The Use of Wearable Technologies in Australian Universities: Examples from Environmental Science, Cognitive and Brain Sciences and Teacher Training

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Abstract. Innovation and increased access to wearable technologies are poised to inspire a new generation of technology-enhanced learning environments. Wearables provide students and teachers with hands-free access to contextually-relevant knowledge, which can be displayed as a 3D virtual world or overlaid on smart glasses, accessed via a smart watch or wristband, or used for providing biofeedback through EEG monitoring. A wide range of wearable devices is available, and it is often difficult for educators to introduce these advanced techniques into higher education contexts. This paper presents three examples of the kinds of educational applications that have been delivered in Australia and indicate key considerations for educators aiming to develop their practice and embed wearable tools into the classroom.

Keywords*: wearable technologies, technology enhanced learning, head mounted displays, brain imaging, augmented reality, virtual reality.*

1 Introduction and Rationale

There has been a rapid increase in the range of wearable technologies available to educators. Australian universities have set out their first initiatives for using wearable technologies in higher education and related activities. For instance, the University of South Wales uses virtual reality (VR) head-mounted displays in engineering (UNSW 2014), the University of Canberra (Canberra 2014) and Macquarie University (Macquarie 2015) have hosted workshops on the use of wearable technologies in education and training, and the University of Western Australia has used Fitbits in their Self eHealth Challenge (Glance et al. 2016). These are only the first steps into a more comprehensive use of wearable technologies in a wide variety of fields and activities in Australian higher education in learning, health and awareness raising contexts.

Wearable technologies are now available for use in a variety of higher education contexts, but in order for educators to harness the learning and teaching opportunities of wearable technologies, it is crucial for them to develop an understanding of the pedagogical application and technological and logistical issues associated with the technology. However, the scarce examples of application in higher education together with the limited literature on the use of wearable technologies for learning and teaching indicate that the possibilities of wearable technology in higher education are not yet well understood. While there is a need for more comprehensive knowledge and understanding about the uses of wearable technologies in education, other factors affecting technology innovation in higher education need to be considered and addressed.

In particular, a new generation of mobile learning curriculum design and pedagogy provide teachers with new combinations of educational potential for wearable technologies, including the ability to enable provision of in-situ contextual information, recording, simulation, communication, first-person view, in-situ guidance, feedback, distribution and gamification (Bower and Sturman 2015). Many of these, such as re-experiencing learning activities from the first-person point of view, have been supported by other recent research (Fominykh et al. 2015).

In this paper we provide an overview of the current context and introduce three projects that investigate the use of wearable technologies in Australian universities. The insights gained from these examples allow us to examine and compare wearable applications addressing different educational goals, settings and target groups, and offer practical considerations for educators implementing similar efforts.

2 Context

Wearable technologies use devices that are worn on the body. Wearable devices have been available for around twenty years but have become increasingly popular as technology improves, prices reduce and access is opened via greater broadband coverage. The most popular wearable devices include head-mounted devices, smart watches and health-monitoring wristbands, but the number and type of devices is rapidly increasing. As at 21st of June 2016, the Vandrico Wearable Technologies database (Vandrico 2016) included 436 devices across a range of sectors including fitness, medical, entertainment, industrial, gaming and lifestyle sectors. Examples of already popular wearable devices include: Fitbit, Nike+, Misfit and Jawbone wristbands, Apple and Garmin watches, Oculus Rift, Google Glasses and Google Cardboard headsets, and "newcomers" such as Xiaomi bands, Samsung Gear, Epson Moverio, Microsoft HoloLens, Magic Leap's lightweight AR, AMD Sulon and Meta One. Wearables are expected to expand their range into mind reading technology, hearables, wearable toys, smart clothing, smart coaching, lifesaving and even pet monitoring and GPS mapping (Wareable 2015).

While there is considerable literature investigating the development and use of wearable technologies across a range of fields other than education (for example, see Mahoney & Mahoney, 2010; Son et al., 2014), there is less research into the use of wearable technologies in education (exceptions include Coffman and Klinger 2015; de Freitas and Levene 2005; Wu et al. 2014; Yamauchi and Nakasugi, 2003, as discussed later in this paper). The limited literature on wearable technologies for learning and teaching indicates that the possibilities of wearable technology in higher education are not yet well understood. One of the reasons for this could be that educators are not familiar with the action potentials (Bower 2008) of wearable technologies. Another reason could be that the technology is so new that research has not yet been undertaken to inform applications. Few pedagogical models or frameworks can stimulate and inform their practice.

