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Introduction

Two essential skills demanded of today's engineers are the ability to work effectively in teams and the ability to communicate effectively in written and oral forms. The importance of these skills is reflected in both the *Stage 1 Competency Standard for Professional Engineers* defined by Engineers Australia (2013)—upon which the accreditation requirements for engineering degrees are based—as well as the Australian Quality Framework specification for bachelor degrees in general (AQF Council, 2013).

Most meetings in the engineering workplace are currently conducted face-to-face, with some occurring in an official setting, such as in a board room or manager's office, while others are more spontaneous and informal in nature, taking place by the water cooler or at an employee's workstation. Increasingly, due to advancements in web-based and other rich-media synchronous online conferencing technologies, people have become accustomed to meeting virtually. Such technologies remove time and distance barriers, eliminating the need for travel and giving attendees flexibility in terms of how and from where they participate.

In a higher education setting, students stand to benefit substantially from the convenience and flexibility afforded by rich-media synchronous technologies (Bower et al., 2012; Bower, Kennedy, Dalgarno, Lee, & Kenney, 2014; Finkelstein, 2006; Smyth, Andrews, Bordujenko, & Caladine, 2011). Besides making it possible for geographically dispersed students to remotely attend lectures and even jointly undertake laboratory activities (e.g., Jara, Candelas, Torres, Dormido, & Esquembre, 2012), when applied to project-based or other teamwork contexts especially common in engineering courses, these technologies empower students to organise meetings around their disparate timetables and work commitments. At the same time, in order to ensure the engineers of the future have an understanding of how the technology can be used to support new modes of communication, it is crucial for them to learn both *with* and *about* the relevant tools as part of their studies. This paper contains preliminary findings from a study that examined how two different rich-media synchronous collaboration technologies were employed for project team meetings in an engineering design and management subject, and compared student uses and perceptions of each.

Rich---Media Synchronous Technologies for Collaborative Learning

A diverse range of synchronous online tools exists that can be used to facilitate learning and collaboration, with each offering different features, benefits, and drawbacks. Bower et al. (2012) identified three categories of rich-media synchronous collaborative technology and carried out a large-scale, Australia and New Zealand-wide survey aimed at understanding their usage by university educators across the sector:

- *video conferencing* platforms that allow participants to exchange detailed audio-visual information in real-time via microphones and cameras (including room-based video conferencing systems such as those made by Polycom as well as desktop-based solutions like Skype and Apple FaceTime);
- *web conferencing* applications that allow participants to see a common interface in their web browsers from which they can use features such as text, video and voice chat, whiteboards, desktop sharing/screen broadcasting, voting, file sharing, and collaborative authoring facilities together in real-time (examples of which are Adobe Connect, Blackboard Collaborate, Citrix GoToMeeting, and Cisco WebEx);
- *virtual worlds* that allow participants, by proxy of alter egos called avatars, to roam around a computer-generated three-dimensional (3D) environment, interacting with objects and with other participants' avatars in the environment (dominant platforms in this category being Second Life, Open Simulator, and

Open Wonderland).

There has been a convergence of the features and functionality found in web conferencing applications with those found in desktop video conferencing systems, to a point where the distinction between the two categories is now blurred. For example, Adobe Connect (http://www.adobe.com/products/adobeconnect), one of the most widely used web conferencing products, provides ‘pods’ for streaming webcam video (Figure 1).

