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Toward Teachers' Adaptive Metacognition

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In this article, we compare conventional uses of metacognition with the kinds of metacognition required by the teaching profession. We discover that many of problems and tasks used in successful metacognitive interventions tend to be reasonably well-defined problems of limited duration, with known solutions. Teaching has unique qualities that differentiate it from many of the tasks and environments that metacognitive interventions have supported. Teachers often confront highly variable situations. This led us to believe that successful teaching can benefit from what we call adaptive metacognition, which involves change to oneself and to one's environment, in response to a wide range of classroom social and instructional variability. We present several examples to illustrate the nature of metacognition required by teachers and the challenges of helping teachers recognize situations that require adaptive metacognition. We conclude the article by describing an approach, critical event-based instruction, which we have recently developed to help teachers appreciate the need for metacognitive adaptation by seeing the novelty in everyday recurrent classroom events.

Conventionally, metacognitive instruction is often used to help learners monitor and control the effectiveness and accuracy of their own understanding and problem-solving behaviors in a particular subject matter (e.g., reading, writing, mathematics). In this article, we argue that conventional applications of metacognition fall short when it comes to the challenges teachers often face. Teaching has some unique qualities that differentiate it from many of the tasks that metacognitive interventions have supported. For instance, the problems encountered in teaching can require days if not months to resolve. Moreover, what counts as a good solution depends on clarifying and reconciling competing values, for example, those of the teachers, the school district, and the students. Finally, metacognitive research has largely been about one's individual thoughts, but teaching involves adapting the environment (and students), and this presents unique challenges. As a result, we have been led to believe that successful teaching can benefit from what we call reflective adaptation (Lin, 2001a) or adaptive metacognition.

Adaptive metacognition involves both the adaptation of one's self and one's environment in response to a wide range of classroom variability. Many teachers tell us that each class is quite different, and each presents its own challenges and charms. This situation is different from the stable environments for which most metacognitive interventions have been designed. For repetitive tasks, like solving word problems, it is possible to provide students with metacognitive strategies that can eventually be routinized into problem solving schemas. Teachers, on the other hand, confront highly variable situations from student to student and class to class. One solution does not fill all, and teachers need metacognitive approaches that support adaptation and not just improved efficiency for completing recurrent cognitive tasks (Schwartz, Bransford, & Sears, 2005).

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We argue that one of the great challenges of metacognition for teachers is to help them recognize that apparently routine situations often have a number of hidden features that may make it quite different from what they believe, and therefore they require adaptation. This is because teaching is a deeply social act involving peers, students, and parents. Consequently, there are usually many hidden values that need to be made explicit so teachers can determine what type of adaptation is acceptable (e.g., Dweck, 1999; Lin & Schwartz, 2003). Moreover, in contrast to the problems and tasks confronted in typical metacognitive interventions, teachers must find a way to effectively communicate and interact with people of different values to make their adaptations successful. Therefore, teaching is always cross-cultural to some extent, because teachers and students rarely share the exactly same values and experiences. Problem solving that involves making changes to one's social environments and other people has its own set of metacognitive requirements. In this article, we report several of our metacognitive studies that are designed to help teachers see through the surface of the classroom and begin the process of adapting to different social norms and situations that many classes and students bring.

Our article consists of three sections. In the first section of the article, we describe some of the successes in the metacognitive literature and extract contextual characteristics that seem responsible for their success including stable problems, environments, and values. In the second section, we present two examples to clarify how teaching can lack these characteristics, and what that entails for adaptive metacognition. In the last section, we describe some of the techniques we have developed to help teachers appreciate the need for metacognitive adaptation, particularly in situations that appear routine on the surface level. One of our primary goals is to make sure that teachers do not apply assumptions of "routine" metacognition to teaching situations where adaptive metacognition is appropriate. For example, we provide them with recurrent problems, but we help them learn to avoid the tendency to schematize these recurrent problems so they do not seek out the particular, but often hidden, details that require adaptation.

