Evaluating ICT in education: A comparison of the affordances of the iPod, DS and Wii

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This paper uses an evaluation method for Information Communication Technology (ICT) in education adapted from Morgan (2007) to conduct a comparison between the Apple iPod, Nintendo DS and Nintendo Wii, in order to assess the potential cognitive impact on learners of the affordances of each ICT device. The ICT evaluation method uses the concept of 'mediation' to link cognitive impacts on learners of specific learning activities with the affordances of mediating artefacts employed during those activities. For each device a set of designed affordances are described along with as series of initial suggestions about how these affordances could be applied to educational contexts. A comparison of the different development options is then conducted to assess the relative educational potential of each device. Finally several avenues for further research are discussed.

Keywords: affordances, mediation, artefacts, cognitive impact, evaluation

Background

Increasingly Information Communication Technology (ICT) devices, such as mobile phones, digital cameras, PDAs, games consoles and MP3 players, are saturating the social environment of today's young learners. Yet few of these devices have been adapted for use in educational applications despite their significant interactive affordances and educational potential. This study focuses on three ICT devices that are having a major impact in cultural environment of many of today's learners, the Apple iPod MP3 player, the Nintendo DS (NDS) portable games console and the Nintendo Wii games system. These three devices have been chosen for this analysis because each has a unique combination of novel affordances and therefore may lend themselves to the design of new forms of learning interactions and activities. Increasingly many young learners are likely to not only have access to these devices but are also likely to be very familiar with the expanded range of interaction methods that these devices enable. This situation contrasts strongly to the static range of interactive possibilities afforded by the traditional classroom or via the PC for online learning. So far only the iPod has made any significant impact on educational practice (such as Chan et. al., 2006; Colbran & Tynan, 2006; Duke University, 2005; Maag, 2006; Miller & Piller, 2005) but even the impact of the affordances of this ubiquitous device are poorly understood. The NDS and Wii have a range of innovative affordances that may transform educational practice and pedagogy in unexpected ways.

Evaluating the affordances of ICT in education

In order to analyze the potential educational affordances of the iPod, NDS and Wii a systematic method is required to describe the nature of the affordances and constraints of each device and to evaluate their potential learning effects. A more detailed evaluation scheme is described in Morgan (2007) but for the purposes of this paper this method has been simplified and restructured to assist in the current analysis, which focuses on affordances. Table 1 depicts a simplified evaluation scheme for assessing the affordances of ICT in education in relation to the cognitive impact engendered by the use of these mediating artefacts in learning activities. It is comprised of three sections; the first section describes the current affordances, uses and constraints of the mediating artefact, section two focuses on the cognitive implications of the identified affordances and constraints, and finally section three allows a consideration of possible alterations to the technology or methods of use of the mediating artefact in order to positively influence the cognitions of learners.

Table 1: A simplified evaluation scheme for the affordances ICT in education

<table>
<tr><th colspan="6">Affordances of ICT mediating artifacts for education</th></tr>
<tr><th colspan="4">Positive characteristics and affordances</th><th colspan="2">Constraints</th></tr>
<tr><td>Designed (1)</td><td>Contexts and pedagogy (2)</td><td>Activities (3)</td><td>Innovation trajectory * (4)</td><td>Designed (5)</td><td>Unintended (6)</td></tr>
<tr><td colspan="6">1. What was the original context of creation and what were the original affordances and constraints of the mediating artefact?
2. What affordances are created due to the use of the mediating artefact in new contexts? What pedagogical approaches have been used?
3. What affordances are created by using the mediating artefact in new learning activities? What teaching strategies have been used?
4. What is the trajectory of innovation (* See (Engeström,1999) and rate of change (Conole and Dyke, 2004) associated with the development of the mediating artefact?
5. What are the educational limitations of the mediating artefact due to its design and configuration?
6. What negative impacts are due to the adoption of tool created in another context to an educational task?</td></tr>
<tr><td colspan="6">Leads to a consideration of
Cognitive impact, learner activity and cognitive targets</td></tr>
<tr><td colspan="2">Base cognitions (7)</td><td colspan="2">Basic activity (8)</td><td colspan="2">Cognitive effects (9)</td></tr>
<tr><td colspan="6">Focusing on the desirable cognitive characteristics of using the mediating artefact in these learning activities.
7. Accretion, Elaboration, Tuning, Restructuring, (Lutz, 2000), Cognitive Dissonance, Internalization, Transfer, Generative Processing.
8. Argumentation, Abstraction, Summarization, Exploration, Experimentation, Application, Browsing, Restructuring, Construction.
9. What level of cognitive processes do learners carry out?</td></tr>
<tr><td colspan="6">Enables further targeted modifications of ICT mediating artifacts
Innovations</td></tr>
<tr><td colspan="3">Technology (10)</td><td colspan="3">Activity and pedagogy (11)</td></tr>
<tr><td colspan="6">10. How can we enhance the affordances and constraints of ICT to better achieve desirable cognitive targets?
11. How can we use the ICT differently to better achieve desirable cognitive targets?</td></tr>
</table>

