Full Paper

Introduction

Experimental learning, traditionally conducted in on-campus laboratory venues, is the cornerstone of science and engineering education. In order to ensure that graduates are exposed to 'real-world' situations and attain the necessary professional skill-sets, as mandated by engineering education program accreditation bodies such as Engineers Australia (www.engineersaustralia.org.au) face-to-face laboratory experimentation with real equipment has been an integral component of traditional engineering course work (Lowe, Murray, Li, & Lindsay, 2008; Sarukkalige, Lindsay, & Anwar, 2010). To satisfy accreditation requirements, the common practice has been to offer off-campus students equivalent remote and/or simulated laboratory experiments in lieu of the ones delivered, on campus, in face-to-face venues (Nedic, Nafalski, Ozdemir, & Machotka, 2011). Laurillard (2009) observed that the delivery of online courses tend to have a focus on technology, instead of pedagogical requirements.

In 2013, the successful submission for an Australian Government Office of Learning and Teaching (OLT) seed grant funded the development and verification of a research framework to explore the affordances of face-to face experimental learning environments where students may have access to real and/or simulated equipment (Banky & Blicblau, 2015). This recently completed project attempted to ensure that education, rather than technology, is the driver for the development of online experimental learning environments.

The provision of quality experimental learning venues has been identified as one of the greatest challenges for distance-education providers (Arbaugh & Benbunan-Fich, 2005; Sivakumar, Robertson, Artimy, & Aslam, 2005). The ability to delve deeper into venue offerings by benchmarking the pedagogical affordances of existing and future remote engineering laboratories will be extremely beneficial to the tertiary education sector.

Purpose

The purpose of this work was to assess the affordances of a real-time supervised augmented reality experimental learning (AuREL) proposal for off-campus engineering student experimentation. Augmented reality is an observer's view of the real world that is complemented by computer-generated inputs, thus enhancing the viewer's perception of reality. The application of augmented reality in this instance facilitates "online gesturing" by a remote supervisor.

Furthermore, the acquired data from this pilot investigation may be used, by content providers, to fine tune existing and/or future cyber facilities, in order to potentially obtain a vital advantage in the very competitive market of online STEM education.

Approach

"You know the place where nothing is real
Well here's another place you can go
… Looking through a glass onion." (Lennon & McCartney, 1968)

Data collection

Following the receipt of ethics approval from Swinburne University Human Research Ethics Committee (SUHREC), the data collection involved observing first-year electronics laboratory classes where students carried out their experiments, under real-time supervision, using real components and test instruments (a typical workspace is shown in Figure 1). The laboratory experiment the students were scheduled to undertake involved their introduction to the basic behaviour of a capacitor, and then to investigate the frequency characteristics of a simple resistor-capacitor (RC) circuit.

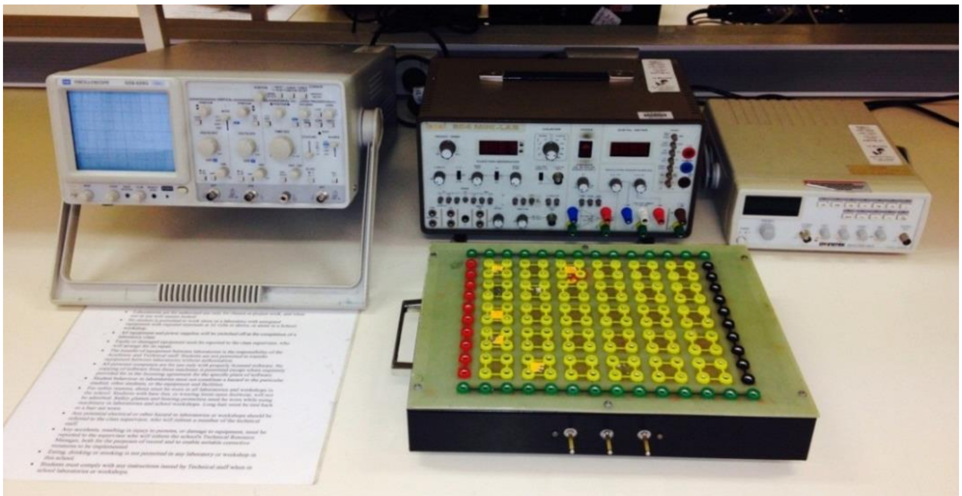


Figure 1: Example of face-to-face electronic systems experimental work space.

