

End-user programming and deconstructionalism for co-creative laboratory activities in a collaborative mixed-reality environment

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Abstract. As Immersive Learning matures, and moves from the lab to the market, there is an increasing need to provide non-technical users with simple but effective tools. An especially important need is the development of tools that empower instructors and learners to create and interact with Units of Learning (UoL) in a simple (non-technical) way that promotes creativity and engagement. End-user programming is a paradigm that allows users to “program” a sequence of actions inside technological environments to customise them. In this particular case, we analyse the use of end-user programming applied to education from two different perspectives: the learner and the instructor. Both are considered end-users and they can both create “programs” inside our learning environment. In this paper, we extend our previous work towards the *InterReality Portal*, our collaborative mixed reality learning environment. The *InterReality Portal* applies Problem-based Learning (PBL), a constructionist student-centred method, and co-creative learning in the realization of mixed reality laboratory activities for learning computing fundamentals based on a combination of *xReality* and *Virtual* objects using end-user programming to produce creative *Internet-of-Things* computer projects using collaborative interaction between geographically dispersed students.

Keywords. End-user programming; mixed reality; dual reality; xReality objects; blended reality; virtual laboratory; learning design; co-creative learning; constructionism; problem-based learning (PBL); Internet-of-Things; embedded-computing; immersive learning; deconstructionalism; interreality portal.

Introduction

The arrival of the Internet has acted as a catalyst for distance learners to experience new technologies to enhance the educative process. Examples include videocasts through online programs to diverse virtual learning environments (VLE), virtual worlds and even virtual laboratories. The increasingly connected nature of our world is driving an ever expanding virtualisation of our lives one of which opens a range of opportunities to experience education outside the traditional classroom. One of these

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approaches is the use of immersive learning, a combination of interactive 3D graphics, commercial game and simulation technology, virtual reality, voice chat, webcams and rich digital media with collaborative online course environments and classrooms [1] that promote possible solutions to the problems of presence and engagement by allowing the learners to participate and interact as if they were sharing the same geographical location [2] [3].

In this paper, we extend our research towards the creation and use of virtual laboratories by combining *xReality* objects, *Virtual* objects and learning activities within our mixed reality collaborative learning environment. We introduce, briefly, the implementation and conceptual architecture of our work-in-progress test bed – the *InterReality Portal* – and explore the use of end-user programming in learning activities. Finally, we provide conclusions and identify challenges to be addressed in our future research.

1. The InterReality Portal

Current research on laboratory activities for distance learners is focused on simulations, virtual laboratories and remote laboratories where there is no interaction with real equipment and the activity is mainly performed with idealized datasets and restricted collaborative interaction [4].

In previous papers [5] [6] [7] we presented a holistic conceptual model – the *Mixed Reality Intelligent Learning* (MR-iLearning) Model – as a research context for an innovative learning environment – the *InterReality Portal* (Fig. 1) – that allows geographically dispersed students to collaborate on mixed reality laboratory activities using combinations of cross reality (*xReality*) and virtual objects.

Virtual objects are elements that can only exist in a virtual environment (e.g. a virtual learning environment (VLE)) and all its characteristics and properties are linked to the existence of the virtual environment. *xReality* objects are physical elements that have a virtual representation of them in a virtual world. The main characteristic of these objects is their *dual reality state*, resulting from the data interchange between the real world and the virtual world, as is mediated by networks of sensors and actuators [8]. Each object, in the real and the virtual representation, is complete by itself and can exist without the other, however the *dual reality state* enriches both objects by the bi-directional process that can reflect, influence and merge real-time information. The interaction between physical and virtual elements within an environment can be defined as Cross-Reality (*xReality*) [9].

The ability of users to perform real-time work within a Cross-Reality environment, by switching context between environments and blend traces of one into the other in a socially unconscious manner – often seemingly as simultaneously – is defined as Blended Reality [10]. This allows users to extend realities and combine them as if they were one, avoiding the “*vacancy problem*”. Lifton et al. defined the “*vacancy problem*” as the capacity of user’s *presence* and engagement to a single reality at a time. This is a consequence of the user’s real immersion. A user can be absorbed in a virtual reality, having a lack of *presence* in their local “*reality*” during this time and vice versa [11].

