# Looking Toward the Future of Technology–Enhanced Education:
## Ubiquitous Learning and the Digital Native

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# Chapter 10
# A Case Study of Augmented Reality Serious Games

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## ABSTRACT

*The study introduced in this paper examines some of the issues involved in the design and implementation of serious games that make use of tangible AR environments. Our motivation is to understand how augmented reality serious games (ARSG) can be applied to some very difficult problems in the real gaming world. Emphasis is given on the interface and the interactions between the players and the serious games themselves. In particular, two case studies are presented, ARPuzzle and ARBreakout. Results from both case studies indicate that AR gaming has the potential of revolutionizing the way that current games are played and used as well as that it can help educate players while playing.*

## INTRODUCTION

Serious games are part of a new emerging field that focuses on computer games that are designed for non-leisure and often educational purposes. During the past few years there has been an explosion of serious games mainly because of the evolution of computers, communications, intelligent software agents and accurate physics models. Their main advantage over traditional games is that they can be reused for other simulations in a number of commercial areas such as military operations, medical education, emergency management training, and many others. This allows modern game technology to make a bridge between entertainment and work changing their image from 'toys' to 'serious tools'.

Serious games evolve from military games originally conceptualized around simulated play and role play, and as a result are particularly used in training and pre-live training situations at present. However, as the tools evolve uses in medical training, cross- agency training and business training are becoming more widely used. The term serious games has developed as a rebuttal to the idea that games are purely for leisure purposes and its use

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goes back to Plato's work on the importance of play as a teaching method. Recently, the serious games movement has emerged from academic communities identifying the power of play for supporting non-leisure activities such as education and training. Recent case studies have identified the power of games technologies for supporting online communities and distributed training groups, for explaining difficult concepts and for engaging and motivating learners (de Freitas & Neumann, 2008; de Freitas & Jarvis, 2008). The power of the formats to engage and motivate in particular has attracted interest from schools and tertiary education institutions, leading to a re-conceptualization of what learning is and stimulating debate around how games might be applied to support specific user groups.

These immersive tools together are offering greater advantages for teaching and training particularly with respect to supporting collaborative learning, supporting social interactions and illustrating complex environments and concepts. The tools certainly do not imply the end of traditional teaching they do however necessitate a re-evaluation about learning and a need to revisit traditional models and modes of learning. One of the authors argues elsewhere (de Freitas & Neumann, 2008) that a new form of learning theory is needed to support these more 'immersive' technologies, and has proposed a model of exploratory learning that focuses upon learning considered as sets of immersive experiences. The work extends from the constructivist models of Kolb's experiential learning, and experimental work being undertaken as part of the UK Technology Strategy Board part-funded Serious Games – Engaging Training Solutions (SG-ETS) research project (with partners Blitz Games Studios and Selex Systems) (de Freitas & Jarvis, 2007; de Freitas & Jarvis, 2008).

The model extends from Kolb's experiential learning cycle with more emphasis upon the role of learner control and exploration and upon social and peer interactions as underpinning effective approaches to learning with immersive tools. Through a consideration of learning as sets of immersive experiences, we can focus upon learning design as crafting these experiences through role plays, modeling specific processes from real life into virtual environments and editing scenarios that allow for multiple outcomes. Serious games come in many different formats, from simple Flash quizzes animations to high fidelity first person style challenge games. Studies are revealing that the range of games used also have distinct appeal to certain gender and age groups. Although this is changing, on the whole the differences are central to designing the most effective game for the particular target group.

On the other hand, augmented reality (AR) has existed for a few decades now and it refers to a technology that combines virtual information onto the real environment in real-time performance. AR technology is developing rapidly, but it is still in its infancy. The main characteristics of AR, includes accurate registration and seamless interaction between the users and the superimposed information. This information may be any available format that can be digitally reproduced. Users can visualize the superimposed information with a selection of display technologies and can interact with it in a natural manner by employing software interfaces, physical markers and hardware interaction devices. Up to now a number of experimental prototypes have been developed mainly from universities and research institutes targeting numerous application domains including gaming, but commercial applications are not widely available.

