# Augmented Reality:

## A Review of available Augmented Reality packages and evaluation of their potential use in an educational context

**November 2010**


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**Learning and Teaching Innovation Grants (04/08)**

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## 1. ‘Augmented Reality’

Every now and again a ‘new technology’ appears which seems to capture the public imagination. Invariably the technology enables a new means of interacting with screen-based entertainment or a computer game - 3DTV, the Nintendo Wii. The proliferation of so-called ‘smartphones’ with their abilities to run once-complex computer applications, in-built cameras and ‘GPS’ capability has unleashed the potential of ‘Augmented Reality’ – to date a regular feature of science fiction or ‘near future’ movies.

Picture the scene – a Terminator® has just arrived from the future. A real drawback of time travel even in the 22nd century is that you aren’t able to take anything with you including your clothes! Here’s our Terminator then desperately trying to blend in as he seeks out an outfit and of course that essential pair of sunglasses. He stumbles on a roadside bar and sizes up the clientele. Using ‘Augmented Reality’ (AR) the Terminator can check out everyone’s clothes and shoe size and decide who to target and ‘borrow’ their attire to continue his mission. ‘Terminator vision’ provides an overlay of ‘tactical’ information about the environment similar to that of a fighter pilot using a projected ‘heads up display system in a combat theatre. Arnie himself would be really impressed by how far AR technology has progressed to the point that today anyone with a Smartphone is able to see like a Terminator!


Figure 1: Pilot’s ‘HUD’ image

So, what is it about smartphones that has got everyone excited about a technology that has been around for quite a while now? AR isn’t ‘Virtual Reality’ (VR) nor is it ‘immersive’ - the technology now readily available on smartphones provides a view of the *real-world* blended with computer generated data in the form of text, graphics or rich multi-media content.

> ‘Augmented reality adds information and meaning to a real object or place. Unlike virtual reality, augmented reality does not create a simulation of reality. Instead, it takes a real object or space as the foundation and

incorporates technologies that add contextual data to deepen a person's understanding of it.'
Educause (2005)

Objects or places in the real world are unique by virtue of their location, history or context. It is now possible that a rich, educational experience could be provided by enabling interactions to take place between those objects and places with anyone equipped with a smartphone. The potential of AR is being realised on many different devices including the new iPhone, Android and Nokia mobile phones as well as tablet devices such as the Samsung Galaxy Tab (see figure 2).

Figure 2: Smartphones & Tablets in 2010

AR has been readily exploited in the world of advertising and retailers have been quick to have locational information about their outlets and products made available through a new generation of browsers which display 'floaticons' (figure 3) and directional information through a smartphone's camera and screen.

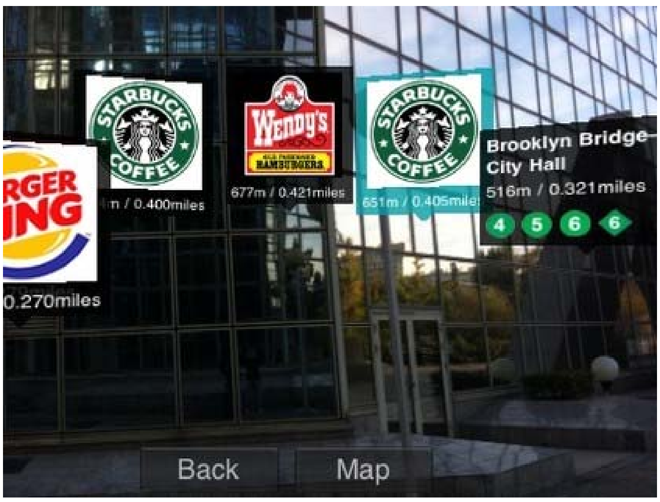

Figure 3: Augmented Reality View with Floaticons

## 2. Augmented Reality in Education

In a blizzard of augmented reality graphics and ever-more pervasive advertising, can the technology really be used in an educational context? The 2010 *Horizon Report* (Johnson *et al*, 2010) suggests this could be the case, and identifies Augmented Reality (AR) as an emerging technology that is likely to have a significant impact on teaching and learning within the next 5 years. The report places AR at the 'second adoption horizon' set two to three years from now, when it is believed widespread adoption of the technology, which makes use of the global cellular networks, will be in evidence. 'Simple augmented reality' described in the report refers to the shift that has made AR accessible to almost anyone largely because of the proliferation of ubiquitous and significantly portable handheld computing devices including smartphones. The report notes that 'wireless mobile devices are increasingly driving this (AR) technology into the mobile space' where it is believed the applications offer promise and relevance to teaching, learning and creative enquiry.

