Designing Metacognitive Activities

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Designing metacognitive activities that focus on both cognitive and social development is a theoretical and practical challenge. This balanced approach to metacognition concerns itself with many aspects of student development, ranging from academic competence to knowledge about the self-as-learner. In this article, I examine two basic approaches to supporting metacognition: (a) strategy training and (b) creation of a supportive social environment for metacognition. There are also two kinds of content that are taught using these two approaches: (a) knowledge about a specific domain and (b) knowledge about the self-as-learner. These approaches and contents have been used frequently in metacognitive interventions over the past two decades. Each offers unique contributions to metacognitive development. However, programs that address these approaches and contents simultaneously are rare. Maintaining the coordination, on one hand, between strategy training and creating social supports, and on the other hand, between knowledge about the subject domain and knowledge about the self-as-learner, is a challenge for most design efforts in metacognition. Future design issues include: (a) developing a system approach to promote coordination among these approaches and contents; and (b) finding ways to build knowledge about the self-as-learner.

☐ Some 20 years ago, Ann Brown and John Flavell introduced the concept of "metacognition" to the American research literature (Brown, 1975; 1978; 1987; Flavell, 1976; 1979; 1982). Their early studies involved controlled laboratory experiments that showed that young children could be helped to improve their own memory performances when researchers helped them think about the tasks they faced and possible strategies they might use (e.g., Brown, 1975; 1987; Flavell, 1976; 1987). Since that time the research literature on metacognition has flourished, and it has moved from a context that is primarily laboratory based to one that also involves the creation of social support in classroom environments that foster metacognitive reflection (e.g., Brown, 1997; Brown & Campione, 1996; Scardamalia & Bereiter, 1996; Vye, Schwartz, Bransford, Barron, & Zech 1998; White & Frederiksen, 1998).

The purpose of this article is to propose a framework for thinking about how metacognitive research might apply to design activities. In this context, I define *metacognition* as the ability to understand and monitor one's own thoughts and the assumptions and implications of one's activities (Brown, Bransford, Ferrara & Campione, 1983; Butterfield & Belmont, 1977; Flavell, 1979). Students are said to be metacognitive to the degree to which they are engaged in thinking about themselves, the nature of learning tasks, and the social contexts (Brown, 1987). Research shows that effective learners are those who are aware of their strengths and limitations and find ways to remedy the latter (Bransford, Brown & Cocking, 1999, Chapters 3, 4 and 7). When students are engaged in metacognitive activities (e.g., self-assessment, self-explanation, monitoring, or revising), their learning is enhanced. Weaker students are found to benefit even more than stronger students from such

activities (White & Frederiksen, 1998). However, students do not spontaneously engage in metacognitive thinking unless they are explicitly encouraged to do so through carefully designed instructional activities (Berardi-Coletta, Buyer, Dominowski & Rellinger, 1995; Bransford et al., 1999; Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Lin & Lehman, 1999). Therefore, it is important to include metacognitive support in the design of learning environments.

My goal is not to contribute to the design field by doing a comprehensive literature review on metacognition. In fact, at this point, a book-length monograph would be needed in order to do so. Rather, in this article, I highlight some of the key approaches and contents that have been used by researchers to support metacognition, thereby helping designers use the research findings that have been gathered over the past two decades. The goal is to bring this work together in one location to help designers make sense of and apply this corpus of research to design. As such, it is my aim to fulfill one part of Dewey's notion that educational research is a bridging science between psychology and the craft of the classroom instruction.

A FRAMEWORK FOR ANALYZING METACOGNITIVE INTERVENTIONS

Research on metacognition is moving toward an educational goal that emphasizes the importance of developing students who are balanced in terms of cognitive and social competence (Bransford et al., 1999). This approach to metacognition concerns itself with many aspects of student development (Lewis, 1998; Lin, 2001; Sato, 1997). Students' academic achievement and strategies for learning are taken seriously, but so is their ability to create a role for themselves in a community, where they build friendships, contribute to the values of the community, and involve themselves in its academic, social, and civic activities. Developing cognitively and socially competent metacognitive learners raises a number of important issues about the design of learning environments (e.g., Brown, 1992). Some issues center around approaches to designing metacognitive supports. Others concern the content that is taught using these approaches. These issues serve as a foundation for the framework developed in this article for analyzing metacognitive research interventions.

Over the past decades, researchers in metacognition have adopted two basic approaches to supporting metacognitive development. They are (a) *strategy training* and (b) creating a supportive social environment (or social supports) as ways to foster metacognitive activities. There are also two kinds of content that are taught using these two approaches. They are knowledge (a) about a *specific domain* (e.g., science, mathematics, reading comprehension, writing skills, or problem solving) and (b) about the *self-as-learner* (e.g., personal or self knowledge developed from participating in both academic or community activities, including social skills for becoming a contributing member of a community) (Bandura, 1997; Dweck, 1999; Dweck & Leggett, 1988; McCombs, in press). Most of the research programs focus on just one approach and content, even though all are important aspects of metacognitive development (e.g., Brown, 1987). By analyzing the unique impact each approach and content may have on learning, we can begin to develop a system view toward designing metacognitive activities.

In the sections that follow, I begin by analyzing examples of metacognitive interventions that fall into each approach and content in the framework. I then discuss important issues for future design and research.

ANALYSIS OF METACOGNITIVE INTERVENTIONS

A few example programs serve to illustrate the approaches and contents of metacognitive interventions. Early on, a majority of those studying metacognition used a strategy-training approach, instead of creating social environments to support metacognition. The content of training usually is exclusively on either domain-specific tasks or on knowledge about the self-as-learner. However, in recent years, research has emphasized creation of social environments to support metacognition, as well as integration of

strategy training into the context of everyday social activities. The content of metacognitive training is also shifting from an emphasis solely on domain-specific knowledge or on knowledge about the self-as-learner to a more balanced training that consists of both (e.g., for a comprehensive review of the history of this movement, see Brown, 1992). The framework used in this article is derived from this balanced research movement.

