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The InterReality Portal: A Mixed Reality Co-creative Intelligent Learning Environment

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Abstract. Technology has become an inseparable part of everyday life, as we use it at home, at work, in school etc. For education, technology is frequently used as a tool to support classroom-based learning. However, an emerging challenge is the application of technology, beyond the traditional classroom, to a diverse mix of pedagogical techniques. Traditional education is based on the process of transmitting knowledge; however, it is necessary for education to encourage the formation and strengthening of skills such as creativity, innovation, analysis, communication and other capabilities that are important aspects of professional life. This paper extends our previous work towards developing an *InterReality Portal* learning environment. The *InterReality Portal* applies Problem-based Learning (PBL) pedagogy and co-creative learning to the realization of mixed-reality laboratory activities for learning computing. To reach this goal we propose a series of structured lab activities created using IMS Learning Design, with a combination of *Cross-Reality (xReality)* and *Virtual* objects, to produce Internet-of-Things-based computer projects using collaborative interaction between geographically dispersed students.

Keywords. Mixed reality, intelligent learning, learning design, cloud learning, co-creative learning, constructionism, interreality portal, end-user programming, xReality objects.

Introduction

Learning is one of the topics in which progress in technology has enabled major innovative advances in practice (e.g. from web-based education to ubiquitous learning or intelligent tutor agents). However, we need to ask whether advances in technology, that enable learning outside the traditional classroom, are really bringing significant educational gains? Papert's constructionism theory established that the acquisition of long-life learning was a consequence of performing active tasks that construct meaningful tangible objects in the real world and relating them to personal experiences and ideas [1]. New trends on education technology take the view that learning should not be focus on only memorizing information but should also develop problem-solving skills. Problem-based Learning (PBL) is a constructionist student-centred pedagogy where students work on co-creative problem solving, where learning occurs as a side-

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effect of problem solving [2]. Are these approaches being taken into consideration by the new technology-based learning environments?

In a previous work [3] we presented a Mixed Reality Intelligent Learning (MR-iLearning) Model as a context for an online learning environment. The MR-iLearning Model was based on:

a) *Intelligent Learning* (iLearning), an innovative paradigm of learning that is able to offer ubiquitous personalized content via a context-aware environment [3].
b) A *cloud learning infrastructure* [4], which provides strategic benefits such as storage capacity, resource sharing and adaptation, mobility and accessibility, plus the possibility to keep a unified track of learning progress, thereby providing attributes such as synchronous sharing, asynchronous storage and high-availability [5].
c) The *Instructional Management Systems (IMS), Global Learning Consortium Learning Design specification* for the creation of learning activities. This enables learning objects to be designed to achieve particular goals, regardless of the pedagogical methods utilised [6].

In this paper we explore the application of these concepts to a holistic learning environment. We begin by introducing an innovative online learning environment, the *InterReality Portal* (our work-in-progress test bed), its conceptual architecture and implementation. This is followed by a description of the operation and design of our exemplary virtual lab (based on embedded-computing) in the *InterReality Portal* using *Cross-Reality (xReality)* and *Virtual* objects. After this we discuss the use of end-user programming for customization issues. Finally, we provide conclusions and identify challenges to be addressed in our future research.

1. The InterReality Portal

Grounded on the learning-by-doing vision of constructionism, our research is inspired by an innovative learning environment, derived from a science-fiction prototype, described in "*Tales from a Pod*" [7]. In this story we described how advanced technology might create a futuristic educational environment where learning can be provided within an immersive mixed-reality teaching environment (*pods*). Students can experience personalised learning, along with collaborative learning, through a network of interconnected *pods* distributed geographically to create large-scale education environments. In a similar way, the *InterReality Portal* is able to deliver personalised online content enhanced with co-creative mixed-reality activities that support a PBL pedagogy and co-creative learning [8] in an immersive learning environment.