CHARACTERISTICS OF TYPICAL METACOGNITIVE INTERVENTIONS WITH AND WITHOUT COMPUTERS

Cognitive Characteristics of Interventions

Metacognition, or the awareness and regulation of the *process of one's thinking*, has been recognized as a critical ingredient to successful learning (Brown, Bransford, Ferrara, & Campione, 1983; Flavell, 1987; Hacker, Dunlosky, & Graesser, 1998; Pressley, Etten, Yokoi, Freebern, & Meter, 1998). Over the past decades, there have been two main approaches for teaching metacognitive monitoring skills: Strategy training and creating social environments to support reflective discourse (Lin, 2001b). Strategy-training studies originally used direct instruction, usually in a one-to-one situation (Brown et al., 1983). More recently, there has been an increase in the use of modeling and prompting. For example, Lin and Lehman (1999) used prompts to help preservice teachers learn about strategies for controlling variables in a computer-simulated science experiment. Some students received periodic questions about how well they were achieving their goals. Other students received alternate prompts (e.g., how are you feeling about yourself right now) or no prompts at all. The students prompted to reflect on their goals outperformed the other students on a subsequent transfer problem that did not include any prompting. Similar results have been obtained in other studies with children and adults, using tasks like the Tower-of-Hanoi, the Katona card problems, chess problems, human circulatory system problems, mathematics problems, and computer-simulation problems that included search (Safari Search), patterns (The Pond), and logic (Rocky's Boots; e.g., Berardi-Coletta, Buyer, Dominowski, & Rellinger, 1995; Chi, Deleeuw, Chiu, & LaVancher, 1994; King, 1992; Schoenfeld, 1987).

Computers have been successful in modeling metacgonitive strategies. For example, they can make often tacit thinking processes overt so they become externalized and accessible as objects of close reflection and evaluation (Lin, Hmelo, Kinzer, & Secules, 1999). Graesser and McNamara (2005) used computers as tutors to help students generate questions (e.g., why, what-if, how) and develop self-explanation strategies while reading text. Other researchers use technology to help students develop self-correction skills for problem solving (Mathan & Koedinger, 2005), as well as use effective monitoring strategies in their online scientific inquiries (e.g., change their topic if they fail to quickly find related information, Quintana, Zhang, & Krajcik, 2005). Computers have also been used to facilitate collaborative problem solving and reflection. These include the uses of computers as advisors for science inquiry (White & Frederiksen, 2005) and creating an online forum that allows learners to share and critique each other's understanding (Computer-Supported Intentional Learning Environment [CSILE], by Scardamalia & Bereiter, 1991; and Learning Through Collaborative Visualization [Co Vis], by Pea, 1994). In this work, the emphasis is on the creation of social support for the adoption of effective metacognitive strategies. For example, in the CSILE program, after being exposed to reflection discourses in the classrooms, students tended to develop the habits of using explanation strategies to engage in metacognitive social conversations about the tasks and problems at hands. In a more automated version of social support, Biswas, Schwartz, Leelawong, Vye, and TAG-V (2005) had fifth-grade students teach a computer agent to solve problems about the oxygen cycle in pond ecology. The "teachable agent" initiated observations about how well it understood; for example, it would refuse to take a test, stating that the student had not asked it enough questions to make sure it understood. In a transfer test a month later, students learned about the nitrogen cycle on their own. Students who worked with the metacognitive teachable agent learned more during the transfer test than students who learned the oxygen cycle without metacognitive support from the agent.

Broadly speaking, these studies have focused on the fundamental question of whether instruction in effective metacognitive strategies can facilitate learning and problem solving. The findings repeatedly suggest that people can be very successful at metacognitive monitoring and that comprehension and problem solving are usually improved, especially when the utility and function of these effective metacognitive strategies are made apparent.

Contextual Characteristics of Tasks Commonly Targeted by Metacognitive Interventions

As we reviewed the metacognitive literature, we noticed that the target tasks often involved underlying contextual features that may have helped to make the metacognitive interventions successful. These contextual features, however, may not characterize many teaching situations; therefore, it is important to consider whether previously studied metacognitive interventions are ideally designed for the contexts that teachers confront. Here, we briefly review the contextual features of the tasks addressed by prior metacognitive training, including (a) well-defined problems with known optimal solutions; (b) stability of the learning environment; and (c) shared values and goals.

Well-defined problems. Many of the problems used in successful metacognitive interventions are well-defined problems of limited duration. In most of the studies, participants handle one problem or step at a time, and the problems have an optimal solution procedure. For instance, in our own study with variable control problems, we used metacognitive strategies to help people monitor their application of experimental designs that yield confound-free findings about insect habitats. Because the problems have an optimal solution path and a natural segmentation, the metacognitive emphasis is on monitoring and regulation during each step of problem solving, rather than on the reflection that might occur in between problem solving episodes.

Stable learning environments. The learning environments for most metacognitive interventions are relatively stable. The problems are usually identified for the students rather than arising naturally from their own practices, so there is limited emphasis on problem finding. Plus, the setting of problem solving and learning is often fixed, so that there is little opportunity for adapting the environment or one's range of solutions. For instance, we have yet to read a positive metacognitive report about a situation in which the participants wisely refused to complete a task as given, because they decided it was intractable.