To give a picture of what this movement in metacognitive research implies for instructional design, a few examples of intervention programs are chosen to illustrate the instructional goals and the design characteristics used to achieve these goals. These programs are chosen because they provide explicit examples of how a particular instructional approach and content are taken into consideration in an actual metacognitive intervention. For example, the intervention designed by Brown and Campione (1996) provides an excellent example of why and how researchers decide to create a social learning environment to foster metacognition. Similar criteria apply to the selection of other examples. Table 1 highlights the underlying instructional goals and design characteristics for each approach and content that is taught. This table is used to frame discussion throughout the article. For instance, each approach (i.e., strategy training and a creation of a supportive social environment for metacognition) is discussed with regard to the content that is taught: (a) knowledge about a specific domain and (b) knowledge about the self-as-learner.

Strategy Training

Most strategy training programs involve the introduction of a set of rules and effective strategies an individual can use in learning about domain-specific subjects, such as reading, science, mathematics, and writing (Brown et. al., 1983; Flavell, 1987; Hacker, Dunlosky, & Graesser, 1998). These strategies may include error detecting, effort and attention allocating, elaborating, self-questioning, self-explanation, constructing visual representations, activating prior knowledge, rereading difficult text sections, and going back to revise. The main purpose of most research in strategy training is to explore: (a) how specific sets of metacognitive strategies contribute to monitoring conflicting thoughts and building a coherent understanding of a subject domain; and (b) how different

Table 1 ☐ Instructional goals and design characteristics for two approaches to supporting metacognition and the two contents that are usually taught.

Instructional Approaches	*Contents That Are Taught*	
	Domain-specific knowledge	*Knowledge of self as learner*
Strategy training		
Underlying goals	• Teaching effective strategies • Monitoring conflicting thoughts • Building coherent understanding	• Teaching self-oriented strategies (e.g., self-rewarding, setting personal goals, etc.) • Developing a strong sense of self-as-learner
Design characteristics	• Modeling • Prompting	• Social or peer modeling
Creating social support		
Underlying goals	• Building supportive metaculture • Developing deep learning principles • Fostering community metadiscourse	• Developing a strong sense of self-as-learner • Building an identity
Design characteristics	• Creating communities of practice • Creating virtual community	• Changing social context for learning a specific domain • Providing choice for roles • Creating virtual social support

types of instructional support for metacognitive strategies influence student engagement in these metacognitive activities. Students usually stop at fixed intervals while learning specific subject domains to reflect and revise their work. The interventions usually do not involve changing the existing school curriculum and classroom culture. Below, I describe strategy training that focuses on the acquisition of either domain-specific or self-as-learner knowledge.

Domain-specific knowledge and skills

Early metacognitive strategy training studies tended to use direct instructional approaches, usually in a one-on-one (experimenter-child) situation, explicitly to teach students effective strategies for domain-specific and problem-solving tasks (e.g., Brown et al., 1983; Pressley, Etten, Yokoi, Freebern & Meter, 1998; Pressley et al., 1992). In recent years, there has been an increased use of modeling and prompting to help students learn metacognitive strategies.

Modeling. Bielaczyc and her colleagues used modeling to provide metacognitive supports for college students to learn computer programming (Bielaczyc, Pirolli & Brown, 1995). They employed video technology to model effective learning strategies employed by the good problem solvers in the domain of LISP (*lis*t *p*rocessing) programming. The interventions were carefully designed and structured so that students could use effective metacognitive strategies to gain a deep understanding of the instructional materials before moving to the problem-solving stage. Students were exposed to specific metacognitive strategies and received explicit training in their use. In the video, the good problem solvers modeled strategies, including explaining instructions to themselves, determining both the form and meaning of programming code, monitoring positive states of comprehension, clarifying confusions, and taking action to address comprehension failures.

They found that mere exposure to good learning models was not sufficient. The key to the success in their design was to have students experience these strategies in their own learning, explicitly compare their own performance with that of the model, and take action to revise ineffective learning approaches. Students said that the explicit discussions about metacognitive strategies helped them become more effective in their learning, showing them where to focus on both the instructional materials and their own understanding. In addition, the students thought that it was crucial to experience firsthand the usefulness of the strategies through experiencing changes in their own understanding when using these strategies. Further, becoming aware of the strengths and weaknesses in their understanding aided students to identify which learning strategies to apply and to determine their effectiveness.

It is important to note that the successful instructional designs emphasize what Brown and her colleagues (1983) call "informed training plus self-control," in which students are informed of the conditions within which the new strategies are most useful. These strategies also enhance self-control skills such as planning, checking, self-monitoring and evaluating. For example, studies by Brown and her colleagues often teach students to monitor their reading comprehension and evaluate the effectiveness of the strategies they use. In addition, the students are also provided with a rationale for each new strategy that is taught and are informed of the conditions that are most appropriate for the use of the strategy. Without such "conditionalized" knowledge, students face difficulties in using learned strategies in new settings (Brown et al., 1983). The interventions that have resulted in failures of understanding and transfer involve "blind training," where students are taught strategies without understanding *why, when,* and *how* they are useful (Duffy & Roehler, 1989).

Prompting. Another way to teach metacognitive strategies is to use online procedural prompts (Berardi-Coletta et al., 1995; King, 1991; 1992; Scardamalia & Bereiter, 1985). For example, King's interventions (1992) used prompt cards and peer groups to engage students in learning strategies that would help them generate metacognitive questions. They provided students with prompt cards to explain, "What is a new example of . . .?"; "Why is . . . important?"; or " How does . . . effect . . .?" They found that

these prompts effectively taught students to generate critical metacognitive questions about learning tasks at hand and to construct a deeper understanding of the domain.