We define an *InterReality Portal* as a collection of interrelated devices (both real and abstract) comprising a 3D virtual environment, physical objects and software agents that allow people to complete activities at any point of Milgram's Virtuality Continuum [9] [3]. For the application of PBL pedagogy, we propose the use of mixed reality lab activities, that enhance effective problem solving and collaboration skills by enabling students to work in groups and utilise real and virtual objects to co-creatively construct computing systems. The interaction between the elements can be defined as

Cross-Reality (*xReality*) [10]. During this interaction, networked sensors obtain real-world information and pass it to the 3D virtual environment, where the data is processed to trigger events previously programmed by the teacher or student. In a similar way, interaction performed by virtual objects can be reflected into the physical world through a diverse set of physical artefacts.

1.1. Conceptual model

Our *InterReality Portal* has four layers. The first layer is the *Client layer* or real world, where the user interacts directly with the *xReality* objects. The second layer, the *Data Acquisition layer*, is responsible for obtaining real-world information produced by interactions between the user and the *xReality* object or between the user and the learning environment. The main actor at this level is the *Context-awereness* agent, which identifies the object being used in a learning task with the aid of QR codes, cameras and network eventing data. This information is sent to the *Mixed Reality (MR) Agent*, in a subsequent *Event Processing layer*. The MR agent obtains, from the *Resources Repository*, a set of rules and actions (behaviours) available for the object. Finally the MR agent instantiates a virtual representation of the *xReality* object with its properties and rules in the *Virtualization layer*.

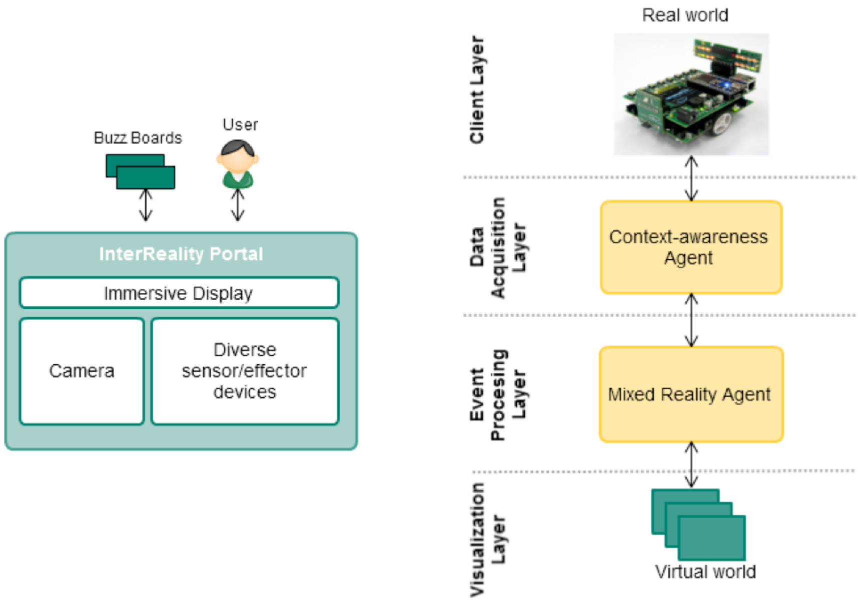

Figure 1. InterReality Portal Conceptual Model.

1.2. Implementation

For the implementation, we are utilising a semi-spherical sectioned screen, the ImmersaStation, manufactured by Immersive Display's Ltd. [11] (Fig. 2). One characteristic of this device is that it allows the completion of mixed-reality activities in a less intrusive way by offering a traditional work-desk that allows a free-range of head movement without the need for any other body instrumentation (e.g. special glasses).

Our prototype includes a camera that, in addition to enabling videoconferencing, is used to read QR codes that allow the automatic identification of actors and objects.

The *InterReality Portal* uses two different types of objects: *xReality* objects and Virtual objects (Fig. 3). *xReality* objects refers to objects that have a physical (or optionally, virtual) form and contain rules, that determine the behaviour and interaction with other objects or the environment (e.g. all FortiTo buzz-boards can work with any other Buzz-Boards and must behave according to the laws of physics, etc.). *Virtual* objects can only exist inside the 3D virtual environment although they can have rules and behaviours associated with them (e.g. software created for the virtual lab activity).