(Adapted from Morgan, 2007)

The first stage in this evaluation process is to describe the original context of development of the ICT mediating artefact and to discuss in detail its original affordance in this context. For this discussion it is import to accurately identify the specific affordances of the device itself, rather than the affordances of the surrounding technologies (such as the PC in the case of the iPod) in order to allow a true comparison of the three devices analyzed in the paper. In the following sections the essential affordances and context of the iPod, NDS and Wii will be discussed.

Describing the affordances of the iPod

The iPod was first introduced in October 2001 as a digital audio file player but has steadily increased in capabilities with over 100 million units sold by April 2007 (Apple Computer, 2007). A number of models and styles of iPod are available but this review will focus on the latest top end model available in early 2007, the 5th generation iPod video. The video iPod has a storage capacity up to 80 GB and a display screen of 2.5 inches (diagonal), is a backlit LED, displays over 65, 000 colours with a resolution of 320 x 240 pixels. This device is portable with a small form factor. It can play a variety of video and audio formats and the drive can be formatted to storage files from the Macintosh or Windows platforms. The iPod also has 64 MB of RAM built in which is used to load the custom operating system and to cache media file to prevent skipping on play back. The iPod has a proprietary connector that may be connected to an iPod dock but that may also be connected by a cable to a computer, which will enable data transfer and power through a USB port. The iPod device itself has no inbuilt speaker and only has a headphone mini-jack to connect earphones or external speakers can be connected through the dock connector. The battery life for the device is approximately 20 hours for music playback and 6.5 hours for video playback. A variety of add-on devices can be connected to the iPod through the use of the iPod's connector. An example of such a device is a microphone that will allow the iPod to capture audio files but the effective microphone range is limited, (Duke, 2005).

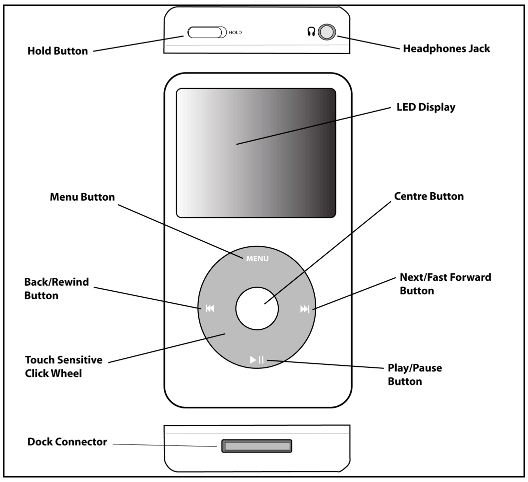

Figure 1: Features of the iPod

The interesting issues in terms of the affordances of the iPod are evident when the modes of interaction are discussed. Two basic modes of interaction are possible; 1) synchronization of files with a computer via the iTunes software, and 2) using the 'click wheel' interface of the device. Both these interaction methods have strict constraints and only provide a limited range of actions. In terms of the synchronization process, since the iPod itself has no connectivity to the internet, such as the network and wireless capabilities of other devices discussed in this paper, content must be first loaded into the iTunes software on a PC for later transfer to the iPod. Content creation is not an affordance of the iPod but is usually accomplished on a PC for upload to the iPod. The one exception to this may possible be that a microphone can be added to the iPod to allow the user to record audio files. Educators often cite the creation of podcasts as an educational use of the iPod but this is in fact an affordance of the PC on which the content is authored rather than the iPod on which it is played. Users can create content on the PC such as MP3 audio files and MPEG4 video files. The creation of video content for the iPod is problematic due to the custom screen size required and the custom file compression required. Therefore some expertise is required to convert existing content for use on the iPod.

