It only took 2 clicks and he'd lost me: Dimensions of inclusion and exclusion in ICT supported tertiary engineering education

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***Abstract**: Current conceptualisations of the digital divide have broadened beyond the notion of 'haves' and 'have nots' to include a more multifaceted perspective in which individuals and the contexts in which they learn are explicitly considered. This paper reports on a qualitative case study of a compulsory Engineering foundations course at a tertiary institution in New Zealand. The course provides a broad introduction to engineering concepts, with particular emphasis on problem solving, the design process, and use of 3-dimensional computer-aided design (CAD) software. Findings illustrate and illuminate the multidimensional nature of information and communication technology (ICT) inclusion/ exclusion and are described within three themes – technological, conceptual, and aspirational/ professional. Implications are presented for course designers and lecturers interested in providing more inclusive learning environments.*

Introduction

Current conceptualisations of the digital divide have broadened beyond the notion of 'haves' and 'have nots' to include a more multifaceted perspective in which individuals and the social, cultural, and cognitive contexts in which they learn need to be explicitly considered (Yu, 2006). Such change has been shaped by evidence that digital inequalities and inadvertent marginalisation persist in regard to tertiary student access to and use of information and knowledge (Kennedy, Judd, Churchward, Gray and Krause, 2008). Investigations of the complex nature of digital equity and inclusion have highlighted the need to examine the nature of the digital divide along dimensions such as student participation in tertiary institutions (Selwyn, 2010), and motivations for ICT use, types of ICT skills required and nature of ICT usage (van Dijk, 2005). These ideas recognise the inadequacy of mere individual access to ICTs and argue for their use "as and where appropriate" (Selwyn and Facer, 2007, p. 14) in order to exploit the full potential and affordances of ICTs and engage meaningfully with them. Existing Engineering programme goals have been critiqued as being too narrow in their focus and preparation of Engineering graduates, specifically with regard to their "knowledge, skills and attitudes that confer employability in the present and a foundation that enables them to function effectively and productively in the future" (Natarajan, 2009, p. 30).

This paper reports on a qualitative case study of a compulsory Engineering foundations course at the University of Waikato, Hamilton, New Zealand and was part of a larger-scale investigation of ICT/ e-learning across multiple disciplines. The study investigated pedagogical issues related to the uptake and adoption of CAD software (SolidWorks) within an Engineering course in which different student cohorts studied together. Our discussion focuses on the multidimensional nature of ICT equity and has implications for the creation of more inclusive digital learning environments. The paper is not concerned with learning outcomes, but rather focuses on how different cohorts reacted to using CAD software as a tool for learning basic engineering design concepts.

Research Context

Overview of the Engineering Course and 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 course 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 student groups (syndicates) to design, build, and then race remote-controlled model speedboats as part of an assessed task. During the initial four weeks of the course, students are introduced to SolidWorks during lab-based instruction. This software is used for teaching 3D visualisation, but moreover is a "real" CAD tool that engineers use in the workplace. Also, being able to manipulate CAD software so that changes can be made quickly to designs can increase engineering productivity.

As CAD is just one component of the course, students' exposure to SolidWorks was limited to six hours of supervised computer lab time. Students could, however, use the lab in their own time or install the software on their own computer. In the initial three-hour lab the tutor introduced students to selected tutorial exercises that helped them acquire some proficiency with the software. During the final three hours each student was expected to use CAD independently (but with the tutor available to assist) to draw a basic boat hull. Each syndicate selected one or two best designs, which the group then built together.

The course had an enrolment of 165 students. Of this number, there were two cohorts – 142 students enrolled in an Engineering qualification and 23 students enrolled in an Education qualification. This latter group was comprised primarily of mid-career trades people who were retraining as secondary school technology education teachers. In spite of the different groups' backgrounds and potential career paths, key resourcing issues (time, staffing, and access to software) limited the lecturer's choice to one common CAD tool.

From previous experience, 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, but the lecturer believed that procedures for learning how to use the software could be improved.

