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Mimicking of face-to-face experimental venue affordances in an on-line real-time supervised remote experimental learning context

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ABSTRACT: The focus of this work was to identify the affordances provided by a head-mounted augmented reality immersive device for the real-time supervision of experimental learning for off-campus engineering student experimentation. The data collection involved recordings of two different first-year electronics laboratory classes; in one class, students were supervised in a traditional face-to-face environment, whilst in the second class, students were in an electronics laboratory, but supervised remotely, on-line, in real-time. In both classes, the students performed the same experiments using actual components and test instruments. Data from both types of classes were collected to establish kikan-shido events, so enabling the identification of affordances, which were present in both the face-to-face and remotely supervised experimental sessions.

Keywords: Affordances, augmented reality, experimental learning, kikan-shido, on-line real-time supervision

INTRODUCTION

In the fields of medical and technology education, a variety of augmented reality (AR) applications, commonly known as *apps*, are being developed for use with smartphones, tablets and other mobile devices. Computer interfaces tend to *…draw users away from the real world and onto the screen*, [while] *AR interfaces enhance the real world experience*. It has been suggested that *AR could enable: learning content in 3D perspectives; ubiquitous, collaborative, and situated learning; learners' senses of presence, immediacy, and immersion; visualizing the invisible; and bridging formal and informal learning*. AR's capability to present personalised views within physical space, has been its most often stated affordance [1].

In engineering, as in all sciences, laboratory work targets four broad educational objectives: conceptual understanding, design skills, social skills and professional skills. Some researchers have identified statistically significant differences in the learning outcomes of those students who are exposed to different delivery modes of laboratory experimentation that ultimately *could change the effectiveness of their education*.

Both partial and fully immersive technologies, such as augmented, mixed and virtual reality headgear, have been found to induce strong feelings of *presence* and encourage active participation. Mixed reality describes a view of the real world that has anchored virtual objects in order to treat them as *real*. The term *virtual reality* describes totally software generated realistic images, sounds and other sensations that replicate a real environment. The gaming community is the driver for the development of these devices aiming to enhance the game player's experiences; video game culture is a worldwide new media subculture formed by video games. The potential size of this community will ensure the on-going development of the headgear and its anticipated reduction in cost. In order for educators to harness the pedagogical opportunities of wearable technologies, it is crucial for them to develop an understanding of their potentials or affordances in and out of the classroom.

Experimental learning, traditionally conducted in on-campus laboratory venues, is the cornerstone of science and engineering education [2][3]. In order to ensure that graduates are exposed to *real-world* situations and attain the necessary professional skill-sets, as mandated by engineering education programme accreditation bodies, such as Engineers Australia, face-to-face laboratory experimentation with real equipment has been the dominantly preferred delivery mode in engineering course work. 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. This component of the curriculum tended to be handled with (unsupervised) on-line simulations, home experimental kits, or intensive laboratory weeks on campus or at other conveniently located physical venues.

The provision of quality experimental learning venues has been identified as one of the greatest challenges for distance-education providers [4]. The ability to delve deeper into venue offerings by benchmarking the affordances of existing and future remote engineering laboratories will be extremely beneficial to the tertiary education sector. Furthermore, 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 experiential on-line education, may use the framework for this investigation. In a letter of support, the EA National Manager Accreditation indicated that exposure to wearable technologies, in such a context, would ensure that all engineering graduates may have the opportunity to experience supervised experimental learning, in order to attain the necessary professional skill sets, as mandated by accreditation bodies, such as Engineers Australia.

The immersive on-line experimental environment that was implemented and evaluated, facilitated the student attainment of high quality pedagogical outcomes, as well as reduced social isolation and facilitated greater engagement from remotely-located student experimenters as highlighted by Nedic [5] and Considine [6].