Prompting has also been used to stimulate self-explanation for metacognition. These prompts, rather than teaching students strategies, serve to guide student attention to conflicting thoughts and build coherent understanding of the domain tasks at hand; this may lead to extensive inference generation (e.g., Chi et al., 1989; Chi, Deleeuw, Chiu & LaVancher, 1994; Lin & Lehman, 1999). In Chi et al.'s 1994 study, a group of middle-school students were prompted to self-explain what it meant to them after reading each line of a passage on the human circulatory system. The researchers found that the prompted group had a greater gain from the pretest to the posttest. Moreover, the prompted students who generated a large number of self-explanations (the high explainers) learned with greater understanding than did the low explainers. As pointed out by Chi and her colleagues, ongoing explanation "allows conflicts to be recognized and resolved at many loci, where the changes are more minute and more easily repaired." (p. 473).

Lin and Lehman's (1999) study provides another example of using prompts to elicit self-explanation. In that study, a computer-simulation program was developed to aid students in designing biology experiments. The computer program prompted students to stop before, during, and after designs to explain their decision-making and interpretation of the scientific phenomenon. Sample prompts included: "How do you plan on going about the design?"; "Why did you set up this particular experiment?"; and "What would you do differently if you designed this experiment all over again?" These process prompts engaged students in self-monitoring of contradictory thoughts and constructing new understanding, without direct teaching of specific strategies.

However, not all types of prompts led to successful transfer in complex problem solving. Process prompts (monitoring how and why certain decisions were made) were effective because they helped students pin down specifically where and what they did not understand. Instead of self-assessing at a general level, " I don't understand" or " I am confused", the students were able to explain specifically what they did not understand and where the difficulty occurred. Other programs used these process prompts to help students self-assess their own learning against a set of criteria. For example, White and Frederiksen (1998) used such prompts to engage students in monitoring their misconceptions in physics learning.

Knowledge about the self-as-learner

There have been considerable discussions about the importance of knowing the self-as-learner in promoting metacognition. Several observations can be made about this body of research. One observation is that most researchers who consider the self-as-learner in metacognitive interventions acknowledge the importance of looking at the self-as-learner in relation to society or a specific social context (e.g., Bandura, 1986). This is because the self-concept is highly changeable and responsive to the social contexts within which one lives and works (Markus & Wurf, 1987; Stein & Markus, 1996). Researchers usually look at various ways that social sources can be used to help students develop effective strategies, academic competence, and a sense of the self-as-learner. In particular, they address the role of social or peer modeling, community participation, and feedback on student strategy learning and self-as-learner knowledge building. For example, Bandura (1986, 1997) and other researchers view the development of knowledge about the self-as-learner as a series of reciprocal interactions between personal variables (e.g., behavior, thinking, decision-making, affect, confidence, emotion) and the social environment (Borkowski & Muthukrishna, 1992; Patrick, 1997; Schunk, 1989; Schunk & Ertmer, 1999; Schunk & Zimmerman, 1997). Knowledge about the self-as-learner is usually developed using social modeling provided by other people.

Social models are an important source for conveying cognitive skills and for building knowledge about the self-as-learner. For instance, a student might observe a peer or a teacher engage in effective problem identification and conceptualization of principles for

problem solving. By observing their social peers, students may begin to think that they also can be creative and effective problem solvers. Other researchers interested in knowledge about the self-as-learner point to the cultural self as defined by roles or status in a community (Cole & Scribner, 1974; King, 1995; Lewis, 1998; Lin, 2001; Meyrowitz, 1985; Neisser, 1988; Schwartz, 1999; West, 1994). For example, we can define ourselves as learners by the roles we take on within a classroom or the types of social interactions and contributions we are able to make to a specific domain or cultural environment. I will talk more about cultural self-as-learner in the section on creating supportive social environments for metacognition.

It is important to note that those researchers who favor focusing strategy training on building knowledge about self-as-learner often use a more biological metaphor, which argues for the importance of helping students develop knowledge about self-as-learner as an "innate or self actualized" agent (McCombs & Marzano, 1990, p. 52). This knowledge about self is determined by the inherent natural systems of the human, including basic needs to survive and to be motivated by personal goals and desires to learn and interact (McCombs, 1999). Such knowledge can motivate students to monitor and regulate their actions and provide a basis for the awareness of their own learning experiences (Kihlstrom & Cantor, 1984; McCombs, 1999; McCombs & Whisler, 1997).

A key point is that it is not enough to teach individuals only domain-specific strategies and expect them to develop knowledge about self-as-learner. It is necessary to nurture student self-knowledge and domain knowledge simultaneously. Programs emphasizing this teach by providing sets of strategies that students and teachers can apply to improve their knowledge of the self-as-learner and other kinds of skills. The research of Zimmerman and his colleagues provides an example of how students can develop knowledge of the self-as-learner through strategy training (Zimmerman, 1998; Zimmerman & Kitsants, 1999; Zimmerman & Martinez-Pons, 1986). In their training, students are provided with 14 classes of effective self-oriented strategies, ranging from personal goal-setting, self-rewarding, and seeking social assistance to environment structuring, managing information, and self-evaluating. Zimmerman and his colleagues also suggest that learners can acquire and make use of these self-oriented strategies by observing different models that use these strategies well.

Interestingly, those researchers who emphasize the importance of social sources in developing knowledge about the self-as-learner rarely use design approaches that involve changing the existing cultural contexts within which students learn. On the other hand, it is truly a challenging task to change culture at a society level compared with teaching individual students sets of metacognitive strategies. It is important to recognize that there is much beyond the control of researchers, designers, and teachers.