Research Methods

A qualitative, interpretive methodology framed the collection and analysis of the case study data (Maykut and Morehouse, 1994). Data was gathered from lecturer and tutor interviews, two student focus group discussions, an online survey about students' ICT/e-learning practices, and observation of students' lab-based use of SolidWorks. Consistent with qualitative research, a constant comparison approach to data analysis was adopted to identify emergent themes.

The participants in this study represent a convenience sample of a lecturer and students in one university-level context and are not representative of possible participants across different university settings. While the case study findings cannot be generalised to a wider population, nevertheless they can be related to similar tertiary education teaching contexts and can provide nuanced insights into digital equity issues and practices. The study received formal university-level human research ethics approval and all respondents participated on a strictly voluntary basis.

Findings

Three key themes emerged from the findings and highlight the complex and multidimensional nature of digital inclusion/ exclusion – technological, conceptual, and aspirational-professional. The technological theme highlights differences in students' background ICT competence along with key resourcing issues. The conceptual theme illustrates how students' prior conceptual knowledge and experiences lead to different learning preferences and expectations. The final theme demonstrates how differences in aspirational/ professional goals affected students' meaningful engagement with ICT.

Technological theme

Fifty five percent of the students in the course responded to the online survey. Of this number, 86% were from the Engineering student cohort, while 14% were from the Education cohort. Clear differences were noted between the groups as regards age and levels of engagement with ICTs for learning. The Engineering students were younger (78% were 21 or less) while all of the Education students were over 31. The survey indicated differences in terms of comfort levels in engaging with ICTs (see Figure 1). Almost 17% percent of Engineering students indicated that they loved experimenting with new technologies, while another 24% admitted to being an early adopter. However, none of the Education students loved experimenting with new technologies although 29% did admit to being early adopters.

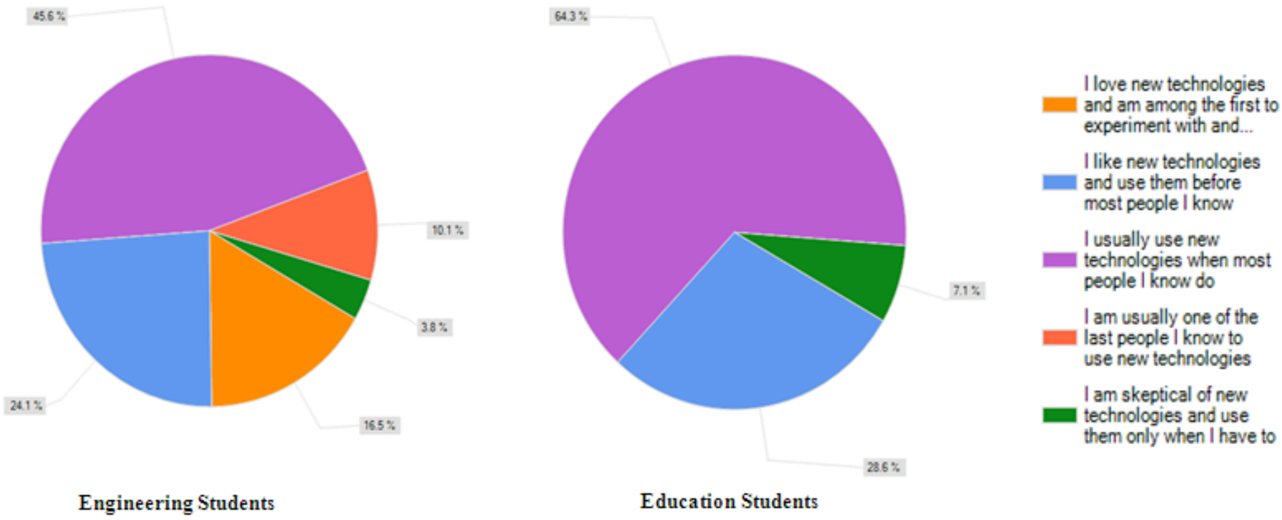

Figure 1: Differences in ICT engagement comfort levels among the student cohorts

In addition, significant course resourcing and technical issues existed including inadequate tutoring support for lab-based work and insufficient copies of SolidWorks (proprietary software) for students to download. Only one tutor ran each lab session (attended by about 20 students). Although there were ten copies of the software for students to borrow and download to their own computer, the logistics of accounting for the borrowed copies made this number inadequate to meet student needs. However, those who did manage to download SolidWorks found it worthwhile.