Shared values and goals. A third assumption of many metacognitive interventions is that the participants and the instructors share common learning goals and values. We have not encountered studies that address issues where most of the participants believe that successful problem solving and deep comprehension are not their goal for learning. The assumption seems to be that any given task should ultimately induce the same set of optimal activities from everybody involved. Hence, within the metacognitive literature, there is minimal activity dedicated to illuminating cultural values that might influence what constitutes a meaningful problem or an acceptable solution. This might be because most of the problems used are reasonably value free—there is little debate about whether a problem should be addressed or what constitutes an optimal solution. Additionally, in most interventions, people engage in individualistic metacognitive processes in which the focus is on how they are thinking and progressing. Even when students are invited to monitor and evaluate other people's argumentations, as in many of the recent computer-supported collaborative learning programs, the focus is often on other people's thinking about the content knowledge and tasks, rather than monitoring other people's values, goals, and the cultural contexts that contribute to the formation of such values and goals.

In sum, successful metacognitive strategy interventions have chosen tasks that are reasonably well defined and value free; the environments for which they are preparing people are fairly stable; the trainees and the instructors share common learning goals and values; and learners are responsive to the need for methods of metacognition. As we describe next, these features are often missing in the reality of teaching practice, which suggests that additional forms of metacognitive training might be useful.

TWO CASES: TEACHER METACOGNITION AND THE CHALLENGES OF TRIGGERING ADAPTIVE METACOGNITION

Teachers confront many problems that share characteristics with tasks found in the metacognitive literature. For example, grading papers efficiently is a highly routine activity that presents a challenging well-defined problem in a stable environment of clear values, and teachers always have an eagerness to learn more effective methods and how to avoid skimming. At the same time, teaching introduces new metacognitive challenges, assuming that teachers do not treat teaching like following a recipe. Lampert (2001), for example, pointed out how teaching problems are often ill-defined and involve a variety of values that may not be in complete harmony. She explained that when she is teaching fifth-grade mathematics in an open classroom of discussion, she simultaneously has to teach the mathematics content, the need to complete assignments successfully, and the value of being civil and equitable to classmates. Teaching involves handling many interacting factors simultaneously that often cannot be neatly decomposed and treated one at a time (see Darling-Hammond & Bransford, 2005). There is usually not a single algorithm for achieving an optimal solution. Hence, teachers cannot metacognitively monitor whether they are deviating from that algorithm. Instead, teachers often need to reflect on their values and the consistency between their own values and those of the other members in the community (parents, students, principals) to guide them towards an acceptable solution.

In this section, we present two cases. The first cases shows how the common contextual features that are found in many typical metacognitive interventions disappear, particularly when a teacher is introducing new curriculum to the students. This suggests that it may be worthwhile to entertain alternative approaches to metacognition for teachers. The examples in the second case illuminate some of the relatively unique metacognitive challenges that teachers face, including the discovery and negotiation of conflicting values and practices. These clarify the challenge of triggering adaptive metacognition in teachers' everyday classroom practices.

Case One: Teacher Adapting New Curriculum and How the Common Contextual Features That Are Present in Typical Metacognitive Interventions Disappear

Lin (2001a) conducted a study that illuminates how the context of teaching introduces task characteristics unlike those found in many successful metacognitive interventions. The setting of the study is not representative of all teaching, but it nicely brings to light the situation faced by many teachers, in a more modest fashion, when they choose to try new methods of teaching. The study documented how a fifth-grade teacher in Hong Kong responded to the introduction of a new technology artifact into her classroom—a 20-min, video-based math problem, called the Adventures of Jasper Woodbury (Cognition and Technology Group at Vanderbilt [CTGV], 1997). The teacher and the school principle were interested in finding new ways to use technology in the school to help spruce up the school's reputation. Jasper problems use a story narrative complete with characters to present a complex planning task that depends on a number of related mathematical calculations and numerical information embedded in the narrative. At first the teacher attempted to fit the novel Jasper into her usual routines, but as she quickly found out, it is hard to embrace novelty without adapting. This was when the unique qualities of her metacognition began to appear.

When the teacher started, she worked to maintain her usual classroom structure. This structure flowed through a set sequence of activities every day: a review of homework, an introductory lecture, a period of practice, a brief quiz, and an assignment of homework. She approached Jasper in the same way, for example, by beginning with a lecture on how to proceed solving Jasper. The lecture and her highly scheduled class structure did not work very well, because the Jasper video is more complex than bite-sized math problems. Jasper usually takes children several days to solve working in teams, and there are different possible solutions. Students disagreed with the teacher and with each other about what the problems were and what were the best approaches to solve the problems. The students also wanted to work in groups, but they had not done group work on open-ended problems like this. Over time, many situations developed that were unfamiliar to the teacher: Students competed over whose ideas were correct within the group and who deserved credit; the teacher had difficulty assessing student understanding with brief quizzes at the end of each class; and the teacher had difficulty leading class discussions when students offered many different possible solutions.

This situation denied the teacher three contextual features that we identified as common to most metacognitive interventions. The problem of implementing the new curriculum did not have a single, optimal solution. The classroom resisted the usual stability of the teacher's well-designed daily routine. The values of the students differed from the teacher, and with each other. The demands of adaptation to the artifact and its effects led the teacher to reflect on what she was doing and why. Much of her reflection had qualities often associated with metacognition, including careful planning and monitoring of success. At the same time, there were some unique qualities to her adaptive metacognition.

