Students' Perception of Knowledge Activation on a Guided Collaborative Problem Solving Organizer

Wei-Chen Hung, James Lockard, Northern Illinois University, DeKalb, IL60115
Email 1: whung@niu.edu, Email 2: jlockard@niu.edu

Abstract: While problem solving may seem like an intuitive process as demonstrated by experts, there are steps in the process that are clearly identifiable and can be systematically applied. To understand a problem and to develop effective problem-solving skills, students must learn to identify learning issues and locate, evaluate, and apply resources relevant to those issues. The purpose of this study was to investigate the design and impact of an innovative learning and performance-support system to facilitate students' development of metacognition and problem solving skills. Detailed descriptions of the theoretical and design frameworks are provided and discussed. A field test including survey and group interviews was conducted to initially study the impact of this innovative design approach. Findings related to the design and how the system supports problem solving activities are discussed, and future research suggestions are offered.

Introduction

Traditionally, PBL activities take place in face-to-face instructional settings with paper-based resources. In recent years, computer technology has assumed the media-support role in PBL (Koschmann et al., 1996; Rosenbaum, 2001). Computer systems have been designed to support a variety of PBL processes. The most common support features include non-linear digital video for presenting problems and search and retrieval tools for accessing electronic documents and other resources (Bottge & Watson, 2002; Pedersen, 2003). Additional support features, such as one that facilitates peer interaction and tutoring processes, also have been documented in the literature (Friedman & Deek, 2002; Scardamalia & Bereiter, 2000). These support features serve two functions: to provide students easy access to resources needed for solving the assigned problems and to facilitate group communications. While these features can enhance learning, they do not take advantage of more advanced capabilities of computer technology. In addition, communication features in PBL (i.e., email, threaded discussion and chat room) for facilitating peer interactions and tutoring processes are often ineffective or inefficient as these tools primarily were developed for either business communication or casual discussion. Studies have shown that these features do not provide tools for tracking student discussions and reasoning processes; for evaluating what or how much each student knows; or for determining how students identify issues, generate ideas, and develop action plans for solving a given problem (Edelson et al., 1999; Cruickshank & Olander, 2002). The designs of such off-the-shelf systems are simply inadequate to support PBL. Difficulties in facilitating peer interactions and assessing individual learning performance have been attributed to the lack of tools in such systems for guiding students when they engage in brainstorming, ideas exchange and other activities. Also, these systems do not offer tools for enabling sharing across teams. Finally, the lack of a tracking function hinders objective assessment of individual contributions on team projects.

In this paper, we have documented a PBL support system, *ActionOrganizer,* that was designed for individual and collaborative problem-solving activities. The paper begins with the theoretical and design framework of *ActionOrganizer,* discussing how the researchers created a database driven problem solving support tool to foster critical thinking and problem solving skills. Following that, a formative evaluation was conducted to elicit students' perceptions of and attitudes toward the use and effectiveness of *ActionOrganizer* in supporting their problem solving process in PBL activities. The goal is to provide an environment for students to emulate the thought processes of an expert when solving problems, such as the approaches they take to find clues associated with a problem; the systems they employ in gathering, filtering and organizing information; the reasoning processes they use in selecting solutions; and their overall strategies for tackling a complex problem. ActionOrganizer addresses this goal by offering a set of tools and a problem-solving framework that guide students through the process of (1) articulating, debating and documenting ideas and hypotheses, (2) gathering, organizing and synthesizing facts, (3) tracking and resolving learning issues, and (4) identifying, comparing and selecting solutions and action plans.

Theoretical Foundations

A primary goal of PBL is to help learners capture and understand the process of learning through problem-solving, self-directed learning, and collaborative learning skills (Barrows, 1986). It does not pre-define the level of skills required to accomplish a task. Learners bring their own understanding and interpretation to the problem. The task of PBL, at the beginning, is not to solve the problem, but to analyze it and to generate as many hypotheses as possible. According to Roschelle (1992), through analyzing and generating hypotheses, learners have the opportunity to build their own understanding of related topics. Furthermore, without being given any prior instruction or guidelines, learners have opportunities to test their own ideas and experiences on the problem. Although learners might find a problem too complex, under the guidance of a facilitator the learner will find initial confusion and puzzlement gradually giving way to coherence, understanding, and resolution. In this instance, providing a scaffold to support learners' learning *process* in the PBL activity becomes an essential instructional strategy to foster the development of problem solving skill.

