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Getting serious with iPads: The intersection of game design and teaching principals

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Abstract
Mobile devices, such as tablets and smart phones, are increasingly being utilised as tools for education, with tablets such as the Apple iPad being introduced into many classrooms. These devices are seen as enablers of learning through a fun, interactive interface; however the process of producing a pedagogically valid, yet entertaining application is often poorly understood. This problem motivated the authors to work collaboratively on the design and development of an iPad game targeted at foundation level classrooms and linked to the Australian science curriculum. In this paper we review the tools and processes that are available for the production of educational games. We begin by reviewing the technology and development paths available for targeting a variety of mobile platforms. Following this, we examine theories of game design as applied to educational settings. This review frames our discussion of the design features of the iPad game “Aussie Explorers” produced as an outcome of the project.

INTRODUCTION
The landscape in education is changing with the introduction of increasing types of technologies to support teaching and learning. Personal mobile computing devices are on the rise and there is significant interest in iPads and the range of downloadable applications currently available. There are a range of applications available to support Early Childhood education; however there is a lack of science resources that align with the Australian Curriculum. This need provided the focus for an IT based Masters level project facilitated by academics from Edith Cowan University (ECU). The projects in this Masters level unit require students to demonstrate their grasp of software development within a managed project that is designed to address a real world problem, thus providing the opportunity for students to create a product that has a tangible benefit to the project sponsor. For the current project, which is the focus of this paper, a need was identified for a mobile application that is appropriate for educating foundation level students in science within an Australian context. The iPad game produced from this project titled “Aussie Explorers”, is now freely available from the iTunes App Store.

As the name suggests, “Aussie Explorers” is set in an Australian context and provides opportunities for young children to develop inquiry skills as they explore concepts related to weather and materials. Design features were included to ensure an interactive multimodal learning environment was created within the game. It was asserted that the child centred and interactive nature of the game would promote deeper cognitive processing of science concepts in the learner. The game included a system for immediate feedback, with corrective responses and positive reinforcement for task completion. As an assessment tool, the time taken for the completion of the game was included in the design. The application is expected to provide children with an engaging and conceptually interactive approach to exploring the environment and for making choices based on their observations. Children playing “Aussie Explorers” are engaged within a framework that is realistic and closer to their real world surroundings than present mobile applications currently on offer.

To begin the description of our game development process we describe the emerging use of mobile computing devices in schools and consider the game development pathways for mobile devices. The technical aspect of our game creation is then situated with a discussion of the curriculum drivers and pedagogical principles that underpinned the design of the digital learning environment. The specific features of “Aussie Explorers” are then described as an elaboration and illustration of these design principles.

Mobile computing devices used in education
Mobile computing devices have an increasing role in education. The trend began in the 1970s (Suydam, 1979), when pocket calculators found their way into classrooms and replaced traditional problem solving tools in mathematics education. Over the years, the original non-programmable calculators were replaced by more sophisticated programmable versions with graphical abilities. This flexibility enabled their use as more than just calculation machines, and allowed experimentation with educational games (Durapau, 1979).

Separately to the development of calculators, other mobile computing devices have emerged over the years. Early portable game consoles, such as the Nintendo Gameboy and Sony PSP provided a high entry barrier for purely educational applications due to the complexity of development and cost of development kits. This barrier resulted in their use in education being mostly limited to larger budget applications such as for the military. One example, initially for the Sony PSP, is a game for the teaching of foreign language skills to Marines (Johnson, 2008). Personal Digital Assistants (PDAs) were hardware devices with similar features to handheld consoles and provided a lower entry barrier due to lower cost development paths, as such more educational games were developed for them. Examples include grammar exercises exploiting the lure of gambling (James, 2003) and collaborative games to help students explore genetics (Danesh, 2001). The mobile phone has also evolved from being able to send simple messages and make phone calls; modern smart phones can now perform similar functions to larger desktop computers.

Currently, in 2012, the mobile technology landscape is consolidating towards a single multi-purpose computing device. Mobile smart devices include multi-core processors, high resolution touch-sensitive displays of various sizes, network connectivity (including phone calls), and are interfaced to a variety of sensors such as cameras, touch screens, and accelerometers. These features add potential for such smart devices to be used for education. The major variable between different devices is screen size with screens of up to 10 inches available for tablet devices such as the iPad. Studies have shown that increased screen size can lead to greater enjoyment (Kim, 2011) and importantly, a positive impact on learning (Maniak, 2008).