Augmented Reality has been used within an educational context for around 10 years. In the field of medical imaging AR is used to develop skills in interpreting Computed tomography (CT) scans and systems have been developed that allow patients and physicians to experience better communication during medical consultations. Used in this way AR systems superimpose augmentations of human body components onto the real patient's body, and these virtual annotations serve to improve dialogue and understanding between the two parties. An annual conference – 'MIAR' (Medical Imaging and Augmented Reality) brings together leading exponents in the field and provides a forum for new developments.

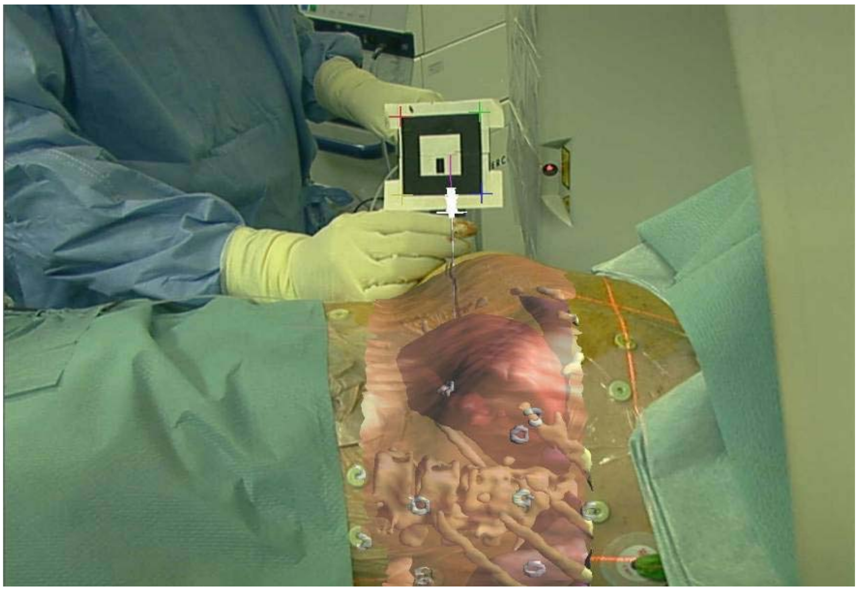

Figure 4: Augmented Reality used in the field of medical imaging

The *Horizon Report* goes on to observe that AR has the potential to provide 'powerful contextual, in situ learning experiences and serendipitous exploration and discovery of the connected nature of information in the real world… applications that convey information about a place open the door to discovery-based learning'.

Using AR it should be possible to unlock a 'hidden curriculum' associated with a particular location or objects, for example by revealing the significance of place or an object and the unique attributes it possesses or the stories with which it is associated.

We are firmly in the territory of 'interpretation' - a well-established feature of informal education. In the context of , for example, Heritage Tourism, visitors to sites of historical significance have for many years been shown panels of information and graphic images which reveal, say, how the castle, house or prehistoric monument looked in the past. The ruins or empty battlefield are brought to life for the visitor by a combination of text and graphics displayed on an interpretation panel. Augmented Reality offers a new user-owned means of interacting with information which would previously have been accessed via such a panel. Possibilities include 3D re-constructions, links to websites and most recently geo-referenced data which enable visitors to explore sites in a more dynamic, interactive way.

Educational applications of Augmented Reality include the 2007 iTacitus (Intelligent Tourism and Cultural Information through Ubiquitous Services) project - see figure 5. This European research project has explored how AR might provide compelling experiences at cultural heritage sites. Possibilities include 'Superimposed Environments', where 3D objects are placed into an AR view on the spot to overlay reality revealing missing artifacts or architectural reconstructions. 'Annotated landscapes' overlays information showing images, text and videos about a particular location. 'Spatial Acoustic' overlays transport a place's original ambience by placing audio clips in the surroundings using AR. iTacitus (2007) is also looking at how 'contextual filtering' based on the user's location and interests can determine what information to present to the visitor's mobile device.