In this study, seven face-to-face laboratory sessions, with a maximum of twenty students in each, were observed. In a physically separate space, as shown in Figure 2, a volunteer group of two students were asked to perform the same experiment, as their peers in the face-to-face laboratory venue. The supervisors of these sessions were expected to guide all the students irrespective of their location during the session. With the use of augmented reality glasses, shown in Figure 3, from *META Co*. (www.getameta.com), the volunteer students were supervised remotely in real time, over the university's local area network (LAN). The configuration of this interconnection is shown in Figure 4. Since the supervisors were physically separated from the volunteer groups, the classroom collaboration software utility, *NetSupport School* (www.netsupportschool.com), facilitated communication between the various computers, which were used to collect the data.

Furthermore, the augmented reality feature of the glasses enabled the online mimicking of gesturing by the laboratory supervisor. This facility, together with bidirectional audio and unidirectional video links, provided the means to guide the students, who were physically separated from the class, while conducting their experimental work.

The activities of all participants, including the supervisors, were recorded for later analysis. A control group of two students in the face-to-face venue were asked to wear video glasses while the demonstrator interaction was captured with a fixed video camera directed towards the control group. The computer screen recording utility, *Camtasia Studio*® (www.techsmith.com), was used to record the remote group's activities, as well as the supervisor's interactions with them.

Figure 2: “Remote” experimental workspace for the volunteer group of students.

Figure 3: Augmented reality glasses used in this investigation from META Co.

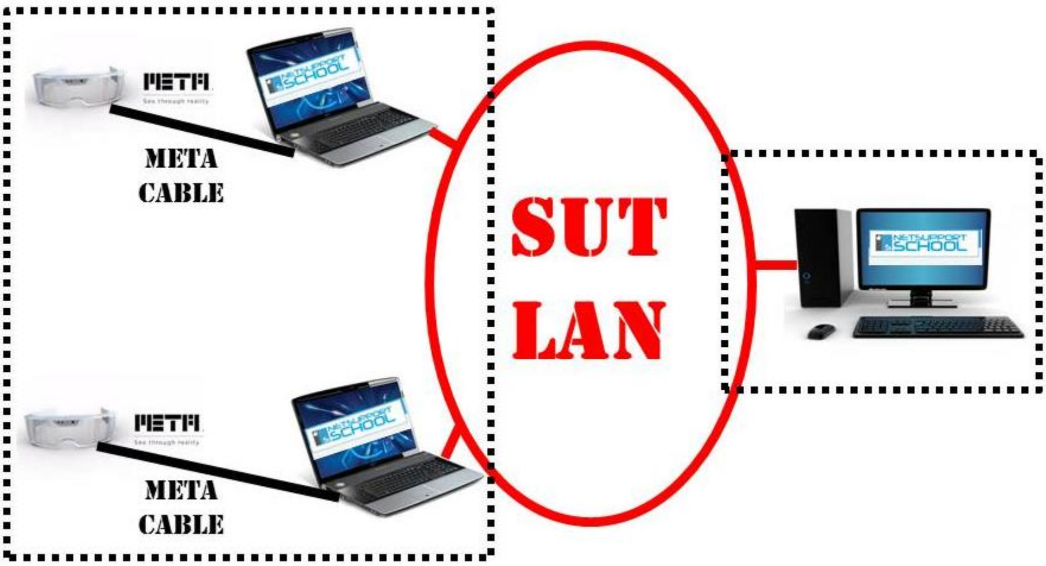


Figure 4: Configuration of remote supervision setup.