Creating Supportive Social Environments for Metacognition

A main purpose of creating social environments for metacognition is to build a supportive learning culture for metacognitive growth (e.g., Brown & Campione, 1996; Herrenkohl, Palincsar, DeWater & Kawasaki, 1999; Lampert, Rittenhouse & Crumbaugh, 1996; Scardamalia & Bereiter, 1991). Researchers who favor creating social environment for metacognition concern themselves with issues such as: (a) how to create a metacognitive culture where people feel comfortable to acknowledge what they do not know; (b) how to use a systems approach to design metacognitive activities; (c) what it means for everyone to take on a helpful and intelligent role in a community; (d) what it takes to help students develop deep learning principles that can apply across different curricula and domains; and (e) how to support diversity and metacognitive discourse in a community. Unlike strategy training, creating a social environment for metacognition usually requires teachers, designers, and researchers to work collaboratively to change classroom culture and social interactions, in order to foster metacognitive activities and reflection. For example, students engage in spontaneous reflection when they compare their work with that of others or are exposed to multi-

ple perspectives in the classroom (e.g., Scaradmalia & Bereiter, 1991; Vye et al., 1998). Designs that rely on the creation of social environments are also more dynamic and less predictable than designs that use only a strategy training approach, because in these social environments, metacognitive reflection does not occur at fixed intervals as in strategy training. Metacognitive reflection and strategy training are part of everyday activities to foster habits of reflection, rather than only moment-to-moment specific task-related activities.

The rationale for creating social environments for metacognition has been discussed extensively by many instructional theorists (e.g., Barron et al., 1998; Cobb, 1994; Cobb & Yackel, 1996; Hacker et al., 1998; Herrenkohl et al., 1999). Students and teachers will have a difficult time practicing metacognitive reflection if the environment does not value and support such activities (Brown & Campione, 1996; Lin, 2001; Lin, Schwartz & Holmes, 1999; Vye et al., 1998). In addition, students need multiple perspectives and group feedback on their performance and understanding. Often, understanding deepens when one's thinking is compared with that of others (Collins, 1991; Lin, Hmelo, Kinzer & Secules, 1999). Other researchers further contend that monitoring and revising become more motivating when there is a public audience to evaluate and judge students' working and thinking (Schwartz, Lin, Brophy & Bransford, 1999). Thus, shared metacognitive experience through supportive social discourse is regarded as an important aspect of metacognitive development (Collins, 1991; Scardamalia & Bereiter, 1991).

Domain-specific knowledge and skills

When creating metacognitive social environments for domain-specific learning, interventions are usually designed around challenges derived from a specific-subject domain. A unique design feature shared by these interventions is to create a system of purposeful metacognitive activities built into recurring learning cycles. Like an ecosystem, these different activities are interdependent and feed into each other to provide different, yet complementary, support to deepen learning and understanding.

One way to create social support is to develop communities of metacognitive practice. The Fostering Communities of Learners (FCL) program by Brown and her colleagues provides an excellent example (Brown & Campione, 1996).

Creating communities of metacognitive practice. Brown and Campione's (1996) interventions brought changes to the social structure in Grade 1–8 classrooms in the subject areas of ecology and biology.

The domain-specific learning goals are to understand deep disciplinary content, develop scientific and metacognitive thinking skill, and increase literacy. The goals for learning about self-as-learner include the development of self-knowledge about how one is performing both academically and socially in order to become a contributing member of a community. There are three key components in FCL: (a) researching; (b) sharing; and (c) performing. Metacognitive activities are embedded in each of the components and are arranged into a learning cycle. The cycle begins by researching a set of topics in a specific domain subject, moves into sharing the research, and ends by performing consequential tasks to demonstrate learning. For example, in a second-grade class, the big scientific principle underlying student research is that of animal-habitat interdependence (Brown, 1997). Six research groups are formed to study (a) defense mechanisms; (b) predators; (c) food chain; (d) reproductive systems; (e) animal communication; and (f) protection systems. Even though each group is majoring in a specific area of research, overlaps among the topics require students to communicate and reflect in order to fully understand the principles. That is, each group is one piece of the puzzle, and together they contribute to the understanding of the whole puzzle (e.g., Jigsaw collaboration, Brown & Campione, 1996).

Students begin by researching complex domain-specific issues. Teachers and students make joint decisions on which metacognitive activities to engage in, based on the learning tasks at hand. For instance, reciprocal teaching

activities (e.g., Palincsar and Brown, 1984) are called for when a research group senses trouble in understanding and explaining reading materials. Group collaboration is encouraged when students and adults take turns being the leader, so that students are exposed to mature modeling of self-control, comprehension, and monitoring strategies and then practice these strategies (Brown & Campione, 1996). Students engage in guided writing and composing activities to clarify their own thinking, set priorities, and communicate the findings of their research to other members in the community. When students confront either issues of fundamental importance to the discipline or naive scientific misconceptions, they engage in face-to-face or on-line electronic consultation and reflection with peers or domain experts.

In the sharing cycle, students communicate their research findings with members of other groups, by engaging in Jigsaw and cross-talk activities. During the cross-talk, a whole class engages in discussions led by students or teachers taking on metacognitive roles and asking each other to self-assess and report their research findings to date. Students often realize that they do not understand their research when they are unable to answer other people's questions or to explain what they have researched.

The cycle ends by performing a consequential task, where a variety of forms of assessment is offered. These assessment activities include clinical interviews, transfer tests, and thought experiments. The consequential tasks are intended to help students revise their own learning; understand why they do what they do, rather than following a set of procedures; and provide teachers opportunities for feedback before the next instructional unit.

Creating virtual learning communities. Another way to create social support is to develop virtual learning communities using various forms of technology. Examples include the Science On The Web Project (see Wallace, Kupperman, Krajcik & Soloway, 2000) and Scardamalia and Bereiter's (1991) Computer Supported Intentional Learning Environment (CSILE). CSILE supports social aspects of metacognition through on-line metacognitive discourse among students, teachers, and content experts. Graphic visual representation capabilities are also built into this networked multimedia learning environment to foster better communication and reflection. For example, students create visual representations to communicate their theory about an endangered animal to other members of the community. They also reflect on their theory by contrasting their hypothesis and evidence with those generated by their peers, teachers, and content experts. By responding to and evaluating peer theories, students also have an opportunity to reflect on what they do and do not understand, and why (see Lin, Hmelo, et al., 1999 for a specific example of such social metacognitive discourse).