Presence is a particular psychological experience described as the sense of “being there”. Applied to collaborative environments, *co-presence* is defined as the sense of “being there together” with other geographically dispersed users [12]. Immersion can be defined as the objective and measurable property of the system or environment that encompass both the physical aspects of the environment and the psychological sense of *presence* [12]. This enables a different idea of immersion, as virtual reality and the real world would become one, people concentrated in a particular task within the blended reality could be considered as completely immersed in virtuality/reality at the same time and space.

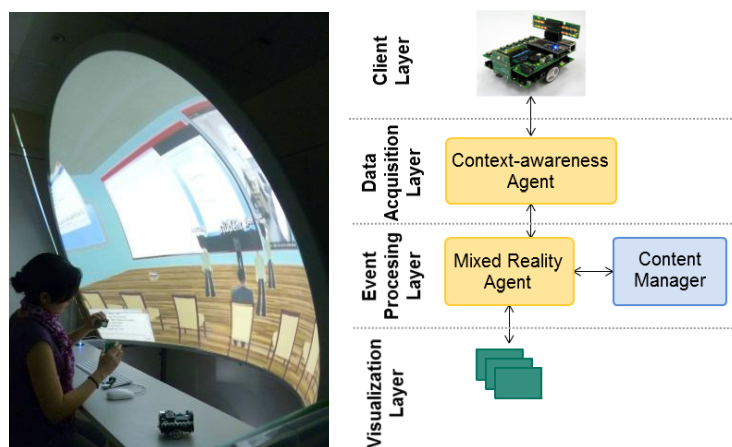


Figure 1. InterReality Portal (implementation & conceptual model) [5].

The learning goal of our mixed reality lab activity implementation is to produce *Internet-of-Things-based* computer projects grounded on co-creative and collaborative interaction between learners using problem-based learning (PBL), a constructionist method that allow students to construct their own knowledge by the correlation between concepts and proposed solutions to real world problems performed in realistic settings [13] [14].

1.1. Implementation

The implementation of the InterReality Portal is based on three major components:

- a) *A real environment:* To implement an immersive real environment we combine 1) a semi-spherical sectioned screen, the Immersive Displays Ltd.’s ImmersaStation², based on a specification from the sci-fi story “*Tales from a Pod*” [15]; 2) a camera that allows students to interact between them and the environment, 3) a network of sensors and actuators to obtain real-time information for object identification and replication for dual reality states. Although virtual worlds used on personal computers (PC) – “*Desktop Virtual Environments*” – introduce people to immersive technology, a Cave Automatic Virtual Environment (CAVE) provide a high-degree-of-freedom with the aid

² Immersive Display Group - <http://www.immersivedisplay.co.uk/immersastation.php>

of input devices and video tracking systems. Our implementation, the eDesk, delivers the characteristics of a CAVE and includes a desk allowing the user to be sit in a natural position to perform learning activities, with a free-range of head movement without the need of any intrusive body instrumentation (e.g. special glasses).

- b) *A 3D virtual environment*: Wann & Mon-Williams defined a 3D virtual environment as *an environment that capitalizes upon natural aspects of human perception by extending visual information in three spatial dimensions* [16]. For the implementation of the *InterReality Portal*, we use Essex University's MiRTLE project as our virtual environment. MiRTLE is a 3D-VLE that promotes teacher/student interaction for remote learners by linking a physical classroom with a virtual classroom providing an instructional educational setting [17] [18]. Created on Open Wonderland³, a java-based open source toolkit for creating collaborative 3D virtual worlds, MiRTLE provides some of the benefits of the use of virtual worlds in remote education such as social interaction and sense of presence and engagement within the class [2]. By taking MiRTLE as our 3D virtual environment, we extend its use from an instructionist 3D-VLE to a constructionist model for co-creative learning.
- c) *xReality objects and Virtual objects*: for the construction of mixed reality lab activities, we utilise Fortito's Buzz-Board Educational Toolkit⁴ (Fig. 2) [19]. This educational toolkit comprise 30 pluggable hardware boards that can be interconnected, and together with software modules can create a variety of *Internet-of-Things* applications [20] such as mobile robots, mp3 players, heart monitors, etc. The hardware boards allow discovery and identification via network events. The hub base board can be integrated with mbed microcontrollers⁵ or with Raspberry Pi⁶ – the low-cost computer able to work with Linux – improving the possibilities of creativity, ease of use and integration with diverse IDEs and end-user programming tools.



Figure 2. Fortito Educational Toolkit.