There are only a few empirical examples regarding the use of wearable technologies in education in the literature. In an early experiment, Yamauchi and Nakasugi (2003), used head mounted displays to provide street-view overlays of incidents from the past so that students could acquire a more experiential sense of history in the actual places of occurrence. More recently, Wu et al. (2014) used Google Glass during medical training role-play activities to provide a first-person viewpoint and recordings. In another recent trial by Coffman and Klinger (2015), teachers and students were provided with access to Google Glass to use during Educational Psychology and Organisational Behaviour classes. Outcomes from these trials include: students feeling a deeper connection with events and people (Yamauchi and Nakasugi, 2003), deeper student analysis and understanding of scenario-based practices (Wu et al. 2014) and seamless integration into student learning workflows (Coffman and Klinger 2015).

There is a current wave of enthusiasm and conceptual development from companies and institutions worldwide interested in making wearable technologies applicable to users. Examples include: using virtual and augmented reality to experience Earth as it was a hundred million years ago (BBC 2016), overlaying visual information of the Mars landscape for training purposes (NASA 2015) and seeing inside the work of Salvador Dali (Wired 2016), not to mention opportunities for disabilities, impairments and the provision of care or rehabilitation services.

3 Examples of Wearable Technology Applications in Australian Universities

In order to provide educators with models that exemplify the pedagogical potential of wearable technologies in higher education we present three examples from Murdoch University, Macquarie University and the University of New England in Australia. These projects detail the application and utility of using mobile wearable technologies in their particular domain: environmental education, cognitive and brain sciences and teacher training. In the following, we describe each one of the scenarios and experiences.

Conserv-AR - A Mixed-Reality Mobile Game to Promote Awareness of Wildlife Conservation in Western Australia.

Conserv-AR addresses the potential of using mobile, wearable, augmented and virtual reality technologies in natural environments for environmental education and community awareness. It is a serious game that engages students in a real-world experience to promote awareness of wildlife conservation in Western Australia. The current version is developed for the Epson's wearable smart glasses and it can also be run on Android smartphones and tablets.

The storyline of the game revolves around an excursion or field trip, where the player traverses a real-world course with the goal of gathering information about endangered species and their habitats, learning about wildlife-related risks and developing strategies to address conservation threats. The game includes a 3D virtual reality environment where users can review all the information collected during the excursion.

Figure 1. **Conserv-AR: A Mixed-Reality and Wearable Game for Wildlife Preservation**

Conserv-AR has been applied to environmental conservation at Murdoch University, specifically focusing on the Carnaby's Black Cockatoo, an endangered WA bird species (Phipps et al. in press). Murdoch students are using the application to gain an awareness and understanding of the campus natural environment (Figure 1). Automatic tracking of the activity will be used along with interviews and surveys to evaluate the usability and didactic effectiveness of this application.

Portable Teaching Laboratory: Using a Gaming Headset to Monitor Brain Activity in the Cognitive and Brain Sciences.

This project was designed to promote research-based learning and leveraged the latest in consumer-grade gaming technologies to deliver highly interactive lab-based learning experiences for undergraduate students in the cognitive and brain sciences. Specifically, a fully portable and cost-effective human brain imaging teaching laboratory was developed that implements the Emotiv EPOC EEG system (pictured). The EPOC is an affordable, wireless gaming system that monitors electrical brain activity. The EPOC has recently been validated as a research tool in the cognitive and brain sciences by several members of the team involved in this project (Badcock et al. 2013, 2015).

Building on this platform, a number of scaffolded lab-based research activities were developed and incorporated in the curriculum of the core unit for the undergraduate major in Cognitive and Brain Sciences. During the lab sessions, students work collaboratively in small groups to use the EPOC to visualise and record their own brain activity during the performance of simple experimental tasks (Figure 2). The interactive learning tasks give students the opportunity to explore and deepen their understanding of foundational concepts and methods typically used in the field of cognitive and brain science, as well as foundational research steps. Illustrating how these activities compliment the other learning activities in the unit are the following quotes from our 2016 cohort in which they describe the lab sessions as giving them "The sensation of being a real scientist and actually seeing what my own brain was doing" as well as "being able to put what we had been learning about into practice so that we could gain a better understanding of what the content was based upon."

