Making the Processes of Design Explicit Within an Information Technology Environment

Paper Code: STEO1296

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Paper presented at the annual conference of the

Australian Association for Research in Education (AARE)

2 – 6 December 2001

University of Notre Dame

Fremantle Australia

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Abstract

In this paper, technology is described as involving processes whereby resources are utilised to satisfy human needs or to take advantage of opportunities, to develop practical solutions to problems. This study, set within one type of technology context, information technology, investigated how, through a one semester undergraduate course, elements of technological processes were made explicit to students. While it was acknowledged in the development and implementation of this course that students needed to learn technical skills, technological skills and knowledge, including design, were seen as vital also, to enable students to think about information technology from a perspective that was not confined and limited to "technology as hardware and software". This paper describes how the course, set within a three year program of study, was aimed at helping students to develop their thinking and their knowledge about design processes in an explicit way. An interpretive research approach was used and data sources included a Repertory Grid "survey"; student interviews; video recordings of classroom interactions, audio recordings of lectures, observations of classroom interactions made by researchers; and artefacts which included students' journals and portfolios. The development of students' knowledge about design practices is discussed and reflections upon student knowledge development in conjunction with their learning experiences are made. Implications for ensuring explicitness of design practice within information technology contexts are presented, and the need to identify what constitutes design knowledge is argued.

Theoretical Underpinnings

"Technology involves the application of knowledge, resources, materials, tools and information in designing, producing, and using products, structures (physical and social), and systems to extend human capability to control and modify natural and human-made environments" (Raizen, Sellwood, Tod & Vickers, 1995, p. 1). This description of technology incorporates the five dimensions of meaning for technology that have been discussed in the literature in the past decade (e.g., Custer, 1995; Gardner, Penna & Brass, 1996; Mumford, 1972). The five dimensions are (a) technology has a human dimension – it is a purposeful activity, conceived by inventors and planners and can be promoted by entrepreneurs; (b) technology has a social dimension – it is used and implemented by society, it has effects on society and it is influenced by value judgements; (c) technology is a process – it involves doing, making and implementing with materials, design practice, expertise and knowledge itself, it is subject to the laws of nature and it may be enhanced by discoveries in science or may often precede science and it is used to solve problems; (d) technology is situated – it is conducted within contexts and constraints; and, finally, similar to the dimension that underpins the majority of the research studies referred to above, (e) technology leads to the development of products or artefacts. Technology education with this broad definition at its heart is a recent phenomenon (Layton, 1993). Incorporating technology education into general education is an acknowledgement of the profound influence that technology has on all parts of human life, and there is a critical need for all individuals to develop at least minimal levels of understanding of technology (Custer, 1995).

While technology education has often been rated as less important than education in, say, science, at all levels of schooling, including university (Raizen, et al., 1995), during recent years, the need for people to become more technologically literate (Lewis & Gagel, 1992) has been realised. Technology in its many forms (e.g., as part of general education, and as part of more specialised courses at TAFE and university, such as engineering and information technology) is a means through which learners, through iterative, cyclical and recursive interactions develop their knowledge, understandings and skills of the processes of investigating, ideating, producing and evaluating, as they create products and processes to meet human needs (Queensland School Curriculum Council (QSCC), 2000). The importance of strengthening the design component within information technology education at tertiary education levels, particularly in software engineering, is recognition that the processes of technology and design are not just relevant for general education. There is a growing awareness of the importance of the designer aspects of a software engineer's role in developing computer environments that acknowledge the interconnection between humans and computers (Winograd, Bennett, Young & Hartfield, 1996).

Exploration and investigation of design and design processes have been undertaken extensively in the past as educators in the fields of, for example, architecture (e.g., Schön, 1987) and engineering (e.g., Fordyce, 1992; Travers, 1993; Christiaans & Dorst, 1992), have sought to understand more about learning and teaching design. Various approaches have been used to gather data and studies have repeatedly confirmed that design processes are not linear sets of steps that one takes to solve problems (Matchett, as cited in Jones, 1992), but a complex interplay amongst various elements within a context or situation, such as the designer/s themselves, the materials, the overall purpose and problem, the "client" or "audience", knowledge, skills, tools, theories, and including, in educational settings, the teacher, too (Roth, 1998). To gain a better understanding of this complex interplay, researchers have used various means in their attempts to reveal what happens when a designer engages in designerly thinking and action. Think aloud protocols (e.g., Christiaans & Dorst, 1992; Eckersley, 1988) have been used, as have diagrammatic representations of group interactions (McRobbie, Stein & Ginns, in press) to acknowledge that identifying what happens during design thinking requires a richer data source than can be produced by verbal data alone (Middleton, 2000). Yet others have tried to identify and name types of knowledge types drawn upon during design activity (Faulkner, 1994) and the cognitive structures created and utilised (Oxman, 1999). Including a design perspective within the activities engaged in by information technologists has been regarded as being increasingly important in recent years (Winograd, et al., 1996).

While no one "answer" has emerged from these investigations, where design education is concerned, the continuing existence of these types of studies suggest strongly that there is an acceptance of the need to make design processes explicit within learning environments and to move away from the "black box" idea of design, and the "learning by osmosis" approach. In recent years, where general education is concerned, researchers have grappled with the need to identify both conceptual and procedural knowledge of technology education (and this includes design education) (e.g., Jones, 1997; McCormick, 1997). It has been argued that to ensure teachers (and consequently their students as well) see a uniqueness to design and technology education, to highlight its differences from, say, education in art or science (Stein, McRobbie & Ginns, 2000), there is a need to identify and make explicit the design concepts and processes involved in technological activity.

The typology devised by Faulkner (1994) has been found to be useful in providing a basis upon which to analyse classroom events in terms of knowledge types - which include an integration of concepts and processes - drawn upon in technological activity with a strong design component (Ginns, Stein, McRobbie & Swales, 2000; McRobbie, Ginns & Stein, 2000). The knowledge types Faulkner identified include (a) knowledge of the natural world, which draws upon scientific and technological theories and knowledge of properties of materials; (b) knowledge of design practice, or the major activities involved in the process of innovation, including setting design criteria, making detailed specifications from the criteria, choosing from alternate concept designs and making a detailed design of the final artefact, and design concepts such as fundamental principles and configurations of components; (c) knowledge of developing and testing designs which includes experimental and test methods or procedures, as well as the ability to use them appropriately and to predict and interpret their outcomes; (d) knowledge related to final products, which is knowledge about a product or artefact's ultimate use, purpose, and place; and finally (e) knowledge about design knowledge itself, which is an awareness of, and an ability to draw upon and use, relevant language, terms and ideas related to a particular field or area appropriate to the task, artefact, or innovation (Faulkner 1994). Using Faulkner's typology, it has been possible to identify changes in student knowledge of concepts and processes occurring during the course of design activities in "natural" classroom settings. These "natural" settings included small groups of students working on open-ended design tasks, which offered different degrees of structure and support. The basis behind this research into school student and pre-service teacher-oriented designerly behaviour and thinking was the design studio (Schön, 1987), where learners/participants are encouraged to form communities of learners (Lave & Wenger, 1991; Prawat, 1996) who interact to solve problems. Faulkner's (1994) typology may be one way of analysing curricula to describe how design can be made explicit within various technology contexts, including an information technology context.

