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Abstract: Increasingly higher education institutions are being asked to be more pro-active in delivering instruction through on-line facilities, while at the same time being more effective in fostering higher order thinking skills for students. This action research case study considered the effects of tertiary students working in teams to collaboratively solve ill-defined problems in an on-line environment. The framework adopted for analysis of higher order thinking investigated types of talk that were indicative of reasoning processes. Results indicated that the students' capacity to display higher order thinking increased as a result of the students collaborating and communicating through the custom built on-line problem solving environment. The implications of the study are that on-line collaborative environments can facilitate the development of higher order thinking skills that are increasingly expected of graduates.

Introduction – Integrating higher order thinking and on-line technology

The ultimate educational goal for all educators that cannot be disputed must be enhancing students' ability to think and reason (Paul, 1993; McPeck, 1990). Research and interest at all levels of the educational system is promoting an increased emphasis on higher order cognition and lifelong learning (Australian Council for Educational Research, 2000; Candy, Crebert, & O'Leary, 1994; Brown, 1997). At the same time, students are increasingly being required to become familiar with using technology as a means of collecting information, and also as a means of communicating, collaborating and value-adding to their jobs.

Tinkler, Lepani & Mitchell (1996) propose that in a knowledge economy, where data and information are raw material, value-adding will require higher order thinking skills not only to convert information to knowledge, but also to convert knowledge into insight, foresight, and ultimately wisdom. This is supported by Candy, Crebert & O'Leary (1994) who also promote that access to and use of information technology is absolutely vital to lifelong learning and accordingly "no graduate – indeed no person – can be judged educated unless he or she is information literate" (p. xii). This view is supported by other reports which suggest that graduates must be technology literate in the new economy (Mayer, 1992; Finn, 1991; National Office of the Information Economy, 1998).

In Australia, as in many other countries around the world, this push toward technical literacy, generic skills and higher order thinking has resulted in formal testing being developed. The Department of Education, Training and Youth Affairs (DETYA) has funded the Australian Council for Educational Research (2000) to develop a "Graduate Skills" survey instrument and is being implemented in 2001 across all universities in Australia. This will enable universities to compare the variance in students' generic skills over the course of study, differences in student profiles between fields of study, and differences between universities. So the move to develop student generic, life long and higher order thinking skills must be taken seriously by all tertiary institutions. They can no longer just deliver content and ignore the importance of these skills.

However, the term "higher order thinking" is not clearly defined in the literature (Resnick, 1987). Talk of higher level cognitive processes evokes different views and perspectives from researchers, and this has been referred to as the great debate (Weinstein, 1993). Nevertheless, there is some consensus that when we speak of higher order thinking processes, we refer to thinking which is complex, multi-faceted and self-directed, and that the learner plays an active role (Resnick, 1987; Coles, 1995; Nastasi & Clements, 1992). In this study, we document the design and learning processes that took place in an on-line learning environment that aimed to promote the development of higher order thinking skills. Through the design of tasks that are authentic, collaborative and self-directed, students were engaged in solving ill-defined problems and self and peer assessment of others. Teamwork as facilitated by enabling students to give and receive feedback as well as comments on each others' work.

Context of study

Final year students enrolled in the Interactive Multimedia course at Edith Cowan University are required to develop skills and expertise in project managing the development of multimedia product, such as web sites. These skills are taught through the IMM3228/4228 "Project Management Methodology" unit where students practice developing web sites using project management models, performing needs analysis, developing design specifications, (storyboards, concept maps and rapid prototypes), conducting formative and summative evaluation.

The unit consists of thirteen, three-hour class sessions and runs over a full semester, or thirteen weeks. Each session consists of a one-hour lecture followed by a two-hour group-based activity. Team skills and collaboration are continually promoted and reinforced throughout the unit with teams of four students working together to build the web site. Learning outcomes include:

- communicating and collaborating in a team-based environment to effectively problem solve, resolve conflict and make appropriate decisions
- making a significant contribution to the development of a team-based web-based product
- developing a suitable project management model
- documenting and reporting on QA procedures, communication strategies, timesheet estimates, overall costs , proposal, legal, design etc which are representative of industry expectations
- evaluating the quality and effectiveness of the product

Students are required to complete three assignments that consist of a project proposal, design specification and final web site. Each assignment contains four assessment components. A team mark for the quality of documentation, final web product, and solving of the on-line problems. Individual marks are gained for reflective reports, which are designed to encourage students reflecting on their and others contributions. Peer assessment is encouraged and negotiated with the team at the end of each assignment (team members who are not performing lose points that are added to the score of other team members).

There were 73 students involved in the study, which was delivered through a web site in order to make the learning resources available to both internal and external students. The site include problem solving software, a Listserv, anonymous bulletin boards, time management tool, syllabus and assessment materials, lecture notes, legal/QA templates, relevant URL's, web sites developed by previous students and a student details database (see http://www-scam.cowan.edu.au/ and go to IMM3228).