One quality was that the teacher did most of her metacognition offline, when she was not caught up in the time-sensitive, complex, and novel issues that occurred during the class. After each class period, she engaged in intense self-questioning. A second quality was the character of this self-questioning. It was less about the "effectiveness" of her solutions and more about her values and identity as a teacher. For example, she worried that letting the students pursue their own problem-solving inclinations would erode her authority in class. She also wondered whether letting students work together to sort things out before her lectures would indicate to them that she did not know the material and was not a good teacher. A third quality was that she had to think of how to adapt the classroom and the Jasper problem so that it met the emerging values of the students, yet still allowed her to communicate her values and knowledge about mathematics. As she pointed out during an interview, the most difficult thing for her as a teacher was how to handle different goals from the class and to decide the valuable actions to take. For instance, she had to ask herself several times about her goals as a teacher, what a good teacher should do in the difficult situations she encountered, and how to make sure that students learn.

As a consequence of her reflections, the Hong Kong teacher made a series of justified decisions to adapt some of the affordances of the new artifact (focus on subproblems so students can deal with smaller problems one at a time) and reject others. She also adapted her role as a teacher by providing lectures on a need-to-know basis instead of using prelecturing at the start of each class period. She let go of her desire to give in-class memorization quizzes at the end of each day. As a result of these changes, she also discovered new insights about herself and her students as revealed in her comments, "students were a lot more creative than I have ever imagined" or "I did not know that I was kind of controlling actually."

The level of metacognition and adaptation was intense for this teacher as she began the transition from a routine to an adaptive teacher (Hatano & Inagaki, 1986). Metacognition served as a mechanism for problem finding, for setting adaptive goals, for identity building, and for value clarification. These uses of metacognition seem quite different from what appears in moment-to-moment logical problem solving and is not normally covered in the strategies that have been found in conventional metacognitive interventions that use scripted problems. Characterizing successful metacognitive strategies for adaptive situations appears to be a fruitful area for further research.

Case Two: The Challenge of Triggering Adaptive Metacognition in Everyday Classrooms

Unlike our first case involving a novel curriculum, teachers may not recognize that something needs adaptation in more subtle situations. Teachers already possess a great deal of experience and knowledge about teaching (after all, they were students for at least 16 years). This leads to the problem of assimilation, where people understand things in terms of familiar habits of seeing and doing things instead of recognizing there is something that requires metacognitive reflection (Bransford, Brown, & Cocking, 1999). We provide two examples that highlight two variants on this problem. One is the problem of not recognizing that a situation could use improvement, and the second is being dismissive of new models for doing things.

The difficulties in recognizing situations that warrant adaptation. Our first example comes from a study with 280 American and Chinese fifth-grade students and their teachers in both public and private schools (key schools in China; Lin & Schwartz, 2003). The students and teachers were asked to list the five most important characteristics of an ideal student. The Chinese students in both public and private schools, and the American students in private schools, emphasized learning-oriented characteristics (e.g., explains and understands deeply, knows when one makes mistakes). In contrast, the American public school students were concerned mostly with good behavior in class (e.g., does not fight, sits still during lectures). To validate our ad hoc categories of learning versus behavioral characteristics, we subsequently asked students what would happen if a boy or a girl did not do the homework assignment. Those students who listed learning characteristics tended to say "The boy or the girl would not learn." The students who listed behavioral characteristics tended to say "The boy or the girl would get in trouble."

We do not intend to claim that these results are representative of all public or private schools—this will require a much larger sample of schools. Rather, the importance involves the relation between the students' ideal students and the teachers' ideal students. Figure 1 presents the percentage of students and teachers from each nation and school type who mentioned learning and/or behavioral properties for their ideal students. The key pattern to notice is how the American public school results differ from the other school types. In particular, one should notice that the teachers in the American public schools, and not just the students, emphasized behavioral qualities at a very high rate.

Once the implicit values and implied practices associated with those values were brought to the teachers' attention, this triggered adaptive metacognition. They first expressed surprise at their students' complete emphasis on behavior relative to other schools. They also noticed that they too were emphasizing behavior more than teachers from other schools. The teachers began to reflect on their own assumptions about schooling, what they had been doing, how to improve their own practice and reintroduce learning as a central part of the students' ideal. This finding suggests that one important component of metacognitive training for teachers should help them see the values that they and their students hold so they can begin to reflect on whether changes are appropriate. As this example suggests, providing contrasting cases is one way to help.