As with FCL, CSILE organizes its reflective activities into a learning cycle. The cycle begins by having students create individual representations, notes, and then community notes; moves into revising and building on community notes; and ends by synthesizing notes in community discourse. The underlying goal is for these activities to promote both individual and community learning. A unique aspect of CSILE is that it sustains metacognitive discourse about a specific domain at a community level. Students can discuss their confusion, compare different perspectives, and reflect on their individual and joint understanding of a problem.

Scientific and Mathematical Arenas for Refining Thinking (SMART) program developed at the Learning Technology Center at Vanderbilt University offers another example where community metacognitive activities are anchored around a set of authentic domain-specific challenges (Barron, et al., 1998; Vye et al., 1998). Central to a SMART learning community is a technology artifact called STAR.LEGACY, a software shell developed to help teachers organize complex learning situations. STAR stands for Software Technology for Action and Reflection, where the learning cycle begins by looking ahead, meeting challenges, and generating ideas for researching a specific domain, followed by multiple perspectives from virtual experts, research and revision of one's ideas, and testing one's understanding. It ends by "going public" with one's thinking and leaving a legacy to help the next group that explores a similar topic (see

Figure 1 ☐ Software technology for action and reflection Legacy (adapted from Schwartz, Lin, Brophy & Bransford, 1999).

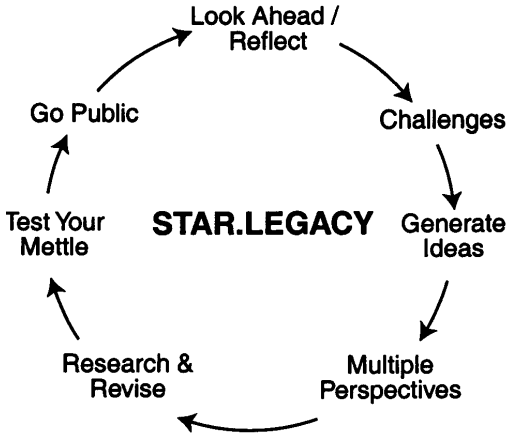

Figure 1). In this way, legacies for learning grow over time with multiple uses (for detailed examples of STAR.LEGACY, see Schwartz et al., 1999).

STAR.LEGACY supports social aspects of metacognition by providing opportunities for students to generate their own ideas, compare their ideas with multiple perspectives and reflect on the differences, and share their learning products with broader communities. Students have multiple opportunities to reflect and revise their work throughout the learning cycle. Designers of STAR.LEGACY also provide teachers with various resources and tools to engage students in metacognitive thinking, including hands-on activities, textual resources and video segments, simple simulation games, and tools that allow teachers to analyze student thinking efficiently.

Rather than focusing on teaching individual strategies, all of these interventions are targeted at changing social environments to support metacognitive activities, where school curriculum and daily social interactions are reorganized. Another common design feature shared by all these interventions is to provide a system of metacognitive activities occurring in learning cycles. These learning cycles provide activity structures to all members in the community in a purposeful manner. Usually, domain-specific challenges and learning goals drive the choices of metacognitive activities and the sequence of the cycles. As a system, the sequence and form of learning activities can also be modified, dropped, or replaced, but only if the fundamental metacognitive synergy is maintained (Brown & Campione, 1996). It is also important that teachers be metacognitive about both their instruction and student thinking in order to make pedagogically sound decisions (Bransford et al., 1999).

Knowledge about the self-as-learner

When people choose a day-care or school for their child, they often ask, Is this social environment designed to help my child flourish and grow? It is apparent that researchers who favor creating social supports acknowledge the importance of looking at how an environment can affect an individual's growth. However, as mentioned earlier, creating a new culture or a new social structure at the society level, so that an individual can develop a balanced cognitive, metacognitive, and social competence, is almost an impossible task. Many researchers find that the bigger the sociocultural environments get, the harder they are to change or recreate (e.g., Bransford et al., 1999; Brown, 1997; Cobb & Yackel, 1996; Lamon et al., 1996).

There have been a number of attempts to create social environments to help individuals develop a strong identity and knowledge about the self-as-learner. Most of these efforts occur in a manageable setting, such as a specific subject domain in a school context. As such, there is a need to integrate knowledge about specific content domain and about self-as-learner. One reason for reaching the individual self through a specific domain is that in these settings, it is easier for researchers to choose specific environments which they can create (e.g., Vye et al., 1998). Another reason that has been recognized by several classroom-based research projects is the difficulty in developing knowledge about self-as-learner with no reference to a specific domain or social context (e.g., Barron et al., 1998; Lin et al., 1995; Vye et al., 1998). These research-

ers find that domain subjects provide a set of learning criteria that make the development of knowledge about self-as-learner a possible task. This also helps individual students contextualize their knowledge of self-as-learner with respect to a specific domain situation.

So far, there have been two approaches to creating social environments to develop student knowledge of self-as-learner. One involves creating choices of roles for students to take on, such as scientist, teacher, or historian, and creating a social environment to support them in their roles. These roles are typically associated with a specific domain, or a specific kind of metacognitive thinking. It is hoped that students can gain their knowledge about self-as-learner by taking on a role offered by a particular cultural practice (Lin, 2001; Schwartz & Lin, 2001). An example of this was recently developed by White and her colleagues, who designed a technology-rich social environment that offers students a wide range of roles associated with physics learning (White, Shimoda & Frederiksen, 1999). In their environment, students are given a broad range of choices to take on certain roles and to work with different advisors. For example, if students take on the role of being an investigator or a hypothesizer, they work with the advisors in these areas and contribute to the scientific inquiry in the community. A student can also be a self-assessor who takes on the role of monitoring and revising the work for a group. Students develop a sense of self-as-learner in association with a specific domain by making choices about whom they want to become and what contribution they want to make to a community. The importance of providing students with control of their own role for developing self-knowledge is recognized by many researchers (Brophy, 1999; Deci & Ryan, 1991; Husman & Lens, 1999; Perry & Weinstein, 1998; Schunk & Zimmerman, 1997).