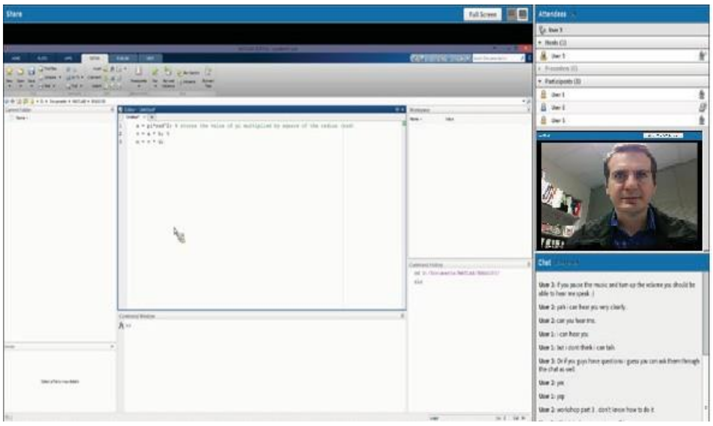

Figure 1: Typical collaborative scenario in Adobe Connect

Key benefits of web and desktop video conferencing include their affordances (Gibson, 1977) for strengthening social presence and fostering the exchange of affective supports, which are important for rapport and community building (Park & Bonk, 2007). However, what differentiates these technologies from virtual worlds is that while the former provide users with a flat, two-dimensional (2D) work area and toolset from which to choose, the latter offer a more open and unconstrained experience within an immersive 3D space users can freely navigate from a first-person perspective (Mikropoulos & Natsis, 2011). According to Dalgarno and Lee (2010), by exploiting the unique characteristics of 3D virtual environments as well as the construction of identity, sense of presence and co-presence arising from those characteristics, learning tasks can be facilitated that lead to better spatial knowledge development and to learning that is arguably more deeply experiential, engaging, contextualised, and collaborative than what can be achieved in 2D. Additionally, virtual worlds permit the use of natural semantics in the place of symbolic representations that may cause misconceptions and are difficult to learn and remember (Mikropoulos & Natsis, 2011).

One potential downside to virtual worlds is that they can impose on users a high level of cognitive load (Sweller, 1994), and this can be exacerbated by certain environment and task design decisions (Lee & Dalgarno, 2011; Nelson & Erlandsson, 2008). Furthermore, in contrast to a web conference in which users are able to see one another via video feeds, in virtual worlds the reliance on artificial representations (avatars) means facial expressions and body language cannot be seen—only represented synthetically. This can detract from the connectedness and social presence experienced by participants and the authenticity of interactions between them (Farley, 2015; Wang, Anstadt, Goldman, & Lefaiver, 2014). Many virtual worlds make it possible for users to invoke animations or other multimedia effects to convey emotions and gestures, but this is unwieldy and likely to add further cognitive load.

A relatively new entrant into the virtual worlds arena is iSee (http://www.isee-meetings.com), which brings together the communicative fidelity of desktop video conferencing with the spatial representation and interaction capabilities of 3D multi-user virtual environments. Floating windows called mevatars containing live video from users’ webcams and that can be moved around the virtual world are used in place of conventional avatars, and directional audio sensitive to the mevatars’ relative proximities makes it possible for multiple concurrent voice conversations to be held in a single contiguous environment

(Safaei, Pourashraf, & Franklin, 2014). Built into iSee is also the ability to create interactive boards to which a variety of file types (e.g., Microsoft Office documents, PDFs, images) can be uploaded for display and onto which users can mirror their computer desktops. Among the advantages of iSee is that it can accommodate a large number of video-based participants (over 50—see iSeeVC, 2014), unlike in web conferencing, where bandwidth and logistical factors often make it problematic for more than 10 users to simultaneously broadcast video (Bower et al., 2014). Figure 2 is a screen shot of an event in progress within an iSee meeting venue.

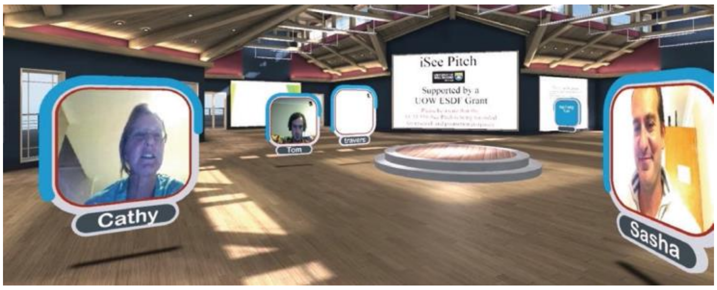

Figure 2: Typical collaborative scenario in iSee

The goal of the present study was to evaluate the efficacy and suitability of Adobe Connect, as an instance of a 2D web conferencing application with video capabilities, and iSee, a hybrid desktop video conferencing and 3D virtual world, from the point of view of engineering students using each of these platforms for self-organised online project team meetings.

Method

The context for the research was a third-year undergraduate engineering design and management subject catering to students majoring in electrical, computer, telecommunications, and mechatronics engineering at the University of Wollongong's Faculty of Engineering and Information Sciences. The subject is project-based and its aim is to provide students, working in teams of six to eight, with the opportunity to undertake a significant product development exercise from target specification through to product launch. Rich-media synchronous technologies were being trialled in the subject with a view to more permanent, longer term use and to application in other subjects. This took place amid a wider curriculum redesign and renewal exercise, and it was being done as part of a broader effort within the Faculty aimed at improving student engagement and satisfaction through the infusion of new online technologies and resources into learning and teaching (Nikolic, 2015; Nikolic, Ritz, Vial, Ros, & Stirling, 2015; Vial, Nikolic, Ros, Stirling, & Doulai, 2015).