The study reported in this paper investigated the developing understandings of technology and design held by a group of 1st year undergraduate students enrolled in an information technology degree program. The study extended earlier studies undertaken in primary school students (e.g., Ginns, et al., 2000; Stein, McRobbie & Ginns, in press) and with postgraduate preservice teacher education students (McRobbie, et al., 2000), by investigating the learning of the undergraduate students aiming to become competent practitioners within a specific professional technological context, namely, information technology.

The aim of the study was to investigate the general understandings about technology and technological practice (this includes design) held by a group of students, and how those understandings developed over the period of one semester as they engaged in a design studio course as part of their information technology degree program. More specifically, the study intended to:

1. investigate changes in students' understandings of design during a one semester studio course in information technology; and
2. draw implications for the teaching of design in student education in information technology contexts.

Design and Methods

An interpretive research methodology (Erickson, 1998) was utilised, as this approach is able to provide "the meanings and purposes attached by human actors to their activities" (Guba & Lincoln, 1989, p. 106), which was the focus of this study. The study employed the criteria of Guba and Lincoln (1989) for quality interpretive inquiry - trustworthiness, authenticity and the benefits of the hermeneutic process. Trustworthiness was enhanced by prolonged engagement over 13 weeks, persistent observation, peer debriefing, and member checks with participants, including returning transcripts of interviews for checking. Authenticity was enhanced by fair presentation and analysis of assertions, including actively seeking negative examples and a range of interpretations. A hermeneutic cycle was employed in developing and testing assertions as the study progressed. Emerging assertions were discussed with students and colleagues, and tested and refined in the light of further evidence. Triangulation involving the use of multiple data sources maximised the probability that emergent assertions were consistent with a variety of data. With extended classroom observations, the tendency for participants to exhibit contrived behaviours was minimised.

Participants

The participants in the study were drawn from a cohort of approximately 60 students enrolled in a first year, first semester, design studio course that was one subject within a three year information technology degree program, leading to a Bachelor of Information Environments. The study was set at one of the three campuses of a university in south east Queensland, Australia. While the researchers interacted with many of the students across the cohort during the semester, 20 students volunteered to be part of a focus group to be monitored more closely. During the semester, four of the focus group students withdrew from the course. One of the authors (MD) was the program director and co-ordinator of the studio course.

Data Sources and Analysis

The multiple data sources included: audio recordings of interviews (described further, below); student responses to repertory grid statements about design activity (described in more detail, below); video recordings of tutorials and workshops; audio recordings of lectures and short "on the run" interviews with students and tutors during or immediately after classroom events; field notes of classroom observations made by the researchers; artefacts, such as handouts and notes provided to students during lectures, tutorials and workshops; students' reflective diaries which were compiled by all students during the semester, containing their written thoughts, ideas, sketches, drawings and other notes made as they worked on their design activities and reflected on their learning.

The repertory grid

At the beginning and end of semester, all students in the cohort completed a repertory grid, concerned with ascertaining students' perspectives on the nature of design activity and processes. The repertory grid had been constructed prior to this study, following a process developed by Shapiro (1996), and it was enhanced through work undertaken in an investigation into preservice teacher education students' perceptions of technology (McRobbie, et al., 2000). The grid was made up of a set of*constructs* (terms and phrases commonly used by students about technology and the conduct of technology investigations within formal learning environments) and a set of *elements* (typical situations or experiences in the conduct of a technological investigation) (see Tables 1 and 2). Students rated their perceptions for each element for each construct in turn on a seven point rating scale situated between pole positions (see Table 3). For example, the first element was *Selection of a problem for investigation by you*, and students rated each of the constructs as they pertained to this element. They then rated the same constructs on the next element, and so on.

Table 1

Repertory Grid - Constructs

Label	Descriptor - One pole	Descriptor - Opposite pole
a.	I will be creating my own ideas	I will be just following directions
b.	I will find this process challenging, problematic, troublesome	It will be easy, simple
c.	I will have some idea beforehand about the result	I will have no idea what will result
d	I will using imagination or spontaneous ideas	It will be recipe-like prescriptive work
e.	It will be a frustrating experience	It will be a satisfying experience
f.	I will be doing real technology	I will be doing things unrelated to technology
g.	There will be theoretical considerations	There will be practical considerations
h.	I expect to use a specific method to solve the problem	I expect to not using any particular method
i.	The experience will be process oriented	The experience will be product oriented
j.	I expect group based/collaborative discussion	I expect individually based work

Table 2

Repertory Grid - Elements

Label	Descriptor
1.	Selection of a problem for investigation by you
2.	Identifying and exploring factors which may affect the outcome of the project
3	Decisions about resources, materials, equipment, etc may be needed
4.	Drawing of plans and diagrams may be involved

5.	Building models and testing them may be required
6.	Modification of original plans may be required
7.	Modification of original models may be required
8.	Appraisal of the process and product may be required
9.	Solving of problems may be needed

Table 3

Sample Repertory Grid Chart

The following statement is a brief description of a typical experience you, as a participant, might have whil conducting a design and technology project.

ELEMENT #1: Selection of a problem for investigation by you.

Rate this experience on the scale of 1 to 7 below for the following constructs, or terms and phrases, you m when describing the steps in conducting a design and technology project. CIRCLE YOUR RESPONSE.

CONSTRUCT SCALE CONSTRUCT

a.	I will be creating my own ideas	1 2 3 4 5 6 7	a.	I will be just following directions
b.	I will find this process challenging, problematic, troublesome	1 2 3 4 5 6 7	b.	It will be easy, simple
c.	I will have some idea beforehand about the result	1 2 3 4 5 6 7	c.	I will have no idea what will result
d.	I will using imagination or spontaneous ideas	1 2 3 4 5 6 7	d.	It will be recipe-like prescriptive work
e.	It will be a frustrating experience	1 2 3 4 5 6 7	e.	It will be a satisfying experience
f.	I will be doing real technology	1 2 3 4 5 6 7	f.	I will be doing things unrelated to technology
g.	There will be theoretical considerations	1 2 3 4 5 6 7	g.	There will be practical considerations
h.	I expect to use a specific	1 2 3 4 5 6 7	h.	I expect to not using any

	method to solve the problem			particular method
i.	The experience will be process oriented	1 2 3 4 5 6 7	i.	The experience will be product oriented
j.	I expect group based/collaborative discussion	1 2 3 4 5 6 7	j.	I expect individually based work

The repertory grid responses from the beginning of the semester were reviewed on an individual basis, to gain a sense of the breadth of the understandings about design activity held by each student. The repertory grid responses gathered at the end of the semester were compared with the first responses, again on an individual basis, to detect changes in ratings. Particular attention was paid to the responses where the student had made a change of more than two pole positions.