The study introduced in this paper examines some of the issues involved in the design and implementation of serious games that make use of tangible AR environments. Emphasis is given on the AR interface, the presentation as well as the natural interactions between the players and the serious games themselves. Our motivation is to investigate whether augmented reality serious games (ARSG) can be used effectively in the real gaming world. The main objective is to understand whether a combination of educational and entertainment experiences while playing serious games in AR environments can be beneficial. To address these issues, two diverse case studies in ARSGs are presented, ARPuzzle (Liarokapis et al., 2005) and ARBreakout (Liarokapis, 2006) using a previously implemented AR platform (Liarokapis, 2007). The former is a simple 3D game designed for geography students that consists of six physical pieces and focuses on tangible interaction and collaboration between the players. For the purpose of the interactive ARPuzzle a big part of City University campus in London was accurately modeled and geo-referenced in correspondence to cognitive tuning. Then the 3D map was split into six equal 3D pieces and players can first visualize the 3D geographic information in both VR and AR interfaces and then try to reconstruct the puzzle which is in essence the 3D map of City University campus. Using the interface menu, they can receive audio-visual feedback in various formats including text, images and spatial sound (Liarokapis, 2007). Furthermore, to address accessibility issues, the size and the color of the superimposed text can be changed interactively by the users using the interface menu or predefined keyboard keys. The latter is a 3D arcade game that includes a physics engine and focuses more on user centreed interface that provides accurate and reliable control of the game. A traditional 2D video game was implemented first in VR and then transformed into AR. The traditional 2D Breakout is one of the first interactive video games available on personal computers. The main idea is to knock down a set of 2D bricks using a 2D racket and a ball moving at constant speed. As soon as the ball collides with a brick then it vanishes. The goal of the game is to make all bricks disappear from the game arena.

Both games were exposed to undergraduate students at City University and Coventry University. The ARPuzzle was evaluated with 30 students whereas the ARBreakout with 30 students. Results from both case studies indicate that AR gaming has the potential of revolutionizing the way that current games are played and used as well as helping to educate players while playing. In particular, the ARPuzzle game seemed to be much more appropriate as far as AR serious games are concerned in terms of visualization, interaction, collaboration and learning. We also considered that AR could help learners to understand and learn difficult concepts (like topology and geography) much quicker than traditional methods (i.e. paper maps). On the other hand, for the ARBreakout results indicate that with AR games it is much easier to familiarize with and adapt to the gameplay compared to VR games.

## BACKGROUND

The aim of this section is to provide a background of *serious games* methodologies and *virtual and augmented reality* case studies relevant to the study presented here.

### Serious Games

The gaming industry grew enormously during the past decade ranging from console, pc and mobile based games. However, most of them are not designed to have any educational flavor. Serious games are computer games that have an educational and learning aspect and are not used just for entertainment purposes. The addition of pedagogy also plays a significant role to makes games serious. However, according to Zyda (2005), pedagogy must be subordinate to story and that the entertainment component comes first. Previous studies illustrated that games can promote learning (e.g. van Eck, 2006). It is worth mentioning, that spatial abilities can be also improved by playing arcade games (de Lisi & Wolford, 2002). Further potential benefits of games include improved self-monitoring, problem recognition and problem-solving, decision making, better short-term and long-term memory, and increased social skills such as collaboration, negotiation, and shared decision-making (Rieber, 1996; Mitchell & Savill-Smith, 2004).

Moreover, Mingoville (Sørensen, & Meyer, 2007) is a serious game based on the idea that children learn and are motivated by problem-solving and game activities rather than traditional skills-based and textbook based material focusing on reading, writing, spelling and listening. The project intends to explore, build and implement prototypes in collaboration with companies, using their products and experience to develop knowledge about serious game challenges, educational design, and assessment with the aim of innovation. In another study, content was combined with pedagogy through a multi-player educational gaming platform designed for students (Annetta et al., 2006). Evaluation results showed potentials to advance gaming theories and problem-based solving approached in multi-player educational gaming platforms. Furthermore, a good overview of serious games has been recently documented (Susi et al., 2007).

A very popular platform for serious games is online gaming. The availability of various online platforms such as Second Life (Linden Research, 2008), Active Worlds (Active Words, 2008) and the OLIVE platform (Forterra Systems, 2008), allows for a number of operations in virtual environments. Some of them include: social networking, collaboration, learning, training, experimentation as well as custom-based applications. A recent application of the Olive platform by Stanford Medical School project involves practice innovation through supporting training for cardio-pulmonary resusitation (CPR), mass casualty and assessment in acute-care medicine (de Freitas & Neumann, 2008). However, the main disadvantage of these platforms is that they do not support high-level graphics or advanced interaction techniques. In addition, a number of serious games are using game engines. One of the most popular areas is in training situations. A characteristic example of a serious gaming application developed based in game engines, to train traffic accident investigators how to attend a virtual traffic accident (BinSubaih et al., 2006). To measure the system's effectiveness it was empirically evaluated with 56 police officers.