Possibilities of being dismissive of new models for doing things. Our second example involves the challenge of recognizing the possibility of doing things in new ways. Like the Hong Kong teacher, this requires receptiveness to new ways of doing things. It also requires seeing that there is

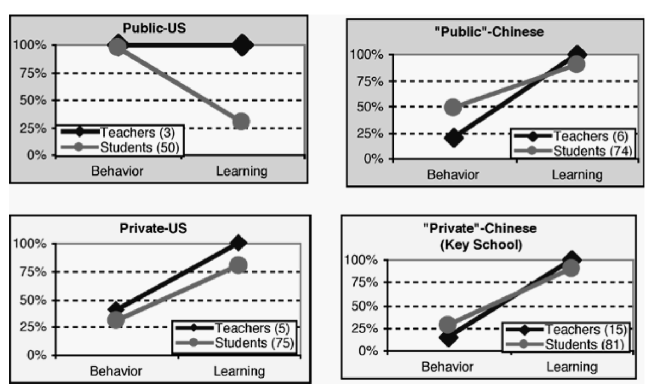

FIGURE 1 Percentage of students and teachers from United States and Chinese private and public schools who mentioned learning or behavioral properties for their ideal students.

something new and of potential value in other ways of doing things, rather than being dismissive. People have a strong tendency to assimilate potentially new situations to their routine ways of living. Instead of seeing what is new and adapting, they often reject what is new (Cohen, 1991; Lin, 2001a). Presumably, an adaptive metacognitive teacher would keep an eye open for what was new so he or she could begin the process of reflection and adaptation. But this also requires both the willingness and the ability to search for what is novel beneath the surface level. We have encountered many situations in which teachers' routinized beliefs prevent them from seeing and being receptive to new ideas. It is only when we have increased the variability by introducing new technologies or by providing explicit contrasts that teachers have had a chance to see the need for reflection and adaptation.

In one study, we asked in-service, American teachers to view videotapes of Chinese teachers (Lin & Schwartz, 2003). The American teachers tended to dismiss the instructional techniques used by the Chinese teachers. For example, one American teacher stated, "These methods are great. But, that can only happen in Asia. We cannot do that in America." Another stated, "Typical Chinese. Too strict." The teachers tended to discount the video of alternative teaching practices, because it simply represented another culture. As a consequence, they did not reflect on how they might adapt their own practices.

These results can be contrasted with American teachers who had completed an intervention to make them more receptive to new ways of doing things. The teachers who completed the intervention were much more reflective about the sample of Chinese teaching, and they related it to their own classroom practices. For example, one teacher saw the apparent strictness in the Chinese methods in another light. She stated, "Maybe I have let my standards drop too low."

The intervention put American and Chinese teachers together online. It used a three-dimensional interactive virtual learning space (VLS) with an activity about conducting experiments to find out about an insect's preferred habitat. We asked each intervention teacher to coteach a lesson in the VLS with a Chinese teacher. We also arranged to have six students (three from America and three from China) in the VLS at the same time, so it was a real lesson with implications for student learning. The teachers and students appeared as avatars in the VLS, and they moved from location to location to conduct their experiments.

The VLS intervention is not easily scaled up for working with many teachers (there is a great deal of logistical overhead in arranging times across nations and so forth). At the same time, it had a feature that we think was particularly important for supporting the onset of adaptive metacognition when the teachers subsequently watched the sample videos. During the intervention, the teachers had been involved in the process of making decisions about their own practices rather than observing other people and commenting. As indicated by the dismissive responses of the American teachers who had not completed the intervention, the role of detached observer is not ideal for triggering thoughts about personal adaptation. This finding is echoed by studies of teachers learning from multimedia cases (Hewitt, Pedretti, Bencze, Vailiancourt, & Yoon, 2003). In these studies, preservice teachers reflected more deeply about their decision-making processes when they were asked to make personal choices about instructional situations compared to when they simply watched and analyzed somebody else's teaching. Thus, we think it is valuable for promoting metacognition to put people in a position in which they have to make decisions about a situation of their own actions. This seems obvious. Traditional metacognitive strategy training would hardly work if students only observed other people and never had to use metacognition coupled with active problem solving. At the same time, teacher training often asks teachers to reflect on other people's cases without making decisions about their own potential actions in the same situation. So, perhaps the point is not that obvious.