Figure 5: AR Reconstructions at Heritage Sites Source: iTacitus (2007)

The School of Mechanical Engineering at the Korea University of Technology and Education has been developing an educational system for automotive engineering based on Augmented Reality (Farkhatdinov & Ryu, 2003). AR is used to give instructions on assembling and disassembling processes of real vehicle transmission systems with the help of augmenting virtual reality objects on a video stream viewed by students (see figure 6). 3D instructions on the technological workspace are used as interactive educational material, which is believed to make learning more interesting and intuitive.

Figure 6: Automotive Engineering based on Augmented Reality
Source: Farkhatdinov & Ryu (2003)

## 3. Augmented Reality Applications

There are two common approaches to employing AR in this or any context when the aim is to present information from a database or website on a smartphone.

### 3.1 Marker-based Augmented Reality

Marker-based AR applications use specific visual cues such as a logo or any other simple graphic device to call up information from a database or direct users to, for example, a website. The roots of this approach lie in 'Quick Response' ('QR') codes (figure 7) - essentially 2D bar codes which take the form of a pixilated square which can now be 'read' by mobile phones equipped with an appropriate software application ('app').

Figure 7: QR Code

A derivative approach using ‘magic symbols’ typically triggers a more dynamic, multimedia response, usually revealing either a 3D object or video embedded within a computer-generated object creating a sense of interaction. Marker-based AR is regularly used within the advertising industry and adopted by marketing campaigns using pre-printed or downloadable symbols printed in magazines or advertising hoardings. Many campaigns provide downloadable AR software applications and printable symbols from their websites (figure 8).

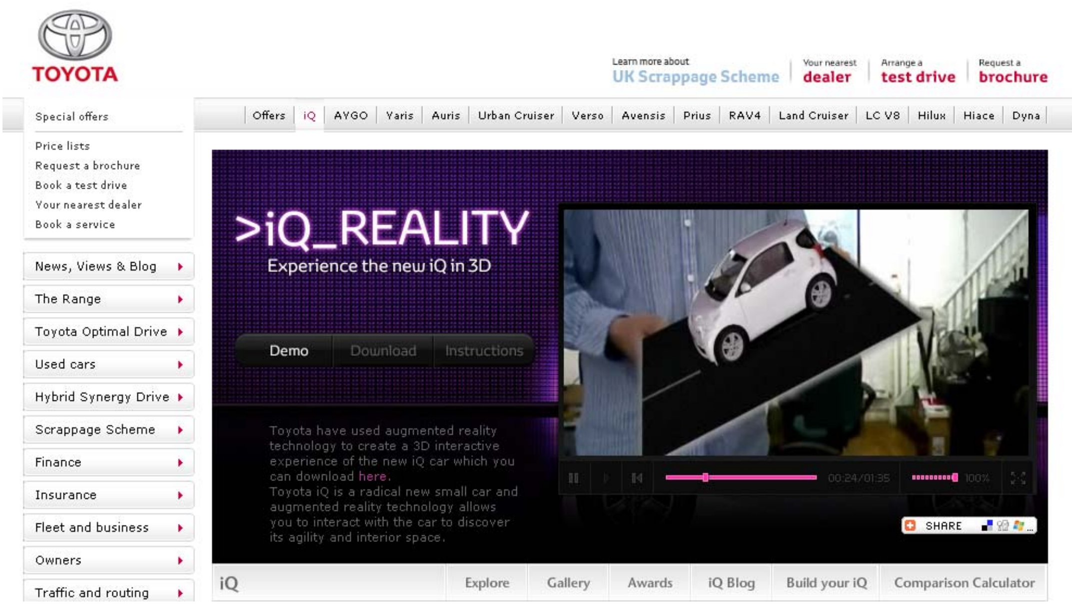


Figure 8: Marker-based AR in Advertising Source: Toyota (2010)

An effective example has been developed by the BBC to complement its successful ‘Merlin’ TV series.

Viewers show downloaded printed ‘magic symbols’ to their webcams which then reveal multimedia content via a webcam connected to their PCs. The experience is afforded more ‘realism’ by the viewable content being seemingly attached to the card which can be moved in 3D space (figures 9 and 10).