Game development paths for mobile platforms
Currently, the two dominant operating systems for mobile smart devices are Apple’s iOS and Google’s Android (Gartner, 2012). To develop mobile games, three broad categories of development technology are available: native software development kits (SDKs), multi-platform SDKs, and mature game engine technology. Native SDKs are...
provided by the developers of each particular mobile operating system, for example the iOS SDK by Apple targets iPhone and iPad devices. The advantage of native SDks is that they can produce fast, efficient programs and give the developer access to a broad range of device capabilities. The major disadvantage is that they target one particular operating system. Converting a program written using the iOS SDK to run on an Android platform is not trivial as both use different programming languages and development environments.

Due to the prevalence of both iPhone and Android devices and the non-compatibility of their native SDks, multi-platform mobile SDks are increasing in popularity. These typically provide a programming interface and various software libraries for simplifying the programming of elements such as graphics and networking, similar to native SDks. The advantage to the developer is that multi-platform SDks provide a single development platform, where the same program code can then be packaged and deployed to multiple devices. A disadvantage of this is that performance may be lower (Paananen, 2011) due to the overhead of translating the device independent code to the particular hardware device. In addition, the multi-platform SDK may only implement a subset of functionality of the hardware and may not implement all of the features for every platform (Paananen, 2011).

Fully fledged game engines are also entering the space of mobile game development. Game engines are a step above SDks in that they provide an assortment of tools for rapid construction and editing of the game environment by larger teams. Game engines arose due to the increasing complexity of computer games and the large amount time and resources that are needed to construct the basic game framework that includes many non-trivial components such as 3d graphics, artificial intelligence, and physics. A game engine packages functionality that is generic to most games and provides an easier entry point to developers, who can focus on their own specific game play code and art assets, rather than needing to implement every aspect of the game. Game engines that were initially build for developing PC and console games, but are now also targeting mobile platforms include Unity3D, and the Unreal Development Kit. Ideally, these game engines make it possible to deploy the same game to mobile devices as well as PC based systems, however as with the simple platforms independent SDks, only a limited subset of the game engine is available for use on mobiles, and the resulting programs tend to be much larger and performance intensive than native mobile applications.

For “Aussie Explorers”, we chose the Corona SDK (Ansca, 2012). This multi-platform SDK supports iPhone, and iPad hardware, as well as Android phone and tablet platforms. Although we were targeting iPads, the use of Corona SDK makes deploying to an Android device possible, making it a more flexible development option. As “Aussie Explorers” is graphically simple, employing 2D graphics, the extra functionality a game engine would provide was not necessary.

**An education focus in gaming**

Early mobile-based education applications focused on exploiting the mobility aspect of the device, such as applications for outdoor exploratory learning (Nilsson, 2009), whilst desktop and laptop PCs were used in the classroom. In contrast, modern mobile smart devices are increasingly being exploited for their convenience as replacements for traditional PCs. For example, the Western Australian Department of Education announced in February 2012 the provision of iPads for Year 1 and 2 classes in selected schools (Barnett, 2012). In response to these mobile devices being increasingly tied to a classroom environment, there is a need for suitable software in order for their educational potential to be realised.

In an ICT enriched social constructivist classroom where it is assumed knowledge and understanding are actively constructed through social interactions and not passively received from the teacher or environment, teachers would match the use of technology to learning objectives goals and outcomes. Our aim was to develop a game which was aligned with the Foundation Year outcomes of the Australian Science Curriculum (ACARA, 2010), which are listed in Table 1. Although specific to the Australian curriculum, these science skills and understandings are also relevant to other country’s curriculum.

| Earth and Space Science Understanding | Daily and seasonal changes in our environment, including the weather, affect everyday life | linking the changes in the daily weather to the way we modify our behaviour and dress |
| Science as a Human Endeavour | Science involves exploring and observing the world using the senses | recognising that observation is an important part of exploring and investigating the things and places around us |
| Science Inquiry Skills | (i) Questioning and predicting - Respond to questions about familiar objects and events | considering questions relating to the home and school and objects used in everyday life |
| | (ii) Planning and conducting - Explore and make observations by using the senses | using sight, hearing, touch, taste and smell so that students can gather information about the world around them |
| | (iii) Processing and analysing data and information - Engage in discussions about observations and use methods such as drawing to represent ideas | taking part in informal and guided discussions relating to students’ observations |
| | (iv) Communicating - Share observations and ideas | working in groups to describe what students have done and what they have found out |
| | | communicating ideas through role play and drawing |

Connecting with the curriculum ensured the game was usable and relevant to Foundation level classrooms across Australia and offered a tool to teachers for facilitating children’s development of scientific literacy. What should be recognised here is that the quality of curriculum and educational resources is only ensured through effective teaching and learning. Principles of effective early childhood pedagogy are embedded into the game design but they must also be evident in the use of the game in the classroom.