For this work, the term *affordance* describes how an object or an environment impacts on the actions of its user, and is attributed to Gibson [1]. Consequently, affordances must be context specific. The wearable device chosen for this study was able to facilitate bi-directional audio (built-in microphone and ear-bud speakers) and uni-directional visual communication (with its frame-mounted video camera), as well as real-time on-line gesturing by a physically remote supervisor/demonstrator (via transparent display screens which are within its lenses).

The aim of this work was to examine the mimicking of face-to-face experimental venue affordances in an on-line real-time supervised remote experimental learning context. This was accomplished by identifying the affordances of an environment that was created using a head-mounted AR immersive device [7][8].

METHODOLOGY

The participants in this study came from a first-year engineering undergraduate cohort enrolled in an electronics subject. For this investigation (a total of 120 students), six, two-hour long, face-to-face undergraduate laboratory sessions, with a maximum of twenty students in each, were selected. Each session's attendees were divided into ten further groups of two students with two supervisor/demonstrators sharing the responsibility of looking after all the students in each session. As mandated by ethics requirements, the authors did not participate in the supervision of any student groups.

From the ten groups, one volunteer group of two students was observed and recorded, while completing the experiment in the face-to-face laboratory venue. A different volunteer group of two students was required to perform the same experiment in a physically separate space, while wearing optical see-through AR head-mounted devices from META Co. were used to remotely supervise this second group of volunteer students in real time. Such application of head-mounted devices have been identified to provide the ideal AR experience. In addition, it was able to facilitate bi-directional audio (built-in microphone and ear-bud speakers) and uni-directional visual (frame-mounted video camera) communication, as well as real-time on-line gesturing (AR overlay screen that floats within its lenses) by a physically remote supervisor/ demonstrator.

Following the receipt of the appropriate ethics approval, the data collection process focused on observing first-year electronics laboratory classes, where students carried out their experiment, under real-time supervision in a face-to-face venue, using real components and test instruments as shown in Figure 1.

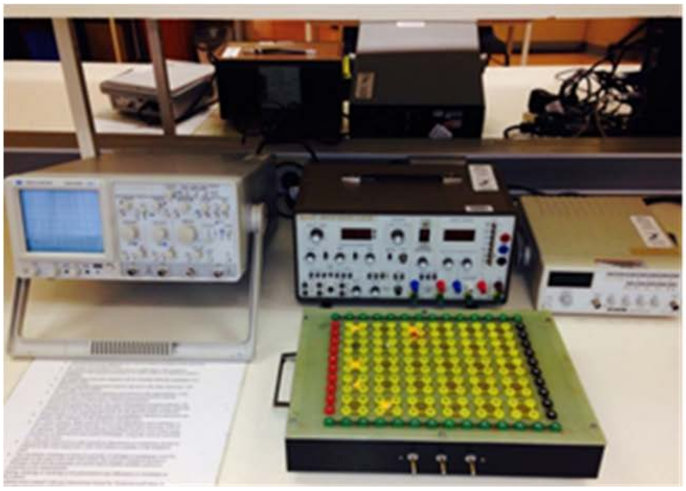

Figure 1: Experimental workspace used by all student.

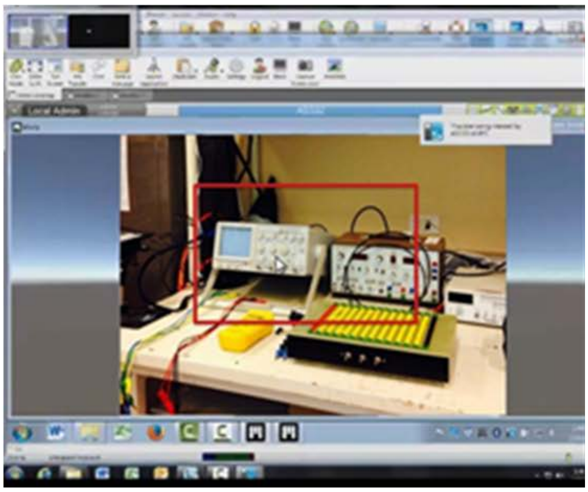

Figure 2: Supervisor/demonstrator computer screen showing remote experimental workspace.