The foundation of the data analysis is to identify in the video data the occurrences of *kikan-shido* events (a Japanese term meaning '*between desks instruction*') as detailed by Clarke (2006). The process utilised a three-layered interpretive model for media-rich research into social interaction, attributed to Wortham and Derry (2006). This model ensures a traceable path from the analysed data, through any intervening depiction(s), back to the recorded data. One of the benefits of this technique is an implied link between the various data forms and the raw data. The identification of data in the video recordings was logged with the aid of *Studiocode*® (commercially available video analysis software from *Studiocode Business Group* (www.studiocodegroup.com)). These logs and the video recordings of the data collection sessions will result in permanent records that will permit a researcher and/or any other expert(s) and/or interested parties to repeatedly review the affordances depicted in the video recordings, thereby facilitating coding or re-coding at any time (Fraenkel & Wallen, 2006). Furthermore, in order to ensure internal code-recode reliability, the team adopted Miles and Huberman's (1994) recommendations that a random portion of each recording was independently re-coded on at least two occasions several days apart, requiring 100% agreement by the different researchers.

Benchmarking

An affordance measuring tool (Banky, Blicblau, Egodawatta, Vuthuluru, & Vcelka, 2015) was used to benchmark the implemented augmented reality experimental learning (AuREL) environment with respect to the face-to-face laboratory venue while the students conducted the same experiments in both settings. The term "affordance" describes how an object, or an environment impacts on the actions of its user and is attributed to Gibson (1977). Therefore, affordances must be context specific. In our context, the affordances of the laboratory environment includes teaching and learning activities such as real-time monitoring of student work, real-time collaboration between all the participants, etc.

The underlying methodology for this benchmarking activity is founded on the assumption that: *if affordances impact on activity then identified activity reflect on a venue's affordances.*

Preliminary Results

The analysis of the recorded data has commenced, however it is still proceeding at the time of writing this paper. For now, the preliminary results for the identified *kikan-shido* events, as described in Figure 5, are summarised in Table 1. The completed analysis outcomes will be detailed at the conference.

Discussion

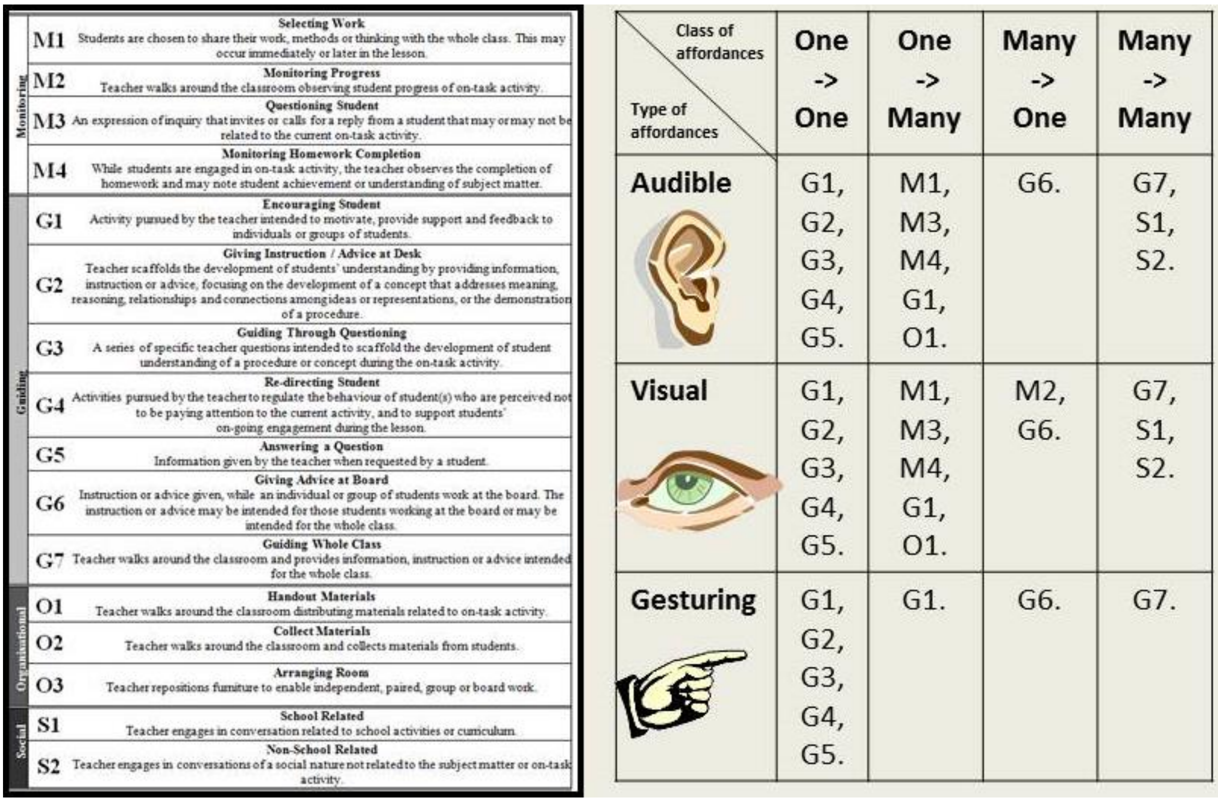
As mandated by ethics approval, the collected video data was de-identified for analysis. The analysis procedure focused on identifying and noting all supervisor-student *kikan-shido* occurrences, thereby ascertaining the affordances of both the face-to-face and the AuREL venues - the latter having been created with the glasses from META Co.