**Interactive multimodal pedagogy**

Teaching activities in an interactive learning environment are dependent on the actions of the learner and as such should be flexible and responsive. The child is at the centre of the learning experience and is both physically and mentally active. With this in mind, we aimed to develop a game which promoted and supported pedagogical interactivity or put simply, included practices that mediated communications between the teacher, students and the technology. The interactive learning environment should allow learner input and support different learning paces and style, which is assumed to promote deeper cognitive processing of targeted concepts.
in the learner. A review of research literature conducted by Moreno & Mayer (2007) suggests there are five main types of interactivity that can be embedded into a learning environment. These are dialoguing, controlling, manipulating, searching and navigating. Design features of our game “Aussie Explorers”, ensured children could control the order and or pace of the sub games and could manipulating objects and images. Furthermore, Moreno & Mayer (2007, p. 312) stated that “interactivity is a feature that can be used to promote deep cognitive processing in the learner.” They further argued that learners are supported in building mental representations as they “select, organize and integrate new information with existing knowledge.” The game play required physical interactivity with a focus on the child manipulating objects on the devices touch sensitive surface but also at a higher level, conceptual interactivity, which extended the use of the technology to exploring, unpacking and constructing understanding of simple science concepts and inquiry skills. Focussing questions were included in the game design which directed learners actions but also their thinking about the key science concept and inquiry skills.

Interactive practices in our digital learning environment included multimodal representations of the target science concepts and skills. We used two different communication modes within the one space to represent the content knowledge; verbal (printed or spoken) and non-verbal (pictures, photos etc.) It is argued that student understanding can be enhanced by the addition of non-verbal knowledge representations to verbal explanations and it creates opportunities for learners to experience knowledge and demonstrate what they know in an increase range of modes (Murcia, 2010, 2012). Specifically in science, learning concepts and methods involves understanding and conceptually linking different representational forms. Lemke (1998, p. 1) argued that multiple representations of concepts are central to learning science and explained, “We need to see scientific learning as the acquisition of cultural tools and practices, as learning to participate in very specific and often specialized forms of human activity.”

Science as a discipline has a community of practice that includes particular ways of seeing, thinking and acting. We used both verbal and non-verbal representations to focus learners attention and thinking on a particular conceptual feature and to highlight key aspects of the phenomena being explored. There was a consistent style of multimodal representation used across each sub games to assist learners in constructing understanding of the science concept that sat across each example of the target phenomena. In this way multimodal representations were used to scaffold the construction of understanding, scientific explanations and reasoning.

**Game design principles**

A challenge when designing educational games is to make them both fun and effective. First, the game needs to be fun in order to motivate students to keep playing it. Second, the education needs to be embedded into the game as central to the fun so that the educational content is what is capturing the students’ attention, rather than being used to break up a compelling experience (e.g. playing an action game and having to solve a maths problem every so often).

In seeking to understand what makes a compelling experience, Csikszentmihalyi, (1990) observed and studied the phenomenon that some activities are so appealing to a participant that they become completely immersed. In this ‘optimal experience’ state, called flow, the participant can tune out the outside world, including the sense of time, and experiences a sense of control over the activity. Flow is often cited in the game design literature (Murphy, 2011).

Activities that promote the flow state obey four principles (Csikszentmihalyi, 1990):

- The participant understands clearly what they must do.
- Immediate feedback is given when the participant does something right or wrong.
- The challenge is matched to the participants’ skill.
- The activity allows the participant to focus, rather than dividing their attention.

As a counter-example, flow will be broken, resulting in a sub-optimal experience if the player is confused about what they need to do, are not sure if a particular action resulted in success, repeatedly fail due to the challenge being too hard, and miss crucial information due to their focus on other events.

**Game features of ‘Aussie Explorers’**

In “Aussie Explorers”, a key element to maintain flow is the role of the teacher as facilitator. As found in the recommendation of others (Hansen, 2011), the game is designed to be played in a classroom environment with the teacher guiding and promoting the exploration. Further, the game is designed with the four flow principles in mind. Audio instructions are given on each screen, such as ‘observe the weather’, with a small number of options to choose from. Audio and visual feedback is given in regards to the selected choices as soon as they are made. The matching of challenge and skills was guided by the Australian Science Curriculum (ACARA, 2010) and what is expected of that particular age group regarding the topics of weather and materials. Finally, the game is split into multiple screens, focusing separately on location to explore, weather observation in that location, and materials needed to spend the day in that location. This helps keep the players focused on a single goal on each screen.