To design such a scaffold to support learners' learning *process* in PBL, we first used Barrows' PBL format; group formation – problem analysis – problem follow up – performance presentation (Barrows, 1986) as the problem solving phases to help us plan the structure of the scaffold. We then designed a set of problem solving steps in each phase as the performance indicators, as shown in Figure 1. Learners will need to complete these indicators in order to become competent learners and problem solvers. Next, based on the indicators, we incorporated metacognitive prompts and cues in the scaffold to stimulate and foster learners' thinking and problem solving strategies toward problems. The following is a discussion of the theoretical foundations for the system.

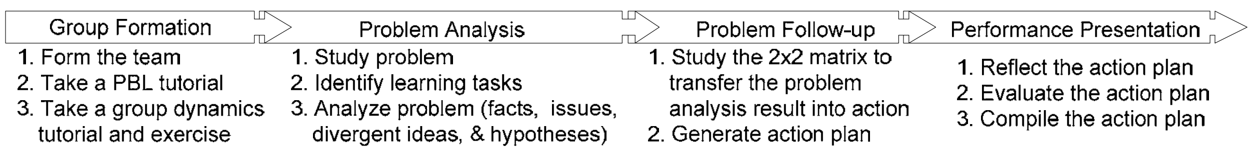

Figure 1. Problem solving phases and steps

Identifiable steps in the problem solving process

In the PBL environment, learners are encouraged to engage in free inquiry and construct their own understanding through group collaboration and problem reflection. When a learning issue or problem is presented, it is generally ill-defined. Learners are required to approach it with minimal information presented to them. Learners develop problem-solving strategies to identify learning issues, then locate, evaluate, and apply resources relevant to those issues. The instructor or facilitator assumes a major role in modeling the metacognitive thinking and group interaction associated with the problem-solving process. This method allows learners to solve problems in much the same way as they would in the real world, not merely memorize information from textbooks. The issue of designing such an environment centers on how to help learners understand the problem-solving processes of experts, such as their methods of finding clues associated with problems, their cognitive processes, and the reasoning processes they use in selecting solutions. Our instructional strategy, therefore, is focused on the learning process – to teach learners to become responsible for their own learning and to replicate authentic practices through problem-solving activity and social interaction in a way similar to the real-world event. In this case, the instructional design strategies used in PBL are to help learners recognize the issues involved, understand the context, see how their knowledge is dependent on that context, and know why they are choosing a particular way to solve the problem. In other words, it is a kind of cognitive apprenticeship with scaffolding designed to support the learner in developing metacognitive skills (Brown, Collins & Dugid, 1989).

Coordination of meta-knowing skills and problem solving process

The term metacognition, i.e., *knowing about knowing*, was originated by Flavell and Wellman (1977) who described metacognition as the "explicit consciousness of ourselves as problem solvers." Flavell identified two types of metacognitive activities: a) knowledge about cognition and b) regulation of cognition. *Knowing about cognition* is the ability of learners to recognize their own learning styles and understand how they learn best. *Knowing how to regulate cognition* is the ability to control one's own learning through such activities as planning, monitoring, testing, revising, and evaluating. Other researchers have further extended the concept of metacognition to include learning processes that involve connecting new information to former knowledge, deliberately selecting thinking strategies, and planning, monitoring, and evaluating thinking processes (Borkowski, Carr, & Pressley, 1987; Dirkes, 1985; Kuhn, 1999).

Metacognitive processing provides for self-monitoring of comprehension and self-explanations that can dramatically improve both text comprehension and problem solving. Several studies have shown that students required to monitor their metacognitive processing acquire greater understanding than those who do not monitor their cognitive processes (Hartman, 2001; Schraw & Moshman, 1995). In addition, multiple studies have demonstrated that requiring individuals to engage in metacognitive processing increases both their comprehension of text materials and their ability to solve problems effectively (Berardi-Colleta et al., 1995; Chi et al., 1994). In one study, subjects demonstrated significantly improved problem solving capabilities when they were required to verbally self-reflect each time that they made a "move" while attempting to solve a problem. In a second study, students who were required to respond to metacognitive prompts during a learning session, learned to solve problems more efficiently than students who responded to problem-oriented prompts. During the portion of the experiments when students were no longer required to verbalize, those who had received metacognitive prompts during the learning sessions, required fewer moves to solve the most difficult problems as compared to students who had received either problem-oriented prompts or the instruction to just "talk-aloud" during the learning sessions. More recent studies have shown that metacognitive processing in one subject area not only improves performance within the class of practiced problems but also improves performance on problems from a class unrelated to the training problems (Buyer et al., 1997).