The interviews

The twenty students who volunteered to form the focus group for the study were interviewed individually, once at the start of the semester and again at the end. During the first interview, questions were asked to ascertain the students' perceptions of technology as a phenomenon (e.g., When you hear the word, "technology", what springs to mind?); their thoughts about what was involved in technological activity (e.g., Describe the steps you think would be involved in developing a technological artefact.); and their predictions about the nature of the design activities in the upcoming course (e.g., What sort of activities do you think you will be involved in this semester?). This first interview, was analysed in the light of the definition presented at the start of this paper, namely: "Technology involves the application of knowledge, resources, materials, tools and information in designing, producing, and using products, structures (physical and social), and systems to extend human capability to control and modify natural and human-made environments" (Raizen, et al., 1995, p. 1). Together with their responses from the repertory grid, a determination was made about whether the students held a limited (students described technology using very few references to the inclusions in the Raizen et al. definition) or broad (students described technology using references very like the Raizen et al. definition) understanding of technology and technological activity. Particular attention was paid to how the students expressed their understanding of technological activity, specifically, their expressed understanding about design and design processes, which is the focus of this paper.

During the second interview, the sixteen focus group students (four of the original twenty withdrew from the course during the semester) were asked to summarise their experiences and to describe their knowledge development. Each semi-structured interview was framed around Faulkner's (1994) typology of knowledge types. Questions included, for example:

Q. What sort of knowledge did you draw upon to do the project – knowledge of software; of hardware; of the topic itself? *(Knowledge of the natural world)*;

Q. Tell me about the design criteria you developed. Where did they come from? How did you refine them? *(Knowledge of design practice)*;

Q. What sort of testing did you do? How often? When did the testing occur? *(Knowledge of developing and testing designs)*;

Q. Where did your ideas for the product come from? To what extent were your ideas influenced by what you had seen before? *(Knowledge related to final products)*;

Q. Did you find that you had to seek extra information or assistance to help you to complete your project? Where did you go to get that assistance or extra help?*(Knowledge about design knowledge itself)*.

Other questions stimulated students' reflection upon the course itself and their perceptions about how the elements within the course had helped or hindered them in the development of their knowledge and skills. Snippets from the video recordings and field notes made by the researchers during the semester were used to stimulate recall of classroom interactions. For example:

Q. The course was made up of a number of different structures like lecture, tutorials and workshops. *(Video snippets from classroom interactions are shown.)*Comment on how these structures helped or hindered you in your learning about the design of information environments.

Each student was asked to respond to the repertory grid statements for a second time. Students were invited to comment on why they responded as they did and particularly when they made different responses to the ones they made at the start of the semester.

Finally, assertions that were emerging from the study were presented to students for their comment.

All interviews were recorded on audiotape and transcribed as soon as possible after the interviews were held. The transcripts were returned to the interviewees for checking. The interviews were analysed using Faulkner's (1994) typology of knowledge to assist in determining the knowledge about design developed by the students across the semester. The repertory grid responses were reviewed as described in the previous section in combination with the interview data.

At the end of the study, case studies of focus group students were assembled. The case studies described students' knowledge (concepts and processes) development, particularly as it related to design and design activity, and made links with the learning opportunities provided through the studio course implementation.

The Studio Course and Degree Program

The Information Environments program focussed upon the development of skills to implement highly sophisticated, networked, and distributed computer-based information environments. This study was of one course within that program. The aim of the program was to develop students' understanding in three core areas: design, with particular reference to the design of virtual (i.e. computer-based) artefacts; information technology; and organisational structure and communication. Each semester included a studio project as the major focus with a surrounding family of courses designed to complement and reinforce the studio work (Course materials). The course, which was the focus of this research study, was the first studio course for the whole of the program. It aimed to introduce the idea of the design of information environments to the students and provide structures and support for them as they undertook a number of design projects and design exercises (Course materials).

The series of interactions within the studio course included lectures, during which one lecturer presented key ideas, about for example, VRML, information architecture, learning skills, features of well-designed information environments. Lectures were also used as opportunities for providing organisational information and updates to students. A web site was used for ongoing updates of this nature as well. During tutorials, tutors led the groups through various exercises to engage thinking processes and support planning activities. For example, early in the semester tutors led the students through brainstorming activities during which ideas were generated using letters of the alphabet. The intention was to teach creative thinking skills and to alert the students to the opportunities and extent of their abilities to be creative, an attribute which is part of being a designer. Later in the semester, tutorials were used as opportunities for groups to work on their individual and group projects which included the design and development of a poster and a website to publicise the Information Environments program, and the presentation of a talk on a topic of choice supported by slides developed using a presentation package. Workshops were run by various lecturers, during which some specific features of some software packages were explained. Specific software packages, which were to be used in the projects, included a presentation package, web development package and a graphics package. Other individual and group activities, usually conducted through tutorials/workshops included tasks such as: critiquing websites; exploring the use of sketching as a means to developing concepts and sorting through ideas; thinking tasks to generate creative ideas and lateral thinking; and an activity which took place in the streets near to the university campus which aimed to help students to develop a concept of information environments by having them consider the way people navigate through physical space as a metaphor for navigation through virtual space.

To give an example of the general approach taken to each of the individual and group projects, one of the projects, the poster, will be described briefly to give an indication of how support was offered through the planned structures in the course to help students in their designing and development tasks.

The purpose of the poster project was to publicise the Information Environments program in which they were enrolled. The intention of the poster was provided for the students: "The idea is for you to show what Information Environments means to you, or what you understand Information Environments to be/incorporate" (Course materials). First, the students had to produce a concept design, preferably as a sketch or series of sketches, displaying their design intentions of their posters clearly. They then each had to construct a poster using Photoshop. Some direction was given concerning the inclusion of the university logo, as well as specifications on the size and resolution of the poster, and how their how their files had to be saved. The section of the course dedicated to providing specific support for this project spanned four weeks and included two lectures, one on an introduction to Photoshop and one on more advanced skills; a practical session during which students were led through basic tools of Photoshop (converting physical to virtual images and image types); a second practical session on web graphics, templates, mock ups and tricks; and a non-teaching week during which the students were given an opportunity to concentrate on their project work and elicit specific one-to-one assistance from tutors, if needed. Students presented their projects to the group and received comments and suggestions. While they were eventually to receive marks for their project work, they did not receive them until the end of the semester. The outcomes of each project, including any developmental work, such as concept designs, was added to a portfolio, which became the final "document" for submission for assessment at the end of the semester. That meant, that even though various projects were expected to be presented and submitted by certain dates across the semester, it was acknowledged that students may have wanted to develop their ideas further, in response to any feedback they received each time they presented their work, and also as they reflected on their learnings or developed new skills across the semester. If they made any changes to their growing collection of portfolio entries, they were to note these in their reflective journals, as part of their ongoing thinking about their learning.

Results and Discussion

In this section, students' views about design and design processes at the start of the semester will be presented. Then, the views they held at the end of the semester will be discussed and links between their expressed experiences of their learning and the intentions of the structures within the course will be made. Evidence from course materials, interviews, the students' journal entries, video recordings and researcher field notes are drawn upon to support the discussion. The repertory grid responses are not referred to directly in the following discussion, as these were analysed on an individual basis in conjunction with the interview data.