The use of the Australian landscape was selected to allow for a wide selection of environmental features, thus broadening the options for weather types and the expected equipment requirements. The use of Uluru, an iconic symbol of the Australian landscape on the title screen is an immediate indicator to the student that this is a game focused on Australian content. To reinforce the theme of exploring the Australian landscape, a voice over style was selected that was distinctly Australian, as well as sounding cheerful and encouraging. Once the student moves beyond the title display, generic environments are used for each screen, to focus the students' attention on the general properties of the types of environments, rather than becoming fixated on the features of specific, well known Australian landmarks.

The ability of the student to make observations and learn from their decisions is enabled by the interactive features of the game and the multimodal nature of the feedback the game provides. Each screen in “Aussie Explorers” follows a consistent format. An environment is displayed, a voice over prompt asks the student to describe the weather, and weather icons appear along the bottom of the screen. When touched, the weather icon is surrounded with a box, the name of the weather appears below the icon, and the voice over pronounces the name of the weather. The icon, written, and spoken words reinforce each other. Once the weather has been selected, the voiceover then prompts the student to select equipment that would be appropriate for that environment. The weather icons are replaced with equipment icons, and the student gets the same interactive experience that is, icon, written and spoken name together.

Positive reinforcement is applied at three different levels within the game to encourage the student to continue. With each choice made, the student will receive a “Yes!” for

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correct selections, or a “Try Again” message for incorrect selections. Once all correct selections have been made for an environment, a gem will appear and a “Congratulations” message will be displayed. Finally, once all environments have been completed, a final congratulatory screen will appear, allowing the student to enter their name for the scoreboard. These three levels of feedback serve to guide the player through the game, and to encourage them to keep trying after incorrect selections.

To enhance “Aussie Explorers” as a teaching tool, several support features have been included. A Help screen has been included with the key steps and objectives of the game. This has been included as an initial reference point for teaching staff, to help plan how the game can be integrated into guided learning. Before beginning the game, display screens can be selected that display all icons available in the game. These icons display the same functionality as they do in the game, that is, selection will present visual and audio feedback of their names. This allows students to explore the icons in an open ended fashion, before entering the more goal oriented game. “Aussie Explorers” also records the time taken for each session, and stores the quickest and most recent game activities. This allows the teacher to review activities performed by one or more students at the end of the learning session.

Initial reception
A free version of “Aussie Explorers”, with six levels (approximately 2 minutes of focused game play), was submitted to the Apple app store on the 5th December 2011 and accepted on the 9th December 2011. By the 15th April 2012 it had been downloaded 423 times. For the period from 22nd January to 15th April 2012, the majority of downloads (27%) were from the US, followed by Australia (25.45%), and the UK (5%).

Games built using the Corona SDK feature instrumentation which collects data on session times. For the 31 days leading up to 23rd April 2012, a total of 213 game sessions were played. The majority of these (81%) lasted less than 20 seconds. We postulate that some possible reasons for this may be: parents downloading the game and checking its suitability for their kids with a quick session, people re-playing a particular level, and people simply “app surfing” by trying out many free apps. Of the remaining sessions, the number of sessions of a particular maximum length is shown in the graph Figure 1. The average session time for these games was 2 minutes and 31 seconds.

Conclusion
Importantly, to capitalise on the investment in mobile computing devices for young children effort must be given to the development of games that are based on sound pedagogical principles that include opportunities for active learning and multimodal design features. The design theory and principles underpinning the development of our iPad application “Aussie Explorers” prompted the revisiting of curriculum and the interactive pedagogy that enables the delivery of relevant and engaging tasks in ICT enriched early years learning contexts. In particular, the game development process highlighted that educational games need clear links to curriculum, have goals that are meaningful to the player and that the difficulty of achieving a goal must be balanced with the player’s skill level.

However we are mindful that, “interactivity and multimodal presentations do not cause learning, but rather that there are a growing set of research-based principles for using interactive multimodal learning environments in ways that promote learning” (Moreno & Mayer, 2007, p. 321). This game development project has highlighted a need for future teacher practitioner research to explore the impact of mobile computing devices such as iPads on how children learn with technology in early childhood contexts. Furthermore, it was evident in this project that collaboration between computer designers and educators was essential for ensuring the development of a targeted and worthwhile resource that could potentially improve learning opportunities for children.
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References

Authors Note

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Martin is a Senior Lecturer in Computer Science at Edith Cowan University, Coordinator of Games Programming and Honours degrees and Co-Director of the Research Centre for Transformational Games. He has an established track record of research in image processing, mobile computing, and the use of computer games as tools to transform their players.

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Jason is an application programmer with fifteen years experience in developing IT solutions for government and private businesses. Jason has recently completed his masters from Edith Cowan University in Games and Simulation Programming as a means of pursuing his interest in developing educational games.