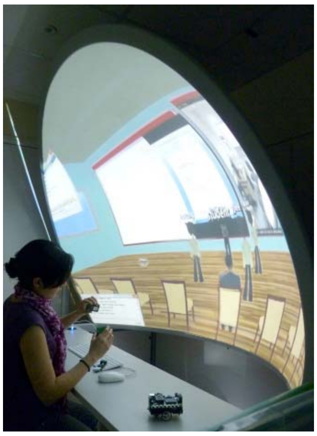

Figure 2. InterReality Portal.

Finally mixed-reality lab activity, based on the above, can be created using combinations of *xReality* objects and *Virtual* objects to create *Internet-of-Things* applications. The *Internet-of-Things* definition establishes a union between the virtual world of 'information' with the real world of 'things' allowing numerous interesting applications to be constructed [12]. The learning goal of our activity is to create a computer science project that includes hardware and software modules, emphasising computing fundamentals.

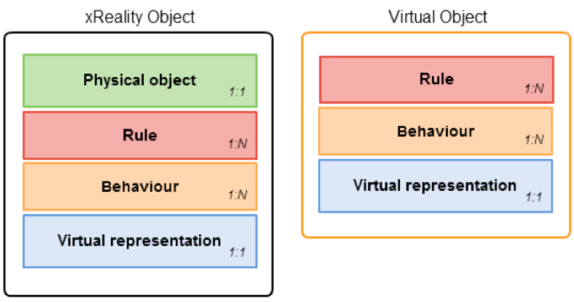

Figure 3. Types of objects.

1.3. 3D Virtual Environment

Virtual worlds are used in distance-learning because they enhance social interaction between remote people giving them a greater sense of presence and engagement within the class. The University of Essex MiRTLE project (Fig. 4) is a virtual learning environment based on teacher/student interaction that links a physical classroom to a virtual classroom, providing an instructive educational setting [13] [14].

The application of this technology, based on Papert's Instructionism, is an example of the use of technology for traditional classroom-based education, where the knowledge is transmitted from teacher to student based on isomorphic concepts [1] [16].

MiRTLE is based on Open Wonderland, a java-based open source toolkit for creating collaborative 3D virtual worlds [15]. Some of the benefits of using this toolkit are the integration with other technologies, such as immersive audio, sharing live desktop applications or documents and the extensibility afforded by the tools that enable the creation of new worlds and features.

By taking MiRTLE as our 3D Virtual World platform for the InterReality Portal, we will experiment with the transformation from an instructionist pedagogy into a constructionist model for co-creative learning.

Figure 4. MiRTLE.

1.4. XReality Objects

For the construction of mixed reality lab activities we are utilising Fortito's Buzz-Board Educational Toolkit (Fig. 5) [17] [18]. This educational toolkit comprise over 30 pluggable hardware boards that can be interconnected that, together with software modules, can create a variety of *Internet-of-Things* applications [19] such as mobile robots, mp3 players, heart monitors, etc. The modularised set of objects (hardware & software) allow the students to create projects using the deconstructed appliance model. In this model a number of elementary services can be combined to create higher order functions [20]. The hardware boards communicate via network events. The software modules care developed by students using the C & C++ language.

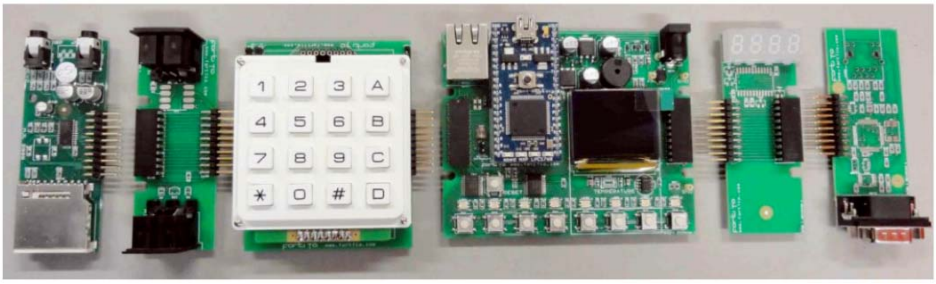

Figure 5. FortiTo Educational Toolkit.