The interface for the iPod device itself is innovative in terms of layout and ease of use but is very restrictive in terms of actual affordances. The click wheel interface has only five buttons, four of which are integrated into the touch sensitive circular wheel. A mechanical switch on the side of the device locks and unlocks this interface. Two main types of interactions are possible; i) a modal navigation through nested menus systems to select items, and ii) a scrolling behavior that controls functions such as volume control and scrolling through a menu list. The operating system, iTunes and other software provided by Apple for the iPod is closed source thereby limiting the opportunity for third-party develops to modify or add features to the device through software.

Although a large number of studies have been conducted into the educational uses of the iPod in education the results have been limited. In the Duke University study (Duke University, 2005) 1600 first year students were given iPods, which were used in 48 courses by approximately 1200 students. Five academic uses of the iPod were identified by the Duke study; i) course content dissemination, ii) classroom recording, iii) field recording, iv) study support, and v) file storage and transfer. Only the 'study support' category, makes use of the unique affordances of the iPod in mobile contexts. The other functions can be achieved more cost effectively and/or more reliably by other devices, such as video cameras and thumb drives. In any case three of the functions are not the result of the affordances of the iPod itself. In fact the PC enables the dissemination function and an add-on microphone device supports the recording functions. Most educational uses of the iPod revolve around the 'study support' function where learners can review content such as lecture material in their own time and in a variety of contexts. The Duke report provided some evidence that for subjects where the learner is required to be immersed in audio content, such as in language studies or in music studies, the ability for students to experience the audio content on demand in any place may be beneficial. The Duke report also reported a learner preference for being able to access recorded lectures for later review, particularly for examinations or if the learner had difficulty in attending classes. Review of content is however a fairly limited and passive learning interaction.

In regard to the rate of change in the technology, it must be recognized that the iPod has been developed as a propriety device rather than as a development platform, as is the case with the other two devices discussed in this paper, which are games development platforms. The consequence of this difference is that the manufactures of the iPod, Apple Computers, are free to make any revisions to the device and its software at any time in order to meet changing market conditions without regard to the consequences of these changes for developers. Five generations of the iPod have been released since October 2001. This is in addition to one model of the iPod mini, two models of the iPod Nano, and two models of the iPod shuffle. The 5th generation iPod Video was released in October 2005 and had a minor but significant hardware revision, version 5.5 which was released in September 2006. In 2007 the new iPod Touch was released. Each generation of the iPod also has one or more configurations. Each of these configurations may use a variety of different components, which might in turn influence software development issues. This frequent updating of the technical specification of the devices creates problems in terms of content development, since each new configuration must be investigated by the development team. Also existing applications must constantly be updated and maintained. Indeed some technical revisions to the device may make existing software solutions totally incompatible with the new model. While new features are being added to the iPod regularly in practice it may be difficult for educational developers to take advantage of these changes due to issues of rapid obsolescence.

Describing the affordances of the Nintendo DS

The Nintendo DS (NDS) is a hand-held gaming console first released in 2004 and revamped as the DS Lite in 2006. On its release the device was a major step forward for hand-held gaming, due in part to its dual screen configuration, but primarily due to its use of a touch-sensitive screen, microphone, and wireless network connectivity for game play. To date the DS and DS Lite have sold over 40 million units combined (Nintendo, 2007 a). The device is extremely portable, with the DS Lite weighing only 275 grams, (Nintendo, 2007 b). Many of these affordances make the NDS a prime candidate for development as an educational ICT.