³ Open Wonderland Foundation - <http://openwonderland.org>

⁴ Fortito Educational Technology - <http://www.fortito.com/buzz>

⁵ Mbed - <http://mbed.org>

⁶ Raspberry Pi Foundation - <http://www.raspberrypi.org>

2. Co-creative Mixed Reality Learning Activities

Learning activities within the InterReality Portal are structured as a sequence of activities based on the IMS Learning Design specification. This sequence of activities – Units of Learning (UoL) – can be preceded by zero or more conditions before starting or completing the tasks [21].

In the implementation of our test bed, the learning objective is to build a computer science project combining hardware (xReality objects) and software modules (virtual objects) to create *Internet-of-Things* (IoT) applications emphasising computing fundamentals.

Figure 1 illustrates the conceptual model of the *InterReality Portal* and figure 3 exemplifies the interaction between system components when a collaborative *Virtuality Continuum Learning Activity* is taking place. In both, the *Context-awareness* agent (CA) identifies the object(s) (xReality or/and virtual), actor(s) and learning activity to be completed. Then sends this information to the *Mixed Reality* (MR) agent in the *Event Processing* layer. The MR agent obtains, from the *Content Manager*, a set of rules and behaviours available for the identified object. This information is sent to the *UoL Manager*, which constructs the sequence of activities in the UoL. Finally, the MR agent reacts by performing an action within the *Virtualization* layer. In the case of an xReality object creates a *single dual reality state*, a virtual representation of the change in the object.

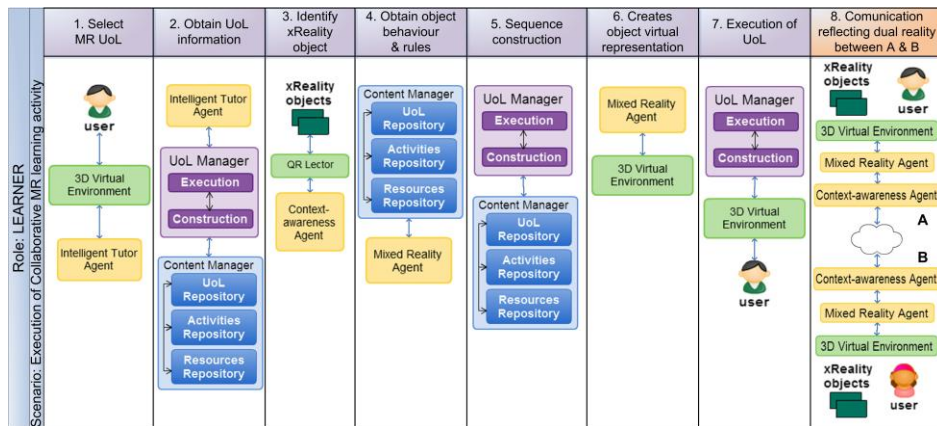


Figure 3. Execution of a Collaborative MR learning activity [5].

To perform a collaborative learning activity, after the establishment of a *single dual reality state*, the *InterReality Portal* establishes communication with other remote learners and creates a second representation of the event performed in the first environment, thus extending the *single dual reality state* to *multiple dual reality states* (Fig.3 & 4). As long as the session continues, changes in any of the objects will be managed by the Context-Awareness agent and the Mixed Reality agent considering the following scenarios:

- a) A change in any Virtual object of a given InterReality Portal results in identical changes to all subscribing InterReality portals.
- b) A change in an xReality object of a given InterReality Portal results in changes in the representation of the real device on all subscribing InterReality portals.