The greatest metacognitive processing effect results from the provision of information at exactly the time that an individual becomes aware of the need for the information. Technology (e.g., databases) provide a tool through which metacognitive prompts can be provided immediately to help learners clarify problem goals, understand meanings and concepts, draw inferences, apply existing knowledge to reach goals, look for relationships, reformulate information in one's own terms, and monitor progress toward a solution. By integrating metacognitive prompts into a database-driven problem solving support system, we create an opportunity to increase learners' self-directed learning, which, as shown by Gourgey (1998), will promote gains in learners' problem solving and critical thinking skills.

The Design Framework of *ActionOrganizer*

Real-world problems are typically complex and ill defined with minimal information available about them. While problem solving may seem like an intuitive process as demonstrated by experts, there are steps in the process that are clearly identifiable and that can be applied systematically. To understand a problem and to develop effective problem-solving skills, students must learn to identify learning issues (knowledge gaps) and then locate, evaluate, and apply resources relevant to those issues. The instructor assumes the critical roles of modeling the meta-cognitive process employed by experts in the discipline and facilitating group interaction in collaborative problem solving. It is through this cognitive apprenticeship and scaffolding process of free inquiry, group collaboration, and problem reflection (all of which are characteristics of PBL) that students learn to develop meta-cognitive skills and to "think like an expert" in problem solving (Brown, Collins & Dugid, 1989).

To support this inquiry process in problem-solving activities, *ActionOrganizer* provides an environment for learners to emulate the thought processes of an expert when solving problems, such as the approaches they take to find clues associated with a problem; the systems they employ in gathering, filtering and organizing information; the reasoning processes they use in selecting solutions; and their overall strategies for tackling a complex problem. *ActionOrganizer* offers a set of tools and a problem-solving framework that guide learners through the process of (1) articulating, debating and documenting ideas and hypotheses, (2) gathering, organizing and synthesizing facts, (3) tracking and resolving learning issues, and (4) identifying, comparing and selecting solutions and action plans. The overall design strategy aims to understand and facilitate learners' critical thinking and metacognitive skills development, based on the assumption that appropriate actions are derived from domain knowledge mastery and effective/correct problem framing in context through an iterative cycle of perception, articulation, and reflection.

How ActionOrganizer works.

ActionOrganizer offers a framework that leads users through four problem solving phases in eleven steps, as shown in Figure 1. Among the 11 steps, seven steps are essential to our design of scaffolding (exploring problem – stating problem – abstracting problem – analyzing problem – choosing solution – implementing solution – evaluating solution). The seven steps are grouped under three of the four problem solving phases: problem analysis (Assimilate), problem follow-up (Analyze), and performance presentation (Action Plan). In the Assimilate phase, learners focus on a complex problem given by the instructor and try to identify and understand various dimensions of the problem. In the Analyze phase, learners continue their problem-framing task and they further refine their understanding of the problem through reading, brainstorming, and systematically documenting and organizing facts, ideas, issues, and hypotheses generated from discussions. When the learners are ready to move from studying the problem to identifying possible solutions, they can use a 2x2 *Action Planning Matrix* to document the problem they are trying to solve, the knowledge that they have gained in the process, the problem context and constraints, and finally the appropriate action.

Since *ActionOrganizer* is built upon a relational database with a graphical user interface, learners can query and cross-reference information entered at various problem-solving phases, and request a customized report containing any information they have recorded, such as one that prints out a list of learning issues that require further research. Other features in the system, including data exchange and communication, are available for learners to support their collaborative efforts. To better illustrate how *ActionOrganizer* supports problem solving, screen captures of the system are presented below with explanations.

Upon logging into *ActionOrganizer* for the first time, students are prompted to enter their group members' and facilitator's names and email addresses. This is a one-time task. At the bottom of this screen, students have the option of viewing an online guide (PBL tour) describing the overall problem-solving process and strategies. By clicking on the *Yes* button, the students will see the PBL tour online help. After taking the PBL tour, or if the students choose to skip it and view the guide at another time, a simple navigation instructions page is displayed to quickly guide students in how to navigate through the system.