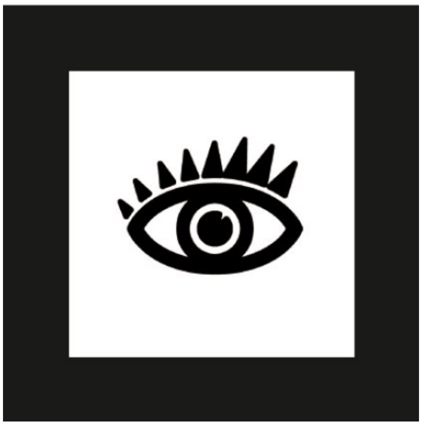

Figure 9: AR Marker
Source: BBC (2010)


Figure 10: AR Marker used in Conjunction with Standard PC Webcam
Source: BBC (2010)

### 3.2 Marker-less Augmented Reality

An alternative approach to AR involves using a smartphone's GPS (Global Positioning System) capability (figure 11). Smartphones 'know where they are' to a high standard of positional accuracy.


Figure 11: Smartphone GPS & Compass

Software developers have produced a number of 'AR Browsers' which enable smartphone users to navigate to Points of Interest (POIs) which appear in their camera views as 'floaticons' (figure 12).


Figure 12: POIs as seen with a smartphone

Directions to the POIs can be accessed either by travelling in the direction of the moving floaticon or using directions sent to, for example, Googlemaps. AR applications designed for specific navigational contexts have also been developed, such as 'Nearest Tube' which provides users with a virtual view of the London Underground transport network showing directions to access points and lines (figures 13 and 14).



Figures 13 & 14: Acrossair's 'Nearest Tube Application for iPhone

## 4. Available AR Technologies

Three aspects of AR technology are outlined below: Smartphones, Platforms and AR software.

### 4.1 Current Smartphone Ownership Patterns

The increasing power and portability offered by mobile devices have been a key factor in the rise of the smartphone market over the past two years. Over the mid-1990s and early 2000s, Personal Digital Assistant (PDA) devices – offering comparable, if more primitive functions to today's smartphones – had acquired a niche following. However, it was the development of flagship devices such as the Apple iPhone (first launched in 2007) that mass-marketised the ownership of portable devices with advanced computing functionality combined with telephones.

Due to the ever expanding goalposts of the computer hardware industry, there is no minimum standard to define a smartphone. However industry players describe notions of advanced computing power and data connectivity allowing functions not possible with their predecessor 'feature phones'. Today's smartphones typically feature large touch screens, geo-locational awareness and always-on 3G data connections. On the software side, such devices function through dedicated operating systems which provide a platform for the development of third-party applications ('apps'). Such apps have performed the basis for many augmented reality functions, such as those featured in figures 12-14.

Whilst most consumer perceptions suggest smartphones are a recent innovation, phones with similarly advanced connectivity functions have been commonplace in the business market since the mid-1990s. However, over the past few years the processing power of these phones has vastly increased allowing the development of more complex applications including AR. Additionally, the 2007 iPhone launch popularised advanced phones with its focus on non-business orientated functionality such as casual gaming and use of third-party applications for an increasing variety of functions. Later models, as well as smartphones made by other manufacturers, began to include GPS capability allowing for augmented reality applications to proliferate.

The ambiguous, relative definition of smartphones makes accurate longitudinal comparison of ownership figures difficult; however Canalys note that sales of smartphones increased rapidly from 2005 to 2007, as shown by figure 15.