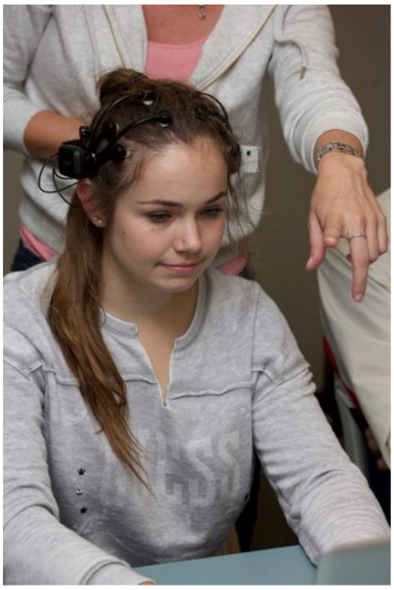

Figure 2. **Student of Cognitive and Brain Sciences Uses the Portable EEG System**

This exemplar project demonstrated how the latest in wearable technologies could be leveraged to adopt a research-enhanced approach to learning and teaching and provide a novel learning experience for students – an initiative awarded the Faculty of Human Sciences Dean's Citation for Innovation in Learning and Teaching. The successful implementation of this portable teaching lab in a first-year core unit has been vitally important as it has created a robust active-learning foundation for students pursuing a major in Cognitive and Brain Sciences. In addition, the project has provided a useful model for developing lab-based curricula that is extendable to other units in the Cognitive and Brain Sciences Program, as well as units in allied disciplines.

Virtual Teacher: Enhancing Virtual Teacher Professional Experience using Wearable Devices

This application uses wearable technologies in pre-service teacher education as a means of enhancing learning and engagement in virtual professional experience activities. This project builds upon the significant work by the case study leader in the creation of Virtual Practical Experience (VirtualPREX) activities (Gregory et al. 2013; Dalgarno et al. 2016) and the use of role-play activities in virtual worlds (Reiners et al. 2014) to examine how the Oculus Rift head-mounted virtual display can be used to enhance the presence and immersion of pre-service teachers practicing classroom management during virtual world simulation exercises.

Students undertake two 2-hour sessions in a 3D virtual world. The first session is an introduction on how to use the 3D virtual world using desktop computers, providing a context as to how it could be used as a teaching and learning tool. The second session utilises a VirtualPREX scenario (a 3D virtual world designed for teacher professional experience practice) for pre-service teachers undertake teaching role-play activities (Figure 3). For this second session there are two groups. Most students undertake the session in a normal context as described in the first workshop. The remaining students undertake the session using an Oculus Rift or similar wearable technology. Comparisons are then made between the two groups relating to their sense of presence, immersion and engagement. All students are invited to complete pre- and post-tests to gauge their perceptions of the impact of the wearable technology on their experiences. Open-ended responses relating to engagement, immersion and presence are also collected to see if there was a difference between those using the wearable technologies and those who were not.

These workshops are available to on campus or online students if they have access to the Oculus Rift. It provides insights into the use of wearable technologies to enhance immersion, presence and engagement in teacher education. Research undertake by this case study leader has been ongoing since 2008, however, the inclusion of wearable devices is in its infancy.

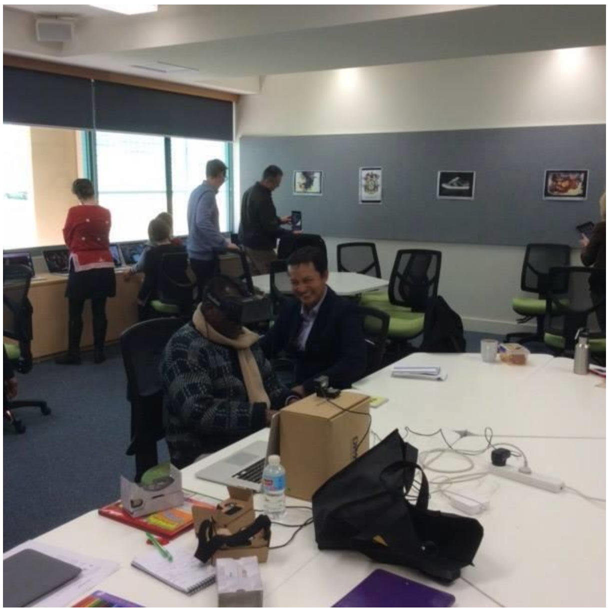

Figure 3. **Virtual Teacher: Students Engaging in Virtual Professional Activities**

4 Practical Considerations and Adoption in Education

The adoption of the use of wearables can be challenging, with costs of devices, technical support, pedagogic application and student readiness amongst some of the inhibitors to successful uptake in universities. We use a framework proposed by de Freitas and Oliver (2006) to allow comparison between studies and facilitate uptake. This 'four-dimensional framework' suggests that the four elements of context, pedagogy, representation and the learner need to be considered when evaluating the efficacy of game-based approaches. Similar considerations can be applied to wearable applications in learning settings.