In the main work area, the seven problem solving steps are divided into the three task phases -- assimilate, analysis, and action plan -- as represented by the three tabs on the left margin. The tabbed work area supports easy navigation among the problem solving phases, and this interface encourages non-linear, iterative problem solving by allowing easy access to previously captured and generated information. Of the seven problem solving steps, the first three (exploring, stating, and abstracting the problem) are grouped under the *Assimilate* phase (Figure 2). As a reminder of the problem solving process, all seven problem-solving steps are available in the right-hand panel. To explore the problem (Step 1), students can click on the *PROBLEM* button to read or watch a multimedia file describing the problem posed by the instructor. Also available are assignment requirements, resources links, and the evaluation rubric. Having gained an initial understanding of the problem, students proceed to Step 2 where they articulate what they understand to be the problem and negotiate any differences of opinion within the group.

In the *Analysis* phase (Figure 3), students document problem facts and ideas, identify learning issues, and begin developing hypotheses. Guided by *ActionOrganizer,* students learn to use a systematic approach to seek and analyze information, and to identify knowledge gaps. From problem framing to hypothesis building, students proceed in a manner that closely mimics that of an expert. In addition to the notes organization function, multimedia and communication functions in *ActionOrganizer* allow audio recording of notes (controls shown in Figure 3) and also information sharing and discussions across groups through email.

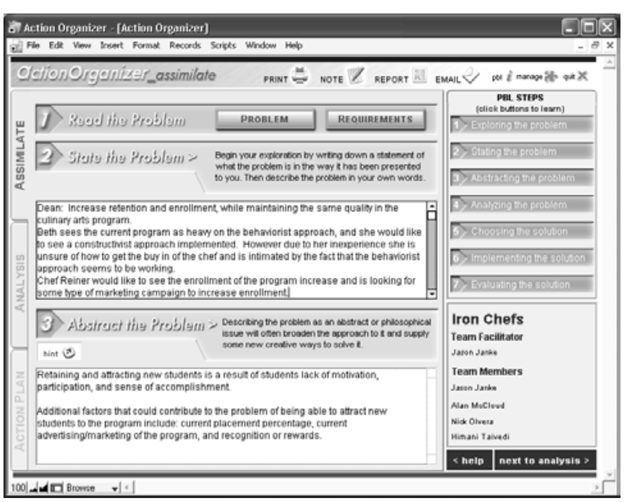

Figure 2. Assimilate phase

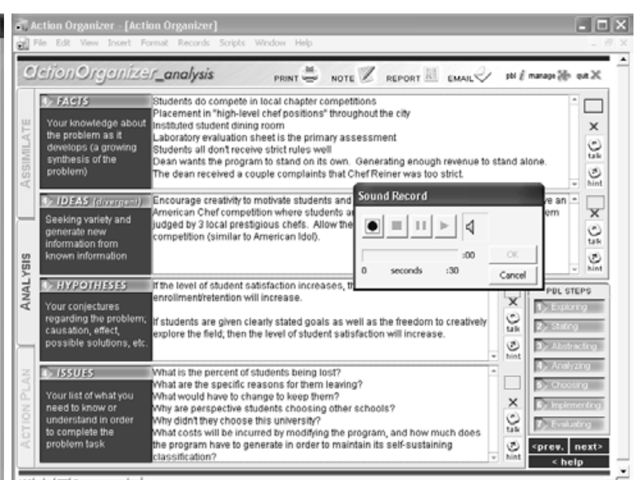

Figure 3. Problem analysis and follow up

When students have completed or partially completed the problem analysis (as in Step 4), they can move on to the last phase, *Action Plan,* to brainstorm and document possible solutions for the problem. The final phase includes three steps: choosing, implementing, and evaluating the solution. In Step 5, *Choosing the Solution* (Figure 4), students review information gathered and created in phases 1 and 2 (e.g., problem abstract, facts, and hypotheses), and propose a solution and action plan. In order to identify an appropriate solution, students must learn to balance domain knowledge mastery and problem framing in the proper context (i.e., situation specific requirements and constraints), through an iterative cycle of perception, articulation, and reflection. The 2x2 *Action Planning Matrix* provides students a visual framework to guide them in the action planning process. Through the *hint* button, a step-by-step tutorial is provided to guide students in how to use and interact with the 2x2 matrix.

