THE WEAKEST LINK: IS WEB-BASED LEARNING CAPABLE OF SUPPORTING PROBLEM-SOLVING AND METACOGNITION?

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Abstract

In the context of higher education, the development of students' problem-solving skills continues to be an area of ongoing research. Effective teaching of problem-solving requires the adoption of process-based approaches that reveal to students the ways that experts solve problems, and the coaching of students in higher order and metacognitive skills. It is suggested that online environments and computer resources can scaffold the acquisition of metacognitive skills and efficient problem-solving. However, many current online resources do not go beyond the provision of heuristics and strategies that can be applied to well-structured problems. This study focuses on the need to link metacognitive and problem-solving support by harnessing technology-based affordances that support process skills, and the anchoring of problem-solving strategies with collaborative social discourse and models of effective problem-solving that prompt reflection on performance.

Keywords

problem-solving, metacognition, scaffolding, online

Problem-solving Skills as Central to Learning

In tertiary education, there is an urgent need for professionals who can solve real problems, anticipate and predict problems and find realistic solutions. To meet this need effectively tertiary educators must now reexamine methods of teaching problem-solving. Taconis, Ferguson-Hessler, and Broekkamp (2001) have recently analysed articles appearing in international journals between 1985 and 1995 on the effectiveness of teaching strategies for science problem-solving. Very briefly, this analysis showed that in student performance and achievement, providing strategy training and practice in problem-solving turned out to have little effect, whereas effective teaching of problem-solving gives attention to contextualised strategies related to domain knowledge. The learning conditions recognised by Taconis et al. (2001) as significant for building problem-solving skills were those which provide learners with guidelines and criteria they can use in judging their own problem-solving processes and products. These conclusions are congruent with earlier research carried out by Mayer (1988) and Lajoie (1993), indicating the need for the integration of metacognitive training and support for problem-solving.

The Learning Paradox

Jonassen (1997) argues that ill-structured, real world problems must become the basis for improving learning, and that effective pedagogy should include the provision of support for learning problem-solving processes. Over the past decade much attention has been paid to the diverse applications of technology that support active student centered learning, but much less attention has been given to the development of problem-solving skills that are the foundations for effective higher-order thinking. A number of contemporary designs of learning environments require student self-direction and high-level metacognitive control. Exploratory and open-ended learning environments enable students to generate knowledge and engage in critical thinking. Similarly, project-based approaches assume that students are able to generate questions and produce a final product that represents knowledge integration. Many students, however, lack essential metacognitive skills and a repertoire of learning strategies to enable them to maximise their learning in innovative learning environments (Hannafin & Land, 1997). Table 1 shows how a range of contemporary learning designs assume metacognitive knowledge.

Example	Learning scenarios	Metacognitive skill needed
Anchored instruction	Narratives, stories, real life anchors	Capacity to define problems and abstract from case
Open ended learning environment	Multiple scenarios and viewpoints	Self-direction and self - management
Project based learning	Collaborative, task based learning environments	Management of information, self and others
Problem based learning	Presentation of cases and events that present potential problems	Capacity to identify the problem and select resources to solve it

Table 1: Metacognitive requirements of contemporary student–centered learning environments

These environments, though learner-centered and constructivist, assume that students are goal-driven and self-directed. Other research has shown that the processing demands of these environments are problematic and need to be investigated. One of the issues of most concern is that of the learning paradox noted by Schank and Cleave (1995): *"how can students learn by doing what they do, when they do not know how to do what they have to do to learn?"*. Stated quite simply, project and problem-based learning assume that students can access and apply knowledge and metacognitive strategies and engage in self-regulated learning. It is well established that in order to learn effectively, a repertoire of learning strategies and the capacity to manage one's own learning are fundamental (Boekaerts, 2000; De Corte, Verschaffel, & Op'Teynde, 2000). It is this range of skills that we refer to as metacognition.

The Role of Metacognition in Learning and Problem-Solving

Success in problem-solving skills is linked to metacognitive knowledge. Research on problem-solving expertise shows that it is not sufficient to learn procedures and problem-solving heuristics such as defining the problem, planning a solving, testing and checking a solution. It is not enough to know what to do, but also when to apply such strategies. This is *metaskill*, such as self-monitoring and orienting oneself, planning how to proceed, and self-evaluating one's performance. Metacognition is a learner's knowledge about strategies and cognition and the ability to control and monitor those processes (Metcalfe & Shimamura, 1994). Four categories of metacognitive knowledge are recognised as important in problem-solving (White, 1999). These are as follows:

- **Self-knowledge:** Self-knowledge entails the individual's capacity to recognise their strengths and weaknesses and to evaluate themselves.
- **Task-knowledge**: This involves understanding the demands of tasks and what they require.
- **Strategic knowledge**: This refers to the knowledge of usefulness of strategies available for achieving learning goals.
- **Knowledge of plans and goals:** This refers to learner's capacity to set and maintain goals and to record what they intend to do through their learning.

