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Developing on-line tools to support learners in problem-solving activities

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Developing On-line Tools to Support Learners in Problem-Solving Activities

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ABSTRACT

In recent years, research has focused on understanding how learners can benefit from tools that can assist in the development of informal reasoning skills when constructing arguments in collaborative learning with web-based learning environments. A common approach taken by each of these systems is to use support mechanisms (scaffolding) to facilitate student learning through the development of improved reasoning and argumentation skills. The authors of this paper have been developing computer-based learning environments for the past ten years, and have developed several award winning CD-ROM packages that feature a range of cognitive tools designed to assist learning. The development of these products has provided a rich source of information about learner use of cognitive tools. Our research has shown that two recurring issues keep emerging:

1. *There is a need to develop generic cognitive tools that assist learners to understand and solve problems that relate to different knowledge domains*
2. *There is a need to help learners to analyse and structure information gathered, when they use cognitive tools.*

This paper reports on the outcomes of a study into the reasoning and argumentation skills of pre-service education students engaged in problem solving within a computer-based learning environment. The implications for the design of a support framework to assist in this process will also be discussed.

KEYWORDS

Cognitive tools, scaffolding, problem solving, argumentation

BACKGROUND TO THE PROJECT

As prevailing learning theory has moved from an information processing approach in examining problems to a constructivist approach, the importance of the structure of the learning task and how learners are supported in its achievement becomes more critical. David Jonassen (2000) has organized the work of several designers into a classification framework based on the different types of cognitive demands that the problem tasks place on learners. His framework schema identifies the type of problem and the degree of structure and abstract nature of the problem. In this paper we explore the world of 'trouble-shooting problems' and 'diagnosis-solution problems' (Jonassen, 2000) and the methods that can be used to create a range of possible solution strategies for them.

The research team has been developing effective technology to support collaborative forms of teaching and learning for the past ten years. The outcomes of this research resulted in the development of the International award winning educational CD-ROM packages, *Investigating Lake Iluka* (1993), *Exploring the Nardoo* (1996) and *Stagestruck* (1999). Each of these products encourage learners to be actively involved in knowledge construction through the use of cognitive tools (Jonassen, 1996) that support them in thinking, problem solving and learning.

The development of these products has provided the research team with experimental environments in which to explore the development and use of a range of cognitive tools by learners. However, research on their use has demonstrated that some tools did not support learners as well as intended. In particular, research showed that:

1. The existing cognitive tools needed to be refined so that learners could use the tools more effectively to solve problem with varying degrees of complexity.
2. Learners needed better support to analyse and structure the information generated when they used the cognitive tools in creating effective arguments to support their solutions.

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ASSOCIATED RESEARCH PROJECT

Constructivist learning theory shifts the focus for organising knowledge construction from the teacher to the learner. Learners therefore need to develop a range of information processing skills to cope with this change. When faced with the responsibility for knowledge construction, they are thrown on their own management resources. While some may have the metacognitive skills to cope, many fend poorly in the increased complexity of such a learning environment. Many see the task as daunting and complex and feel ill-prepared for such creative freedom and choice of direction. Such learners need tools to support them to represent the knowledge they are acquiring and to facilitate higher-order thinking.

This research used the findings from previous studies as a foundation to investigate cognitive frameworks that support learners' problem-solving skills. The research for the framework has focused on the three main areas: *problem clarification* (identifying the nature of the task and what information was required or provided); *solution formulation* including data collection and the solution process (sorting out the resources and generating new information as required); and *presentation of argument* for the solution (identifying propositions and the appropriate evidence for support or refuting the argument).

Using *Exploring the Nardoo* (1995) as the investigative tool, the current investigation sought to develop a better understanding of how learners identify problems in computer-based learning environments. This information would then be used to help guide the development of a cognitive tool (or tools) to assist learners with their reasoning and problem solving skills.

Research Questions

The study's objective was to gain a better understanding how learners identify, organise and present information when problem solving in computer-based learning environments. To support this objective the following questions were used in guiding the research:

1. What cognitive strategies do learners use in problem clarification and problem resolution, when attempting ill-structured problems within a technology-supported learning environment?
2. What strategies support problem clarification and assist learners in accessing and making effective use of information when completing a specific task?