Since in this study, all the student groups were conducting the same experiments, and the AuREL environment was designed to facilitate the affordances of the face-to-face venue, it is the expectation of the research team that the *kikan-shido* events observed in both delivery modes (AuREL and face-to-face) will be the same, as evidenced in Table 1.

Figure 5 summarises the relationship between a *kikan-shido* occurrence ("M", "G", "O" and "S"), as defined in O'Keefe, Xu and Clarke (2006, p. 77), and the corresponding types of affordances within experimental learning environments.

Table 1: Preliminary results of video data analysis

Identified *kikan-shido* event	**Face-to-face**	**AuREL**
M1 - Selecting work		
M2 - Monitoring Progress	✓	✓
M3 - Questioning Students	✓	✓
M4 – Monitoring Homework Completion	✓	✓
G1 – Encouraging Students	✓	✓
G2 – Giving Instruction/Advice at Desk	✓	✓
G3 – Guiding Through Questioning	✓	✓
G4 – Re-directing Students	✓	✓
G5 – Answering a Question	✓	✓
G6 – Giving Advice at Board		
G7 – Guiding Whole Class	✓	✓
O1 – Handout Material		
O2 – Collect Material		
O3 – Arranging Room		
S1 – School Related	✓	✓
S2 – Non-School Related		



Monitoring	M1	**Selecting Work** Students are chosen to share their work, methods or thinking with the whole class. This may occur immediately or later in the lesson.
	M2	**Monitoring Progress** Teacher walks around the classroom observing student progress of on-task activity.
	M3	**Questioning Student** An expression of inquiry that invites or calls for a reply from a student that may or may not be related to the current on-task activity.
	M4	**Monitoring Homework Completion** While students are engaged in on-task activity, the teacher observes the completion of homework and may note student achievement or understanding of subject matter.
Guiding	G1	**Encouraging Student** Activity pursued by the teacher intended to motivate, provide support and feedback to individuals or groups of students.
	G2	**Giving Instruction / Advice at Desk** Teacher scaffolds the development of students' understanding by providing information, instruction or advice, focusing on the development of a concept that addresses meaning, reasoning, relationships and connections among ideas or representations, or the demonstration of a procedure.
	G3	**Guiding Through Questioning** A series of specific teacher questions intended to scaffold the development of student understanding of a procedure or concept during the on-task activity.
	G4	**Re-directing Student** Activities pursued by the teacher to regulate the behaviour of student(s) who are perceived not to be paying attention to the current activity, and to support students' on-going engagement during the lesson.
	G5	**Answering a Question** Information given by the teacher when requested by a student.
	G6	**Giving Advice at Board** Instruction or advice given, while an individual or group of students work at the board. The instruction or advice may be intended for those students working at the board or may be intended for the whole class.
	G7	**Guiding Whole Class** Teacher walks around the classroom and provides information, instruction or advice intended for the whole class.
Organisational	O1	**Handout Materials** Teacher walks around the classroom distributing materials related to on-task activity.
	O2	**Collect Materials** Teacher walks around the classroom and collects materials from students.
	O3	**Arranging Room** Teacher repositions furniture to enable independent, paired, group or board work.
Social	S1	**School Related** Teacher engages in conversation related to school activities or curriculum.
	S2	**Non-School Related** Teacher engages in conversations of a social nature not related to the subject matter or on-task activity.