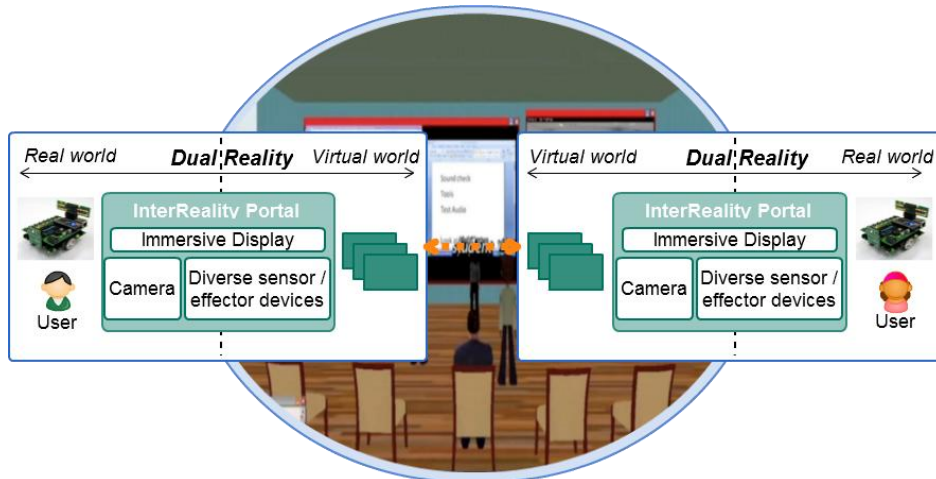


Figure 4. Multiple dual reality states [7].

3. End-user programming for Co-creative Mixed Reality Learning Activities

The interaction between users and the co-creative mixed reality learning activities can be analysed from two different angles:

a) From the learners view: During the learning session when they interact with the environment and between them, they are programming a series of actions to be executed by the objects.

b) From the instructors view: While they are creating a UoL, they are establishing a sequence of activities to be performed by the learners during the educational session.

In both cases, the learning environment should allow users to create and execute learning activities regardless their expertise on computers. Chin et al. [22] proposed a classification of rules to identify and separate the behaviour of different actors inside an intelligent environment: *pre-programmed rules*, *agent-generated rules* and *user-generated rules*.

Pre-programmed rules are usually created by the developers or manufacturers to define the properties and capabilities of the objects/services, in the case of our xReality object implementation these are the pre-programmed code inside buzz-boards or the properties assigned to each virtual/xReality object. *Agent-generated rules*, created from intelligent agents, artificial intelligence or machine learning mechanisms. These are the rules generated by the Context-awareness agent (CA) and the Mixed Reality agent (MR) when the user interacts with the environment (Fig. 1). Finally, *user-generated*

rules created by the users via end-user programming. These involve the creation of UoL by instructors and the execution of UoL by the learners to create Internet-of-Things projects. End-user programming can be defined as a number of techniques that allow non-technical people to create “programs”, which describe a sequence of actions to be performed by a particular environment [23].

To create *user-generated rules*, different approaches have been used to encourage and empower users to create programs. One approach is the use of drag-and-drop programming. In this, graphical representations of objects (e.g. an icon of a physical artefact), statements (e.g. an if-then-else conditional expression) and variables are transformed into concrete objects that the user can see and manipulate, *making them easier to understand through tinkering and observation* [24]. Some examples of this are MIT’s *Scratch*⁷, Carnegie Mellon’s *Alice*⁸ and Kent University’s *Greenfoot*⁹ in which users ‘assemble’ different objects and statements to create blocks that represent a form of algorithms without knowing logic programming or a particular programming language. The forms of each graphical representation allow only to assemble particular items in order to avoid errors due to grammar syntax.

Ko et al. identified six learning barriers, aspects of a programming interface that are prone to generate invalid assumptions and thus produce an error. These are: a) design (*I don’t know what I want the computer to do...*), b) selection (*I think I know what I want the computer to do, but I don’t know what to use...*), c) coordination (*I think I know what things to use, but I don’t know how to make them work together...*), d) use (*I think I know what to use, but I don’t know how to use it...*), e) understanding (*I thought I knew how to use this, but it didn’t do what I expected...*), and f) information (*I think I know why it didn’t do what I expected, but I don’t know how to check...*) [25]. A benefit of program visualisation is that frustration associated with debugging is minimized because students can directly map instructions to the result of what they see onscreen [26]. These “programming” environments are based on Papert’s constructionism theories and implement some of the ideas of Papert’s Logo, a computer language designed specifically for children [27].

A particular use of end-user programming tools is the possibility to create “programs” for diverse pieces of hardware to interact with the real world. Projects such as The Playful Invention Company’s Picoboard¹⁰, integrate visual interfaces for programming real-world prototypes. However, these solutions do not consider options for collaborative work for geographically dispersed students.