Another approach is more in line with Bandura's (1997) social cognitive theory of modeling. That is, if students are provided with an environment where metacognitive mindfulness is valued and encouraged, then it is likely that students will eventually adopt the habit of being reflective. CSILE is a good example. CSILE designers create a culture of intentional learning by having students and teachers engage in metacognitive discourse about everyday learning activities. Students are encouraged to question who they are and what contribution they can make to the community. Understanding of oneself as a learner is more likely to occur when everybody in the community models metacognitive behaviors. The power of having a reflective culture in support of knowing self-as-learner is also evident in the research conducted in Japanese schools where students develop a strong sense of self through the powerful reflection that goes on in their daily life activities (Lewis, 1998). Hatano and Inagaki (1998) also draw our attention to cultural influence on personal effort. They posit that children who grow up in a culture that values being competent in mathematics tend to seek mastery in these culturally imposed skills.

Currently, Lin and her colleagues are experimenting with another approach to helping students develop knowledge of self-as-learner (Lin, Schwartz, et al., 1999). Their approach is to have students develop a sense of self-as-learner by teaching others in a virtual learning environment (e.g., technology-based social simulations). These "virtual kids" are equipped with many different kinds of personalities. The students' job in the classrooms is to teach the virtual kids how to develop appropriate goals for learning and personality, including self-beliefs, attitudes, and knowledge, for a wide range of learning. In addition, students are also asked to create different social environments that support the personalities. It is hoped that by teaching others and creating a supportive virtual environment, students will, in turn, develop a stronger metacognitive knowledge of self-as-learner and may eventually create social supports for themselves to flourish and grow. This kind of learning may also help students identify factors they need to consider in designing a supportive social environment. There are some exciting research opportunities in this area.

SUMMARY

I have discussed two basic approaches to supporting metacognition: (a) strategy training and (b) creation of a supportive social environment

for metacognition. The underlying instructional goals and design characteristics for each approach are analyzed with regard to two kinds of content that are taught: (a) knowledge about a specific domain and (b) knowledge about the self-as-learner. These two approaches and kinds of content are not mutually exclusive because each offers a unique contribution to metacognitive development, and together they provide a balanced system to support metacognition.

There is a strong agreement among researchers that strategy training should be conducted in a supportive social environment. As discussed in previous sections, particular kinds of strategy training might interfere with or be best supported by certain kinds of social environment and vice versa. Implementing a particular strategy training tends to create a specific kind of social structure, and creating a particular kind of social structure may require a specific kind of strategy training. Similarly, it is also important to consider both academic and social aspects of the self-as-learner when designing metacognitive activities. Knowledge of the self-as-learner plays a pivotal role in the success of learning a subject domain (Dweck, 1999; Stein & Markus, 1996). On the other hand, participating in learning about a subject also helps students contextualize their sense of identity and knowledge of the self-as-learner. As such, there is a dynamic and interdependent relationship among strategy training, creation of a supportive social environment, and the kinds of content that are taught. However, achieving coordination and stability with regard to these interdependent relationships over time is a challenge for most of the design efforts (e.g., Brown, 1997). Instructional technologists need to take this interdependent relationship into design consideration and make the approaches mutually supportive to one another for developing learners who are knowledgeable about both domain subjects and the self-as-learner.

Designing effective metacognitive activities requires a systems approach. There are many aspects of the design, implementation, and assessment of metacognitive learning that need to be further articulated and explored jointly by members from different research communities. In the next section, I will discuss issues and implications for the future design of metacognitive activities.

ISSUES AND IMPLICATIONS FOR DESIGN

One set of issues for design focuses on factors to consider in developing coordination among the different kinds of learning goals underlying these approaches and kinds of content. A second set of issues involves a focus on helping students build and maintain a strong identity through knowledge of the self-as-learner in relation to a specific domain and social environment. Each will be discussed in turn.

Importance of Coordination

Clearly, there is a need to build coordination between strategy training and creation of a supportive social environment for developing knowledge about both domain subject and the self-as-learner. Students may learn valuable strategies, but these cannot be applied unless they are supported by broad learning goals and cultural norms in a community. Similarly, students may learn the skills to excel in academic performance, but have little sense of who they are and what it means to be a contributing member of a community. Without coordination among these different relationships, it is difficult to achieve the goal of educating cognitively and socially competent learners.

Schools often use checklists in designing metacognitive activities, such as reciprocal teaching or the Jigsaw method, prompting students to explain themselves and to use formative assessment (Brown & Campione, 1996). Often, it is hard for these activities to be coordinated with one another and with overall learning goals. For instance, students might be encouraged to work collaboratively, such as by taking on different social or cultural roles, yet be graded on a curve or a narrow performance standard (Bransford et al., 1999).

One way people have tried to develop such coordination is to make sets of learning goals explicit to all members of a community. These goals should give balanced consideration to

both academic and the self-as-learner knowledge building, as well as to the social environments where particular sets of metacognitive strategies and skills are more likely to develop. For instance, Brown and Campione's (1996) FCL has embedded specific training of metacognitive strategies in different kinds of social participation structures to form a system of interdependent, purposeful learning activities. All of these activities are congruent with the ultimate learning goals. The program does not implement metacognition in isolation. Each of the activities has a clear function within the instructional system. The activities can be replaced and sequenced differently according to learning goals as long as the metacognitive spirit does not get lost. This spirit includes an atmosphere of being honest about what one does not know and of consciously searching for the rationale behind metacognitive activities. In addition, this metacognitive spirit should also include the fostering of communal discourse, progressively deepening one's content knowledge and reflection, and providing frequent opportunities for students to make their thinking visible.