1.5. Virtuality Continuum Learning Activities

In order to create meaningful activities, that enhance and promote learning, it is necessary to establish appropriate learning goals and consider the design of such activities. For our research we have defined a classification for learning activities according to characteristics such as temporality (time learning/teaching) and context (type of action and scope of action) [3]. This classification enables the use of the MR-iLearning Model in different learning environments. However, in our system, the *InterReality Portal* activities are performed within the *Virtuality Learning Continuum*, where the scope (physical-virtual) of the action performed, is relevant to the completion of the task.

According to IMS Learning Design, the structured sequences of learning activities are known as Units of Learning (UoL) and can be preceded by zero or more conditions before starting or completing the tasks [6]. The learner is the person who performs this sequence of actions in order to fulfil one or more inter-related learning objective. In these activities the teacher becomes more of a facilitator than a lecturer, and the learning environment allows a teacher to create learning activities regardless their expertise on computers.

Figures 6 & 7 shows the interaction between system components in a collaborative *Virtuality Learning Continuum* activity. The first diagram relates to the beginning of the learning session. In this the *Context-Awareness Agent* (CAa) identifies the object being used in the learning session with the aid of QR codes, camera and network eventing data. This information is sent to the *Mixed Reality Agent* (MRa), which obtains, from the *Resources Repository (*via the *Content Manager)*, a set of rules and actions (behaviours) available for the object. This information is sent to the *UoL Manager*, which constructs the sequence of activities in the UoL. In support of these activities, the *Mixed-Reality Agent* instantiates a virtual representation of the *Buzz-*

Boards and other objects in the *3D Virtual Environment*. Finally the *UoL Manager* starts with the execution of the activities. At this point the *Context-Awareness Agent* and the *Mixed-Reality Agent* will handle a single "*Dual-Reality*" state in which the objects in the virtual world are a copy of the real world and if there is any change performed in either the virtual or the real world, the *Context-Awareness Agent* will perceive it and send the updates to the *Mixed Reality Agent*.

For the co-creative virtual lab, additional learners perform the same steps, and then through the *3D Virtual Environment* they establish communication with other remote learners. As long as the session continues, changes to any of the Inter-Reality Portal objects will result in the *Mixed-Reality Agent* handling the following situations:

a) A change in any *Virtual object* in a given InterReality Portal results in identical changes to all subscribing InterReality portals.

b) A change in a *xReality object* of a given InterReality Portal results in changes in the representation of the real device on all subscribing InterReality portals.

While this synchronization processes occurs between the *Context-Awareness Agent* and the *Mixed Reality Agent*, our connected InterReality Portals extend the single "*Dual-Reality*" concept to a multiple *"Dual-Reality"* states in which all the virtual world views should be symphonises and synchronised with each other.