From the instructor point of view, the use of Learning Management Systems (LMS) – such as CooperCore¹¹ or LAMS¹² – could be considered as an end-user interface to implement the structural specification of IMS Learning Design into VLEs. We should remember that LMS also considers the learner’s perspective, by allowing

⁷ MIT Media Lab Scratch - <http://scratch.mit.edu>

⁸ Carnegie Mellon University Alice - <http://www.alice.org/>

⁹ University of Kent Greenfoot - <http://www.greenfoot.org/door>

¹⁰ Picoboard - <http://www.picocricket.com/picoboard.html>

¹¹ CooperCore - <http://coppercore.sourceforge.net>

¹² LAMS Foundation - <http://lamsfoundation.org>

them to perform UoL previously created by the instructor within the LMS environment; however, learning activities inside LMS environments currently do not consider the use of cross reality elements, therefore learner's perspective in LMS is not considered in our research.

Some work on the integration of instructor's perspective (LMSs in virtual worlds [28] [29]) and learner's perspective (end-user programming software [30] [31]) into virtual worlds has been done. Ibáñez et al. [29] explore the integration of LMS, mixed reality activities (using virtual objects) and collaborative activities, however the use of xReality objects mixing real objects and virtual objects to promote a co-creative learning process between a group of learners has not been explored yet. Additionally, the integration of end-user programming software with virtual worlds have been used to create collaborative simulations inside the virtual reality [31], available only in the virtual world.

Clearly, the combination of both perspectives in 3D Learning Environment could provide homogeneity and structure to the creation of mixed reality learning activities, adding collaborative learning [32] on xReality objects to current research on this area.

3.1. Using the Deconstructed model

One proposed solution is the use of the *Deconstructed* model. Based on the disaggregation of physical/logical devices and services, this model propose the creation/identification of a number of elementary services (atomic functions) which can be combined in various ways to create complex functions (nuclear functions) [33].

Deconstruction has been used extensively in education for teaching and learning. MacDonald [34] suggests considering teaching as dividable tasks, and proposes a model for deconstructing them into basic sections. Self explores [35] [36] the constructionist part of deconstructionism applied to learning computer science fundamentals. He explains that the deconstructionist perspective emphasizes that learning comes from differences between the model and the situation where it is applied, rather than from similarities, which the abstractions of rationalism emphasize.

In our work, deconstruction is used as a key learning principle of understanding and creation. Modularisation techniques – such as the divide and conquer perspective that involve recursively breaking down a problem into sub-problems until these become simple enough to be solved directly – are used in engineering to comprehend problems and design solutions.

Applying these ideas to the *Interreality Portal*, we identify from the instructors' perspective that the creation of UoL is based on activities (atomic functions) which can be combined to create nuclear functions (a complete UoL). From the learners' perspective the idea is similar, xReality and virtual objects (atomic functions) can be considered as part of a deconstructed set of components that students can reconstruct in any combination to generate their own unique xReality project – or to reconstruct a xReality project that is prescribed by the instructor – (nuclear functions). From a technical (system architecture viewpoint) the deconstructed elements become sets of autonomous networked resources, that may be inter-connected to form different

combinations (constructed) thereby forming a variety of student projects or UoL as required by the teacher or student. In practical terms each element is either a process/thread or a processor (examples being the BuzzBoard modules [20]), neatly solving the practical issues in implementing this model. Table 1 shows a correlation between these concepts.

Table 1. The *Deconstructed* model as an unification architecture for instructors, learners and technical infrastructure

Role	Atomic function	Nuclear function
Learner	Objects available in the environment, actions available (programming statements).	An Internet-of-Things project
Instructor	Resources available in the environment, activities available (sequence of activities).	A Unit of Learning (UoL)
Technical infrastructure	Processes, threads, processors or FPGA	xReality toolkit and system

Thus, from the above discussion, summarised in Table 1, *deconstruction is the essential glue, and enabling principle, that unifies the pedagogical and technical elements of our model.* In more detail, the use of deconstructionism in our collaborative mixed-reality laboratory architecture unifies a constructionist pedagogy (in which learning is a consequence of the correlation between performing active tasks that construct meaningful tangible objects in the real world and relating them to personal experiences and ideas), with a set of hard and soft objects in the form of BuzzBoards [20] and their supporting software (i.e. the networked atomic/nuclear functions comprising processors, logic and processes). Therefore, in summary, deconstructionism is the key element that unifies the physical model of distributed mixed reality objects with the pedagogical model of constructionist laboratories enabling the creation of a blended reality distributed system. In this view, xReality objects become deconstructionist architectures fitting both the constructionist pedagogy and a physically distributed architecture permitting the creation and execution of mixed reality learning activities within the *InterReality Portal*.