Another approach one might consider is to identify a set of higher-level design principles that help teachers and designers create a balance in a design space among the two approaches to supporting metacognition and the content that is taught. These principles are not recipes or procedures to follow. Rather, they serve as guidelines for coordinating and balancing these dynamic relationships. For example, in an attempt to build a balance between these two approaches and their content, we can develop a set of interdependent design principles. These principles feed into each other in a system way. They include:

- Provide frequent opportunities for students to self-assess what they know and do not know;
- Help students articulate their own thinking;
- Foster a shared understanding of the goals for metacognitive activities;
- Develop knowledge of the self-as-learner with respect to one's role in a specific culture.

High-level design principles

Principle 1: Provide frequent opportunities for students to self-assess what they know and do not know. Engage students in metacognitive activities that will help them to assess themselves and to explain specifically both what they know and what they do not know. By identifying what they do not know, students can focus their attention and resources toward resolving such difficulties (Bielaczyc et al., 1995; King, 1992; Lin & Lehman, 1999). In addition, by knowing what they already know, students become aware of the potential knowledge and skills that they can bring to bear, which provides them with more confidence in learning (Lambert & McCombs, 1998; Zimmerman, 1998). This has become a guiding principle for most strategy-training programs, particularly for domain-knowledge acquisition. For example, the 1995 study of Bielaczyc et al. used good student models to teach effective self-control strategies to help people monitor what they know and what they do not know. Other researchers used prompts to elicit self-explanations as ways to assess the understanding of a specific domain.

Principle 2: Help students articulate their own thinking. Developing knowledge about the self-as-learner through metacognitive activities involves helping students acquire an ability for articulating their thoughts and emotions. Metacognitive strategy-training programs that consider the self-as-learner emphasize the importance of providing students with supports for explaining and justifying their thinking (e.g., Zimmerman, 1998; Zimmerman & Kitsantas, 1999). King's (1992) study used guided questions to help students express where they were in the thinking and learning process (e.g., King, 1992). Chi et al. (1994) used prompts to help students self-explain their understanding of the science text. Bandura (1997) and Zimmerman employed social modeling to foster student ability to articulate personal goals for learning. These studies suggest that students do not spontaneously explain their thinking during the process of learning unless they are encouraged to do so. Explaining where they are in the learning process is important in making thinking explicit

to other people, such as teachers, who are trying to assess student progress and provide appropriate guidance (Brown, 1997).

Principle 3: Foster a shared understanding of the goals for metacognitive activities. Researchers suggest that students who are aware of the value and usefulness of metacognitive activities in problem solving are usually more willing to engage in these activities in future learning (Brown & Campione, 1996; Coleman, Brown, & Rivkin, 1997; King, 1992; Zimmerman, 1998). That is, "informed" training is much more powerful than "blind" training (Brown et al., 1983). Most programs that consider creating social supports for domain learning value the importance of helping all the members of a community to know why specific metacognitive activities are needed and when they should be used. For example, in Brown and Campione's FCL program, students and teachers are fully aware of where they are in the learning cycle, and the reasons for engaging in different metacognitive activities. All of the programs that consider creating social environments have explicit purposes and functions for implementing each metacognitive activity. They also make the inquiry cycles explicit, so that a shared understanding of the purpose of metacognitive activities can be achieved (e.g., Brown & Campione, 1996; Schwartz et al., 1999).

Principle 4: Develop knowledge of the self-as-learner with respect to one's role in a specific culture. Programs that consider the self-as-learner in creating social supports often explicitly focus on helping students learn about themselves with respect to the specific roles they choose to take on in a given culture. Researchers suggest that it is important for students to reflect on academic content, as well as on the learner characteristics and personality dimensions that interact with content learning (e.g., Lin, Schwartz, et al., 1999). For example, if we know that certain personal habits (e.g., not listening to others, not asking questions, etc.) may interfere with a specific role we take on, we are more likely to work on these personal weaknesses. Most of the research programs that attempt to create supportive social environments recognize the importance of helping students identify their strengths and the limits of their ability to learn. When students can make these identifications, they are able to uncover some key beliefs and assumptions that may be getting in the way of their learning. They start to realize how their attitudes and beliefs about both themselves and their learning situations affect their learning and problem-solving performance. This suggests that understanding oneself as a learner may increase confidence and motivation for learning, which in turn affects the kinds of learning goals and feedback that one is seeking (e.g., Zimmerman, 1998; Zimmerman & Martinez-Pons, 1986). For example, White and her colleagues achieved this principle by creating choices of roles for students to take on (White et al., 1999). FCL created a metacognitive community to achieve this principle (Brown & Campione, 1996). Lin and her colleagues implemented this principle by having students teach virtual kids who were equipped with different kinds of personalities (Lin, Schwartz, et al., 1999).

In summary, most strategy-training interventions provide students with frequent opportunities to assess what they know or do not know with respect to a specific domain (Principle 1). Strategy training that considers the self-as-learner in metacognition emphasizes a need to help students acquire an ability to articulate their own thoughts (Principle 2). Interventions that create supportive social environments for domain-specific learning stress the importance of achieving a shared understanding among community members for why metacongitive activity is useful (Principle 3). Interventions that attempt to reach the self-as-learner by creating social supports argue for the importance of helping students know who they are with respect to the role they take on in a specific task and social context (Principle 4). Together, these principles may provide general guidance for design decisions at a systems level. Whether these principles are valid for all designs and social settings is an important question for future research. We have only a beginning understanding of how to provide balanced metacognitive supports both at a classroom and personal level. Future designs should further explore the level and the kind of guidance that are needed by different

types of students and learning contexts. In addition, the kinds of support that teachers need in mediating student metacognitive activities should also be explored.