The case studies of four of the focus group students are will be used in this section. These students were Tony, Simon, Tricia and Laurence (all names are pseudonyms). These four students expressed a range of views and perspectives, and we would argue that the statements made below, using evidence from the case studies, could be taken to represent, in general, the variety of experiences and perspectives of students across the cohort. References to the various data sources used as evidence to support the discussion appear in parentheses throughout the discussion.

This section serves to explain how objective 1 of the study (see the Theoretical Underpinnings section), to describe the development of students' knowledge about design across the semester, has been achieved, specifically in terms of Faulkner's (1994) knowledge types. Objective 3 of the study, concerning explicitness of design within the course is addressed mainly in the Implications section, but referred to frequently in the results and discussion section.

It is acknowledged that the course that was the focus for this study was planned as one course within a progressive series that made up a whole program. It was the intention of the course and program developers for this first studio course of the first semester in the first year of a three year degree program to introduce ideas about design and to lay some foundations for further development as the program proceeded across the years. The discussion now presented highlights, in the light of Faulkner's (1994) typology, where opportunities for knowledge development were capitalised upon and possible missed opportunities for learning as well. It serves to raise awareness for course developers and implementers, of some possibilities and limitations of making design knowledge explicit within information technology courses. It is up to readers to determine relevance for their own contexts from the circumstances described in this report.

Students' Views about Design Processes at the Start of the Semester

At the start of the semester, most students could express an understanding about what was involved in overall design processes. When asked to describe the main phases or steps that would be involved in designing and developing a technological artefact during the first interview, the students were able to describe the need for gathering ideas as an important early task.

> … start brainstorming ideas doesn't matter how stupid how far out they are. The more you have the better it'll be, start from there, start sketching and work it through from there. (Simon, interview 1)

There was a sense that users were extremely important and that because they were to be ultimate receivers of any product, it was important to think about user needs.

> You have to think of people who are going to use it … So when you're actually designing, you've got to take into account just about every range of person you can possibly think of. And then you have to narrow it down to your core group of users…. (Tricia, interview 1)

While there was mention of users' needs, there was little expression of processes that could be put in place to find out those needs or the problem that the product would eventually solve. On the other hand, a need was expressed to gather good quality information for inclusion in a computer-based product, such as a web site. Research was thus highlighted as being an important part of design.

> Getting credible information. You actually have to make sure you've got credible resources. So a lot of research has to go into it. (Tricia, interview 1)

Early in design processes, students believed that ideas could come from a variety of places, but predominantly from one's own experiences and from easily accessible places such as the Internet.

> [Ideas come from] books, the main things, the web, newspapers, magazines, talking to people, other people, yourself obviously. Just walking around everyday you'll probably pick up on stuff you'll want to use. (Simon, interview 1)

Some students recognized that later in a design and development process, it was difficult to pinpoint where ideas came from originally, as they would meld and integrate so much as a product was formed.

> I actually think most of our ideas are ideas we would have thought of first. And that's the confusing thing about Information Environments. You can, after you've done all your research, think "Now, did I read that somewhere, did someone say that to me or did I think of that?" And it gets very confusing. (Tricia, interview 1)

There was some recognition that plans needed to be made early on. This would include conceptualising the whole problem and thinking about how to tackle it.

> I guess the main stages would be to get in groups think about the problem and like start a plan on how to do that. The next step would be research discovering ways of how to deal with the problem, best method of doing it, has it already been done before, get different ideas from there. (Laurence, interview 1)

Developing a solution would involve a number of design plans being developed and result in the coming together of a number of ideas of how to solve the problems.

> You might have a number of designs you might have to integrate into one. …You're doing that [integrating] really through a whole project anyway, cause you're integrating your design, your thinking, it all goes into one. (Simon, interview 1)
>
> I'd actually playing with information. "I think this should go there. I think this should go here". (Tricia, interview 1)

For the most part, these responses about bringing ideas together seemed to be about the tackling of the immediate problems related to the specifics of a task, rather than statements of a metacognitive nature to do with solving design problems in general, or the type of thinking and phases one works through as one designs products. Many of the students' statements tended to be on a task-oriented or artefactual level, rather than on a principled level. For example,

> Your project could have four different stages to it, you might have, you know, a typical example would be doing a web page you might have a page, then you might have to introduce your links, um, you might have a movie on there or whatever, game on there and they'll all be separate projects and they have to integrated them all in together to comes up with one. (Simon, interview 1)

On the other hand, there were some statements made by some students that were more principled, describing solution-finding as a constant back and forth process between and amongst various dynamic elements within a context, for example, the problem, the ideas, the client, possible solutions.

> It's not just a linear process. [It's] star shaped. … You might branch out each time, take ideas, change things… Or it could be like a spider web. You know, you won't necessarily get it straight up. You have to branch out a little bit and learn something new, to get your ideas. How many times you can do this depends on time restraints and technology restraints. (Tony, interview 1)

It was recognised that teams or groups would be better placed to design than individuals working on their own. For example

> … teamwork's good. Probably, [it] enforces more thinking, more design, throw ideas around more, it's a bit hard to sit there by yourself and start talking to yourself about this, that, and the other. (Simon, interview 1)

Some believed that it was essential that opportunities for team work were built into the course at university because professionals in the information technology industry work as teams as well as individuals.

> The IT industry is based on team-work. But it's also based on individual work. … You have to be able to communicate with everyone on every different level, from the secretary right up to the manager. And also work with people that you might have conflicts with. … Because when you go out into the real world, it will help you work as a team. . (Tricia, interview 1)

It was clear from some students that testing was something that happened throughout the design and development process.

> [Testing happens] all the way through. I don't think you ever stop testing. Even when [a web site is] up there and running and going, someone will say, "Oh, what about this?" And you're always constantly asking, wanting to improve. (Tricia, interview 1)

> Yes [it's] a long process which would involve continuous improvement … (Laurence, interview 1)

> Well, [the prototype is] to see if it works. If it is functional or if there are any design flaws, can even make changes to it, how it's accepted, give it to your

> peers blah blah blah discuss it with them might have to go back do some more brainstorming, some more sketching, more redesign work, another prototype, so sort of takes you through that stage until you get your final product. (Simon, interview 1)

Tool knowledge was regarded as important, being integral to being able to conceptualise as well as actualise the design and development of artefacts.

> The tools will be very important because you need it to be able to do what you want to do and create the sort of graphics you want to create. They're very important. The speed, yeah, you need it to be fast and efficient so you can do it as best and as fast as you can, saving time. And accessibility to those tools is very important. (Laurence, interview 1)

> The ideas behind design. You still need … tools, Java or whatever to realize these ideas … If something is just based fully on the technical aspects, there could be problems with the design of it. (Tony, interview 1)

Other students did not express an integral connection between tools and the conceptualisation of design solutions.

> Well [tools are] not really [important]. They're really only used to put the final product [together]. You don't really need [them] from the start. At the start … you'd be throwing things around on bits of paper, drawing stuff up, how you think it should look, rah rah rah, and then when you finally have the idea and you think well that's what I want the you'll implement it on to your computer as the final step, so it's really not the most important part, it is for the presentation at the end to produce it but not that great importance. (Simon, interview 1)

In summary, at the start of the semester most students were able to describe, in general terms, a number of processes involved in designing and developing technological artefacts. They drew on their past experiences, some of those having to do with past school activities or with hobbies. They saw designing artefacts, as a means to solving problems or addressing needs, in order to make life easier or do things more quickly. Design processes for these students involved being sensitive to users' needs, drawing together ideas, using skills, being able to utilise tools appropriately, making plans, considering alternatives and working with others.