For research questions 1 and 2, the exploratory study (Yin, 1994) focused on the strategies employed by learners as they investigate the problem space to develop understanding. The primary data gathering strategies adopted for this focussed on individual student written work, audiotape transcripts, participant observation and student interviews.

Data Collection Process

Problem solving involves the application of a range of skills, which enable the learner to recognise and identify the problem, form hypotheses, search for and collate information through observation and measurement, and to interpret and analyse the data in proposing a solution(s) to the problem. Many of the steps in the problem solving process are quite simple manipulative skills but others involve complex thinking ability and some structural knowledge. Structural knowledge is knowledge of how the relationships within a domain are integrated and interrelated (Diekhoff, 1983; Beissner et al, 1993). In an attempt to support the structural knowledge of each participant during the problem solving process four specific support frameworks were identified for use in this study. Each of these support frameworks, Concept Mapping (Novak, 1990), Venn Diagrams (Gunstone & White, 1986), Critical Thinking (Ennis, 1991) and Six Thinking Hats (De Bono, 1992) have been identified as alternative learning strategies that assist learners in processing and analysing information. It was thought that the support framework would provide cognitive support for problem solving and the development of higher order thinking skills that would facilitate more efficient problem clarification, together with better reasoning and argumentation outcomes.

Participants. Volunteers were called from a cohort of 250 students (200 female, 50 male) enrolled in Information Technology for Learning, a first year undergraduate information technology class in the Faculty of Education at the University of Wollongong. Of this group of students a sample of 32 participants (27 female, 5 male) agreed to participate in the study. Participants were randomly assigned to one of four tutorial groups for the purpose of training in their allocated strategy and in the use of the CD -ROM.
The researcher, as participant observer, attributed meaning to the participants' words and actions following transcription of audio recordings.

The Study. The study was carried out over a period of twelve weeks and conducted in two phases, a training phase and a problem-solving phase. The training phase was conducted with four groups of eight students, each group being assigned to one of the four problem solving strategies. Group membership was fixed during this phase. Components of the training phase were:

problem solving strategy tutorial: each group was issued with and instructed on the theoretical principles of their designated support strategy. Designed by the researcher, this booklet provided a theoretical outline of the strategy and a series of non-domain specific problems to work through using the designated strategy. The researcher modelled the problem solving process using the strategy assigned to each group. All group members were provided with the strategy outline in written form and given time to work on example problems using their assigned strategy. Participants were encouraged to work collaboratively and present their solutions to the group for reinforcement of the strategy concepts.

CD-ROM tutorial: all groups were instructed on the use of the investigating tool and given an opportunity to develop their skills, with both the software tools and their designated strategy, using alternative problems to those investigated in the study.

The problem-solving phase was conducted on an individual basis as it was considered that a deeper understanding of the individual problem solving strategies of each participant could be obtained. Components of the problem-solving phase were:

Apple iMac computer and software: Each participant was seated in front of the computer containing the interactive computer program, *Exploring the Nardoo*. This software possesses many of the attributes of a constructivist learning environment (Jonassen et al, 1999) providing learners with opportunities to actively manipulate a range of information sources and knowledge construction tools while engaged in problem solving. Time was allowed for all subjects to reacquaint themselves with the software and ensure they were comfortable with the setting before commencing the assigned problem. The researcher only intervened or answered questions if participants had difficulties with the equipment or expressed confusion with navigational aspects of the CD-ROM.

electronic notebook (PDA): *Exploring the Nardoo* provides the learner with a flexible set of cognitive tools made available through the metaphor of a personal digital assistant (PDA). This device provides access to navigation and measurement tools. It also affords the opportunity to record data, write notes, collect source material (images, text, video, audio) to support the problem before reflecting upon or reworking their ideas.

participant workbook: For both problem-solving sessions participants were provided with a booklet to record their developmental strategies (plans, predictions, summaries, ideas, causal links, solution outlines) in helping them develop their solution to the problem(s).

audio-recorder: Participants were asked to verbalise their thought processes during their problem solving strategies. The audio-tapes were transcribed verbatum, coded appropriately and set aside for later analysis to note the incidences of higher order skills associated with reasoning and argumentation.

researcher's observations booklet: This artefact, designed by the researcher, was used to record each participant's progress through his or her individual information gathering process. This allowed the researcher to accurately record a chronological sequence of events as each participant attempted to solve the problem(s). Also, hand-written notes were taken of any thoughts and actions each participant verbalised during the process.

problem solving support framework: The specific support framework used in the initial training session was available for each participant as a reference source if required. Designed by the researcher, this booklet provided a theoretical outline of the framework together with a series of non-domain specific problems for the participants to work through.

participant survey: Following the completion of both experiments, participants were asked to complete a questionnaire based on their framework use during the experimental phase. The questionnaire consisted of a combination of both open-ended questions (participants were required to generate their own responses) and closed questions (participants were restricted to a choice of specified alternatives).