Serious games are currently being used in a range of different contexts. One study, the SG-ETS project is developing three serious games demonstrators. As part of the study, one user group nurses and ambulance workers have been polled to establish more about their game-playing attitudes and preferences. The study found distinct gender and age differences with respect to game type favored and levels of gaming. As part of the study, we surveyed 223 nurses and ambulance workers in the UK. 89% were female and 11% were male reflecting the demographic audience. The full results of the study are compiled in (de Freitas & Jarvis, 2008). The largest positive response came from males under the age of 30 (81%) played games. This dropped to 26% for the female over-40 group. The frequency of game players is significantly affected by both age and gender. The work indicates both the distinct preferences for game-play and the strengths of games for allowing active involvement of the learners thereby making serious games a powerful tool for training and education. However, there are specific design challenges with making engaging content, and ongoing work with the UK's Serious Games Institute research group is assessing the best methods, frameworks and metrics for evaluating and validating the efficacy of serious games (de Freitas & Oliver, 2006).

## Virtual and Augmented Reality

In the past a number of AR games have been designed in different areas including education, learning, enhanced entertainment and training. One of the earliest examples of education was the MagicBook (Billinghurst et al., 2001). This is a real book which shows how AR can be used in schools for educational purposes providing an interesting method of teaching. It enables users to read the book either like any traditional book or with a handheld display allowing the reader to see virtual 3D images ‘popping out’ of the pages. The MagicBook was also used as a template for a number of serious applications in numerous educational and training domains. Moreover, the BBC’s research identified how children aged five and six responded positively to AR learning. The team argued that AR learning enables children to be more imaginative as he discovered children were becoming the characters and making stories of their own, therefore enabling children to play as they naturally would but also to learn at the same time (Thomas, 2006). Many other research projects have been undertaken with older children. One example is the earth, sun and moon project where children aged 10 years old can understand how the sun and earth interact together. This project showed the acceptance of learning via this method by children aged 10+ and also suggested it is a suitable teaching tool (Kerawalla et al., 2006). In another study, the design and development of AR applications for educational purposes from the area of human medicine was presented (Nischelwitzer et al., 2007). Usability studies with children and the elderly showed that this technology has potential and can be of great benefit. Moreover, examples exist of AR educational applications used to support and simplify teaching and learning techniques currently applied in the higher education sector (Liarokapis, 2007) as well as on learning and performance (Holzinger et al., 2008; Holzinger et al., 2009).

Also AR can be applied successfully for educational and learning purposes in archaeology and cultural heritage settings. One of the earliest examples is the Virtual Showcase (Bimber et al., 2001) which is an AR display device that has the same form factor as a real showcase traditionally used for museum exhibits and can be used for gaming. The potential of AR interfaces in museum environments and other cultural heritage institutions (Liarokapis, 2007) as well as outdoor heritage sites (Vlahakis et al., 2002) have been also briefly explored for potential educational applications. A more specific gaming example is the MAGIC and TROC systems (Renevier et al., 2004) which were based on a study of the tasks of archaeological fieldwork, interviews and observations in Alexandria. The mobile game allowed the players to discover archaeological objects while moving around the site.

In terms of enhanced entertainment outdoor AR gaming can play a significant role. A characteristic example is the Human Pacman project (Cheok et al., 2003) that was built upon position and perspective sensing via GPS, inertia sensors and tangible human-computer interfacing with the use of Bluetooth and capacitive sensors. The game strives to bring the computer gaming experience to a new level of emotional and sensory gratification by embedding the natural physical world ubiquitously and seamlessly with a fantasy virtual playground. AR Tennis (Henrysson et al., 2006) is the first example of a face-to-face collaborative AR application developed for mobile phones. Two players sit across a table from each other, while computer vision techniques are used to track the phone position relative to the tracking markers. When the player points the phone camera at the markers they see a virtual tennis court overlaid on live video of the real world.