The 80 students who were enrolled in the Autumn 2015 offering of the subject were divided into 12 teams. In formulating the teams, a deliberate effort was made to achieve equivalence in the ratio of male to female and local to international students in each team, as well as to incorporate in each a mix of students from the various engineering majors. The teams were required to conduct regular meetings, but were given considerable freedom and were largely unrestricted in terms how they conducted those meetings. For this study, six teams were allocated online meeting spaces within iSee (Version 1.3) and six teams were allocated spaces within Adobe Connect (Version 9).

Students were introduced to iSee and Connect in a tutorial session at the start of the semester, during which they were shown the basic functionality of each platform along with selected additional features. They were asked to explore the software and use it as they saw fit to support their team activities. A request was made for them to have at least four meetings using their assigned online spaces over an 8-week period, but this was not compulsory and was not assessed. The respective meeting environments were recorded for later review and analysis by the research team.

At the end of the semester, an email invitation was sent to all students, inviting them to complete an anonymous online survey. The survey instrument consisted of a mixture of fixed-response and open-ended questions, with the fixed-response questions including a number of Likert-type items that were adapted from Bower et al. (2014). Initial results from selected quantitative aspects of the survey are reported in the next section; more comprehensive findings from the survey as well as from analysis of the recordings will be presented at the conference and in a subsequent paper.

Results

A total of 25 survey responses were received, 12 from students who used iSee for team meetings and 11 from those who used Adobe Connect. The remaining two responses were from students who specified reasons for not participating in meetings using either software.

One of the opening questions in the survey asked respondents to specify the number of minutes it took them to learn to use the software. On this question, students who used iSee for their meetings reported a shorter mean learning time (M = 22.50, SD = 34.08) than those who used Adobe Connect (M = 27.73, SD = 34.74). In preparation to do an independent samples t-test, Levene's test showed no significant difference between the variances in the two groups, F(1, 21) = 0.009, p = .926. However, using the Shapiro–Wilk test, the data for both the iSee and Connect groups appeared to be significantly non-normal: for iSee, W(12) = .517, p = .000; for Connect, W(11) = .694, p = .000—though the distributions were similarly shaped, as assessed by visual inspection. Thus the Mann–Whitney U test, a non-parametric test, was employed to compare medians in this instance. This revealed no significant difference between the length of time that iSee (Mdn = 10.00) and Connect (Mdn = 15.00) users said they had invested in learning the software, U = 55.00, z = 0.711, p = .477.

Students were also asked to rate the ease of use of the software on a scale of 1 (easiest) to 10 (hardest). The boxplots in Figure 3 depict the perceived difficulty levels for each of the software packages. The data suggest students found iSee (Mdn = 3) slightly easier to use than Connect (*Mdn* = 4). The Shapiro–Wilk test pointed to there being a normal distribution for the Connect group, *W*(11) = .935, *p* = .461, but not the iSee group, *W*(12) = .785, *p* = .006. A Mann–Whitney U test was once again conducted. In this case, distributions for the groups were not similar, as assessed by visual inspection. Reported difficulty levels for iSee (mean rank = 10.08) and Connect (mean rank = 14.09) were not significantly different, *U* = 89.00, *z* = 1.447, *p* = .148. A post hoc power analysis demonstrated that on the basis of the comparison effect size that was observed (*d* = 0.58), a sample size of approximately 110 (55 subjects in each treatment condition) would be needed to obtain statistical power at the recommended .80 level (Cohen, 1988).