Development of Explicit Knowledge about Design Processes During the Semester

The typology described by Faulkner (1994) lists a variety of knowledge types that technologists draw upon and utilise in innovative design projects. In a design project, ideas and knowledges are drawn together and combine to produce artefacts that meet needs or fulfil opportunities (Raizen, et al. 1995). Through an examination of the evidence gathered in this study in the form of student interviews, student written reflections in journals, video records of classroom interactions, course materials and field notes of the researchers' observations of classroom interactions, a discussion of the knowledge types that were drawn upon and developed by the students during the course of the semester is presented. Once again, the case studies of Laurence, Tricia, Tony and Simon are used as a means of explaining the knowledges that we believe were developed, and how, it seemed, the course supported that learning.

(a) Knowledge of the natural world (Faulkner, 1994) which draws upon scientific and technological theories and knowledge of properties of materials.

In the information technology context, knowledge of the natural world would include knowledge about, for example, the capacity and potential of hardware and software to perform certain tasks or achieve certain ends; the properties of data and techniques of data manipulation; "normal" configurations including such things as attributes of output images, like principles of colour and navigation.

In the current study, students were able to talk about the software packages and their use to achieve certain ends within the projects set within the course. For example, students referred to the capacity for the software to assist them to manipulate images and sound and to assemble graphics using layering and texturing.

> [In Photoshop] … you have to make sure you've got all your … graphics and colours and everything are right, not too complex, the file's as small as it can be, so then you can transferred [it] into Dreamweaver otherwise it takes too long to load so you've got to really take those into account so doing that you learn a lot in designing that way, trial and error, testing. (Simon, interview 2)

> Well, only one thing I found that was helpful myself was the Dreamweaver prac. I sat through it for sort of like for two and a half hours to get to the end, and he said this is how you do layers and …. then they made us try it in a different browser and when you use layers between different browsers sometimes it stuffs up where it puts it on the page and … so you could use it within any browser …… and [include] layers… (Tony, interview 2)

> [Today we were] introduced [to] basic concepts of Photoshop tools, effects, layers etc. … I want to get really good at Photoshop so that I can create effective graphics for my future projects and websites. (Laurence, journal, week Apr 2)

Some students expressed their frustration due to their inability to learn about the software packages in sufficient detail within the short timeframe allocated (e.g., for the poster project, the students were given four weeks in all, including learning of the use of software, to complete the whole project).

> I spent hours and hours on Photoshop, it's certainly not an easy program to learn, and given one week to learn it in was absolutely ludicrous and there's no way you could end up with a final result that you're happy with. Very, very few people did, because of the time restriction. (Tricia, interview 2)

Others expressed frustration at finding the approach taken in practical sessions not being helpful in assisting them to learn what they believed they needed to know to achieve the ideas they had conceptualised. For example,

> Premiere demonstration was demonstrated .. it was not clearly explained what the purpose of the demo was until [later in the session]. … Personally, after the first couple of steps I was totally lost and could only follow with manual assistance from [the tutor] and the [instruction] sheet was unclear. After this time no help was gained in editing video [from my talk for inclusion in my portfolio]. (Tony, journal, reflection on sections of the course)

Field notes recorded by researchers indicated that the practical sessions were, essentially, quick demonstrations of some of the major functions of the package with little time for attention to be paid to individual needs (even though tutors moved around the room ready to answer individual questions and to provide extra help) (Field notes, video). As a consequence, some students resorted to finding out how to use the packages through books or through the tutorials provided with the software packages.

> That's where I actually learned how to use [Photoshop], not by the class notes or going to the tutorial sessions, actually by doing the tutorial that came the program. (Tricia, interview 2)

This was not the case with all students, however. Some found the practical workshops very worthwhile in helping them understand the software. For example,

> The pracs and tutes, I mean they're really, it's really helpful. You're there and actually doing it at the same time. You can see how it works. You can see what they mean. (Laurence, interview 2)

While the intentions of the course were to provide introductory experiences in using the software packages (Course materials), it seemed that the students, in some cases, found difficulty in discriminating amongst, the (big and often ambitious) ideas they wanted to achieve or include in their final products, the limitations of time and what that would mean in terms of their own learning abilities, and their ability to conceptualise what was "introductory" and what was, in reality for them, "more advanced".

In an informal, "on the run" interview during a tutorial session, as the students were working on ideas for their posters (tutors moving around the room, ready to talk to students, ask questions, provide advise and feedback), the researcher made the following notes.

> One student told me that he had collected images for his poster, but was finding the technical aspects of using the software package difficult. The student said that he acknowledged that he did not have the necessary skills to do what he wanted to do. He thought that he was probably being too ambitious in his design and will have to revisit and simplify his ideas. He said the tutorials were not really helpful. While they gave specific [skills about how to use particular] tools, [they were] not what he wanted. He felt the students were expected to run before they could walk and they were left to their own devices a lot. (Field notes, 23 April)

The format of the practical sessions was meant to acknowledge the varied skills and prior knowledge that the students would have (responses in interviews with the focus group students revealed a wide variety of prior experience - from no experience to considerable experience - with computers and with the software packages). Thus, the variety of structured sessions built into the course (mix of lecture, practical sessions, non teaching time/one to one teaching) were organised to allow different students with different needs to develop their skills and knowledge from a choice of support mechanisms. However, it seemed that for some students more structure was needed to assist them to conceptualise design problems and to differentiate amongst aspects of skills and knowledge that were more or less important for a particular task at hand, to meet the needs of the problem being faced. In forming a clear conceptualisation of the design problems at hand, thinking through and identifying, in explicit terms, the features of the context and situation (e.g., purpose of the task/nature of the problem; specific audience/client; breadth and depth of subject matter etc) is necessary (Stein, et al, 2001). Another "on the run" interview with one of the tutors revealed that he also believed that the students were having difficulties with conceptualising the overall intention of their posters and coming up with a purposeful and well thought out concept.

> [The tutor] says that the students are having trouble with conceptualising the theme and the design [of their posters]. They seem to be brainstorming and then going with their first or second idea and not developing other alternatives. Students choose a theme but not all images are suitable and students haven't all successfully conceptualised their theme, e.g., haven't used most relevant images/design features etc. Some students have not used good design principles, that is, [they have included] visual distractions, unimportant features that stand out too much, important features are not utilised enough, text hard to read, takes too long to decipher the poster's message. (Field notes, April 23)

Learning involves the ability to be able to differentiate between various elements within an experience and to draw from the experience greater or better developed conceptualisations. While planning for breadth of experience within a variety of situations is surely necessary, differences and variations between situations also need to be determined. Then the relevance and importance of the various elements can be made clear (Marton & Pang, 1999). In the studio course, the students were given the opportunity to explore the many elements of a design situation, but because they were novices, many of them were unsure about what was more or less important to achieve the tasks. It could be said that in this course, there were students who may have benefited from being guided through thinking about the explicit features of the context and situation more closely. As was found with primary school students and teachers (e.g., Stein, McRobbie & Ginns, 2001), more guidance/structure/direction at this early stage of their learning may have provided more of an opportunity for them to sort out which features of design and design activity to emphasise and which to de-emphasise, and how to integrate design principles of information technology environments as they concentrated on the context of the particular project they were working on.