In Step 6 (Figure 5), the data field in the left column will be the action plan replicated from the 2x2 matrix. The learners then conduct a final review of their action plan using the action criteria checklist on the right side of the screen and make adjustments to their action plan as necessary. Then in Step 7, the students provide a title for their action plan and enter all the references and resources used for their PBL activity. They then compile a final action report and submit it for review by sending it as an email attachment, exporting it to html format, or simply printing it.

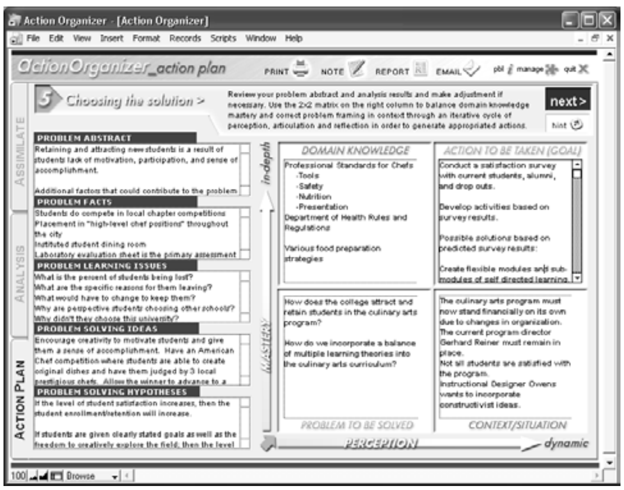

Figure 4: Action Planning Matrix

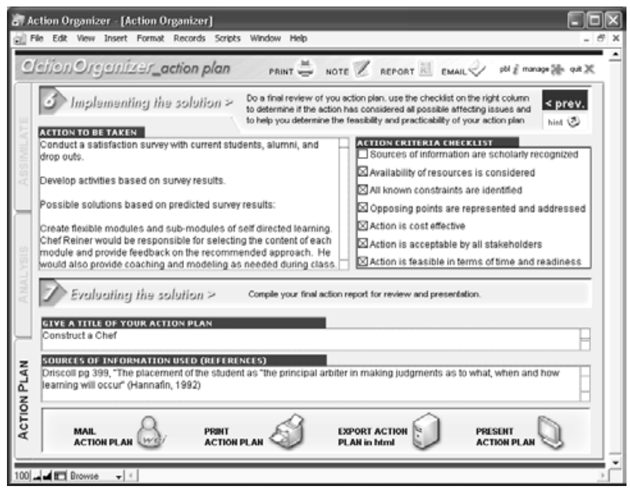

Figure 5: Reflect and evaluate the action plan

Throughout the system, the students can use the toolbar to perform a variety of system functions such as printing a screen, taking notes, generating reports, sending emails (linked with the database query functions), taking a PBL tour, and managing the PBL records. In addition, while problem evaluation is the final PBL step, throughout the PBL process, the students can submit their work in progress to the instructor for comments and feedbacks (via the e-mail and reports functions).

Formative evaluation of *ActionOrganizer*: The initial impact

The system formative evaluation utilized both qualitative and quantitative approaches to explore how the various parts of the system and students' attitudes work together. The goal was to study users' perceptions toward system acceptance and its impacts. After the system was developed, it was distributed to students in a graduate level introductory instructional technology course. Ten graduate students majoring in instructional technology used the system for four weeks to solve two instructional design problems. After this use of the system, a survey and a group interview/discussion were conducted to elicit students' opinions and perceptions toward the system. Results were reported as scores and scores for negative items were reversed during the analysis for scoring scale consistency. The objective of the group interview session was to gain a deeper understanding of the impact of *ActionOrganizer* on students' metacognitive and critical thinking skills and of the ways it facilitates students' PBL process.

Data gathering

The perception assessment instrument, *Students' Perceptions of ActionOrganizer Survey,* was developed and piloted by the senior author. The survey consisted of 60 five-point Likert scale questions related to usefulness and student perceptions of *ActionOrganizer.* The overall reliability coefficient of this instrument was .90 using

Cronbach's alpha. There were four constructs in the survey: items 1 to 10 focus on student opinions of the teamwork and communication functions in *ActionOrganizer,* as compared to traditional email and discussion tools (Alpha = 0.89); items 11 to 20 focus on student concerns about using *ActionOrganizer* (Alpha = 0.68); items 21 to 30 aim at understanding student reactions to the system interface and orientation (Alpha = 0.70); and items 31 to 60 focus on student perceptions of the system and its impact on their learning outcomes (Alpha = 0.93).