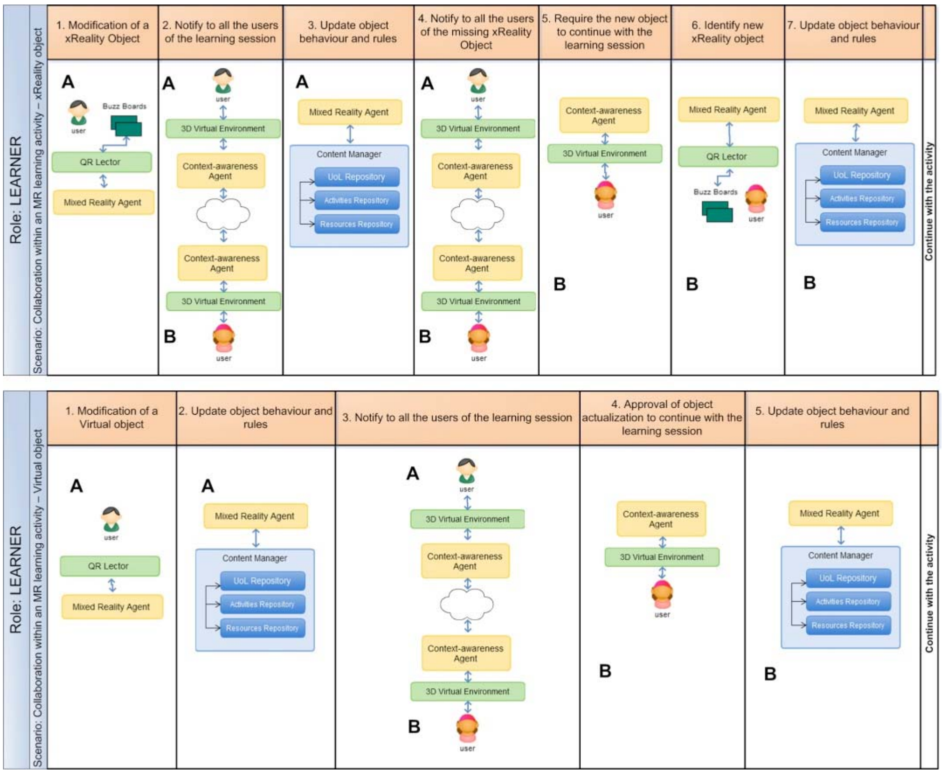

Figure 6. *xReality* and *Virtual Reality* objects interaction in a Collaborative MR learning activity.

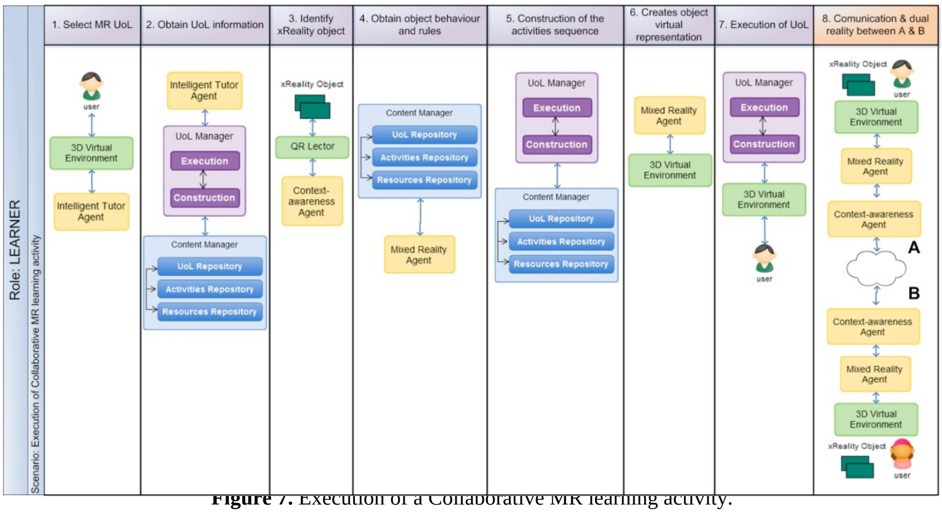

Figure 7. Execution of a Collaborative MR learning activity.

1.6. End-user programming

xReality and *Virtual objects* can be considered as a collection of "atomic" services (software) and devices (hardware) which, could be configured into novel combinations, forming personalised *Internet-of-Things* appliances [20]. To create these mash-ups and participate in the co-creative process of learning it is necessary that the *InterReality Portal* provides a satisfactory end-user programming environment. End-user programming refers to the use of techniques that enable non-technical people to create a set of coordinated actions that the learning environment can perform to mirror some specific designed operations [21].

End-user programming for the *InterReality Portal* can be examined from two different angles:

a) From the learner's 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 instructor's view, when they create a UoL they are establishing a sequence of activities to be performed by the learners during the educational session.

Recently, different approaches to encourage and empower users to create "programs" have been developed. One approach is to use iconic objects (e.g. a graphical icon, a physical artefact) that represent programming constructs and which people "assemble" (e.g. a jigsaw puzzle), to create algorithms without logic programming knowledge [22] [23]. These, combined with *xReality* or *Virtual* object's rules & behaviours and user' profiles, are the mechanisms used in our *InterReality Portal*.

Summary and future work

In this paper we have described a holistic immersive intelligent learning environment that offers a co-creative constructionalist PBS learning to teams of geographically dispersed students. In addition, we have defined and explored how *xReality* and *Virtual* objects can be combined with end-user programming to create an educational mixed-reality object that can be constructed and shared between learners during a *Virtuality Learning Continuum* session. By aggregating such objects students may co-creatively construct a variety of interesting lab assignments. These *Virtuality Continuum* activities and learning sessions are regarded as belonging to the pedagogical schools of "experientialism" and "enactivism" due to the emphasise on interaction with tangible objects, rather than conceptual abstractions [24].