Class of affordances / Type of affordances	One -> One	One -> Many	Many -> One	Many -> Many
Audible	G1, G2, G3, G4, G5.	M1, M3, M4, G1, O1.	G6.	G7, S1, S2.
Visual	G1, G2, G3, G4, G5.	M1, M3, M4, G1, O1.	M2, G6.	G7, S1, S2.
Gesturing	G1, G2, G3, G4, G5.	G1.	G6.	G7.

Figure 5: Mapping kikan-shido events, to face-to-face venue communication affordances (Banky, et al., 2015, p. 24)

Anecdotal observations from participants included the following:

- remotely supervised students felt “ignored” by the supervisors when their requests for assistance were delayed due to the supervisors helping groups in the face-to-face venue;
- goggles were heavy and difficult to wear for long periods of time;
- better training for supervisors in the use of the augmented reality gesturing feature;
- have dedicated supervisors for online supervision;
- overall, a great application that worked well and shows promise with some minor adjustments.

As already stated the great advantage of video recorded data, when compared with other data collection methods, is that each step of its analysis is permanently documented. Furthermore, the data collected in this way was free from participant bias that must be present with: student/staff experience surveys (Bodner, Wade, Watson, & Kamberov, 2013; Corter, Esche, Chassapis, Ma, & Nickerson, 2011; Lang, 2012), focus groups (Jarmon, Traphagan, Mayrath, & Trivedi, 2009), and selected participants’ reflective journals (Jarmon, et al., 2009; Lang, 2012).

Conclusions

Augmented reality experimental learning (AuREL) provides real-time online supervision for off-campus students who are experimenting with real components and real instruments while being exposed to the same affordances that a face-to-face environment offers. In both cases students can communicate with each other, as well as with their supervisor/demonstrator. The important issue for engineering academics, “hands-on” learning with real devices by their students (Loftus, 2013), is facilitated in an AuREL implementation.

It is anticipated that in 2016 an investigation into mixed reality experimental learning with haptic gloves (MiREL+) will commence. The use of haptic gloves will enable the “touching and feeling” of simulated holographic equipment in a real or virtual surrounding. In this proposed experimental learning environment, students will use virtual components and instruments, while being supervised remotely in real time.

The upside of such an environment is that potentially all experimental learning, for all science-based courses can be mimicked online with a student having access to: a smart phone as an audio visual display, a suitable headgear to hold the phone in place, an interface-able haptic glove with the ensuing system connected to a data communication highway such as the National Broadband Network (NBN). Even if the universities subsidise such equipment for each student, the recurring costs associated with such a scheme are anticipated to be magnitudes less than capital and consumable costs that are currently required to provide on-campus infrastructure to facilitate the necessary experimental learning in the sciences, engineering and bio-medical training.

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Acknowledgements

The authors are in receipt of a *Learning Futures Scholarship* from Swinburne University of Technology *Learning Transformations Unit.* Additionally, the authors wish to acknowledge the support received from the Science, Technology, Engineering and Mathematics Education (STEMed) Group within the Faculty of Science, Engineering and Technology at Swinburne University of Technology.

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