ICT/ ELEARNING FOR DEVELOPING VISUAL SPATIAL THINKING IN UNIVERSITY SCIENCE TEACHING

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Abstract: This paper reports on two case studies (in Earth and Ocean Sciences and Engineering) that explored the potential of ICT/ eLearning in first-year university courses. Findings from the research supported the value of adopting three dimensional visualization software and eLearning tools to scaffold students' emergent visual spatial thinking and conceptual understanding. However, some constraints, which limited the potential of the ICT/ eLearning approaches, were also identified. The research contributes to increased understanding of appropriate conditions for the planning and application of ICT/ eLearning tools to bridge students' conceptual, visual, and spatial thinking in university-level science teaching.

1 INTRODUCTION

This paper reports on a two-year government-funded research project based at the University of Waikato, Hamilton, New Zealand, and which has the overall goal of documenting, developing, and disseminating effective and innovative eLearning practice. For the purposes of this research, we have defined ICT as including computers, mobile phones, mp3 players, CDs, DVDs, application software (word processing, spreadsheets, etc), and the Internet (for example). eLearning is defined as resources and activities using the Internet and the World Wide Web (Web) to support teaching and learning.

Findings from two case studies (Earth and Ocean Sciences and Engineering), in which ICT played an important role, will be presented as there were interesting similarities in how the lecturers used ICT to develop students' visual scientific thinking. Both cases were characterized by delivery of academic content through large-group lectures (delivered by senior academic staff) and lab-based practical sessions (supervised by tutors). Findings in this paper derive from the lab-based work, as it was in these sessions that students actively used ICT to develop visual spatial scientific thinking skills and bridge their application to field-based tasks. Such an approach, in which technology is used to scaffold learning, contributes to ongoing academic discussion about the relationship between the virtual and the real in the teaching of science. The paper's discussion focuses on the research approach adopted and the pedagogical implications of the findings as opposed to measures of student learning outcomes.

2 RESEARCH METHOD

The project has been guided by one overall research question that asks "How are different lecturers exploiting the potential of ICT/ eLearning to support university-level student learning?" This paper focuses on the presentation and discussion of qualitative data collected through lecturer and tutor reflections and facilitated student focus group discussions. The research project received formal university-level human research ethics approval and all people have participated on a strictly voluntary basis.

Consistent with qualitative research, a constant comparison approach to data analysis has been adopted (Lincoln and Guba, 1985). As data were collected, emergent themes were identified through a process of inductive reasoning (Braun and Clarke, 2006) and then reported, discussed, and debated by the entire research team at our regular meetings.

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3 LIMITATIONS OF THE RESEARCH

The participants in this research project represent a convenience sample of lecturers and students in one university-level context and are not representative of possible participants across different university settings. Nevertheless, a textured view of instructional practices and multiple participants' beliefs, expectations, and reactions to the implementation of different ICT and innovative pedagogical practices within that setting was obtained and, importantly, is consistent with research findings reported elsewhere (Levin, 2004; Patel, 2010; Whitworth, 2006). However, a key limitation of this study is the possible omission of relevant ideas and perspectives from people who were not included.

4 OVERVIEW OF THE CASE STUDIES

In both Earth and Ocean Sciences and Engineering, lecturers sought to exploit the potential of ICT to contribute to students' development of visual spatial thinking and to help them bridge from lab-based assigned exercises to real-world tasks. Students in the Earth and Ocean Sciences need to develop an understanding of the complexity, yet interrelatedness of the Earth's systems and the various visual means used to represent this complexity (Akpan and Strayer, 2009). In Engineering students must be able to visualize and rotate objects in three-dimensional space and to pictorially represent complex ideas. Across both disciplines, students need to use imagery and narrative to design, develop, and express abstract concepts such as time, energy, and space (Edelson, 2001; Kastens et al., 2009). Recent studies of the ways mathematicians and scientists think indicate that these professionals work in similar ways to generate and validate knowledge – and through a range of agreed practices. Not only do they use discipline-specific technical verbal languages, they also employ a range of mathematical, graphical, diagrammatic, pictorial, and other modalities of representation (Lemke, 2000).