Another interesting project is STARS (Magerkurth et al., 2004) which focused on the nature of state representation in augmented game designs and developed several games based on these principles. Moreover, Mixed Fantasy (Stapleton et al., 2003) presents a MR experience that applies basic research to the media industries of entertainment, training and informal education. As far as training is concerned, the US Army paid more than $5 million to design an educational game based on the Xbox platform to train troops in urban combat (Korris, 2004). Another example is the MR OUT project (Hughes et al., 2005) which uses extreme and complex layered representations of combat reality, using all the simulation domains such as live, virtual, and constructive by applying advanced video see-through mixed reality (MR) technologies. MR OUT is installed at the US Army's Research Development and Engineering Command and focuses on a layered representation of combat reality.

## Important Design Issues

One of the issues arising from the relatively new technologies emerging is the need to develop consistent guidelines and frameworks to support more effective design of games. Towards this end, one model being developed by the Serious Games Institute is the four dimensional framework (de Freitas and Oliver, 2006). The tool is being used both for selection of serious games and for supporting development and evaluation of serious games (de Freitas & Jarvis, 2008). The four dimensional framework (Figure 1) supports a participatory design approach that brings together detailing learner modelling, a consistent use and consideration of the pedagogic models adopted with the game, a consideration of the representational elements of game design including levels of required interactivity and immersion and the context in which the game will be used (e.g. blended, task centred).

The four dimensional framework is being further developed in the exploratory learning model. An overview of the exploratory learning model (de Freitas & Jarvis, 2008) developed in the Serious Games Engaging Training Solutions project is presented in Figure 2. The exploratory learning model includes three levels: the processes of game design, the principles of game design and the tools and techniques for using these. The processes include the development processes driven by the business need, and include the analysis, specification, design, development and testing processes, modeling the learning processes and evaluating the overall process. The game principles include: considerations for selecting the game type (in line with users needs), usability and efficacy of learning. The tools we have developed include: learning needs analysis, human factors analysis, pre-prototypes and the four dimensional framework (de Freitas & Jarvis, 2008).

*Figure 1. The four dimensional framework*

| Four Dimensional Framework | |
|---|---|
| **Learner Specifics**<br>Profile<br>Role<br>Competencies | **Pedagogy**<br>Associative<br>Cognitive<br>Social/Situative |
| **Representation**<br>Fidelity<br>Interactivity<br>Immersion | **Context**<br>Environment<br>Access to learning<br>Supporting resources |

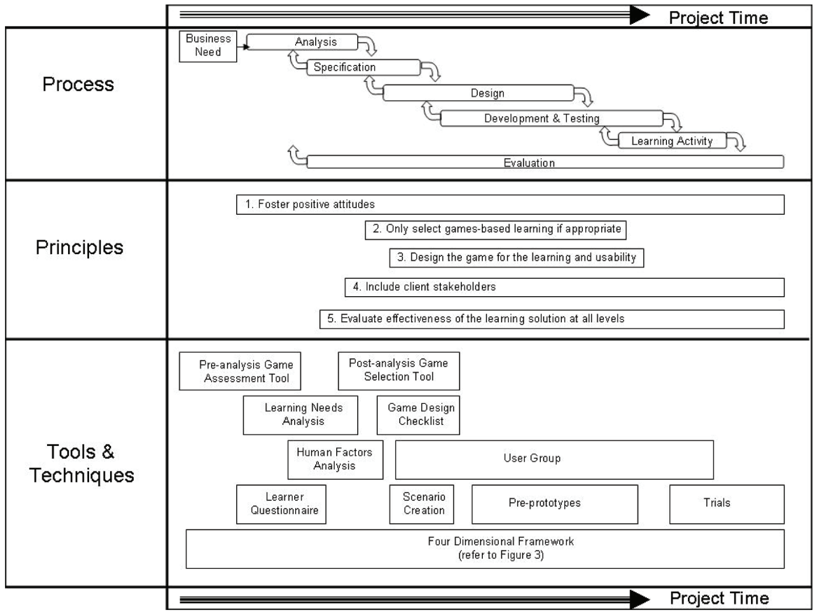
## CASE STUDIES

This section presents first two ARSGs, a puzzle called ARPuzzle (Liarokapis et al., 2005) and an arcade game ARBreakout (Liarokapis, 2006) which satisfy the Four Dimensional Framework presented above. Both games have been designed on top of a previously implemented AR platform (Liarokapis, 2007). A comparative study between these two tangible AR games is presented illustrating the strengths of each type of game.