> I wouldn't produce the drawings [of the boat] I did if I didn't have it at home. It's been valuable to me, I wouldn't spend that time at university.

A lack of class time to practice and learn how to use the software, plus the heavy course demands at university level also inhibited students' learning of the software:

> Six hours is not enough, [it's] enough to give a taste but if you wanted everyone to go away with a little bit of knowledge on how to use the programme, maybe, maybe not. You've got to put the hours in yourself if you want to make the boat

Additionally, although SolidWorks was updated on a yearly basis, the online tutorial material was not. This created a number of mismatches between the software and the instructional documentation. The lecturer acknowledged this constraint but believed that it was the company's responsibility to update the material. Given that lab tutorials were critical to the teaching of SolidWorks, without accurate online resources the tutor was kept very busy answering students' questions during lab time. He attended to each student consecutively, but did not structure or restate information for the entire group. In an attempt to assist as many students as possible, the tutor often took control of the mouse and after a few "clicks" set students on the right track. As a result though, 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.

Students also found the online software tutorial material inflexible such that if they missed a step, they were unable to proceed without the tutor's assistance:

> The software tutorial, if you make a mistake, you have to sit and wait for [tutor] to help.

Conceptual theme

The difference in age and ICT engagement levels between the Engineering and Education cohorts was illustrated by the background conceptual knowledge and experience they brought to the lab. The tutor admitted that visual-spatial thinking skills were needed to fully engage with the software, but students who lacked these skills tended to struggle:

> Yeah, the whole dimension thing is really difficult for students. So for example, the positioning of a circle inside a square…some students just can't think to do that.

The Engineering students tended to be more intuitive and comfortable exploring the software. They were also willing to receive introductory explanations from the tutor and then explore on their own, something which the tutor believed was consistent with his teaching role. Nevertheless, the Engineering students would still have appreciated more tutor time spent on initial concept explanations.

> [I] found tutorials quite easy and straightforward…[I've] never drawn a hull nor been a boat builder but have an interest in building hulls in SolidWorks but don't know how to do it. [I] thought it was pretty cool when given the assignment, it was quite enjoyable!

> I would like him to take us through the real basics, the foundations, one by one get it up on the screen. So we each can virtually do it or there was a video which you can do at your own pace, and you can just click on it and watch it and it would just show you basic set outs. Then once you have that foundation then you can start doing things.

A number of Engineering students also reported that they had located YouTube videos about how to use SolidWorks, plus other publicly accessible online resources. However, these resources were not generally made available to students.

The tutor found the Education students faced more challenges in following the lab tutorials. The students reported that they would have preferred more advance organisers or a "big picture" approach to teaching.

> Ok, if they are not used to doing a lot of work on computer stuff, working from the tutorials, they will really struggle. Particularly for teachers [Education students]! The teachers are not used to following instructions. The students [Engineering students] have been through high school, they are used to following instructions so they'll be fine so they'll just go through. But if you have an adult student who is used to giving instructions not following them, then they can get quite angry if they get lost [Tutor].

> Show us the outline on the board, and say this does this, this does that, and if you click on this it will flip through the difference in the controls and you can get back to here. That would just help so much more….or "what we are trying to do here is…." [Education student].

The tutor assumed that both cohorts could learn the software sufficiently well based on his teaching approach but did not appreciate a need to respond differently to the groups. Students acknowledged the value of the tutor's help but would have appreciated more support in catering for different learning preferences.