4.1 Earth and Ocean Sciences and Google Earth (GE)

The Earth Science and Ocean Sciences case study investigated the impact of combining physical and eLearning activities for the development of geoscientific thinking and context-specific knowledge. Key goals of the Earth and Ocean Science degree program are to develop students' geoscientific thinking and practical skills, specifically their ability to think spatially, develop a geoscientist's understanding of time, view the earth as a complex system, and develop the necessary skills to conduct fieldwork (Kastens et al., 2009). At the University of Waikato, undergraduate papers in Earth and Ocean Sciences make frequent reference to landforms to help students develop an understanding of the earth's layers and how particular landforms have developed over time. Another key aim, particularly at first year level, is to prepare student for practical fieldwork. However, as the student population has become more diverse, an increasing number of learners have had no personal experience of the locations being studied. This lack of prior familiarity with the physical environment limits students' ability to maximize learning experiences in the field and develop competence in observation and data-collection – essential skills for an earth scientist.

Previously in the course, artifacts, such as maps and aerial photographs had been used with first year students, but the diversity of cultural and physical abilities in classes made it difficult to ensure satisfactory engagement and progress by all students. In addition, various multi-media approaches, including geographic information systems (GIS) and virtual fieldtrips, had been trialed as ways to develop students' scientific thinking skills but had been of minimal success due to cost, technological requirements, and user interface complexity. However, freeware such as GE (a virtual map displaying satellite images of the surface of the Earth) now provides an economical and simple interface with relatively low technological requirements. Accessing GE on university or personal computers is straightforward, with no specific licensing restrictions. Further, with the release of Google Streets for New Zealand, there exist a large number of web overlays for New Zealand locations that facilitate three-dimensional (3D) visualization (spatial thinking), with access to environmental data such as glacier extent and real-time wave and weather conditions. Thus, GE has the potential to facilitate new learning opportunities for a diverse range of teachers and students by supplementing physical space (the lecture theatre, labs, and fieldtrips). Moreover, the software's data are updated continuously and so that the virtual lab-based resources are more current than more traditional textbook or other print-based materials.

During the course, students attended lab sessions during which they utilized GE, in conjunction with maps and aerial photos, to examine physical objects around the University of Waikato campus and landforms in nearby locations. Having measured and examined local objects within the GE environment, students then stepped outside the lab and measured the same physical objects, such as a lamppost and bench seat, which they had been viewing virtually. The lab exercise developed students' proficiency using the GE navigation and measurement tools but also allowed them to visit (virtually) the locations referenced in lectures before their fieldtrip to a nearby West Coast ocean beach. As part of the fieldtrip activity, students compared their expectations, determined from the virtual GE "pre-visit", to the physical reality of the beach. In addition, they were later able to use GE to revisit fieldtrip locations and review what they had encountered in the field. Such ability to enhance physical activities through virtual exploration, to compare measurement of objects in GE with the reality of outdoor places, and to review fieldwork offered rich pedagogical opportunities to scaffold the development of visual and spatial thinking processes. However, what was not known were the possible constraints to students' learning posed by either the virtual-real scaffolding approach or GE itself and insight into these potential problems (and any other) were specifically sought in the case study.

4.2 Engineering and Computer-aided Design (CAD)

"Foundations of Engineering" is a compulsory, first-year course for Engineering students enrolled in any of the university's Engineering streams (Mechanical, Electronic, Software, Materials and Process, and Biochemical Engineering). The nature of the course is that it provides a broad introduction to engineering concepts, with particular emphasis on problem-solving and the design process. The laboratory component reinforces these concepts by requiring the students to complete a design/ build/ test group project in which students design, create, and then race remote-controlled model speedboats. During the initial four weeks of lab-based instruction, students are introduced to a CAD software package called SolidWorks© (a 3D drawing package), as knowledge of CAD is considered an integral component of most modern engineering disciplines. SolidWorks is widely used in industry where it is considered to be more intuitive to learn and use than the Pro/ENGINEER package previously used in the course.

As CAD is just one component of the course, not its primary focus, students' exposure to Solidworks is limited to a total of six hours of supervised lab time learning the software but with the possibility of using the computer lab in their own time or installing the software on their own computer. In the initial three-hour lab the tutor introduces students to the relevant tutorial exercises that accompany SolidWorks and helps them acquire some proficiency with it. During the final three-hours students are expected to use SolidWorks independently (but with the tutor still available to offer help as required) to draw a basic boat hull. Each boat-building group (syndicate) is expected to produce CAD drawings of the boat(s) they will build in the lab, however, it is usually only one or two people in the group who will work on the more detailed design drawings. No familiarity with CAD or drawing software is assumed although students are expected to be familiar with the use of computers.

From previous experience in the course, the lecturer knew that some students struggled through the CAD component and achieved the bare minimum, while others produced results far beyond what was required or expected. As with any student group, a range of abilities and motivations is to be expected, however, it was acknowledged that the process of introducing students to SolidWorks might not be as effective as it could be. Due to overall time constraints in the course, providing students increased supervised lab time was not an option but increasing eLearning support was a possibility. Thus, this case study sought to discover the main opportunities and constraints associated with the lab-based teaching of CAD software (specifically SolidWorks) and what tools or techniques could be employed to improve instruction.