### ARPuzzle

The ARPuzzle, is based on an earlier prototype (Liarokapis et al., 2005) and it is a simple game that consists of six equal parts that represent parts of City University campus in London. During the session and as long as the camera is in sight of sight with them, the virtual components of City Campus together is superimposed onto the table-top environment. For the purpose of the interactive ARPuzzle a big part of City University campus in London was accurately modelled and

*Figure 2. The exploratory game-based learning model*




geo-referenced in correspondence to cognitive tuning. Then the 3D map was split into six equal 3D pieces and players can first visualize the 3D geographic information in both VR and AR interfaces and then try to reconstruct the puzzle which is in essence the 3D map of City University campus. Using the interface menu, they can receive audio-visual feedback in various formats including text, images and spatial sound (Liarokapis, 2007). Furthermore, to address accessibility issues, the size and the color of the superimposed text can be changed interactively by the users by using the interface menu or predefined keyboard keys. Figure 3 illustrates an overview of the ARPuzzle. Players can pick up the marker cards and examine the geometrical and geographical information in a tangible manner. An advantage of this game is that it is possible to collaborate with other players that could stand around the table-top environment and either give advice or play the game. Multiple users can naturally experiment with different combinations by randomly placing the marker cards close to each other.

## ARBreakout

Breakout is an old arcade game which was ported into a tangible AR environment. The goal of the game is to make all the bricks disappear from the game arena. To increase the level of difficulty and game-play, later versions make use of multiple rackets and balls and vary the speed of the ball. Collision detection is supported between the graphics components of the application based on Newton laws of physics. The ARBreakout presents a more exciting way of playing video games, by allowing some extra features in terms of visualization as well as interaction experiences. In terms of software infrastructure, the game engine was ported onto a high-level AR interface (Liarokapis, 2007). Implementation details about ARBreakout have been previously published (Liarokapis, 2006). From the visualization (or augmentation) point of view, the game can be positioned anywhere in the real-environment using the reference point (which is the marker card). The player can use a handheld device which is equipped with a camera to superimpose the Breakout game into the

*Figure 3. ARPuzzle unsolved (left image) solved (right image)*

physical world. An obvious advantage of the AR visualization technique is that it makes the users feel more immersed into the gaming scenario as well as promoting collaboration between multiple users. As far as the interaction techniques are concerned, players can manipulate the gaming environment using the controls of the handheld device (keyboard or mouse) or through tangible ways. Figure 4 illustrates how a user can rotate the ARBreakout scene, using his hand to physically rotate the marker cards. This allows getting the best viewpoint in a natural and realistic manner. Similarly, the player can move the scene closer to the camera (and vice-versa) to zoom into the scene instead of scaling the game.

## Analysis

The end-user evaluation took place at City University and Coventry University with undergraduate and postgraduate students studying Information Science and Computer Science respectively. A total of 60 end users took part in this pilot testing at both Universities. The ARPuzzle was evaluated with 30 students whereas the ARBreakout with 30 students. The average time for each assessment was 45 minutes and participants had to complete questionnaires with rating between 1 (= not very good) to 5 (= excellent). Although a number of questions were asked, this section presents only these ones which were relevant to both ARSGs. These include important issues of gaming such as: visualization of the game, interaction techniques, collaboration with other players and education and learning.

In terms of visualization in both games the ARPuzzle (Mean = 3.93, SD = 0.91, SE = 0.17) received much better feedback compared to the ARBreakout (Mean = 3.13, SD = 1.19, SE = 0.22). An overview of the visualization results are illustrated in Figure 5. In particular, the majority of users agreed that the ARPuzzle contains simpler graphics but because the purpose of the game was different, ARBreakout scored less. However, all users agreed that more realism would