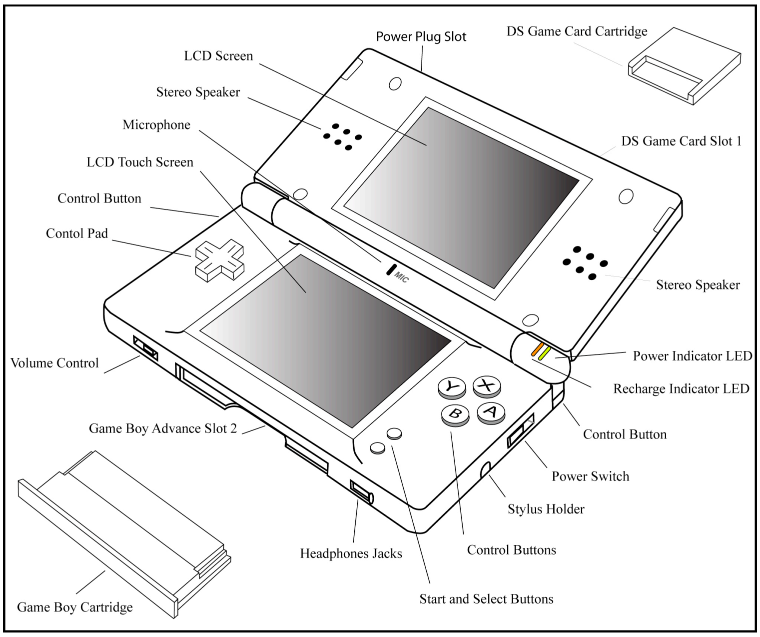

Figure 2: Features of the Nintendo DS Lite

The DS and the DS Lite provide the same technical specifications and affordances and will thus be referred to under the generic title of 'NDS'. Each screen on the NDS is a 3-inch TFT LCD with 256 x 192 pixel resolution and the capacity to display 260,000 colours. The bottom screen also has touch-sensitive affordances that can be utilised with the supplied stylus or a user's fingernail. Controls such as a directional pad and thumb-activated buttons are also present to provide users with 'standard' hand-held gaming controls. Along with stereo sound, the NDS provides an inbuilt microphone for in game use. This may be used for speaking commands or even blowing into the console during game-play, establishing another method of user control. The NDS has two slots in which games cartridges can be inserted. Slot 1 accommodates the Nintendo DS Game Card while Slot 2 accommodates the older and larger Game Boy Advance cartridges. NDS games are provided on proprietary semiconductor ROM memory (Read Only Memory) and are typically 64 MB in size, although it can accommodate games up to 1GB. The NDS has in effect two expansion slots, due to the fact that the hardware interface through which games cartridges are loaded can be used in order to connect other devices such as external memory cards, motion sensors or even GPS systems. Although proprietary memory is used, 3rd party adaptors exist to allow the widely available and inexpensive micro SD memory to be used in the DS, allowing potentially 4GB or more of storage. 3rd party software solutions also exist to allow other non-game multimedia to be accessed from these memory alternatives. The NDS also provides limited built-in memory that is used to store user preferences as well as the provided *Pictochat* software. *Pictochat* utilises the native IEEE 802.11 wireless networking to connect to other NDS consoles, enabling users to chat up to a range of approximately 10 metres. The wireless networking feature is employed in many other games to provide multiplayer game-play, supporting the linking of up to 8 DS consoles in a 'game' environment. This feature has obvious applications to collaborative learning activities for small groups of learners. This feature is even more significant since the device is portable therefore collaborative educational activities can now be taken into the field. Importantly, the wireless networking feature allows NDS users to download games and applications from other NDS consoles or wireless network hotspots. The device also has an element of being 'context aware', with some game titles detecting if other players are in the vicinity. Internet play is also possible with a limited number of game titles. In 2006 a web browser was launched for the device, enabling users to browse the internet.

To further consider the affordances of the NDS, it is easiest to discuss them in the context of several applications. *Dr Kawashima's Brain Training* (Nintendo Publishing) is one of several puzzle games to focus on mathematics and logic rather than traditional role-playing or 'first person shooter' game play. The character Dr Kawashima guides the player through daily exercises to keep the brain "young and healthy", (Nintendo, 2007 c). These exercises include mathematical calculations, memory tests, Sudoku and other activities designed to stimulate the brain. This title has sold over 8 million copies to date (Nintendo, 2007 a), which is particularly impressive given it is not a traditional game title. Extensive use is made of the dual screen configuration, the touch screen and the microphone. The game presents itself as a "book", with the NDS turned 90 degrees from standard game play orientation. The touch screen is used as the primary interface, but text-recognition also plays a significant role with answers to many of the exercises being written by the user with the stylus. Voice recognition is also used, where answers to some mathematical questions are spoken to the device.

