggests that people engage in metacognitive reflection when their identity in normal practices is called into question. People reflect on how to regain or enhance the fit between themselves and the new environment and how to contribute to and be recognized by others in the environment. Change creates a time for deep metacognitive reflection and learning about one's own strengths and weaknesses. This brings up several questions. Why is developing a strong sense of a coherent self such an important aspect of learning within that culture? Is this kind of metacognitive thinking a universal or a cultural-specific phenomenon? How is this kind of metacognitive skill nurtured and developed in students in a specific culture?

We need to understand more to support teachers' and students' role shifting and their subsequent psychological changes when new technology is introduced (Lin & Hatano, 2001; Lin & Yan, 1996). It would be interesting to conduct studies changing various parameters (e.g., learning goals, social participation structures, personal goals, levels of individual contribution, or reward systems) that would affect the balance of the routine classroom culture. This would make it possible to document the kinds of metacognitive thinking students and teachers engage in and the quality of their subsequent task performance. It would also be interesting to study whether any difference occurs in metacognitive thinking, domain subject learning, and tolerance for ambiguities if people are given the choice of deciding what changes to make, as in this study, rather than having changes imposed on them.

Throughout life, we experience situations in which our degree of tolerance for ambiguity varies with the amount of control we have over the situation. It seems that we tolerate the ambiguities better if the change is made by personal choice. In this study, Mrs. Lam knew that her students, their parents, and the principal supported innovations and would be with her in the process. She was more calm in dealing with the uncertainties than were teachers we have observed in classrooms with less community support and assurance (e.g., Bray, 1998). Ogbu's (1992) work on immigrants provided another example of the effect of choice and agency. He found that voluntary immigrants tend to handle cultural changes more successfully than do involuntary immigrants because they have different sets of expectations for themselves and the new environment. Ogbu also found that involuntary immigrants often experience greater and more persistent difficulties in dealing with cultural change.

It is possible that there are benefits in helping people recognize that experiencing ambiguity is a natural part of the growing process. Often we hear new graduate students say, "I don't know what I am doing. This is too confusing and I want to quit." A year later, they will tell us how important it is to experience the initial struggles and uncertainties. When we are at the initial stage of generating new ideas, we tend to go through a period of questioning and struggling about who we are and how other people will perceive us and our ideas. How crucial is it for people to experience these initial ambiguities and struggles? How can we better sup-

port people's initial struggling and metacognitive questioning? What subsequent effects does such support have for people's learning and their ability to take control of the situation when changes occur? These seem like fruitful areas for future research.

This study points to the importance of understanding the usefulness of metacognitive thinking in dealing with classroom change. The acceleration of social and cultural changes in classrooms when technologies are introduced raises a whole new layer of research issues, especially for the role of metacognition in preparing people for sociocultural change and learning. We know very little about this aspect of metacognition and the benefits it may offer in preparing people for change. The study was far from conclusive, and much more needs to be done before we can conceptualize complex and dynamic relations among technological artifacts, cultural environments, and people's active minds. Whether we can prepare people for change remains an unanswered question. Studies along these lines will broaden our perspective about the processes that mediate change and affect people's ability to adapt to change. Such studies would provide important insights about the factors to be considered in designing and developing technologies and instructional materials that can be adapted into different cultural contexts. The goal of helping people understand their new social roles and helping them actively contribute to the environment and their own learning appears to be a fruitful area for research. Educational artifacts may be a key component of this effort because they afford, but do not prescribe, changes in practice.

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