TOWARD ADAPTIVE METACOGNITION

In this section, we describe an approach—Critical Event Instruction—that we have developed to help teachers appreciate the need for metacognitive adaptation, particularly in situations that appear routine on the surface level. One of our primary goals is to prepare preservice teachers for common events that are likely to appear in the course of their teaching. At the same time, we want to help them see the novelty in these familiar events so that they do not apply assumptions of "routine" metacognition to teaching situations where adaptive metacognition is more appropriate. For example, in our critical-event-based instruction, we provide teachers with examples of recurrent problem situations (e.g., poor attitudes toward school assignments). We then help teachers learn ways to avoid the tendency to schematize these recurrent problems so they do not seek out the particular, but often hidden, features that require differentiated solutions through reflection and adaptation. We do so by having people with contrasting values, goals, and experiences look at the same recurrent event. They offer their unique perspectives and discuss what additional information they would like to help solve the problem and determine what actions they might take. Our goal of asking people to search for additional information is to help people learn that all situations do not have a one-size-fits-all solution, and to attune themselves to important types of information that they should seek. This adds novelty and complexity to what appears as simple and familiar problem situations. By doing so, we hope to turn the recurrent problem situations into critical event-based situations where the novelty and hidden properties are made explicit along with the need to seek additional information. It is our hope that teachers are able to develop the habits of seeing past their taken-for-granted view of the recurrent classroom problems to begin the process of seeking for other sources of information in new situations and adapting to different values and social norms that many classes and students bring.

We developed a multimedia-based learning shell, critical-event based learning environment (CEBLE) that contains a series of video vignettes to capture recurrent and authentic classroom events or challenges. For instance, one event is about students' negative attitudes toward science assignments. Other instances present disengagement during group learning, and still others focus on students' difficulties in engaging an inquiry approach to learning math, science, and history. Here is a partial transcript of the critical-event video for negative science attitudes. The critical event comes from videos created for the CTGV Challenge Series (CTGV, 2000; Vye et al., 1998):

> *A student named Billy and his high school class team just returned from monitoring the water quality of a local river, and they were ready to turn in their report. A dialogue between Billy and his teammate Sally is presented:*

Billy: That's it, Sally. We are done.

Sally: I am not so sure, Billy. I think we should recheck our conclusions. We are saying the river isn't polluted, and if we were wrong. It's like we are letting all the fish die.

Billy: Enough, Sally. It's just a school assignment and our report is 5-pages long, single-spaced! We will pass for sure.

The CEBLE shell uses a cycle evolved from a STAR.Legacy software shell (see Schwartz, Lin, Brothy, & Bransford, 1999). The shell includes (a) meet the event; (b) generate responses to questions including "Did you notice anything new in this event?" "Do you need any additional information in order to solve the problem embedded in the event? If so, what is it? If not, why not?"; (c) listen to multiple perspectives offered by people of different backgrounds, goals, and values; (d) act on the perspectives by generating solutions for selected perspectives—the decision about which perspective to act on depends on the individual teachers' needs and their values; (e) reflect on the effectiveness of one's solutions and share their choices of perspectives, solutions and legacies with other members in the community who explore a similar event and topic. In this way, legacies for learning from recurrent events grow over time with multiple uses (see Figure 2 for CEBLE learning cycle).

We believe CEBLE has a potential for supporting adaptive metacognition, because it not only provides experiences with specific and recurrent events, but it also asks teachers to think past the application of their schematic responses. We ask teachers what additional information they need before solving the problem, so they consider potential sources of hidden variability in the situation and can better locate the source of

FIGURE 2 Learning cycle for the critical event-based instructional learning environment.

the problem. Ideally, this can become a habit of mind for teachers. We also ask teachers to adopt a perspective that contrasts with other perspectives on how to solve the problem. This exemplifies that any given adaptation depends on one's values; hopefully, it can help teachers clarify what values they deem most important. Finally, CEBLE offers teachers opportunities to interact with people of different backgrounds, values, and goals through its multiple perspectives, and through sharing thoughts with other members of the communities. These social interactions allow teachers to gain the first-hand experience that the same problem can have many different solutions depending on the goals and values people bring with them.

We conducted a study with 30 preservice teachers to see if CEBLE holds any instructional potential. We presented the negative attitude scenario to all the participants. They were then randomly assigned to two different groups. The adaptive metacognition group completed the aforementioned cycle. The problem-solving group generated solutions without deciding what additional information is needed and they did not see the multiple perspectives. However, they were permitted to talk with another. The conditions were meant to maximize the chances of seeing whether CEBLE leads to adaptive outcomes, rather than showing that CEBLE is better than all other forms of teacher training. We also administered a transfer posttest to see if the students learned differently. For the posttest, both groups saw another critical event about student disengagement during group activities. Everyone received a worksheet that asked them to analyze the event and generate three solutions, and to state whether they would have liked any additional information to make decisions, and if so, what kind of questions they would ask to get the information. All participants said that these events were familiar and that they had encountered both kinds of events during their student teaching or other teaching experiences.

We coded the student solutions for both the original and transfer case along two dimensions. One dimension captured whether a student proposed distinctly different solutions.

The other dimension captured the specificity of the solutions. The interrater reliability was 85% for the negative attitude event and 90% for the transfer, disengagement event.

A student received credit for different solutions when *all* the solutions depended on different information sources. The following three solutions yielded credit for being different:

Solution 1: "I would talk to Billy to see if my assignment is not interesting and motivating to him … then I would … "
Solution 2: "I will think about whether I give them (the students) clear criteria for how their report will be evaluated. If not, I would … "
Solution 3: "Have a talk with Billy's parents to see how they think about science … "

A student did not receive credit for differentiation when all the solutions were based on the same source of information. The following examples all depend on the information that Billy had not organized his experiments well enough.