*Figure 4. ARBreakout*

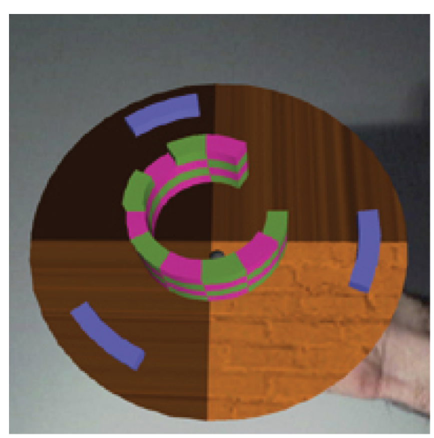
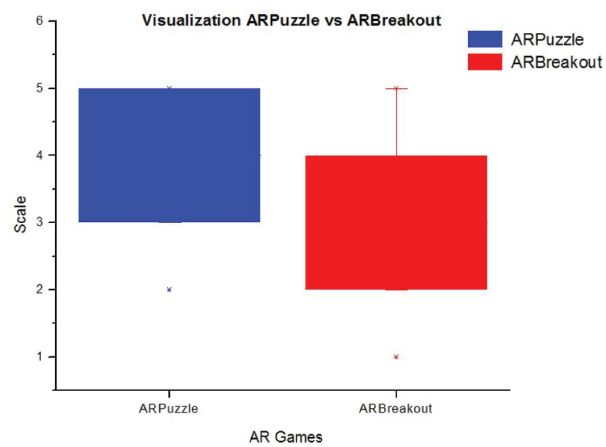


*Figure 5. Visualization comparison for ARPuzzle vs. ARBreakout*




help improving the immersion in both games. As far as the interaction techniques are concerned, the ARPuzzle (Mean = 4, SD = 0.95, SE = 0.17) received again much better feedback compared to the ARBreakout (Mean = 3.17, SD = 1.05, SE = 0.19). On the puzzle game, the users did not have to use any input devices (keyboard or mouse) to interact with the game whereas user input was essential in the arcade game. This made the puzzle game much more attractive and 'easy' to play allowing for a wider age-range. An overview of the interaction results are illustrated in Figure 6.

Next, the level of collaboration in both games was tested. It is worth mentioning here, that to finish either game, collaboration is not required. The ARPuzzle (Mean = 4.07, SD = 1.01, SE = 0.19) is a more collaborative game compared to the ARBreakout (Mean = 2.77, SD = 1.01, SE = 0.18). Participants felt that it is more important to collaborate in a table-top environment in order to solve the puzzle rather than play an arcade game. On the contrary the arcade game requires less space and can be positioned almost anywhere in the real environment but participants mentioned that collaboration might confuse users instead of helping them. An overview of the collaboration results are illustrated in Figure 7.

Finally, the educational and learning aspect of both games were measured. As expected, the ARPuzzle (Mean = 3.97, SD = 0.85, SE = 0.16) received much more positive feedback compared to the ARBreakout (Mean = 2.77, SD = 1.07, SE = 0.20) mainly because users learned about geography and GIS. On the contrary the arcade game educational value was more into the novel interaction techniques in such types of games. An overview of education and learning results are illustrated in Figure 8.

Based on the above results, it is obvious that the ARPuzzle is a more effective educational game compared to ARBreakout for the above-mentioned reasons. For the ARBreakout game, participants indicated that it is much easier to familiarize and adapt to the game-play compared to VR or video games. Regarding the ARPuzzle they found it very interesting, easy to use and good as a learning tool. In general it was recorded that tangible AR interactions are preferred compared to traditional ways of playing games. This was verified according to the game type preferences, puzzle games are preferred by larger numbers of people than arcade games, according to a previous study (de Freitas & Jarvis, 2008). This would seem to indicate that in AR environments puzzle types of games may

*Figure 6. Interaction comparison for ARPuzzle vs. ARBreakout*

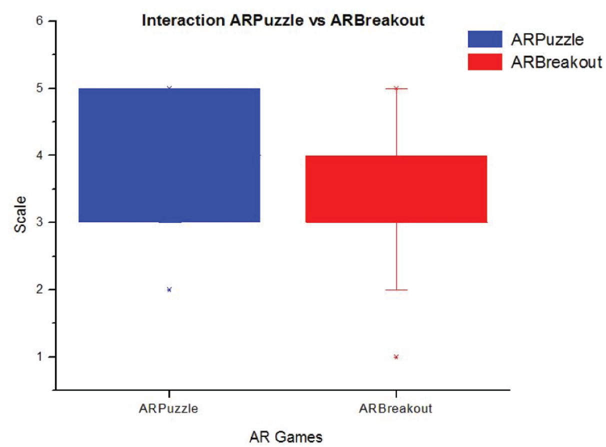
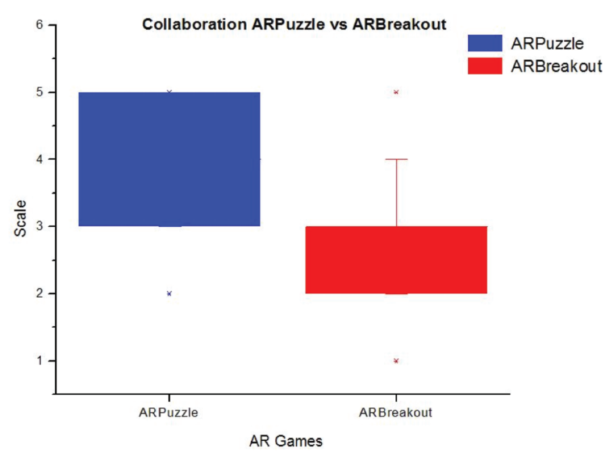