Nintendogs (Nintendo Publishing) provides further insight into the affordances of the NDS. Extending the *Tamagochi* philosophy further, *Nintendogs* provides the opportunity to care for a puppy. Once a dog is chosen, the user has the opportunity to name them, teach them to respond to both voice commands and touch screen interactions, and care for them with feeding and walks. These interactions highlight the strengths of the microphone and touch screen. However it is in *Nintendogs* that the wireless networking capabilities are brought to the fore. If another NDS running *Nintendogs* is within wireless range, the game can enter 'bark mode'. In this mode the two puppies will wander onto each other's console and interact to simulate the visiting dog. This can be done without any user intervention, highlighting a unique approach to networked game play of the device.

The final examples of NDS game play discussed here in order to demonstrate the affordances of the NDS are games that begin to blur the line between gaming and education. Although presented purely as a gaming experience, *Trauma Centre: Under The Knife* presents the user with a series of medical procedures to be undertaken, with the stylus taking the place of scalpel, syringe, and suture. As the promotion material explains, "The stylus will be your scalpel as you make incisions, anesthetize (sic) problem areas, remove tumours, monitor vital signs, apply bandages, and more! Deal with high-stress situations and human drama between appointments…", (Nintendo, 2007 d). This blurring of boundaries between game play and education continues in *Phoenix Wright Ace Attorney*. Taking on the role of a novice attorney, users "use both the dual screen and touch screens to investigate crime scenes, question witnesses and present shocking evidence", (Nintendo, 2007 e). While interactions in the case of *Phoenix Wright* are limited to simple touch screen gestures, it is important for its focus on active role playing in authentic contexts. Both these titles begin to show how these affordances can change the nature of hand-held gaming and potentially educational practice as well. The user is an active participant in each scenario conducting actions that model real world practice, such as using the stylus as a scalpel, rather than simply clicking on objects or typing in text which are the primary forms of interaction in PC based educational applications.

With regard to the rate of change of the technology in the 2.5 years since its launch, the Nintendo DS has not undergone significant technical change. Although the DS Lite provided a cosmetic overhaul, the technical specifications have remained consistent. This may be attributed to the DS's status as a 'game development platform', whereby Nintendo works with and supports a community of content developers. Although Nintendo also develop and publish game titles, they understand one of their core strengths is in having a number of quality game developers producing innovative titles. In order to successfully achieve this, Nintendo provides proprietary development kits to accredited games developers and involves them in technological developments. As a result, the rate of technical change in the Nintendo DS is slower, however this arguably results in a greater pool of innovative developers as the need to write for an ever-changing technology is reduced. Possibly because of this lower rate of change, the community of 'home-brew' Nintendo DS developers is steadily growing. Open source development kits and tools have been developed to enable home enthusiasts to develop DS applications, thanks also in part to the wireless download capabilities of the NDS and third party memory devices. Although application development is still typically the realm of experienced programmers, online resources exist to allow novice game developers begin to develop and transfer their own NDS content. With no reported plans to replace the NDS with another hand-held console in the immediate future, it may be assumed that the development community for this device will continue to grow, potentially resulting in more sophisticated development tools for 3rd party developers such as educational developers. Such development tools could herald a true use of the Nintendo DS for educational purposes. While titles such as *Trauma Centre* and *Phoenix Wright* suggest role-playing and scenario based learning, the potential of the DS in an educational setting is virtually limitless. What is important however in the case of the NDS is to consider its specific affordances of the device in an educational context. While many of the games discussed above can be considered to be educational in nature to date no examples are available of the NDS being applied to specific educational contexts.

Describing the affordances of the Wii

The Nintendo Wii is the newest device to be discussed, being launched in mid November 2006, selling almost 6 million units in 5 months, (Nintendo, 2007 a). The Nintendo Wii provides a significant contrast from the previous two devices, primarily due to being the only non-portable device. The Wii is a 'traditional' gaming system that is designed to be connected to a wide range of standard televisions or similar display and only the controller is portable. Processing in the Wii is primarily driven by a high performance proprietary PowerPC chip, and video processing is performed by an ATI graphics processor, again designed specifically for the Wii. This combination of computing power allows the display of complex 3D computer graphic scenes generated on the fly in real time unlike the other two devices.