The scheduled laboratory experiment involved the students' investigation of the frequency characteristics of a simple resistor-capacitor (RC) circuit. A desktop computer in the face-to-face laboratory was dedicated to the task of monitoring and communicating with the remotely located group. The supervisor/demonstrator observed the remote group's activities via the video camera in the students' headgear that was displayed on the desktop's screen. The supervisor/demonstrator was able to communicate audibly with the students via a telephone headset that was Bluetooth® connected to the desktop.

The only AR imagery utilised in this work was a virtual pointer, which satisfies the AR characteristics as a combination of real-world and virtual-world objects. The supervisor/demonstrator was also able to virtually gesture, with a cursor, as shown in Figure 1, by moving the mouse of the desktop. This cursor was visible to the remotely located students as an AR image in their field of view. Figure 2 shows the experimental workspace and supervisor/demonstrator-generated virtual pointer (cursor) as seen by the student, while wearing the AR headgear. The supervisor/demonstrator-generated cursor is seen inside the red rectangle, which represents the student's augmented reality field of view. The AR feature of the headgear enabled the on-line mimicking by the cursor of any hand pointing by the laboratory supervisor/demonstrator, while guiding those students who were conducting their experimental work physically separated from the rest of the class.

This cursor was visible to the remotely located students as an AR image of a moving pointer in their field of view. While the pointer was not anchored to the real world, it was under the control of the supervisor/demonstrator at all times, thus ensuring that it was only used for student guidance. Figure 3 shows the experimental workspace and supervisor/demonstrator-generated virtual pointer as seen by the student, while wearing the AR headgear. Thus, the student effectively viewed a combination of real and virtual items.

The computer screen recording utility, Camtasia Studio® running on the three communication computers, was used to record the remotely-located group's activities, as well as the supervisor/demonstrator's interactions with them. While a control group of two students in the face-to-face venue was asked to wear camera glasses, and their interactions with the supervisors/demonstrators were captured with a fixed video camera directed towards this group. In this way, the activities of all the student participants, and the laboratory supervisors/demonstrators, were recorded for later analysis.

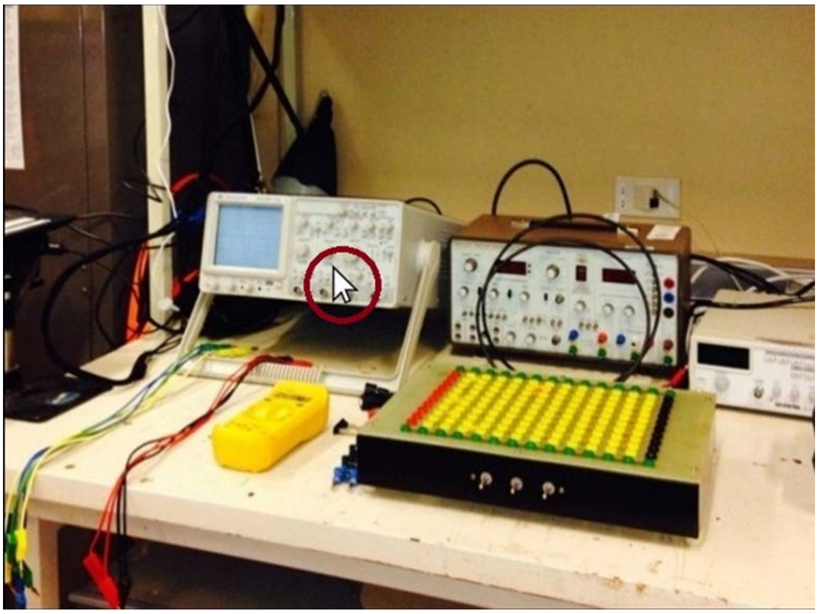

Figure 3: Virtual pointer (the white arrow cursor on the supervisor/demonstrator's screen) as seen by the student, while wearing the augmented reality (AR) headgear.