5 FINDINGS

5.1 Developing Visual Spatial Thinking

5.1.1 Visualization of Key Course Concepts

The Earth and Ocean Sciences lecturer (L1) highlighted the value of GE as a tool to visualize key concepts in the course.

> I started playing with GE and thought, "We could use this" because it's visualizing [the]

earth's surface… GE allows us to visualize what is going on at a site in terms of shape and terrain. … It's one of the hard things for people coming into our area. Some people have good spatial skills, others don't. Our problem has always been how do we teach what we are doing to those who can't innately visualize spatial relationships.

L1's students supported the value of using GE as a tool to help them visualize landforms and other earth features.

It makes it easier because you're actually visualizing stuff, like real stuff. A topography map has mountains and that's nice, but you actually see real features [on GE], an old flood [plain] and bits of deposits. You can't see that on maps.

Similarly, the Engineering lecturer (L2) agreed that using SolidWorks was a valuable tool to aid students' visualization of 3D objects and drawings in the course.

In the past without the software, there may be some issues depending on how well the engineer was able to visualize things in 3D. You get a set of drawings which are on a 2D page with perhaps a 3D model then it goes off to be manufactured…. There would be much greater reliance on physical prototypes whereas the trend now is virtual prototyping. The CAD software helps you to develop CAD drawings that you can manufacture from.

L2's students agreed with the idea that SolidWorks was a valuable visualization tool.

We can use SolidWorks to draw up what we want the boats to look like and take that drawing instead of trying to visualize everyone else's talking and just discussing. You actually have to draw it up and everyone can agree on it.

5.1.2 Visual Manipulation of Ideas

L1 described how GE allowed his students to manipulate the viewing angles of land surfaces so they could visualize the interrelationships between different features.

The advantage of GE is that you can play around with it. You can change the view angle… GE in this course is really to get people to get some experience with it, but also to show the relationships between landforms and place.

The ability to manipulate the viewing angle to explore spatial relationships and concepts helped L1's students.

It was best when we were looking at beaches cause you could turn it onto its side and work out how steep the geography behind it was instead of looking straight down on it.

L2 valued the use of SolidWorks in giving students the opportunity to consider a design from different angles and orientations as part of the conceptualization process.

With the 3D software, because you have this ability to rotate and turn these images around, more reminiscent of holding it and looking at all the different surfaces, potentially you can see some of the issues there because you've got this ability to rotate it around and see all these angles.

L2's students reported being more motivated to learn when given this opportunity to easily explore and manipulate a design concept.

When you can actually just make it on the computer, make it 3D and be able to turn it around, that's just way better, just so much fun.

5.1.3 Visualization of Layers of Detail

L1 and his students both appreciated the fact that GE allowed access to a variety of information and level of detail.

and because it's an online resource, there's a whole lot of other things they can explore... sightseeing pictures, they can see other people's images, there are volcanoes and if you click on the volcano you get the latest data summary of its history, all these things pop up. Here's a tool, we want you to do this, but it's there for you to find other things.

Similarly, the SolidWorks software allowed detailed planning and designing in L2's course.

I've had to design brackets and that kind of stuff and to be able to do it all on a computer and see it all finished before you make it, is like a bonus… learning how to use it, you can design heaps of just anything… and that's what SolidWorks is all about. [student quote]

5.1.4 Learning the "Tools of the Trade"

L1 highlighted how adopting GE in the course could assist students to become familiar with the terminologies, functionalities, and skills of the Earth and Ocean Sciences professions.

In terms of GE, is to introduce them to the functionalities including measuring elevation and size of objects ... [this helps in] teaching students to look at all the information provided to them, thinking about the information on GE, ie what season is it, what is the angle of the sun.

L2 supported the importance of using authentic ICT-based tools to scaffold students' learning in

Engineering.

> … to introduce students to real tools that engineers will use, even if it's not SolidWorks, the CAD stuff is something that engineers will use…

5.2 Constraints Limiting the Potential of ICT

In spite of the potential of GE and SolidWorks, various constraints existed, for example a lack of time to practice and learn how to use the software and the heavy course demands at university level. L2's student stated:

> This [learning to use the software] almost needs to be a course in itself. It wasn't long enough for someone to teach us what we needed to know to design a boat. We can design a boat in here but that's only because of the steps and there is no way I can do it again if I get stuck somewhere.