> *(b) Knowledge of design practice (Faulkner, 1994), or the major activities involved in the process of innovation, including setting design criteria, making detailed specifications from the criteria, choosing from alternate concept designs and making a detailed design of the final artefact, and design concepts such as fundamental principles and configurations of components.*

There was a sense that students considered alternative concept designs to produce a final design,

> I only had one final outcome, but when you're sketching and designing, you have multiple ideas but then you usually collaborated them into your final outcome, as a lot of people do, it's just building up. (Tricia, interview 2)

although one of the tutors working with students at the time of the poster development project did not agree (see "on the run" interview described in the field notes above). The students were exposed to different ways others had solved similar design problems, making it clear that there are common elements in design processes, but no one set method.

> So it's really no specific method. It's not like a recipe where you say ok, well, you're going to start up here, you have to do your background first and you have to do this and you have to plan your images. There's no set method … (Tricia, interview 2)

There was also a sense that many of the students came to believe that that it was the products of design activities, rather than the drawing together of a variety of knowledges, skills, attributes (design processes), that were a major focal point of the studio course. This may have been because those students with limited prior knowledge of the software, for example, expended much time and energy on learning the type of new knowledge and skills associated with learning about how to manage and use a piece of software to produce particular effects or outcomes. Their emphasis was on getting to know and understand tools and to produce the perfect artefact, rather than engaging with and reflecting upon the processes of design.

> It was basically the product, because that's what I assumed that studio would be, would be learning new software applications and implementing them, so it was, yeah the product, very product oriented studio is, at the moment but we're slowly getting into the process orientated as well. (Tricia, interview 2)

This problem of overemphasis on products, rather than a balanced consideration of product and process in technological design activities, has been noticed to occur in school classroom situations too (McCormick & Davidson, 1996). When there is an emphasis on making and/or using technical devices and tools, design process and problem solving skills can be neglected by the students in technological problem solving activities.

Still, there was a sense in the students' talk that they had developed an understanding of the nature of technological problem solving and design activity: that the final outcome of technological activity can only be determined in the making. It seemed that for at least some of the students getting to know how to use the tools, such as the software packages, had not overshadowed their thoughts about the overall design processes in which they were engaged.

> Yeah, it's always the same, you always design something and then do it down and by the time get doing it your changing it and so it never ever looks what you've started with so. . (Simon, interview 2)

The emphasis upon the iterative and recursive nature of design activity and of the centrality of the "client" or "audience" identified in the first student interviews was still evident at the end of the semester, although at the end of the semester many more students were able to describe in more detail what was involved.

> [Design processes involve] refining, testing, more testing. I sort of knew those processes but once again [through the studio course] it's highlighted and emphasized …. Other students who haven't had any design experience at all would have benefited from the processes. Although [the lecturers/tutors] haven't really emphasized the sort of steps, like there's like 5 million steps of design process and they haven't emphasized that at all. … anything you do and come up with requires those steps in some form. … I reckon it would have been heaps helpful [to those with little prior experience of designing] 'cause that way they'd have had a foundation to go off straight away. Like subcategories of what you do in that sort of stage of design and that would have broadened their sort of ideas and concept even more other that just you know telling them OK. This is what you should do, these are the basic steps you need to do. And they just sort of stated that and not really expand from it. (Laurence, interview 2)

> …. you go from the initial idea generation, to showing that to your client and coming back and changing it, how you can do that, arranging that towards the

> technology, keep on getting feedback and eventually getting the final product, which could be completely different. (Tony, interview 2)

However, many students felt that design processes were not made explicit enough, suggesting that much of their knowledge about design practice was already held before the course began, or that they felt they could not explain design any better than they could at the start of the course.

> The design process itself isn't explicit to like a certain format, each time you take up a different technology there's a different design process, and just giving an overlay of things that could be taken into account …..(Tony, interview 2)

Of course, their comments could also be taken to mean that they were not conscious of the fact that they were developing knowledge about design and design practice. To confirm this perspective, the learning journals, too, revealed very few instances where students described principled knowledge about design practice. This could, of course, be attributed to the students' limited ability to write reflectively. All the same, classroom observations indicated few, if any instances, where students were encouraged to reflect on design practices from a principled perspective. While there were many activities that encouraged creative thinking and the use and development of skills such as sketching, and examining and critiquing artefacts (Video, Field notes), there were very limited opportunities for students to draw commonalities from the variety of experiences, and to compare and contrast them on a principled, rather than artefactual, level.

> [The course lecturers'/tutors'] main argument [for not being more explicit about design] is that they don't want to dictate design [and] so be constrictive but, if some people just have no idea at all, it's not going to help. … There are obvious pointers at what good things are, what good things are done. I mean I don't see that as a constriction completely. (Tony, interview 2)

One activity implemented within the course to assist students to develop an understanding of phenomenon of an information environment, and at the same time help them to develop a notion of overall design concepts, was the navigation activity undertaken in the streets near to the university. This activity, referred to earlier, encouraged the students to think about physical space - people's use of it and the affordances it provides or limits in the way it is organised - as a metaphor for virtual space. During this activity, students were asked to think of the way people moved around physical space and to draw from those observations ideas that could be applied in the virtual environment. While the use of the metaphor was useful for some students, for example,

> At first, I did not know exactly why the exercise was being done, but after some time actually doing it I discovered the importance of the exercise. The idea was to get ideas of how people are comfortable in navigating through physical space and try to get ideas on how this could be implemented to virtual space. (Laurence, diary)

for others, the result was confusion and puzzlement.

> Well I don't see the point in walking around the streets. J No I can't really relate that part to navigation on the web really. It's alright if you're doing a site map or like a street directory or something like that, but when you're doing

> like, you could probably incorporate the terminology of nodes and intersections and that to a web page, but just walking around the street looking at things, I (don't think so). (Simon, interview 2)

In summary, while students were able to explain in greater detail in many instances what was involved in designing and design processes, there were some confusions, as students wrestled with the relationship and importance of both products and processes, and developed their own understandings of design concepts and practice.

> *(c) Knowledge of developing and testing designs (Faulkner, 1994) which includes experimental and test methods or procedures, as well as the ability to use them appropriately and to predict and interpret their outcomes*

Some students were able to describe how they gathered feedback on the "success" of the artefacts they were designing. Similar to responses gathered in the first interviews, at the end of the semester, students seemed to be able to express the need for testing to some degree. However, there were no instances of students planning for testing to include explicit testing programs or procedures, even simple ones. During the presentation of design concepts for their web site design projects for example, students included testing on their lists of subtasks to be undertaken, but did not explain what that testing would involve, other than, for example, seeing if the links worked (Video, Field notes).