We have discussed how the benefits to differing educational stakeholders. For example, the learner can benefit from a more natural acquisition of long-life knowledge, constructed by the correlation between concepts and real tasks. The instructor can benefit from the standardised construction of learning activities using IMS Learning Design, allowing him or her to share and re-use learning material. An additional benefit may occur as this learning system can also serve as a rapid prototyping system for entrepreneurs or companies developing Internet-of-Things products.

Finally, by way of providing a signpost to our future work, Figure 8 summarises the implementation phases of our research. The first stage involves the implementation and construction of a fully immersive *InterReality Portal*, able to recognise and work with *xReality* and *Virtual* objects. The second stage concerns the use of the *InterReality Portal* to implement a Learning Design example based around the use of *Virtuality Learning Continuum* UoLs, enabling us to evaluate the first scenario of our pedagogical model; the single immersive mixed reality learning environment.

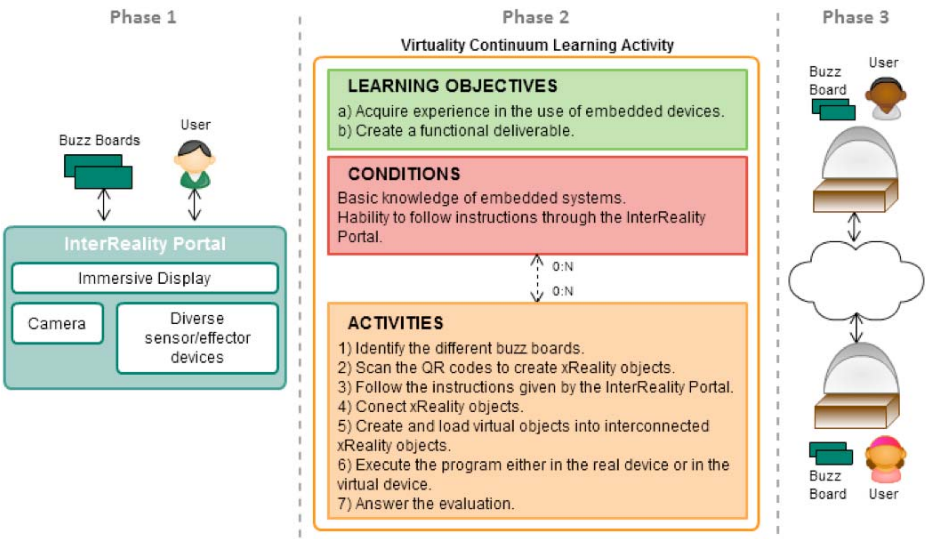

Figure 8. Implementation phases.

The final stage of the implementation consists of the construction of a second *InterReality Portal* to perform the co-creative virtual lab between two people in separate locations. By doing this we will expand usage into a wider geographical and pedagogical context thereby allowing *InterReality Portal* educational resources and immersive environment sharing, based on cloud computing technology, plus a deeper exploration of co-creative PBL pedagogies.

We are currently in the process of integrating the *InterReality Portal* with the learning design concept, and therefore much research will be done over the coming days to answer various research questions ranging from technical issues such as "*how to map the virtual and physical spaces together, in a single and multiple Dual-Reality state*" to educational concerns, such as "*examining whether the interconnectivity between physical and virtual spaces, provides significant advances to collaborative and creative learning*". We look forward to presenting significant progress on these and other issues at forthcoming workshops and conferences.

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References

[1] S. Papert & I. Harel, Constructionism, Ablex Publishing Corporation, 1991.

[2] K. -. K. Ngeow & S. Yoon, «Learning to learn: preparing teachers and students for problem-based learning. ERIC Digest.,» 2001. [Online]. Available: http://www.ericdigests.org/2002-2/problem.htm. [Last access: 03-2012].

[3] A. Peña-Ríos, V. Callaghan, M. Gardner & M. J. Alhaddad, «Towards the Next Generation of Learning Environments:An InterReality Learning Portal and Model,» on *8th International Conference on Intelligent Environments 2012*, Guanajuato, Mexico, 2012.