In addition, significant resourcing and technical issues included inadequate numbers of computers for students to use in the formal GE lab sessions, insufficient numbers of tutors to assist students' lab-based work, and insufficient additional copies of SolidWorks (proprietary software) for students to download to their own computers.

A number of students reported that on their own they had located YouTube videos about using SolidWorks and other publicly accessible eLearning material, but such additional resources were not generally made available in the course. Students also faced problems such as losing files (Engineering), difficulty saving very large files on university servers (GE), and inadequate access to broadband from their homes (GE).

There were also key pedagogical issues across the courses. In Earth and Ocean Sciences, students expressed initial confusion about the objectives of the GE-based tasks, while in Engineering students stated that more detailed explanation and guidelines about the overall boat design project were needed.

Although SolidWorks was updated on a yearly basis, the eLearning tutorial material was not, which presented a number of mismatches between the software and the instructional documentation. L2 acknowledged this constraint and added that it was the company's responsibility to attend to this issue.

> Each year the company releases a new version [of SolidWorks]… [but] the built-in tutorials in the software haven't been updated to reflect the new version. The company needs to do this. The documentation needs to be accurate or else it throws students off but this [updating of tutorial material] isn't the case here.

Given that the tutorials were critical to the teaching of SolidWorks, yet were not up-to-date, the tutor was very busy answering students' questions during lab time. Something he did this serially and without structuring or restating for the entire group. Finally, in an attempt to assist as many students as possible, the tutor often took control of the mouse and after a few "clicks" put students back on the right track. As a result many students were unable to self-assess and correct future problems.

> Taking the mouse off me and then clicking around, he [the tutor] only had to do 2 clicks and he'd lost me. I didn't know where he'd gone. I don't know how he got there. So leaving the mouse in the students' hands and explaining the steps would be better.

6 DISCUSSION AND CONCLUSIONS

In New Zealand, as in other developed nations, the university sector is experiencing challenges to teaching and learning practice. Universities are increasingly adopting ICT and eLearning to engage and motivate students, to provide additional support for teachers, and to extend learning opportunities beyond the classroom walls. While insights from overseas research can guide and inform eLearning practice within New Zealand universities, we believe that the importance of developing a deep understanding of local contexts and practices cannot be underestimated.

A key finding in this research was that 3D visualization software, such as GE and SolidWorks could scaffold students' emergent visual spatial thinking and conceptual understanding. Specifically, the eLearning approach provided students with opportunities to perceive multiple layers of detail in visual representations and taught them how to use authentic "tools of the trade". While it might be argued that the best way to teach abstract concepts contributing to the development of visual spatial scientific thinking is through direct interaction with nature (Earth Science) or materials (Engineering), the reality of modern university teaching precludes or limits the extent to which students can be involved in either. Although in this research we found that ICT did contribute to the development of visual spatial scientific thinking and helped scaffold students' conceptual learning, the practical realities of a lack of appropriate resourcing and time constraints presented limitations. However, overwhelmingly the most serious constraints were pedagogical and lecturers needed opportunities to reflect on course planning, structuring, and assessment issues. In itself, this is not a surprising finding and has been reported elsewhere in published literature (Clark 2009; Crook 2008).

What was different about this research project was the multidisciplinary nature of the team and our regular face-to-face meetings. Through the sharing, debating, and reflecting upon teaching, participants' awareness of possible pedagogical refinements was raised. Whitworth (2006) in his discussion of research into eLearning environments advocates such a holistic and participatory approach, but acknowledges that this method can potentially lead to competing interpretations of research results. In fact, in our context we have not experienced competing views, possible because of the range of our disciplines, but rather have found that our regular and shared "conversations" about technology and its role in teaching and learning have been highly effective for extending our experience of the scholarship of teaching (Shulman, 1999). Such practice is consistent with Patel's (2010) definition of the scholarship of teaching in which practitioners engage in ongoing critical reflective practice about teaching, within a public interdisciplinary forum, and with the explicit goal of designing teaching activities such that meaningful learning can occur – arguably the intended objective of all pedagogical undertakings.

To sum up, the imaginative use of eLearning tools to bridge the virtual and the real domains and to develop visual and spatial thinking have contributed new and different opportunities for learning in our university environment. However, it was the frequent, targeted, and multi-modal communication of research data and emerging findings via face-to-face, print, electronic, and formal and informal communication that generated new opportunities for reflection upon technology-enhanced instruction. There is much to be gained from ongoing critical interdisciplinary discussion about the conceptual understandings that different disciplines share, and the role of ICT and eLearning within university teaching.

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