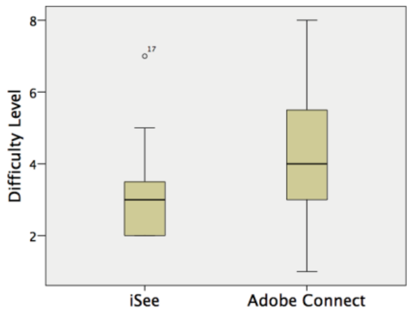

Figure 3: Student perceptions of the ease of use of the software

A subsequent set of questions invited students to rate their ability to effectively perform various communicative tasks using the software, using a 6-point Likert-type scale (ranging from *very strongly agree* to *very strongly disagree*). For the purpose of conducting between- group comparisons on these items, the responses of *very strongly agree*, *strongly agree* and *agree* were combined to form a single 'Agree' category, and similarly, *very strongly disagree*, *strongly disagree*, and *disagree* were merged into 'Disagree'. Fisher's exact test of independence was then applied, because the small sample size and the presence of expected values below 5 in more than 20% of the cells rendered it inappropriate to do a chi- square test (Starnes, Tabor, Yates, & Moore, 2014). Table 2 shows iSee tended to be rated more favourably than Connect for verbal communication, sharing of visual artefacts, and co- creation/sharing of material, though none of the differences were significant at the $p < .05$ level. There was no difference between the iSee and Connect groups in terms of perceived ability to effectively convey user status, with identical frequency counts occurring in both.

Table 2: Student perceptions of the communicative affordances of the software

Question	**Software**	***n***	**Response Category**		***p*[a]**
			Agree	Disagree	
Using the software, I was able to communicate verbally in an effective manner with my teammates.	iSee	11	10 (90.9%)	1 (9.1%)	.149
	Connect	11	6 (54.5%)	5 (45.5%)	
Using the software, I was able to effectively share visual artefacts with others (e.g., documents, images, photos, slides).	iSee	11	10 (90.9%)	1 (9.1%)	.149
	Connect	11	6 (54.5%)	5 (45.5%)	
Using the software, I was able to jointly create, edit, and share material with my teammates in an effective manner.	iSee	11	9 (81.8%)	2 (18.2%)	.635
	Connect	11	7 (63.6%)	4 (36.4%)	
Using the software, I was able to effectively indicate my status to others (e.g., wanting attention, agreeing, being unsure, etc.).	iSee	11	7 (63.6%)	4 (36.4%)	1.000
	Connect	11	7 (63.6%)	4 (36.4%)	

[a]Fisher's exact test (two-tailed).

The items on perceived communicative affordances were followed by another set of Likert- type questions intended to yield an understanding of how students perceived their connection to their team members while using the software, including the degree to which they felt a sense of co-presence with one another, the degree to which the software clearly and accurately represented information and participants, and the degree to which the software enabled collaboration among them (Table 3). Again, the responses were aggregated into 'Agree' and 'Disagree' categories and a Fisher's exact test was run. The responses from the iSee users were generally more favourable, with the differences approaching significance for the co-presence and collaboration items (both $p = .090$).

Table 3: Student perceptions of the degree to which the software enabled co-presence, representation and collaboration

Question	Software	*n*	Response Category		p^a
			Agree	Disagree	
I felt like I was present with my teammates during the online meetings.	iSee	11	11 (100.0%)	0 (0.0%)	.090†
	Connect	11	7 (63.6%)	4 (36.4%)	
The software provided clear and accurate representation of information and people.	iSee	11	10 (90.9%)	1 (9.1%)	.149
	Connect	11	6 (54.5%)	5 (45.5%)	
The software enabled collaboration to occur.	iSee	11	11 (100.0%)	0 (0.0%)	.090†
	Connect	11	7 (63.6%)	4 (36.4%)	

[a]Fisher's exact test (two-tailed).
†$p < .10$.

The final two Likert-type questions in the survey sought to determine the overall effectiveness of the software and meetings from the students' perspective. Table 4 displays the results. A larger proportion of respondents who used iSee were in agreement that the online team meetings were at least as effective as if they had occurred face-to-face (72.7%), as compared to the proportion of those who used iSee who were in agreement (40.0%). However, this difference was not significant at the $p < .05$ level. All iSee-using respondents would recommend the software for team meetings while only about half of Connect-using respondents would do so. This represented a significant difference ($p = .035$).

Table 4: Student perceptions of overall effectiveness

Question	Software	*n*	Response Category		p^a
			Agree	Disagree	
The online team meetings were at least as effective as if they had occurred face-to-face.	iSee	11	8 (72.7%)	3 (27.3%)	.198
	Connect	10	4 (40.0%)	6 (60.0%)	
I would recommend the use of the software for student team meetings.	iSee	11	11 (100.0%)	0 (0.0%)	.035*
	Connect	11	6 (54.5%)	5 (45.5%)	

[a]Fisher's exact test (two-tailed).
*$p < .05$.