Solution 1: "Set up a scientifically accountable method to help Billy report the results … "
Solution 2: "Make him repeat the experiment 3 times for the same results … "
Solution 3: "Conference w/both students until they run the experiments enough times to reach a conclusion"

For the second coding dimension of specificity, students received credit if all the solutions provided procedural details. An example of a specific solution is, "I will conduct clinical interviews with Billy and find out why he thinks that getting C or B is enough." A similar but vague solution was, "Be sure to ask for prior knowledge."

For both events, the groups generated equal numbers of solutions. However, Figure 3 shows that the individuals in the adaptive metacognition condition generated more distinct solutions that were also more specific. The fact that the difference between the conditions does not diminish on the transfer task, where there was no special support, is very heartening and warrants further research into whether these effects hold up after a longer delay or in the teachers' own classes.

On the transfer posttest, we also asked the participants from both conditions if they needed more information, and if so what would they like to know. Figure 4 shows the differences between the conditions. Twice as many participants in the adaptive condition said they would like more information compared to the problem-solving condition. This should not be too surprising, because they had just completed an intervention that emphasized asking for more information. What is more impressive is the type of questions that people in both conditions generated. Of those participants who generated information questions in both conditions, participants in the adaptive condition asked metacognitive How/Why and If/Then questions twice as often as the problem-solving participants, who tended to ask "What" questions or questions require only "Yes or No" answers (see King, 1992; Lin & Lehman, 1999). An example of a How/Why question is "How did the teacher arrange the group work, based on ability or randomly?" and "Why did the teacher decide to use group work rather than use individual seat work?" An example of a "What" question is " What are the details of the activity in the group?"

In debriefing, we asked participants to rate the usefulness of the experience of working with critical events on a 5-point scale ranging from 1 (*least useful*) to 5 (*most useful*) and explain their rating. The average rating for the adaptive group was 4, whereas the average rating for the problem-solving group was 2.5. Their reasons reflected our suppositions about the tendency of people to assimilate events. For example, one student from the problem-solving group wrote, "You guys are making a big deal out of nothing. Disengagement during group work is so common. There is nothing new about it." Moreover, the problem-solving participants stated that they had trouble generating alternative solutions on the posttest, because there was nothing new so they kept saying the same thing in different ways. In contrast, the adaptive metacognition group seemed to appreciate the value of looking past the surface. As one adaptive metacognition partici-

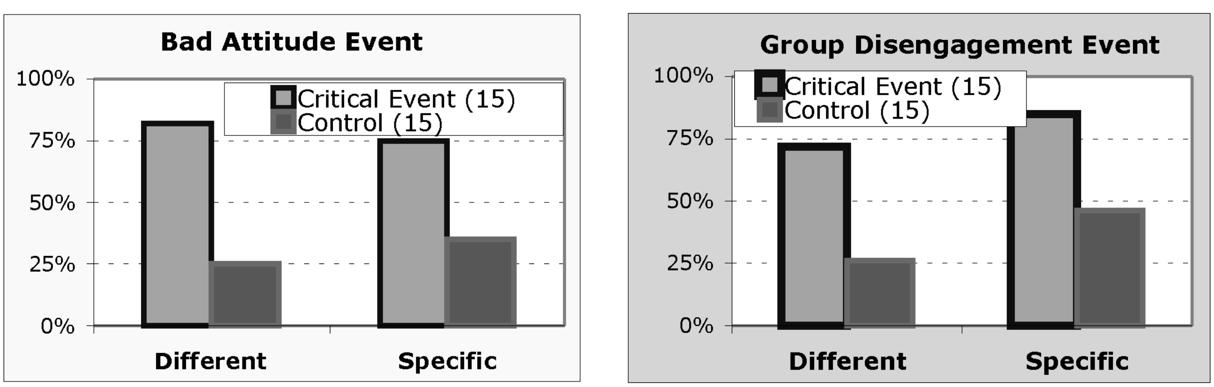

FIGURE 3 Percentage of participants from CEBLE and comparison groups who were able to generate both differentiated and specific solutions to both instructional and transfer events.