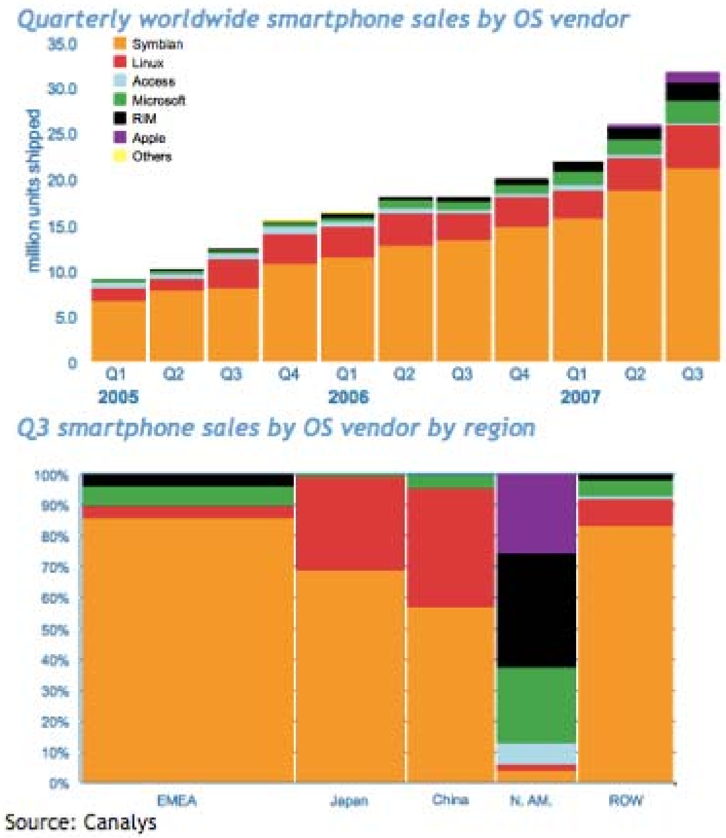


Figure 15: Sales of Smartphones 2005 - 2007

The Ofcom Communications Market Report (2010) provides some useful information on the marketplace in the UK alone, noting a surge in smartphone ownership – up 81 per cent from 7.2 million users in May 2009 to 12.8 million in May 2010. Furthermore, in June 2010, over a quarter of people in the UK (26.5 per cent) reported owning a smartphone - more than double the number from two years previously.

Demographic data on smartphone ownership suggests they are widely used by a variety of age groups with 18-44 year olds owning the majority of handsets (see figures 16. Research cited by Ofcom suggests smartphones (of which the iPhone is an example) are accessible to a reasonable number of users across a range of demographic groups, as shown by Figure 17.

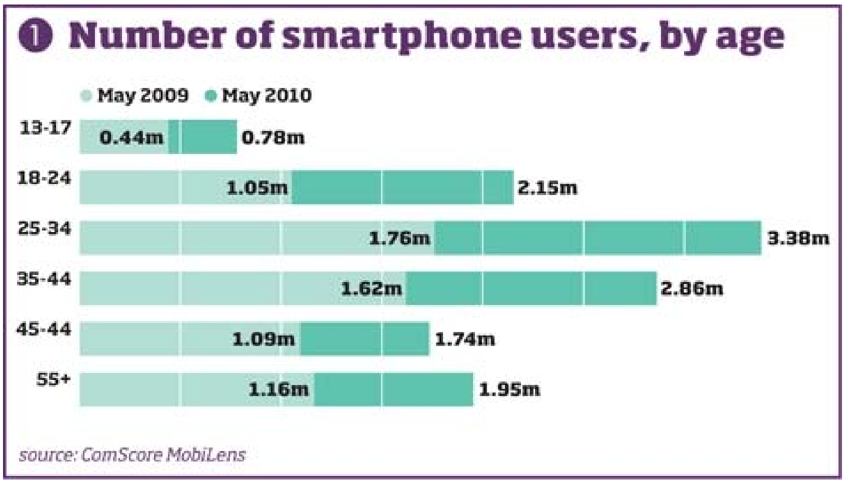


Figure 16: Number of UK Smartphone User by Age


Figure 17: Type of Mobile Phones Ownership

Additional relevant research on the ownership of smartphones amongst learners in Higher Education by the University of Edinburgh appears to confirm the above data. An Eduserv survey, representative of the university population (including international and mature students), found that 49.2% owned a smartphone, with 60% of all respondents reporting being able to access the internet as part of a contract in a way that was at least sufficient for their needs (Eduserv, 2010).

## Tablets: The Emerging Mobile Giants?

As described above, the huge expansion of smartphone ownership over the past years has told a story in itself, with most people unaware of their existence before the popularisation by Apple's iPhone. Industry analysts suggest we are in the early stages of witnessing a similar ownership explosion with tablet devices, perhaps again prompted by a flagship launch of an Apple product: the iPad.