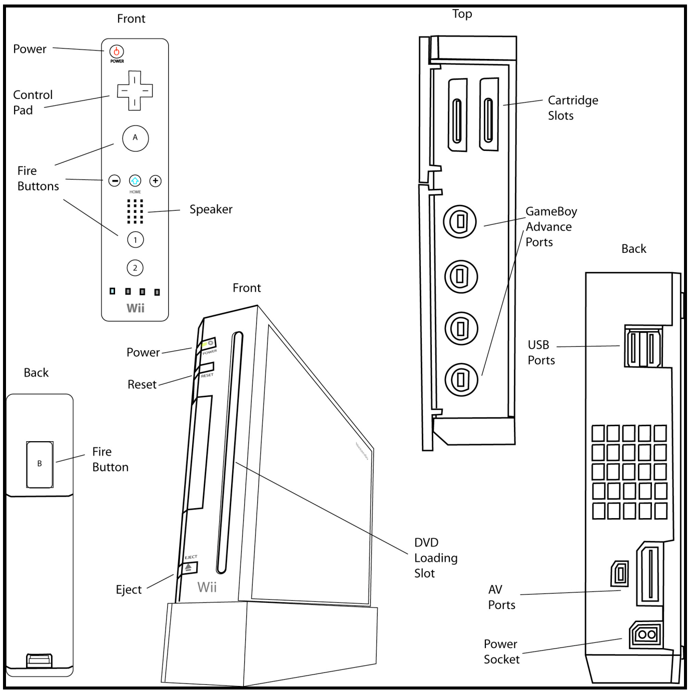

Figure 3: Nintendo Wii Console and Controller

Games are made available primarily through DVD based optical discs, although they can also be obtained online and stored in memory in the console. Storage memory in the console comes under several different categories. 512MB of flash based memory is built in to the unit, while slots for both standard SD flash memory and proprietary Nintendo Gamecube memory cards are also provided. This memory is used for saving game data as well as downloadable games. The console has a number of ports that can be used to connect periphery devices. Along with video connector ports, the console has 2 USB 2.0 ports and 4

Nintendo Gamecube controller ports. Network connectivity is built-in, using standard 802.11 wireless capabilities. This connectivity allows the console to connect to the free Nintendo online gaming community through standard home broadband internet access and wireless routers. The Nintendo service also provides regular free updates to system software and applications, such as an Opera based internet browser.

The most unique element of the Wii is undoubtedly the wireless game controller, also known as the 'Wii Remote'. Appearing similar to a standard television remote control, it houses a number of innovative elements that create a new style of gameplay. Using Bluetooth capabilities, the controller can be used wirelessly up to10 metres from the console. The most compelling technology however is the use of both accelerometers to sense rotational and orientation and acceleration through three axis, as well as optical sensors for detecting where the controller is pointing. This allows the user to make gestures with the controller for gameplay, rather than traditional button pushing. Such gestures include swinging the controller, making slicing motions, steering, balancing, thrusting, and pointing. The controller also has a built in speaker and basic force feedback.

The final aspect of the affordances of the Wii to be discussed involves the creation of personal avatars representing the game player, called 'Mii'. Each player of a Wii console can create one or many graphic characters with customizable features, which represents them while interacting with the Wii console. These characters can then appear in a variety of games in several ways. For example if you are playing tennis or boxing games the other player's character could be represented by the Mii avatar of the friend and it could appear to them that their opponent is your Mii avatar. In some games Mii avatars can populate the spectators in the game watching events, etc. These characters are portable in a number of ways. They can be stored in the Wii controller so that when you take the controller to play on a friends console your Mii can be transferred to their console and you can load their Mii avatars onto your controller for transfer. Mii characters can also be allowed to appear on other consoles around the world by configuring the Wii internet application 'WiiConnect' appropriately. You can go to a screen of the Wii software called the 'Mii Parade' to invite other peoples Mii characters to appear in your games and also to a screen called the 'Mii Plaza' where invited Mii characters can be viewed. The features of the Mii system show what a powerful social interaction tool the Wii console could become. Such systems can allow users to project their personality to other users and to make contact with other users through their avatars in many interesting ways. These features have the potential to be used in many educational situations where social and collaborative activity is desirable for learners.