Summary and future work

In this paper, we have described a holistic immersive mixed reality learning environment, the *InterReality Portal*. Grounded on co-creative constructionist PBS learning theories, the *InterReality Portal* offers the possibility of creating collaborative laboratory activities for geographically dispersed students. To support this, we have defined the learning environment (real + virtual), the technical core elements of our mixed reality activities (the *xReality* and *Virtual* objects) and explored combining them using end-user programming to create a type of educational mixed reality object.

In addition, we presented a series of challenges for constructing this model. First, the pedagogical challenge of using a constructionist student-centred method to create laboratory activities for distance learning. Secondly, a technical challenge of having a representation of a deconstructed world from two different perspectives: learners and instructors, defining a set of components that can be shared and combined (e.g. atomic

and nuclear functions in Table 1) and enabling the technical distribution of objects between different immersive environments to create a blended reality distributed system. Finally, the most important, the challenge of bridging the physical model of distributed xReality objects and the pedagogical model of constructionist laboratories to produce a solution for distributed mixed reality laboratories. To solve this we have proposed the use of a deconstructionist architecture that we have argued has the capability to glue a constructionist pedagogy seamlessly into a physically distributed (but logically holistic) immersive learning environment.

Considering future work, whilst our work to-date, as reported here, has made significant progress with the development of an architecture and supporting theory for the distributed immersive mixed reality learning model, which we hope is in itself a significant contribution, there is remains much for us to do to realise our full vision. Figure 5 summarises the implementation stages of our practical work. Phase 1 involves the construction of a functional InterReality Portal able to work with xReality and Virtual objects (detection, identification and management of a *single dual reality state*). Phase 2 explores the design and implementation of mixed reality laboratory activities from the learner perspective and the instructor perspective using Learning Design UoLs and end-user programming. Phase 3 extends our research to the management of *multiple dual reality states* between two or more InterReality Portals to create blended reality while the learners perform the learning activity in separate locations as described previously.

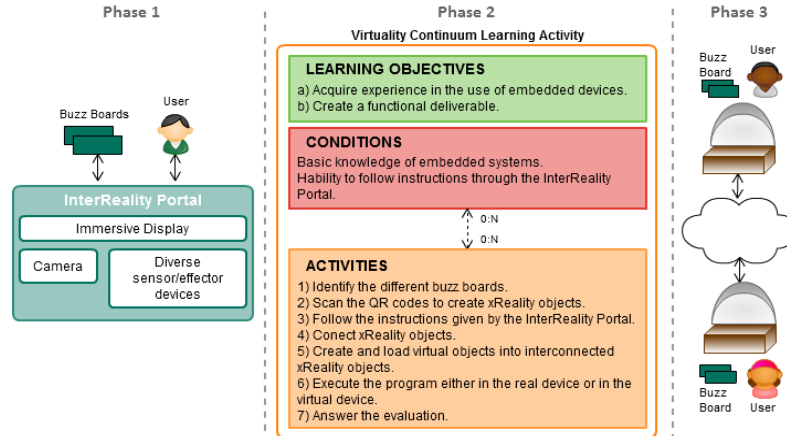


Figure 5. Implementation phases.

Thus, in relation to our future plans, Figure 5 shows that our research is moving from phase 1 to phase 2, integrating the *InterReality Portal* implementation with the end-user programming concepts discussed within this paper. The possibility of combining virtual and xReality objects with deconstructionism and the use of end-user programming to create mixed reality learning activities that can be constructed and shared by teams of geographically dispersed students is our final goal. This project has another two years to run and, over this period, we aim to gradually answer the remaining research questions set out in this paper, which we look forward to presenting in subsequent workshops and conferences.

Acknowledgments

We are pleased to acknowledge King Abdulaziz University, Saudi Arabia for their generous funding of this research project, including the provision of a PhD scholarship to the lead author. In addition, we wish to thank Immersive Displays UK Ltd. and Fortito Ltd. for their support. Finally we are pleased to acknowledge Dr. Jeannette Chin (Anglia Ruskin University) for her important advice with the end-user programming aspects, Prof. Dr. Minjuan Wang (San Diego State University) for her valuable guidance on the educational issues, Malcolm Lear (Essex University) for technical support relating to BuzzBoard technology and Dr. James Dooley (Essex University) for his assistance with the technical aspects of the immersive reality desk.

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