The users were invited to participate in a group interview session to discuss impacts of *ActionOrganizer* on their learning. The assessment strategies focused on the users' learning experience with the support of *ActionOrganizer*. The group interview session was conducted in a loosely structured format using open-ended questions including (1) the effectiveness of *ActionOrganizer* in promoting PBL, (2) students' perceptions of PBL and their ability to solve problems using a systematic approach, (3) the usefulness of *ActionOrganizer* from the students' perspectives, and (4) difficulties and limitations of *ActionOrganizer* in supporting PBL. Six guiding questions were asked in the interview to elicit users' experiences with *ActionOrganizer* in prompting and scaffolding their problem solving approaches.

Findings & Discussion

The quantitative data generated in the survey were based on a five point Likert scale that indicates how much respondents agreed with the variables presented. Results were reported as scores and negative items' scores were reversed during the analysis for scoring consistency. Higher scores indicate a higher degree of agreement and satisfaction among respondents. The survey, composed of 60 questions in four constructs, revealed an overall positive attitude toward the usage of the system. First, when asked to compare the system to traditional communication tools (i.e., email and threaded discussion) for group collaboration support, the participants felt the *ActionOrganizer* was more effective in helping them to reflect on group members' comments and ideas and made it easier to manage information entered into the system (mean= 3.78, SD=0.72). Second, when asked about any concerns they had while using the system, the participants felt comfortable interacting with the system (mean= 3.29, SD=0.55). Third, when asked about the ease of use of the system's navigation and orientation, the participants felt the layout was easy to follow and the amount of instruction was just enough (mean= 3.74, SD=0.51). Lastly, when asked about the system's ability to support problem analysis and action plan development, the participants perceived the system to be helpful and useful to support their problem solving activities (mean= 3.91, SD=0.51). Although the significance of the survey findings is not substantial due to the small group size, its value lies in the knowledge gained from specific items in the instruments and issues that must be addressed for the researchers in the revision and implementation of *ActionOrganizer*. The goal is to seek optimality rather then validity in the instructional design and development process (Reigeluth, 1989).

Subjects who completed the survey also participated in a group interview session. Due to the number of subjects, they were divided into two groups (4 and 6 respectively). As a result, two group interview sessions were conducted. A doctoral student who specialized in focus group process was hired to act as the session facilitator to monitor the process and facilitate the discussion of the interview questions. The interview used a semi-structured technique to gather information about the impact of the system and the subjects' perception of the system. An interview guide with a list of questions was prepared by the researcher to ensure consistency in the questions. During the interview, the facilitator was also free to explore the topic more broadly and to establish a dialog with the subjects.

Overall, subjects commented that the *ActionOrganizer* provided an effective framework for guiding them through their problem-solving process. One of the most helpful aspects of the tool, according to the subjects, was that the framework assisted the project group members to develop a shared understanding of the project process and nomenclature, which made both the project task and communication easier. Another useful aspect of the tool was that it provided a comfortable starting point for students to begin solving the problem, much like a scaffold where students can step through the problem solving process without feeling lost or overwhelmed by the complexity of problem. Major emerging themes were derived from the group interviews including: opportunities for tracing and reflecting upon one's learning when engaged in problem-based learning activities; opportunities of incorporating technology to scaffold, regulate, monitor and thus enhance one's critical thinking and metacognitive skills; opportunities of structured and scaffolded peer interaction and collaboration; and opportunities of illustrating critical thinking and metacognition traits. Detailed descriptions of the group interview session findings will be reported in a future full-length paper.

Conclusions

The *ActionOrganizer* design approach offers an alternate means to systematically and effectively facilitate and evaluate students' cognitive and meta-cognitive skills during the problem solving process. With the integration of an expert problem-solving model, database technology and a graphical user interface, the system has the potential to support problem-based learning in both large classrooms and online learning environments. Wide adoption of the system could have the potential to transform the traditional lecture-based classroom into an active, inquiry-based learning environment. As a logical next step, larger scale field tests should be conducted to identify whether there are discernable differences in students' problem solving and collaborative learning processes across disciplines, to determine the system's effectiveness in assessing users' comprehension of knowledge domains associated with the problem, and to explore how learning and performance theories (e.g., metacognition, scaffolding, and problem based learning) can be better illustrated, promoted, and extended with the support of technology.