The elements of the framework can be summarised as follows:

- The main purpose and use of the technology, including a consideration of the **context of use.**
- The **readiness of the student** cohort, including their technical abilities and comfort, age, subject of study and other demographics.
- The **pedagogy** to be used, including active learning, how the wearables will be used for teaching and learning.
- The **mode of representation** of the learning content (e.g. concepts, engines, mode of deployment, level of fidelity and interactivity).

Table 1 facilitates a critical and reflective understanding of the implementation and comparison between the three examples. Other benefits of using this framework include the provision of support for educators aiming to develop their practice and embed wearable tools into the classroom and reflection upon how wearable tools can support curriculum content most effectively.

In addition to the elements in the framework, the evidence from the three studies highlight the importance of other factors that need to be considered as part of the scheduling and planning of the case studies, such as quality and availability of resources, feedback and evaluation.

Wearable technologies provide a range of tracking mechanisms and their associated feedback processes and analytics. However the possibilities for capturing quantitative data are uneven, e.g. while devices such as sports and brain monitoring systems are specifically designed for biotracking and providing accurate and detailed data about the user in the context of the activity taking place, virtual reality headsets and smart glasses focus on the information that is displayed and require specific software programming in order to allow capturing quantitative feedback.

Table 1. **Application Examples, including an Overview of the Technologies Used, Mapped against the Four-Dimensional Framework (de Freitas and Oliver 2006) and an Outline of the Pedagogical Affordances (Bower and Sturman, 2015).**

Example	Context (Where?)	Learner specification (Who?)	Pedagogic considerations (Nature of learning activities)	Mode of representation (Learning tools)	Pedagogical affordances
Conserv-AR Wildlife conservation (Murdoch University, Western Australia)	• Outdoors (University campus and other outdoor locations) • Real outdoor settings based activities	• University students and a range of differentiated learners • Individually or in groups	• Authentic learning • Active learning • Learning outcomes: Increased empathy with animals, and consideration of how animals behave and act	• Augmented reality • Virtual reality • Smart glasses	• In-situ contextual information • Simulation • First-person view • Distribution • Gamification
Portable teaching laboratory (Macquarie University, New South Wales)	• University classroom • Laboratory based research activities	• University students (First years enrolled in the introduction to Cognitive and Brain Sciences unit) • Small groups (4-5 students)	• Research-enhanced and scaffolded activities • Lab-based experimental tasks • Structured group activity sheets	• Visualization and recording of brain activity • Research role-play • Gaming device	• In-situ contextual information • Recording • Simulation • First-person view
Virtual teacher (University of New England, New South Wales)	• University classroom (blended and online) • Professional experience activities	• University students (enrolled in teacher education) • Groups	• Role-play training • Enhanced immersion, presence and engagement	• Virtual reality • Head-mounted display	• Simulation • Communication • First-person view • In-situ guidance • Feedback • **Distribution**

Central to the design of case studies, evaluation should include an examination of how the wearable technologies impact upon student outcomes and satisfaction. Qualitative feedback can include analysis of student feedback, teacher perceptions as well as video and audio transcripts in search of factors that impact upon wearable technology learning processes. The combination of the use of quantitative and qualitative methods will allow presenting a more detailed evaluation of the case studies and enable future cross-case analyses.

5 Conclusions

Recent developments in technology enhanced learning, and particularly mobile wearable devices, can facilitate learning opportunities built on new educational affordances. In this paper, we outline the potential educational, social and research impact, and discuss possible applications of wearable technologies in higher education.

We describe three projects conducted in Australian universities that explore the application of wearable technologies in a variety of learning scenarios. These examples are compared using a framework that draws on an understanding of the context, pedagogy, technology and learners' needs for each case. In addition, we discuss other factors that can support evaluation, decision-making and uptake in educational settings.

This collaborative effort aims to improve understanding of the use of wearables in education and expand the opportunities for learning innovation within the academic and research communities in Australia and internationally. To that extent we call on any people interested in forming part of a community of practice relating to the use of wearable technologies to make contact with the authorial team.

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