[4] S. Kim, S.-M. Song & Y.-I. Yoon, «Smart Learning Services Based on Smart Cloud Computing,» *Sensors*, vol. 11, nº 8, pp. 7835-7850, 2011.

[5] N. Sultan, «Cloud computing for education: A new dawn?,» *International Journal of InformationManagement*, vol. 30, nº 2, pp. 109-116, 2010.

[6] IMS Global Learning Consortium, «Learning Design Specification,» IMS Global Learning Consortium, 2003. [Online]. Available: http://www.imsglobal.org/learningdesign/. [Last access: 12-2011].

[7] V. Callaghan, «Tales From a Pod,» on *Creative Science Workshop*, Nothingham, 2010.

[8] P. Dillenbourg, «What do you mean by 'collaborative learning'?,» on *Collaborative Learning: Cognitive and Computational Approaches. Advances in Learning and Instruction Series.*, Elsevier Science, Inc., 1999, pp. 1-15.

[9] P. Milgram & F. Kishino, «A taxonomy of virtual reality displays,» *IEICE TRANSACTIONS on Information and Systems,* Vols. 1 of 2 E77-D, nº 12, pp. 1321-1329, 1994.

[10] J. A. Paradiso & J. A. Landay, «Cross- Reality Environments,» *IEEE Pervasive Computing,* vol. 8, nº 3, pp. 14-15, 2009.

[11] Immersive Display Group, «ImmersaStation,» 2011. [Online]. Available: http://www.immersivedisplay.co.uk/immersastation.php. [Last access: 10-2011].

[12] D. Uckelmann, M. Harrison & F. Michahelles, «An Architectural Approach Towards the Future Internet of Things,» on *Architecting the Internet of Things*, Springer Berlin / Heidelberg, 2011, pp. 1-25.

[13] V. Callaghan, M. Gardner, B. Horan & J. L. Scott, «A Mixed Reality Teaching and Learning Environment,» on *Proceedings of the 1st International Conference on Hybrid Learning and Education*, Hong Kong, China, 2008.

[14] M. Gardner & M.-L. O'Driscoll, «MiRTLE (Mixed-Reality Teaching and Learning Environment): from prototype to production and implementation,» on *AcrossSpaces11 Workshop in conjunction with the EC-TEL 2011*, 2011.

[15] Open Wonderland Foundation, «Open Wonderland,» Open Wonderland Foundation, [Online]. Available: http://openwonderland.org/. [Last access: 04-2012].

[16] M. Driscoll & K. Rowley, «Semiotics: Toward learning-centered instructional design,» on *Instructional development paradigms*, Englewood Cliffs NJ: Educational Technology Publications, 1997, pp. 311-334.

[17] Fortito - Educational Technology, «Buzz Products,» 2011. [Online]. Available: http://www.fortito.com/buzz/. [Last access: 10-2011].

[18] M. Wang, V. Callaghan, M. Lear & M. Colley, «Teaching Next Generation Computing Skills: The Challenge of Embedded Computing,» on *Intelligent Campus 2011 (iC'11)*, Nothingham, 2011.

[19] V. Callaghan, «Buzz-Boarding ; practical support for teaching computing based on the internet-of-things,» on *The Higher Education Academy - STEM*, London, 2012.

[20] J. Chin, V. Callaghan & G. Clarke, «Soft-appliances : A vision for user created networked appliances in digital homes,» *Journal of Ambient Intelligence and Smart Environments,* vol. 1, nº 1, pp. 69-75, 2009.

[21] D. C. Smith, A. Cypher & L. Tesler, «Novice Programming Comes of Age,» *Communications of the ACM,* vol. 43, nº 3, pp. 75-81, 2000.

[22] J. Chin, V. Callaghan & G. Clarke, «A programming-by-example approach to customising digital homes,» on *4th International Conference on Intelligent Environments,* Seattle, 2008.

[23] MIT Media Lab, «Scratch,» MIT Media Lab, [En línea]. Available: http://scratch.mit.edu/. [Last access: 04-2012].

[24] Q. Li, B. Clark & I. Winchester, «Instructional Design and Technology Grounded in Enactivism: A Paradigm Shift?,» *British Journal of Educational Technology,* vol. 41, nº 3, pp. 403-419, 2010.