Designing the learning environment

Group based project work (building a web site) and problem solving were chosen for their relevance and congruence to the learning outcomes that were sought. Project work and problem solving are advocated for their capacity to support the development of generic skills and professional expertise and are successful as instructional strategies in may contexts (Collis, 1998; Klemm & Snell, 1996; English & Yazdani, 1999). Learner activities were undertaken in teams, and the on-line problem-based learning activities involved a number of activities and tasks that appeared to provide strong support for the development of a number of key skills. The students were required to undertake the following activities each week:

- Problem solving - the tasks required students to seek information from appropriate sources in order to solve problems that reflected state-of-the-art knowledge about project management. The students are able to use the Web as an information source but had to select from the many resources available, those that were relevant to the task
- Peer evaluation - having solved the problem, student teams were then required to develop criteria to apply to others solutions. The students had to examine the information given by other students, consider the scope of their inquiry and decide on the parameters which they were going to assess with, and also give feedback on.
- Collaboration - each group consisted of four students and required them to organise themselves into productive teams and share the workload, undertake separate tasks and maintain tight deadlines and schedules each week. Such activities demanded that students consider the requirements of others, be adaptive, responsible and flexible.
- Personal reflection on task and process - each student created reflective notes in which personal views of self-progress was recorded. Students considered the skills and competencies they applied, noted the skills that needed to be developed and developed learning goals that carried over to the next task. This provided a strong framework for the development of personal and process knowledge.

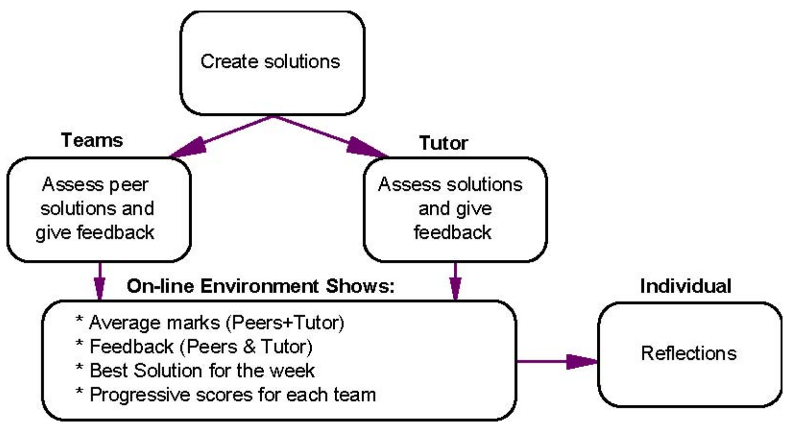
The on-line problem solving process is illustrated below (Fig. 1). From the figure it can be seen that it allows for communication, peer assessment and finally individual reflection on how successful the whole process was. Students post their solutions and then view, assess and give comments to other teams solutions in an anonymous fashion. This enables students to view others solutions and perspective's and also pass comments within the 'safety' of the on-line environment. So students can comment on the overall process and see how the efforts of their team compared to that of others as suggested by both peers and tutor feedback. To help student teams develop an approach to the problem solving process, the "Stair-Step" problem solving process developed by Lynch, Wolcott & Huber [, 2000 #133] was explained and illustrated to the students.

Teams

Figure 1: The on-line problem solving process

For the group project, students were required to complete three assignments that consisted of a project proposal, design specification and a web site. Each assignment contained four assessment components: a team mark for developing the project, a team mark for solving the on-line problems, an individual mark for personal reflections and intra-team self/peer assessment mark. Students were given three problems to solve as follows:

- *Assume that you are building a web site for a difficult client who thinks they know lots about multimedia design and development! Outline how you will scope the project, collect the content, develop acceptance criteria, control scope creep and cost the overall project. (Consider issues such as client objectives, feasibility, end users, hardware/software, use of sound/graphics/video, potential difficulties, evaluation (formative), implementation issues, maintenance issues and content collection issues).*



- *If the client asks for changes in design or content after you have commenced production, what should you do? How can the design specifications be tied into the legal contract? How will the prototype, formative evaluation process or storyboards help with this? What other considerations should you bear in mind?*
- *If you were the client, how would you ensure that the final product met the original objectives? If you were the developer how would ensure that you had satisfied the original objectives to the letter of the original contract?*

Working on-line gave students the opportunity to access multiple forms of peer support through shared tasks, teamwork, collaboration, feedback and peer review. It was hoped that this environment would create an effective climate of support in which students could practice developing generic and higher order thinking skills. To test the effective gain of this on-line environment in developing skills, an key-word indicators were used to monitor instances of higher order thinking, as explained in the following section.