Each of these components requires self-knowledge and are best supported in social settings for learning.

Critique of Current Online Approaches to Supporting Metacognition

As part of our research into problem-solving online, we wanted to ascertain whether there were online resources dedicated to supporting problem-solving, and what form of support was offered. Around 300 URL's relating to problem-solving and metacognition were assessed. Of the total number of sites, only a small number were of direct assistance for students wishing to improve their problem-solving skills. Some comments on a few of these sites, which typify the resources available, are given in Table 2.

The A thru E Approach to Problem-solving http://www.ouc.bc.ca/chem/probsol/ps_A-E.html This is probably one of the best known and widely referred to sites on the Internet for problem-solving in science. It contains around 10 pages of information to help students develop the use of a systematic approach to problem-solving. It does not give actual problems and discuss their solutions, but only outlines the general heuristic, which can be applied to chemistry problems (or other problems) in general.
General Chemistry at Purdue Uni http://chemed.chem.purdue.edu/genchem/probsolv/index.html Shows a solution strategy for several simple chemistry exercises. Students can look at each step of the solution at a time. The examples are straightforward exercises in first year general chemistry, not really problems.
21st Century Problem-solving Howard C McAllister http://www2.hawaii.edu/suremath/home.html A site for problem-solving in algebra, physics and chemistry from high school level up. This site does give worked solutions to example problems using the heuristic developed by McAllister of - Request, Response, Result. As such it does explicitly discuss the processes of problem-solving, however the limitation is that the problems are really well structured as opposed to ill-structured
CheMentor http://www.liv.ac.uk/ctichem/20chment.html CheMentor is an example of interactive tutorial software giving students practice at problem-solving. The educational rationale behind CheMentor is the placing of responsibility for learning with the student. A set of modules have been developed which are highly interactive though there is a certain degree of repetitiveness in terms of doing the same type of problem time and time again.
The McMaster Problem-solving Program Donald R. Woods http://chemeng.mcmaster.ca/mps/ The MPS program is a series of four, required, workshop-style courses to develop process skills and to use small group, self-directed PBL in tutorless groups. The target skills being developed include self-confidence, problem-solving, interpersonal and group, self-assessment, change management and lifetime learning. The total time for the whole course if all units are taken is around 150 hours!

Table 2: Analysis of online resources providing support for problem-solving

The sites listed above concentrate purely on task-knowledge and, in some cases, strategic knowledge. At best they provide lists of tips and strategies, which according to the research on metacognition and problem-solving are insufficient as they make little progress towards developing the four categories of metacognitive knowledge identified by White (1999) - self knowledge, task knowledge, strategic knowledge and knowledge of plans and goals. In addition, recent metacognitive research emphasizes the need to balance cognitive and social competence and the need to create social, interactive and reflective environments with a holistic approach to supporting metacognition (Lewis, 1998).

Supporting Problem-Solving and Metacognition Online

A major challenge for educational technologists is to go beyond information access and provide tools and scaffolds for complex problem-solving and metacognition. Already, there is evidence that research on metacognitive skills development and technology based scaffolding is converging (White, Shimoda & Frederiksen, 2000). New advances have in common the need to present students with complex ill-defined problems, strategy training and a social environment that fosters reflection and self-knowledge. For instance, the essential design ingredients in supporting metacognition proposed by Lin, Hmelo, Kinzer and Secules (1999) in technology-supported learning environments are *as follows:*

- Provide multiple models of real performance;
- Prompt learners to investigate their own thinking while problem-solving;
- Provide visual displays of the processes students have utilised as they solve problems

- Provide students with multiple perspectives on process through reflective social dialogue;
- Scaffold adoption of expert strategies by providing examples and a context for application;
- Develop a strong sense of self as learner and problem solver by enabling goal-setting;
- Create a social setting online with support for interaction and communication.

These features have been embedded in the online tool metAHEAD, developed at UNE to support the metacognitive skills of first year science students (Hollingworth & McLoughlin, 2001). Another example is the SCI-WISE system devised by White et al. (2000) which provides tools to foster meta-level expertise in scientific problem-solving. Similarly, Laffey, Tupper and Mussen (1998) have utilised a bulletin board where students post progress reports and seek assistance on aspects of learning that are problematic. In summary, these designs provide examples of how to make efficient use of the visual, social, reflective and exploratory resources of the Web to scaffold the metacognitive aspects of problem-solving.

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