Potential educational applications and pedagogical approaches

Each of the devices examined, the iPod, NDS and Wii, has a unique combination of affordances that may enable a variety of effective pedagogical approaches. An examination of the affordances of the iPod leads to the conclusion that its limited affordances would tend to produce limited cognitive impacts. For example according to the Duke University study (2005) the review of content for 'study support' was a major use of the iPod. 'Study support' in the ICT analysis method outlined in Table 1 equates to the Basic Activity of Browsing. This use of the device and its affordances dictates that the Base Cognitions of learners may be limited to elaboration and accretion in terms of schema development. This type of passive activity, i.e. listening to podcast lectures, will not necessarily lead to the generative processing required for restructuring and tuning of schemata to take place, as is called for by theories of learning such as Cognitivism and Constructivism. Options to create or manipulate content on the iPod itself are limited therefore opportunities for the device to have a more significant cognitive impact on learners are also limited. In order for the iPod to be considered an effective educational ICT either technical or software changes are required to allow learners to interact with and manipulate the content more extensively. This may involve allowing the user to create content on the iPod. For example, modification of the software to allow the user to record audio annotations for existing files, and to swap those annotations with other learners, is technically possible on existing iPod models with the use of currently available microphones. This would allow learners to process the podcast learning material much more extensively therefore producing a greater cognitive impact on learners.

In contrast the NDS affords many opportunities for learners to access, interact with, and manipulate content. Crucially, learners can also interact with their peers and the teacher in collaborative activities (see Resnick, 1991, on collaborative learning) via wireless connectivity. The extensive affordances of the NDS allow for a variety of generative processing activities such as argumentation, application, summarization, exploration, experimentation, restructuring, and construction. Where learners are manipulating content extensively through a range of activities Base Cognitions, such as accretion, elaboration, tuning, restructuring, internalization, and transfer are likely to occur. Most significantly, the portable and wireless capabilities of the device enable collaboration to be taken into the world outside the classroom. For example a group of learners might visit a historic site or museum and collaborate in an investigation using NDS consoles and downloading additional content appropriate to specific places in the site wirelessly. The learners might sketch what they see on the touch sensitive screen or record an audio annotation that describes their impressions of the experience. In other words the capabilities of the device allow the learners to collaborate with each other at the same time as they collaborate with the environment.

Since the Wii is not a portable device the range of contexts in which it can be used is more limited than either the iPod and the NDS, closer in fact to those of the PC. However the unique affordances of the controller and the capabilities of the console offer interesting opportunities for innovative learning interactions. The controller with its motion sensors has the ability to involve the learner's body in the interaction sequence rather than just engaging their mind. The consequence of this change in emphasis is that the learner is involved in performing actions that mirror real world activity in important ways. For example, if the learner is learning about cooking instead of clicking on an ingredient they will be required to chop, mix and stir the ingredient in order to complete the activity. This type of interaction is applicable to Behaviourist learning theory. It may also suit a whole range of learners who are Kinesthetic Learners (see Gardner, 1983, on Multiple Intelligences). In addition learners may collaborate in multiplayer mode, invoking the social aspects of collaborative activity that may appeal to a wide range of learners, especially adults. The graphical computing power of the device will allow for the recreation of exceptionally rich and detailed 3D environments allowing the embedding of 'authentic tasks' in 'authentic environments' (see Jonassen, et. al., 1993, and Duffy and Cunningham, 1996, on Constructivism, and Lave and Wenger, 1991, on Situated Learning). Finally a variety of rich media content is easily accessible through removable media with a large storage capacity supplemented by Internet connectivity.

A comparison of potential educational development options

The preceding sections have discussed the comparative affordances of the iPod, NDS and Wii but how realistic is it suggest the development of educational applications for these devices? The following section outlines the development resources and methods required for each device. It also outlines the advantages and problems with each device as an educational development platform.