References

Barrows, H. S. (1986). A taxonomy of problem-based learning methods. *Medical Education.* 20, pp.481-486.

Berardi-Colleta, B., Buyer, L.S., Dominowski, R.L., & Rellinger, E.R. (1995). Metacognition and problem transfer: A process-oriented approach. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *21*, 205-223.

Borkowski, J.G., Carr, M., & Pressley, M. (1987). "Spontaneous" strategy use: Perspectives from metacognitive theory. *Intelligence*, *11*, 61-67.

Bottge, B. A. & Watson, E. A. (2002). Using video-based math problems to connect the skills and understandings of incarcerated adults with disabilities. *Journal of Special Education Technology, 17*(2), 25-38.

Brown, J.S., Collins, A., & Duguid, P (1989). Situated cognition and the culture of learning. *Educational Research. 18*, 32-42.

Buyer, L.S., Walsh, S., & Russell, T.A. (1997). Metacognitive training procedures transfer across problem types. Poster presented at the 1997 *American Psychology Society Convention*, Washington, D.C.

Chi, M.T.H., deLeeuw, N., Chiu, M.H., and LaVancher, C. (1994). Eliciting self-explanations improves understanding. *Cognitive Science*, 18, 439-477.

Cruickshank, B. J. & Olander, J. (2002). Can problem-based instruction stimulate higher order thinking? Converting an instrument analysis lab. *Journal of College Science Teaching, 31*(6), 374-77.

Dirks, M.A. (1985). Metacognition: Students in charge of their thinking. *Roeper Review*, *8*(2), 96-100,

Edelson, D. C., Gordin, D. N., & Pea, R. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. *Journal of the Learning Sciences, 8*(3-4), 391-450.

Flavell, J.H., & Wellman, H. M. (1977). Metamemory. In R.V. Karl & J.W. Hagen (Eds.). *Perspectives on the development of memory and cognition*. New York: Erlbaum.

Friedman, R. S. & Deek, F. P. (2002). Problem-based learning and problem-solving tools: Synthesis and direction for distributed education environments. *Journal of Interactive Learning Research, 13*(3), 239-57.

Gourgey, A.F. (1998). Metacognition in basic skills instruction. *Instructional Science*, 26, 81-96.

Hartman, J.H.(2001). Developing students' metacognitive knowledge and skills. In H. J. Hartman .(Ed.). *Metacognition in learning and instruction: Theory, research and practice*. London: Kluwer Academic.

Koschmann, T.D., Kelson, A.C., Feltovich, P.J., & Barrows, H.S. (1996). Computer-supported problem-based learning: A principles approach to the use of computers in collaborative learning. In T. Koschmann (Ed). *CSCL: Theory and practice of an emerging paradigm.* Mahwah, NJ: Lawrence Erlbaum Associates.

Kuhn, D. (1999). A developmental model of critical thinking. *Educational Researcher, 28*, 16 – 25.

Pedersen, S. (2003). Motivational orientation in a problem-based learning environment. *Journal of Interactive Learning Research, 14*(1), 51-77.

Reigeluth, C. M. (1989). Educational technology at the crossroads: New mindsets and new directions. *Educational Technology Research & Development, 37*(1), 67-80.

Roschelle J. (1992). Collaborative inquiry: Reflections on Dewey and technology for situated learning. Paper presented at the American Educational Research Association Meeting, San Francisco.

Rosenbaum, H. (2001). Educating information professionals with problem based learning and collaborative technology. *Proceedings of the ASIST Annual Meeting, 38*, 199-208.

Scardamalia, M. & Bereiter, C. (2000). Commentary on part I: Process and product in problem-based learning (PBL) research. In D. H. Evensen & C. E. Hmelo (Eds.). *Problem-based learning: A research perspective on learning interactions*. Mahwah, NJ : Lawrence Erlbaum Associates.

Schraw, G. & Moshman, D. (1995). Metacognitive theories. *Educational Psychological Review*, 7, 351-371