Discussion

Adobe Connect and iSee are both powerful platforms for interpersonal and team collaboration, the former being a relatively mature product that is widely used in education and industry, and the latter a more recent market entrant. The major functions of the two platforms (video conferencing, document/image sharing, desktop mirroring), though not identical, are sufficiently similar so that it is not unreasonable to treat them as alike when comparing the 2D and 3D aspects. Possibly owing to the small sample size, there was no significant difference between iSee and Connect users' retrospective reports of the amount of time required to learn the software or of how difficult they found the software to use. However, it was apparent from the descriptive statistics that iSee was quicker to learn and easier to use. This most probably has to do with the fact that once students log in to iSee, they can see one another via their webcams and start a conversation with little or no additional setup required. The virtual world provides a familiar feel and sense of place, and when students come across an interactive board, the intended interaction is obvious. With Connect, students are presented with an array of built-in functions and options; unless a starting template is pre-configured, they can be confused as to where and how to begin. In this study, a minimal set of basic templates was provided, which may have caused frustration for Connect users, as evident from some of their comments (e.g., *"the software was just not easy enough to pick up* *and start using and have everything work the way we wanted"*).

On the survey items pertaining to perceived communicative affordances, a larger proportion of iSee users than Connect users were in agreement that the software gave them the ability to undertake effective verbal communication and to share visual artefacts with their peers. It is tempting to attribute the former, especially, to the 3D nature of the iSee environment, with its use of spatial audio to emulate the way face-to-face conversations occur in real life. However, the differences here were not statistically significant, again possibly due to the size of the sample. There was a negligible difference between the iSee and Connect groups in terms of their perceived ability to jointly create, edit, and share material, and no difference at all between groups in their perceived ability to indicate their status to others. This is not surprising as the modalities available for co-creation and sharing of material in both of the platforms are 2D, and hence it is fair to consider them equivalent for the purposes of this study (even within iSee's 3D environment, the material is displayed on flat boards). Moreover, students using both platforms would likely have indicated their status through text and/or video gestures—again, both 2D modalities. Both iSee and Connect also have a "Raise hand" function that can be used for status indication.

Based on student perceptions, iSee proved more effective than Connect at fostering co-presence and enabling collaboration among team members, at a level approaching significance. While this finding will need to be further explored and tested in follow-up studies using validated instruments, it seems consistent with the contentions of authors like Dalgarno and Lee (2010) who identify enhanced co-presence and collaborative learning as potential benefits of 3D virtual environments that set them apart from 2D alternatives.

Perhaps the most promising aspect of the results is that a significantly larger proportion of iSee users said they would recommend its use for team meetings, pointing to a higher overall level of satisfaction as compared with Connect users. This supports, albeit only to a small extent due to limitations in the research design, the notion that a 3D virtual world environment with in-world video conferencing is preferred by students for team meetings over a web conferencing application offering video within a 2D interface. Importantly, the present study did not use a within-subjects arrangement where each participant is exposed to both treatment conditions, nor did it account for a number of possible confounding variables associated with interface and environment design and with the specific activities undertaken by students during the meetings. Analysis of the environment recordings and open-ended survey responses should shed light on the precise reasons why students were overall more satisfied with iSee than with Connect, helping guide and inform future studies.

Conclusion

This paper has reported on a quasi-experimental study designed to compare 2D versus 3D rich-media synchronous collaboration technologies with respect to the perceptions and experiences of engineering students who used them for team meetings in a project-based subject. Since no technology possesses an inherent ability to give rise to collaboration or learning, there little value in attempting to make blanket claims about the superiority of one technology over another. This was not the intent of the present study. Rather, it must be recognised that context and purpose play an important role, as do the way(s) in which the technologies are actually used. Tentative findings point to immersion in a 3D virtual world augmented with live user video offering advantages over the use of 2D web-based conferencing, but the sample size was small, and as with most quasi-experiments, internal validity issues make it difficult to establish results with a high degree of certainty. In order to draw generalisable conclusions about the relative efficacy of the platforms, their attributes, and their constituent tools, randomised controlled trials are needed in which participants are given more tightly defined parameters within which to operate. As well, more targeted investigations are needed to pinpoint features or characteristics of the software to which particular benefits may be ascribed.

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