> [Tutor] was very capable. Just got to be mindful that we all learn at different rates. If you had a video that you can actually look at, you can work through at your own pace. Even online tutorial or something you can take home and play with at home and learn would be good…or something you can watch more than once, doesn't have to be on the Net, can be on the uni's computer server so you can go in whenever you want… at your own pace.

There was also initial confusion about the objectives of the lab based tutorials and more detailed explanation and guidelines about the overall boat design project were needed. Students commented about being unsure whether the objectives were to learn how to use the software or to produce the boat drawings. The lecturer admitted that some learning objectives from the SolidWorks activities were implicit and not stated in the course outline – something that should be addressed.

Aspirational-professional theme

Both the lecturer and the Engineering students believed that learning SolidWorks could scaffold their learning of essential Engineering concepts by introducing them to authentic "tools of the trade".

> … 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 [Lecturer].

> This is like the basis of engineering, we are doing an Engineering degree where you design things and that's what SolidWorks is all about, it's like the common interest here [Engineering student].

Futhermore, the lecturer believed that using CAD was a valuable tool to aid students' visualisation of 3D objects and drawings in the course. Engineering students agreed likewise.

> 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 [Lecturer].

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

The Education cohort had a different view of CAD software. This course was the only required ICT-based one in their programme, and the CAD component represented a (relatively) small portion of only one assignment. Once students had submitted that assignment, no further commitment to learning about CAD was required. Thus the professional and aspirational goals of the cohorts resulted in different motivations for learning and different levels of meaningful engagement with SolidWorks.

Discussion and Conclusion

The findings from this case study illuminate the multidimensional nature of ICT inclusion/ exclusion in terms of technological, conceptual, and aspirational-professional themes and can contribute to better understanding of ICT equity within undergraduate Engineering teaching. These findings are consistent with and add to those reported elsewhere (van Dijk, 2005; Kirkwood and Price, 2005). They also have implications for course designers and lecturers interested in providing learning environments that are more inclusive for tertiary Engineering programs in which different cohorts might be enrolled.

Key resourcing issues need to be addressed if students are to successfully engage with ICTs, but given overall university constraints, that needs to occur in a fiscally neutral manner. For example, in this course, links to publicly available online SolidWorks resources could have been made available to the class in Moodle, the university's learning management system (which the lecturer used). Also, helping the tutor use more effective pedagogical strategies, such as consolidating and repeating instructions to groups of students would be a more effective way to teach.

Explicit recognition of students' varying levels of background conceptual knowledge, experiences, and learning preferences needs to be integrated into course design and instruction. A basic CAD learning task involves the construction and manipulation of geometrical shapes in a virtual 3D space while viewing the result on a 2D computer screen. Such complex learning activity requires time, careful planning, and scaffolding of student learning (Akasah and Alias, 2010). Developing structures so that diverse student cohorts can share knowledge and (together) learn to problem solve, share experiences, and learn from each another can facilitate richer teaching environments (Kumpulainen, Krokfors, Lipponen, Tissari, Hilppö, and Rajala, 2009).

Finally, the fact that students who enrol in a course have different goals, motivations, and aspirations requires that educators explicitly state course goals and learning objectives. Permitting some student negotiation of those goals, as relevant for their (students') needs, could be highly effective in addressing differences. Additionally, "up-front" training in how to use ICTs and making explicit their benefits for learning could facilitate student willingness to engage with technology in more meaningful ways (Kirkwood and Price, 2005). Careful curriculum design, monitoring, and lecturer reflection are essential for ensuring that teaching goals are aligned with, and supportive of students' learning goals (Johnson, Cowie, De Lange, Falloon, Hight, and Khoo, 2011).

Noteworthy from this case study is that the course lecturer reflected on the findings and then made incremental improvements to the course. For example, a second tutor is now available in the lab; additional copies of SolidWorks are available for downloading; and the online tutorial material accurately complies with the software. In recognition of improvements to his teaching practice and the subsequent positive feedback from students and colleagues, the lecturer was awarded a University Teaching Excellence award in 2010.

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