Importance of Building Knowledge About the Self-as-Learner

Our knowledge of self-as-learner is often derived from roles we take on in a culture or a social practice (Lave & Wenger, 1991; Lin, 2001; Schwartz & Lin, 2001). How we define ourselves is usually influenced, to a certain degree, by whom we are with and in which cultural context we situate ourselves. For example, when we are put into the role of being a teacher, we have different perceptions about ourselves than we do in the student role. The key point is that our knowledge about the self-as-learner is often situational or cultural-bound (Boekaerts, 1998; Ferrari & Mahalingam, 1998). Therefore, it is difficult to imagine that changes of social structure in a classroom or a school will not affect our knowledge about the self-as-learner and how others perceive us as learners.

It is apparent that interventions, which involve creating new social environments for metacognition, have brought changes to the roles learners play in their environments. For example, in the CSILE learning environment, certain students have made more contributions to community discourse than they make in normal classroom discourse. In FCL, students take on the role of teacher during reciprocal teaching. In these interventions, the knowledge about the self-as-learner not only changes at an individual level, but also at a classroom or community level. Lin (2001) conducted a case study on how a Hong Kong teacher responded to an American-made technology artifact. The use of the artifact created a new social structure in the classroom. In a major shift of roles and power relations between the teacher and her students, the teacher became less of an authority figure who controlled the classroom flow. As a result, teacher and students all struggled to reconceptualize who they were as learners and teacher, and whether they were perceived as competent members by the class. Meanwhile, the whole class was concerned with whether it could still maintain its cooperative and caring spirit when the classroom social dynamics had changed so that not everybody took on the same role and worked at the same things as before.

Creating supportive social environments seems to have a greater effect on people's knowledge about self-as-learner than does mere strategy training. As learner roles shift, changes in students' personal knowledge about the self-as-learner seem inevitable. Changing social environments bring great opportunities for metacognition, as well as challenges in design and implementation. There is research showing that people tend to engage in more self-reflection when their knowledge of the self-as-learner in routine practice is disturbed (Lin, 2001). People have a desire to regain a coherent knowledge about the self-as-learner, and to make recognizable contributions to a new environment (Lin, 2001; Neisser, 1988). We have only a beginning understanding of how instruction can be designed to support teachers and students in adapting to these changes, at both an individual and a classroom level.

Special attention should be given to how to support teacher and student role shifting and the subsequent psychological consequences when creating new social environments. Interventions may fail to develop a strong sense of the self-as-learner in the absence of appropriate support. It would be interesting to design various kinds of instructional systems either at a domain-specific or personal level for role shifting, and study their impact on students' knowledge of the self-as-learner. It would be equally important to explore how different classroom cultural parameters (e.g., learning goals, feedback, reward systems, social activity structures, choices, etc.) might support or hinder the development of domain knowledge and knowledge about the self-as-learner.

A related issue is the role of technologies in support of development of knowledge about self-as-learner. A majority of these metacognitive interventions make use of new technologies, such as video, multimedia materials, and Internet interactions. As new computer technologies become more available in schools and become part of new social learning environments,

research questions surrounding effective ways to support the new social roles taken on by both teachers and students will continue to arise.

One area for investigation can be on the design and use of new technologies for capturing, on-line or on video, a student's own learning approaches. As suggested by Lin and her colleagues (Lin, Hmelo, et al., 1999), different technologies, such as video, computers, or network programs, can provide powerful scaffolds for reflection by displaying, prompting, and modeling one's own or other's learning processes, as well as providing a forum for reflective social discourse. Such recordings and externalization of the learning process objectify one's growth path, making one's thinking more available for self-reflection or reflection with others (Collins & Brown, 1988; Lin, Hmelo, et al., 1999).

In all of the issues discussed earlier, teachers are the key players in fostering student engagement in different roles. They contribute significantly by creating and mediating various design features that afford students opportunities to develop knowledge about the self-as-learner, to identify learning goals, and to pursue their personal interests in meaningful ways. How best to help teachers in support of student knowledge about the self-as-learner remains a challenge.

CONCLUSION

In this article I have examined ways to design effective metacognitive activities. The discussions are organized around two approaches to supporting metacognition: (a) strategy training and (b) the creation of a supportive social environment for metacognition. The underlying instructional goals and design characteristics for each approach are analyzed with regard to two kinds of content that are taught: (a) knowledge about a specific domain and (b) knowledge about the self-as-learner. In the final section, issues for future designs are discussed.

It is important to view metacognitive activities not simply as domain skills, nor as ways to build knowledge about the self-as-learner, but rather as *habits of mind* for developing a balanced cognitively and socially competent learner. This implies that engaging in such activities should be an integrated, natural part of the learning process rather than an add-on procedure. Habits of mind should have strong links to domain-specific knowledge, personal and cultural values, the language, and the tools of the learning environment, in order to be more accessible and long lasting. This approach to metacognition can be better supported by coordinating between strategy training and creating sociocultural support for domain-specific and personal growth in everyday classroom activities.

Such a balanced approach to metacognition is both possible and beneficial, based on insights from the exemplary programs created in American cultural settings as well as from cross-cultural studies (e.g., Hatano & Inagaki, 1998; Lin & Hatano, in press; Sato & McLaughlin, 1992). For example, both Chinese and Japanese schools emphasize metacognitive reflection as "authentic daily habits" engaged in by learners throughout the course of their schooling. Viewed as habits of mind, metacognitive activities are always embedded in the daily process of teaching, learning, and other community activities, such as parent meetings, morning refreshments at school, and music (Lewis, 1998; Lin, 2001; Sato, 1997). They are not treated as separate or isolated activities. An emphasis on a balanced system design centered around metacognitive activities is of importance in developing cognitively and socially competent learners. □

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