*Figure 7. Collaboration comparison for ARPuzzle vs. ARBreakout*

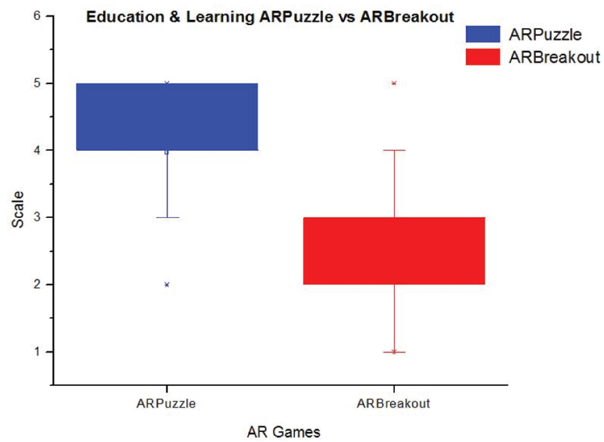



be most appropriate in terms of preferred learning method over other game types tested.

## CONCLUSIONS AND FUTURE DIRECTIONS

This paper has presented an overview of two diverse ARSGs based on an evaluation of the Four Dimensional Framework. In particular, two case studies were presented, a puzzle game called ARPuzzle and an arcade game called ARBreakout. An evaluation with 60 users was performed and important issues of ARSGs were asked including: visualization of the game, interaction techniques, collaboration with other players and education and learning and results clearly illustrated that the puzzle is a more appropriate serious game. If applied properly, AR gaming seems to have the potential of changing the way that serious

*Figure 8. Education and learning comparison for ARPuzzle vs. ARBreakout*




games are played and used as well as helping to educate players while playing. The value of AR applications in serious games has the potential of transforming the way we perceive training and multimodal learning.

The future of serious gaming includes three significant aspects: convergent technologies, widening application areas and efficacy proofs that together will power the wider uptake of these applications over the next three to five years. The video game sector is due to grow at an annual compound rate of 11.4% according to PriceWaterhouse Coopers Global Entertainment and Media Outlook: 2006-2010 analysis of the video games sector. Alongside this, significant growth of leisure games, the use of mash-up applications such as of games with mirror worlds (representations of the real world) like Google Maps, and the use of social software tools such as Facebook, will together fuel a wide range of future applications.

The proliferation of different formats of games as a whole including mobile games will present a diverse range of applications for every client need and learning requirement. The widening application areas for the technologies are presenting unique global reach and potential markets for well developed tools. The studies being undertaken at the Serious Games Institute and elsewhere are beginning to provide evidenced proof of the efficacy of serious games, contributing to metrics and frameworks that can be used to support better development and design of serious games and the potential for benchmarking efficacy via specified metrics. Future research and development work will focus upon the potential of using these emerging tools for testing and validating other formats of serious games.

In the future, the technical characteristics of both games will be improved. Both games will include alternative methods of interaction, such as the Wiimote control and a 3D mouse for the arcade and a virtual glove for the puzzle. The ARPuzzle will also contain more pieces and the 3D buildings will be textured appropriately (according to the actual urban environment). Also, the ARBreakout game will include multiple levels of difficulty. In addition, the tracking component of the AR platform will be combined with a six degree-of-freedom tracker allowing a wider gaming area as well as gestures and voice recognition. Finally, more AR serious games are currently being implemented and future research will focus more user-studies with larger sample sizes.

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