The attending laboratory supervisors/demonstrators were expected to guide all the students, irrespective of their physical location during the sessions. For the remotely located students, the classroom collaboration software utility NetSupport School, facilitated the necessary unidirectional video and bidirectional audio communication over the University's local area network. Extension of such implementation has been successfully implemented by Considine for a remote laboratory environment [9].

DATA COLLECTION AND ANALYSIS

Following the receipt of the appropriate ethics approval, the data collection process focused on observing first-year electronics laboratory classes, where students carried out their experiment, under real-time supervision in a face-to-face venue, using real components and test instruments. The foundation of the data analysis approach was the identification, in the video data, the occurrences of kikan-shido events (a Japanese term meaning *between desks instruction*) as detailed by Clarke [10]. Comparative studies of year eight mathematics and science classes in schools around the world have identified kikan-shido as a regularly practiced pedagogy during the supervision of problem-based teaching activities, particularly in mathematics and/or sciences based syllabi. Previous work in this area, has shown that the occurrences of such kikan-shido events have also been detected in undergraduate engineering experimental learning environments [11]. In particular, Banky et al have detailed the mapping between kikan-shido events (in terms of monitoring, guiding, organising and social) and the venue audible, visual and gesturing affordances that facilitate them for experimental learning [7].

The data analysis process utilised a three-layered interpretive model for media-rich research into social interaction. This technique ensures a traceable path from the analysed de-identified data, through any intervening depiction(s), back to the recorded data [12]. 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® (a commercially available video analysis software utility from Studiocode Business Group). These logs and the video recordings of the data collection sessions, result in permanent records that permit a researcher and/or any other expert(s) and/or interested parties to repeatedly review the kikan-shido events and the implied affordances depicted in the video recordings, thereby facilitating coding or re-coding at any time. The outcome of an OLT-funded seed grant in the form of an on-line video tutorial entitled: *Part 2–Data Analysis*, provided further insight into this technique [8].

A venue affordance-measuring tool was used to benchmark the on-line environment with respect to the face-to-face laboratory venue, while the students conducted the same experiments in both settings. In this context, the affordances of the laboratory environment needed to support teaching and learning activities, such as real-time monitoring of student work, real-time collaboration between all the participants, verbal and gestural communication, etc. The underlying methodology for this benchmarking activity was founded on the assumption that if affordances impact on an activity, then any identified activity will reflect on the venue's affordances. Furthermore, in order to ensure internal code-recode reliability, the independent coder adopted special recommendations for intra-coder agreement [13]. To implement this procedure, after completing the coding of all the recordings, a random portion of an un-coded copy of each recording (10%) was recoded by the independent coder on at least two occasions several days apart. A 90% or greater coding agreement on the outcomes for each such activity was required to establish coding reliability with a single coder.

FINDINGS AND DISCUSSION

In this study, all the student groups were conducting the same experiments. The on-line AR environment was designed to mimic the affordances of a face-to-face venue. Since the focus of this investigation was to examine the mimicking of face-to-face experimental venue affordances in a real-time supervised AR experimental learning context, a binary identification was adopted. This approach allowed the facilitation of an affordance, and not on how it may or may not be utilised during a laboratory session by the participants.

The outcomes of this investigation were the identification of affordances mapped from the occurrence of kikan-shido events. Consequently, a binary identification of kikan-shido events (reflecting affordances) was adopted. This analysis only recorded the fact that an event occurred, at least once, during the recorded class. Hence, non-observed events may not have been required in the context of the investigated laboratory classes. It is acknowledged that analysing for the number of times and/or the time taken for each kikan-shido occurrence would be an indicator of the participants' instructional and learning aptitudes.