Since the iPod software is a closed source development, options for educational applications on the iPod would need to rely on 3rd party open source solutions. Open Source development software is readily available but requires significant technical expertise to implement. In order to develop on the iPod the developer must use the command line to compile and install the following software on the device; i) a bootloader application which allows the user to select which operating system to use when the device is started, ii) a Linux-based operating system kernel and Graphic User Interface package (GUI) that allows programs to run, and finally iii) they must develop and install the appropriate educational application using C++. Several open source applications have already been developed for the iPod but it is a difficult process due to the specific processor embedded in the device. The bootloader application means that learners can retain all the current functionality of the iPod while extending their options through installing other operating systems and software. The advantages of development on the iPod include that the device costs relatively little, is easily available, has a massive user base and has a wide variety of add on hardware available. The open source development community is active, which makes source code and technical information on the device readily available. Problems for development on the iPod include, the closed source operating system and software, rapid changes in the device specification, and the extensive technical and programming expertise require to author applications in C++. Development of educational applications for the iPod is difficult but possible.

Since the NDS has been designed as a games development platform in some ways development for this device is technically easier than for the iPod. A technical specification for developers, software development tools and testing hardware is made available by Nintendo to make the development process easier. However since the average game developed for the device requires tens of millions of dollars, becoming an accredited developer and gaining access to the developer kits is very expensive. Like the iPod an extensive community of open source developers for the NDS is growing that makes available a variety of open source development tools and applications. The provision of 3rd party memory extensions allows the device to be reprogrammed to load an application from the external memory, like the process of loading a game, rather than replacing the normal operating system of the NDS. This process requires some technical expertise but is less difficult than the process of making an application run on the iPod. Like the iPod applications must be authored in C++ but due to the advanced features of the device, such as the touch screen, wireless networking, and voice recognition, the programming task to take advantage of these features may be more difficult. The advantages for development on the NDS include the lower cost of the device, its wide availability, the large existing user base, the stable technical platform, the growing open source developer community, the presence of two expansion slots, and the variety of add on devices becoming available. Disadvantages include the cost of the official development kits and the complexity of the task of programming for making use of the affordances of the device. Development of educational applications for the NDS is again difficult but not impossible. A wider range of affordances are available however for educational developers.

At present there are few options for development on the Wii console without using the official Game Development kit that is intended for professional development companies and is very expensive. In order to develop homebrew applications for the Wii console a mod-chip needs to be added to the console, which voids the warranty and few software tools are available to assist development. Homebrew development is possible in GameCube mode but this restricts the advanced features of the console. No alternate Operating System has been successfully ported to the Wii console as yet. Nintendo has recently made announcements of upcoming support for independent developers to author downloadable games, available through the Wii download service, via the introducing low cost software development kits but these games may have limited functionality. It will be some time before development of educational applications on this platform becomes viable.

Conclusions

This paper has followed an educational ICT evaluation method outlined in Table 1 that has been designed to consider the cognitive impact of the affordances of ICT devices used in educational contexts. Following the evaluation method a detailed examination of the affordances of three ICT devices was first conducted, involving the iPod, the NSD and the Wii. For each device its technical features and uses were described in detail. In the second part of the paper after describing each device the potential educational applications and pedagogical approaches were considered in the context of the possible cognitive impacts on learners of the affordances of each device. It was suggested that the greater affordances of the NDS offered a greater scope to promote generative processing of content than those of the iPod. The next section of the paper implemented the final stage of the evaluation process and discussed possible uses of the affordances of each device. This discussion was framed in the context of the practical options to develop educational applications on each device. A gain the greater affordances of the NDS and its design as a 'games development platform' suggested that this device had greater potential for development as an educational ICT than either the iPod or Wii.

Several directions for future research exist arising from this paper. Obviously, several studies could be conducted into implementing educational applications on the NDS. For example, interaction with audio content is limited on the iPod. An application could be created on the NDS to allow the learner to add and manipulate audio annotations for podcast lecture materials and to swap these with other students. Educational applications could also be created focusing on the touch screen, speech recognition and wireless affordances of the NDS device. Further research on other mobile and gaming devices, such as multimedia phones, the Portable Playstation (PSP) and PDAs, is also possible. Finally an interesting contrast to this paper would be an evaluation of the educational affordances of a variety of virtual worlds, for example GoogleMaps, SecondLife and a massively multiplayer online role-playing game (MMORG), such as World of Warcraft. Instead of focusing on the technical properties of devices such a study would focus on how the features, interactivity and content authoring options of each environment might allow learners to experience and manipulate content for learning purposes. In conclusion assessing the cognitive impact of the affordances of ICT used for educational purposes is a very rich area of further research.

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