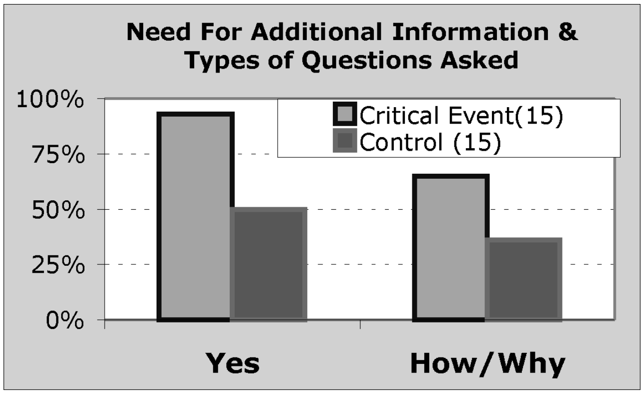

FIGURE 4 Percentage of participants from the CEBLE and the comparison groups who expressed need for additional information for the transfer event (Event 2) and who were able to generate metacognitive questions.

pant wrote, "The idea of asking for additional information to a problem that is so familiar is quite interesting to me." Many commented that the multiple perspectives were very helpful because they let them see new insights to an event.

All told, the results suggest that this instructional approach is promising. People tend to be more reflective around unexpected situations (Flavell, 1979). CEBLE increases the "unexpectedness" of "typical" events by having people with different experiences and backgrounds offer their perspectives to an apparently familiar situation. This helped people consider more specific alternatives and want more information during training; in turn, this helped them avoid dismissing a second event as typical. CEBLE enhanced the benefit of these multiple perspectives by first asking participants to make their own thoughts and likely actions explicit before the arrival of multiple perspectives. Too often, experts' perspectives are used as modeled behaviors for the teacher to follow, rather than being used as resources for teachers to self-assess their habitual ways of seeing and doing things. Our hypothesis is that the timing for providing multiple perspectives matters (Schwartz & Bransford, 1999). CEBLE was also designed to help students hear one another's perspective more clearly, by providing the models of multiple perspectives before they had a discussion. Many of the participants in the adaptive metacognition condition wrote of their surprise to discover that the same event, especially an event that almost everybody has had experiences with, was not reacted to in the same way by other members of the class, which led to reflective discussions afterward.

CONCLUSION

We conclude our article by summarizing the arguments and findings presented so far in terms of suggestions for the metacognitive development of teachers. Four sets of issues arise by contrasting conventional metacognitive tasks with the kinds of adaptive metacognition needed by the teachers. First, instead of assuming that a given task should induce almost the same activity from everybody (a series of actions aimed at a taken-for-granted goal), we emphasize that varied teaching or learning goals can be set, and thus different activities can be derived for apparently the same educational tasks and materials, depending on the values of the participants. Whereas has emphasized whether the participant has an effective metacognitive strategy to pursue the activity or how to teach that strategy, we propose that clarifying the potential goals is the initial critical step of adaptive metacognition, though choosing or inventing an effective metacognitive strategy to achieve a selected goal is also an important component (see Pintrich, 2000).

Second, we propose that planning appropriate activities and observing activities engaged by others with different values or sociocultural backgrounds give a very good opportunity for participants to reflect on their own goals and also learn how best to set goals under given constraints. We believe that the traditional way of metacognitive training has been unduly cognitive in its assumption of a common set of goals. For example, an attempt to directly teach strategies for solving problems may be effective for monitoring and controlling learners' behaviors, but only when the trainer and the trainee share the same goal. Another training procedure is to let a participant observe others' problem solving, but its effectiveness presupposes that the observer can see the problem from the perspective of the solver's metacognition. We would suggest that these training procedures can be used more successfully by considering participants' goals explicitly.

Third, we claim that social, collaborative situations might be used more often in the assessment and training of metacognition. Many important situations for teachers are highly social in nature. So, rather than solving bookish problems, they need to think about how to arrange social matters. We believe that the emphasis of metacognitive research on individual's "inward looking" processes could be broadened to include a consideration of social behaviors designed to alter one's social environment. It is important, however, to avoid an optimistic assumption that any interactions and cultural exposure to new information or new forms of practices lead to productive reflection (Lin & Schwartz, 2003). When people are in the role of a detached observer, they tend to be less analytic and reflective about their own and other people's teaching. This finding was echoed by studies of teachers learning from multimedia cases (Hewitt et al., 2003).

Fourth and finally, we believe that computers can help teachers' metacognition by giving them both (a) a set of experiences with specific and recurrent events where personal decision making is required and (b) opportunities to appreciate what other sources of information are important to consider and to reflect on. This kind of metacognition is useful because, in many situations, especially in complex teaching situations, teachers often lack background information to know what solution can be sought and which strategies will work. People usually do not detect absence of the important information very well. Therefore, it is important to develop the habits of gathering more information so that teachers can determine what strategies and solution to apply.

Our approach to metacognitive learning tries to integrate both specific cognitive skills (e.g., making decisions for specific problem situations) and general adaptive and social abilities (e.g., reflecting deeply on what types of information are needed or useful to make these types of decisions). Our hope is that the example of critical-event-based instruction provides one concrete instance that can help the field move in the direction of increasingly integrative approaches toward metacognitive interventions that use both cognitive and social information to help teachers develop proactive metacognitive capabilities.

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