> [If I had more time I would be] not really seeking feedback, making modifications to what I assumed [Information Environments] group was about, what it meant to me, and it would only be mainly minor changes like mainly the background or something like that. It wouldn't be anything like major, but it was just a couple of those little things that I wasn't happy with. . (Tricia, interview 2)
>
> No [I didn't do any testing]. No pretty much got it down pat straight off. (Simon, interview 1)

Other than references to the need to focus on the client/audience/user during discussions, for example, about good design features to include in websites (Field notes of lecture), there were no formal sessions during the course that addressed testing or the development of testing procedures in the formal sense to ascertain whether the features included in, say, the website, were really addressing users' needs (Field notes).

> *(d) Knowledge related to final products (Faulkner, 1994), which is knowledge about a product or artefact's ultimate use, purpose, and place*

For many students, visualising the final product was a process of developing an idea of what could be, by researching a variety of ideas and considering other similar artefacts in existence, for example, other web pages, other posters.

> [For the presentation on a topic of own choice] I read through the book a bit, got a bit of an update on what was there, a bit of a refresher course and then I just did a bit of web searching and got a few images of the different characters and the likes and just scanned a few images in and just chopped it and changed it and inserted it into PowerPoint and did all my slides up. (Simon, interview 2)

Activities in the course encouraged students to identify features of artefacts and to offer critiques of them (Field notes, Course materials). As mentioned before, some students expressed their notion of good design as being simple, using minimal resources. Elements within the course, such as the expectation that students present concept designs, including ideas in sketched form, as well as task lists, timelines, individual contribution and so on (Course materials), aimed to raise students' awareness of production issues.

Unfortunately, many students' experiences of working with others in groups were not necessarily always positive and design knowledge development, not only of final products, seemed to be overshadowed by difficulties of co-ordinating the group interaction and task completion.

> With the groups you don't get time to think about a process … with the time that we've got, it's just too much at the moment. …it's just sort of people just nominate what they're good at and people are just left stranded and 'what do you want me to do' so they feel like they're not putting enough input in. (Tricia, interview 2)

> Well like this project now we're all at the moment [is] higgle de piggledy, cause a lot of us are working, one bloke working this afternoon, I had to work this morning, another one works Wednesday/Thursdays so it sort of makes it hard. Like you can't come to Uni and not earn money, cause it's just not feasible that's where the group stuff gets a bit difficult, yeah, just finding opportunities to sit down all together and really work it all out. (Simon, interview 2)

In another example, during one session in which groups were formed to work on the web site project, one student sat on his own for much of the whole of one session, because his teammates did not attend the class. In another group, the members spent much of their time sitting at computers, individually, not interacting at all, and working on tasks unrelated to the set web site planning task (Field notes, video).

While the structure within the planning session, mentioned above, gave direction to students to allocate tasks to individual group members, share roles, discuss ideas and so on, not all students seemed to relate to these directions as the scaffolds they were intended to be, to help them to learn about working in groups in order to contribute to the production processes of designing and developing artefacts. Field notes taken at the time of the particular session mentioned above and a later review of the video data, confirmed that little was said by the tutors to emphasise the reasons for such a guided planning session. Group difficulties, it seemed were often, though not exclusively, related to arranging times when all the students in a group could meet. It seemed that the major reason why projects were completed, was the pressure of assessment, with individuals doing what they could, often as individuals (Field notes of web site presentations) rather than the need to design and develop a worthwhile artefact and to learn about the processes and thinking involved.

> *(e) Knowledge about design knowledge itself, which is an awareness of, and an ability to draw upon and use, relevant language, terms and ideas related to a particular field or area appropriate to the task, artefact, or innovation (Faulkner 1994).*

Students seemed to be aware of the need to draw upon sources other than themselves to help them in their designing efforts. These sources included other students,

> Probably a couple of times [I relied on help from other students], just a bit on the Dreamweaver side of things really. One bloke there is pretty good at it, so, he's done it before. (Simon, interview 2)

books and the Internet.

> I actually bought the book [for Photoshop] …. I think I had a bit of a look, just on how different filters and that were used. I think I actually got some off the web or out of the book … I had to show an image on top of another image … to look like it's motion, like a person running and it leaves that blur behind it. (Simon, interview 2)

The reflective journal and specific reflective/creative thinking tasks set early in the semester were aimed at helping students to develop a metacognitive level of thinking about their learning. The sessions early in the semester, which focussed specifically on learning, underlined the importance placed on students developing knowledge of their own learning habits and activities. This feature was recognised by students as being worthwhile and helpful, early in the semester during the first interview. For example,

> Just knowing that that's how every human being learns and I just need to …. When it comes to that bottom of the pit to seek help and it sort of gave me confidence that I can just seek help whenever I need to, to get it back up to the top. (Laurence, interview 1)

However, the learning journal, which had as it aim to continue the emphasis on building up a metacognitive approach to learning and to learning about design, became, for most students, only a place to recount their experiences in writing. Some students included in their journals, a variety of ideas they had been considering as they developed their design concepts. While these sketches and notes were useful in recording thoughts, and gave some insights into the students' ways of thinking, the students did not reflect on their thinking and designing efforts, in these cases. There were few instances where students reflected upon the many and varied experiences they had gained across the semester, to synthesise and generalise, to compare and contrast, and to draw out some principled ideas about design and design processes within the information technology context.

Implications

A number of implications about the course and about design and design processes can be made upon reflection of the results and discussion presented above.

First, it is important that design processes are made explicit to students, if they are to learn about what it means to design, and to develop relevant and appropriate skills, knowledge and abilities of design activity. While the processes of design can be difficult to identify and name (Christiaans & Dorst, 1992; Jones, 1992; Eckersley, 1988; McRobbie, et al., in press), if ideas are not made explicit to learners, there is less likelihood that students will develop appropriate understandings of them. Design will remain a "black box" activity and "learning by osmosis" will continue to occur.

In this study, all the students engaged in design processes, but some students were not always able to describe what design was about in terms other than those they expressed at the start of the semester. This, of course was not true of all students and the course included many planned structures to assist students to learn in a conscious way about design within an information technology environment. However, our reflections on the outcomes of this study, lead us to suggest that opportunities for students to draw from the many course experiences some overarching principles about design activity, may have been a way of capitalising further on the activities already built into the course. For example, the learning journals offered an excellent opportunity for developing reflective and metacognitive thinking. By providing structure and guidance for writing and thinking reflectively in these journals (e.g., providing set stimulus questions or overt guidance about how to reflect on experiences and synthesise ideas on principled level) students could have could have been encouraged to think about design and design processes in information technology on a higher level and to identify some principled knowledge. Principled knowledge, drawn from students' own experiences, can more easily become explicit knowledge because it can be talked about and discussed in a way that disentangles it from particular artefacts and single designing experiences and thus makes it more easily applicable to lots of situations and contexts. While there is no one way of designing, and it was indeed the intention of this course to emphasise this point, students also need some firm foundations upon which to rest their growing knowledge and to make links with their prior understandings. The development of principles about design and designing can be a way to help them develop these important foundations to assist them as their learning continues throughout the program.