INDICATIONS FROM THE STUDY

Even though many of the participants gathered a number of pieces of evidence to support their solution, it appeared that in constructing their responses they preferentially consider only one or two pieces of information rather than discriminating between a variety of issues. However, not all of the supporting evidence was accessed by a number of participants with essential articles being 'missed' in the information gathering process, resulting in the formation of 'weak' responses when developing an argument to support the solving of the problem. Participants used a combination of their individual strategies and their assigned framework. Many participants demonstrated a fragmentary approach to both information gathering and in the analysis and comparing of supporting information for the problem under investigation. Both these skills tended to be more systematic with the investigation of the second problem. In general, for both problems under investigation, a variety of strategies were used in accessing information, in the pattern of exploration in developing mental representations of the problem, in

the use of the media elements and in the use of the 'guides' in helping direct the focus of investigation.

Based on the four problem solving frameworks used in the study, the following generalisations are made: the two frameworks Six Hats and Critical Thinking provide stimulus for students to seek out data and make some preliminary analysis of the suitability of the data in addressing a possible solution to the problem. Participants using these frameworks presented clearer representations and better argued solutions to the problem. The other two frameworks, Venn Diagram and Concept Mapping, focussed more on the organization of ideas once they were identified. In either case, students, when taught one framework and then asked to use it for problem solving, did so with greater allegiance for the first two frameworks than the second two. It is conjectured that this was due to the focus of the framework on data identification.

IMPLICATIONS FOR DESIGN OF AN ON-LINE SUPPORT FRAMEWORK

Problem solving requires a range of skills and background knowledge from the learner. David Jonassen (2000) suggested that the skills required of the learner involved a combination of recognizing variations in the type of problem (degree of structure, complexity and abstraction), the form of representation of the problem (context, cues/clues, and modality), and the individual's knowledge (both in terms of the domain of the problem and the strategies for operating and persevering within the problem domain). This suggests that the strategies in this study would have specific applications to aspects of the solution framework design depending on what aspect of problem solving is highlighted, particularly if learners concentrate on the generation of ideas rather then suggest a mechanism through which a solution might be found. In short they provide not only an idea-generating framework but also ways of organising the ideas to ensure that a solution can be produced. This study has provided agreement for the design elements that Jonassen proposes.

This exploratory investigation indicated that learners engaged in interactive computer-based learning need additional support to represent the knowledge and information they have acquired in the process. This could be achieved through helping learners identify patterns, links and similarities in these complex learning environments. The application of the frameworks in this study supports that contention that there are several processes at work in the development of a problem solution. A series of frameworks each with its own strength is preferable for learners with different processing needs. The concept mapping approach does generate a range of ideas but it requires an additional support to turn the range of ideas into a supported argument. Tools like 'Inspiration'™ assist with the task by enabling the initial map to be re-represented into a different mode to assist with the structured of the argument. However, the nature of the argumentation requires an additional manipulation of the content and hence even this tool cannot help with the final presentation of the ideas. However, the tool exists outside the information collection and where resources are being accessed and directly manipulated the tool is not accessible. Thus if one requirement in the design of a cognitive framework structure is that it be available in conjunction with the problem space, this tool will not be suitable. Further it can be argued that such tools do not support domain-specific reasoning should that be required. The context of this study sought to overcome this issue by linking the tools directly into the problem space.

For this study the importance of domain knowledge has been underscored in that those learners who could operate within the knowledge domain scored a solution framework more expeditiously and their strategies that contributed to the final solution were more direct and focused, although no participants in the study had a specific and strong background in the knowledge domain. Even though each participant was presented with a cognitive support framework, those with less relevant frameworks found that the sequences they followed did not lead to well-reasoned solutions. Thus if the approach does not match the task a solution is not easily achieved and supported. In all cases the results supported the contention that the investigation of a solution(s), and the reporting and support for that solution were two quite different processes.

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