Methodology

A discourse analysis approach was used to identify instances of higher order thinking in student responses developed by McLoughlin & Oliver (1998). This approach used a taxonomy of key-word indicators to signal instances of higher order thinking using the categories of cognitive accountability, critical enquiry, interpretation and reflection. This is based on a collection of words used in the English language which signal a statement is serving the function of reasoning or higher order thinking. For example, inference indicators such as "because" or "whereas" signal that what follows is a reason being given for the statement (Thomas, 1981). Key-word indicators for each of these are based on the following:

- Cognitive accountability, in which students explain or justify a concept, is evidenced when their language use includes "because" or "cos" to link a reason to a claim. Or, when they say "so", "then" or "therefore" to signal conclusion or inference drawn from preceding evidence
- Critical inquiry, in which students challenge, inquire, clarify, investigate or question a concept, and is evidenced through their language by questions such as "what if?", "why" or "you mean" in order to challenge or make deeper inquiry. Also, students can draw a hypothesis through the use of "if…then", "would", "maybe" or "perhaps" to link conditions to inferences
- Interpretation, in which students express opinion, suggest ideas, make rules, generalise, compare/contrast and give examples is evidenced when their language use includes "it means", "that means", "it says", "I think", "always", "never", "in comparison" or "for example/whereas" in order to express understanding or interpretation of text, activity or concept
- Reflection, in which students evaluate ideas when their language use includes "I think" or they make some form of metacognitive statement. Also, when their language includes some form of self evaluation or awareness of learning

Using these key-word indicators to find instances of higher order thinking provided an effective means of substantiating improvement in students' dialogue. By counting the number of key-word instances for each response in each problem solution demonstrated how student language changed over time, which illustrated whether the intervention had been successful in promoting higher order thinking. This type of analysis is supported by a number of studies (Thomas, 1981; Means & Voss, 1996; Tishman & Perkins) which also suggest that reasoning can be assessed by analysing how the discourse is structured.

The study used a computer based text analysis approach (NUD.IST, 1994) which enabled the researchers to search for instances of the on-line text that contained keywords which represented higher order thinking. The corpus of data used was based on feedback responses given by teams to peers' solutions ie student teams were required to assess and give comments (up to five hundred words) justifying the given mark to four other teams. As there were three problems to complete during the semester, we were able to collect three discrete compilations of responses in order to monitor changes.

Results

Because of the large amount of data generated for each problem, it was decided to investigate only a portion of the whole corpus. One of the four classes with twenty students was used over the full semester and their responses for each problem was coded. As shown (Fig. 2), a clear increase in the number keyword indicators used can be seen over the development of the three problems. A closer analysis in the second diagram shows that the main increases resulted from keyword indicators promoting critical inquiry. Keyword indicators for cognitive accountability, interpretation and reflection showed no significant increase.

The system of coding keyword indicators was useful is gaining an understanding of trends in the data. However, it was still necessary to examine the data manually and make decisions about how best to code some elements which didn't fall into any of the specified categories.

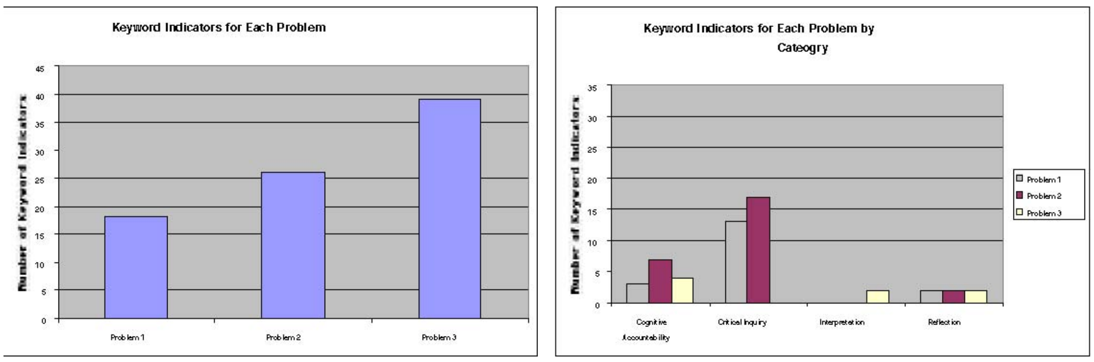


Figure 2: Higher order thinking keyword indicators for each problem

It was evident that as the semester progressed, and students became more confident in giving feedback, they became more direct and critical with their comments. Some examples of the comments made by students follow.

- "If you were the developer, how would you ensure that you satisfied the original objectives to the letter of the original contract"
- "It would be very interesting to see an expanded explanation from this group"
- "Who, what etc? What does this exactly mean? You should have expanded this more, it just doesn't make sense the way it is"
- "We feel that you have significantly missed the point of the question. The question asks how would you ensure that you HAD satisfied the original objectives not how you would ensure…."
- "We found your teams solution unclear and were not sure what you mean. You start talking about the developer then suddenly start talking about the client again. It would be better if you tried to stick with one idea before discussing the next one"

Summary and conclusions

The on-line problem solving application provided an infrastructure for the students to post solutions to ill-defined problems, and then view, assess and critique other solutions. Not only did this provide multiple perspectives on how to solve the problems, but it also encouraged students to reflect on solutions, challenge and question each other and revise their own ideas. Using a discourse analysis approach with keyword indicators to represent occurrences of higher order thinking, showed that there was a clear improvement over the duration of the semester. Our research indicates that online problem solving tasks have the capacity to foster inquiry skills, collaborative dialogue and critical thinking. Furthermore, the analytic approach of discourse analysis applied to online transcripts of tasks provided an indicator of the levels and types of thinking that occurred online. Our research will continue to refine the types of tasks that can be applied in online environments to support higher order thinking processes.

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