A second implication is that to provide better opportunity for learning about design processes, it is necessary for some aspects of design knowledge to be given more prominence than they were in the course at the time of the study. In particular, knowledge of testing and the importance of planning and implementing explicit testing procedures would be, from our perspective, an important aspect to include, so that students are made more aware of the necessity of appraising and reviewing the design and development of artefacts throughout a project, and not just after an artefact had been produced. In this study, the students, while acknowledging the centrality of client/audience/user, and the importance of ensuring elements such as graphical features and links functioned correctly, there was no sense that they had a conceptualisation of the level of reviewing that was necessary to appraise the appropriateness and effectiveness of their artefact on all levels from specific technicalities to the degree of match with overall purpose, intention and context. Even though this course was a very early one in the degree program, it is important that, from the beginning, students are made aware of and begin to develop some explicit planning skills for testing the appropriateness and effectiveness of the outcomes of their designing activities. This is particularly important if the stated goals of the Information Environments program, which include a particular focus the human side of computers are to be met, and if a major criticism of computer-based artefacts that often the purpose of the product or the centrality of the user/audience/client is lost during the development (Winograd, et al., 1996) is to be addressed.

Conclusions/Summary

This paper presented a study of knowledge development of design and design activity of students as they engaged in a first year studio course that was part of an information technology degree program. The course was designed to incorporate an explicit design component to acknowledge the need to develop information technology professionals who recognise the human side of computers. The study showed that while there were structures within the course that were successful in supporting the development of students' knowledge about design and design activities, there were also occasions where opportunities for learning could have been better capitalised upon. One important reflection was that opportunities could have been provided for students to draw from the variety of their specific experiences some principled design knowledge, which they could talk and think about in general terms, rather than artefactually/project bound terms. Extracting principles of design and design activity from the artefact and the specific design activity may help students to see how that knowledge is related to many different design activities. Identifying principled knowledge will assist students to gain understanding of the commonalities of design knowledge and practice, and in turn this will provide an explicit foundation for them to make more complex links in their knowledge as their information technology program progresses.

References

Christiaans, H., & Dorst, K. (1992). An empirical study into design thinking. In N. Cross & K. Dorst & N. Roozenburg (Eds.), *Research in design thinking* (pp. 119-125). Delft, The Netherlands: Delft University Press.

Custer, R. L. (1995). Examining the dimensions of technology. *International Journal of Technology and Design Education, 5,* 219-244.

Eckersley, M. (1988). The form of design processes: A protocol analysis study. *Design Studies, 9*(2), 86-94.

Erickson, F. (1998). Qualitative research methods for science education. In B. J. Fraser & K. G. Tobin, (Eds.) *International handbook of science education* (pp. 1155-1173). Dordrecht: Kluwer Academic Publishing.

Faulkner, W. (1994). Conceptualizing knowledge used in innovation: A second look at the science-technology distinction and industrial innovation. *Science, Technology, and Human Values, 19*(4), 425-458.

Fordyce, D. (1992). The nature of student learning in engineering. *International Journal of Technology and Design Education, 2*(3), 22-40.

Gardner, P. L., Penna, C., & Brass, K. (1996). Technology education in the post-compulsory years. In P. J. Fensham (Ed.), *Science and Technology Education in the Post-Compulsory Years* (pp. 140-192). Melbourne: Australian Council for Educational Research.

Guba, E. G., & Lincoln, Y. S. (1989). *Fourth generation evaluation.* Newbury Park, California: Sage Publications.

Ginns, I., Stein, S. J., McRobbie, C. J., & Swales, A. (2000). A case study of a gifted female primary school student grappling with a design and technology project.*The Australasian Journal of Gifted Education, 9*(2), 43-54.

Jones, A. (1997). Recent research in learning technological concepts and processes. *International Journal of Technology and Design Education, 7*, 83-96.

Jones, J. C. (1992). *Design methods*. 2nd Ed. New York: Van Nostrand Reinhold.

Lave, J., & Wenger, E. (1991). *Situated learning legitimate peripheral participation.* Cambridge: Cambridge University Press.

Layton, D. (1993). *Technology's challenge to science education.* Buckingham: Open University Press.

Lewis, T., & Gagel, C. (1992). Technological literacy: A critical analysis. *Journal of Curriculum Studies, 24*(2), 117-138.

Marton, F. & Pang, M. (1999, August). *Two faces of variation*. Paper presented at the 8th European conference for learning and instruction. Göteborg, Sweden: Göteborg University.

McCormick, R. (1997). Conceptual and procedural knowledge. *International Journal of Technology and Design Education, 7*, 141-159.

McCormick, R., & Davidson, M. (1996). Problem solving and the tyranny of product outcomes. *The Journal of Design and Technology Education, 1*(3), 230-241.

McRobbie, C. J., Ginns, I., & Stein, S. J. (2000). Preservice primary teachers' thinking about technology and technology education. *International Journal of Technology and Design Education 10*(1), 81-101.

McRobbie, C. J., Stein, S. J., & Ginns, I. S. (in press). Exploring Designerly Thinking of Preservice Teacher Education Students as Novice Designers. *Research in Science Education.*

Middleton, H. (2000, December). *Designing research to research design: Some methodological issues in researching design thinking.* Paper presented at the 1st Biennial International Conference on Technology Education Research, Gold Coast, Queensland, Australia.

Mumford, L. (1972). Technics and the nature of man. In C. Mitcham & R. Mackey (Eds.), *Philosophy and technology* (pp. 77-85). New York: The Free Press.

Oxman, R. (1999). Educating the designerly thinker. *Design Studies, 20*(2), 105-122.

Prawat, R. S. (1996). Learning community, commitment and school reform. *Journal of Curriculum Studies, 28*(1), 91-110.

Queensland School Curriculum Council (QSCC). (2000). *Technology: Years 1-10 syllabus-in-development pilot draft. Terms 1 to 3, 2000*. Brisbane: The State of Queensland.

Raizen, S. A., Sellwood, P., Tod, R. D., & Vickers, M. (1995). *Technology education in the classroom*. San Francisco: Jossey-Bass.

Roth, W.-M. (1998). *Designing communities.* Dordrecht: Kluwer Academic Publishers.

Schön, D. (1987). *Educating the reflective practitioner*. San Francisco: Jossey-Bass.

Shapiro, B. L. (1996). A case study of change in elementary student teacher thinking during an independent investigation in science: Learning about the "face of science that does not yet know." *Science Education, 5,* 535-560.

Stein, S. J., McRobbie, C. J., & Ginns, I. (2000) Recognising the uniqueness in the technology key learning area: The search for meaning. *International Journal of Technology and Design Education 10*(2), 105-123.

Stein, S. J., McRobbie, C. J., & Ginns, I. S. (2001). Authentic program planning in technology education. *International Journal of Technology and Design Education 11*(3), 239-261.

Travers, K. (1993, 12-15 December). *Design, the basis of engineering or just another subject?* Paper presented at the Australasian Association for Engineering Education, Auckland.

Winograd, T., Bennett, J., De Young, L., & Hartfield, B. (Eds.). (1996). *Bringing design to software*. New York: ACM Press.