It must be noted that analysing for the number of times and/or the time taken for each kikan-shido occurrence does not necessarily reflect on a venue's affordance. [14]. The kikan-shido events were observed at least once, in each delivery mode are summarised in Table 1, and identification of kikan-shido events are shown in the second and third columns of Table 1.

Table 1: Summary of analysis for the recorded session [7].

Identified kikan-shido event	AR (6 sessions)	Face-to-face (6 sessions)
Selecting work	0	1
Questioning students	6	6
Monitoring preliminary work	4	4
Encouraging students	3	3
Giving instruction/advice at desk	6	6
Guiding through questioning	6	6
Re-directing students	5	6
Answering a question	5	6
Giving advice at board	0	1
Guiding whole laboratory class	0	1
Handout materials	0	0
Collect materials	0	0
Arranging room	0	0
On-task related	0	1
Not on-task related	0	1

These indicate the number of sessions with corresponding kikan-shido events, where all the student groups were conducting the same experiment, and the on-line AR environment was designed to mimic the affordances of a face-to-face venue.

The following results were obtained:

- when the kikan-shido events were identified to be present in order to achieve the same experiences, the supervisory pedagogy requirements were the same;
- when no events were identified, the activity may not have been required in the context of the investigated laboratory sessions and/or could have occurred outside of the laboratory venue; and
- when an event occurred during face-to-face, but not for remote supervision the affordance was not facilitated with the AR-based venue.

It must be noted that, there could have been a sample-selection bias, in that the better students may have been more engaged and subsequently volunteered to participate in the intervention. Other biases potentially include student aptitudes, student motivations, student learning styles and student interaction preferences. While these may have an effect on quality of learning outcomes, they have no effect on the presence or absence of a venue affordance, which is the focus of this investigation. Furthermore, coder variability was minimised by using a single coder whose consistency was maintained by the techniques described earlier.

Anecdotal comments and observations after the experimental sessions from all the participants are summarised in the following:

- supervisors/demonstrators felt that they needed more detailed training in the use of the AR gesturing feature;
- greater field of view and better display resolution for the AR headgear would be extremely beneficial;

while the supervisors/demonstrators were engaged with helping students in the face-to-face venue, the remotely supervised students felt *ignored*, when their requests for assistance were not immediately forthcoming:

- the recommended option for on-line supervision should be the use of dedicated supervisors/demonstrators;
- head-mounted devices were heavy and became difficult to wear for long periods; where all participants agreed that, the application for the headgear worked well and showed promise (with some minor adjustments).

CONCLUDING REMARKS

The immersive on-line experimental environment, that was implemented and evaluated, facilitated the student attainment of high quality pedagogical outcomes, as well as reduced social isolation and facilitated greater engagement from remotely located student experimenters. The outcomes from the current work imply that AR provides real-time on-line supervision for both on- and off-campus students who are experimenting with real components and real instruments, while being exposed to the same venue 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, the delivery of hands-on learning with real devices to their students, appears to be facilitated in this implementation. It is the authors' contention that the findings are applicable to many laboratory experiments, which use real equipment.

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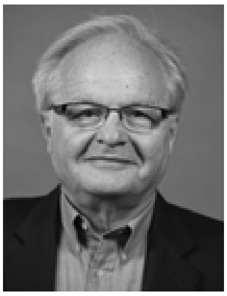
BIOGRAPHIES



George P. Banky (IEAust M'69 - CPEng'75 - IEAust F'12) became a Member (M) of Engineers Australia in 1969, a Certified Professional Engineer (CPEng) in 1975, and a Fellow (F) in 2012. In 1969, he received a BE (Elec) from the University of Melbourne, Parkville, Victoria, Australia, and a MEngSc in 1971 from the same institution. In 2010, he was awarded a PhD from the University of Melbourne's Centre for the Study of Higher Education (CSHE). His research focused on the delivery of on-line experimental/ experiential learning in university electrical engineering courses. He holds a patent for his MEngSc research outcome.

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