In the same way that smartphones occupied a niche market until a few years ago, tablet devices have failed to capture the mainstream imagination, except for some industrial specialist applications.  Apple's track record in setting agendas for new market segments – as evidenced by the 7 million iPad units sold Worldwide in 2010 Q3&4, and a host of rival devices also appearing on the market (Apple, 2010a, 2010b).  This has led analysts ABI Research to argue that tablet devices will become a significant consumer market with sales expected to rocket to 57m units by 2015 (Schofield, 2010).


Figure 18: Popular Tablet Devices: Samsung Galaxy Tab, Apple iPad & Dell Streak

It has been suggested that tablet devices offer increased potential for AR applications since they feature larger screens (typically 7-10" compared to the 3-4" screens offered by most smartphones), and this might promote an improved end user-experience.  However, the increased size of the devices appears to affect users' propensity to use them on the move.  For example, a recent survey of UK iPad owners found that only 16% of owners regularly take their iPad with them when leaving their homes (Cooper Murphy, 2010).  This has clear implications for AR applications since the technology requires users and devices to be present at points of interest outside the home.

**Hardware Specifications**

The principal hardware required for a typical markerless augmented reality system is listed below.  This applies to both smartphone and tablet devices:

- **In-built rear-facing camera** capturing a base layer of 'unenhanced' reality
- **Geo-locational awareness**, most commonly achieved through use of an onboard GPS (Global Positioning System) receiver.
- **Compass** and **accelerometer** both determine in which horizontal/vertical plane the device is operating.

Such hardware can be found in many modern smartphones such as the popular Apple iPhone, as well as numerous devices produced by other manufacturers:

Nokia; HTC; Samsung; LG etc. Supported tablet devices include the Dell Streak and Samsung Galaxy Tab, as well as an increasing range of competitor products from various manufacturers.

### 4.2 Platforms

These smartphones/tablet devices operate with use of dedicated software controlling phone functions, enabling user-input and providing a platform for third-party apps. As such applications are only developed for specific operating systems, market dynamics must be taken into account in determining the longevity of such software. Examples of current smartphone operating systems include:

- **Symbian:** backed by Nokia, Symbian Foundation. Currently the most popular smartphone operating system worldwide, available on a wide range of manufacturers' devices. Recent versions have attracted poor critical reviews due to lack of functionality and usability compared to competing platforms. Symbian^4, launching early 2011, hopes to address these issues.
  *Launched 2001, 2010 Q2 share: 43%*
- **Research in Motion (RIM) Blackberry OS:** Closed-source platform developed solely for Blackberry devices. Similar tablet platform to launch on Blackberry Playbook device in early 2011.
  *2010 Q2 share: 18%*
- **Android:** open-source platform developed principally by Google and backed by several manufacturers. Available across a wide variety of smartphone and tablet devices made by various manufacturers. *Launched 2008, 2010 Q2 share: 17%*
- **iOS:** Mobile operating system developed originally for the iPhone by Apple. Only officially available on Apple devices such as the iPhone, iPod touch and iPad tablet.
  *Launched 2007, 2010 Q2 share: 13%*
- **Windows Mobile/Windows Phone 7 Series:** One of the first platforms to enter the pocket PC market. Developed by Microsoft. New Windows Phone 7 series aims to revive the platform.
  *Windows Mobile launched 2000, 2010 Q2 share: 5%. Phone 7 launch October 2010, 2010 Q2 share: 0%.*
- **Others:** A wide variety of other systems - both proprietary and otherwise - have proliferated in the marketplace over the past few years, including: Palm/HP's **webOS** as featured on the Palm Pre; Samsung's **Bada** platform; and Nokia/Intel's **MeeGo**.
  *Combined 2010 Q2 share: 3%*

The following data gives an indication of the current market penetration of each platform, as well as some comparative statistics over time (figure 19).

*Table A: Worldwide Smartphone Sales to End Users by Operating System in 2Q10*

| **Operating System** | **2Q10 Market Share (%)** | **2Q09 Market Share (%)** |
|---|---|---|
| Symbian | 41.2 | 51.0 |
| Research In Motion | 18.2 | 19.0 |
| Android | 17.2 | 1.8 |
| iOS | 14.2 | 13.0 |
| Microsoft Windows Mobile[1] | 5.0 | 9.3 |
| Linux | 2.4 | 4.6 |
| Other OSs | 1.8 | 1.2 |
| **Total** | **100.0** | **100.0** |

Source: Gartner (August 2010)

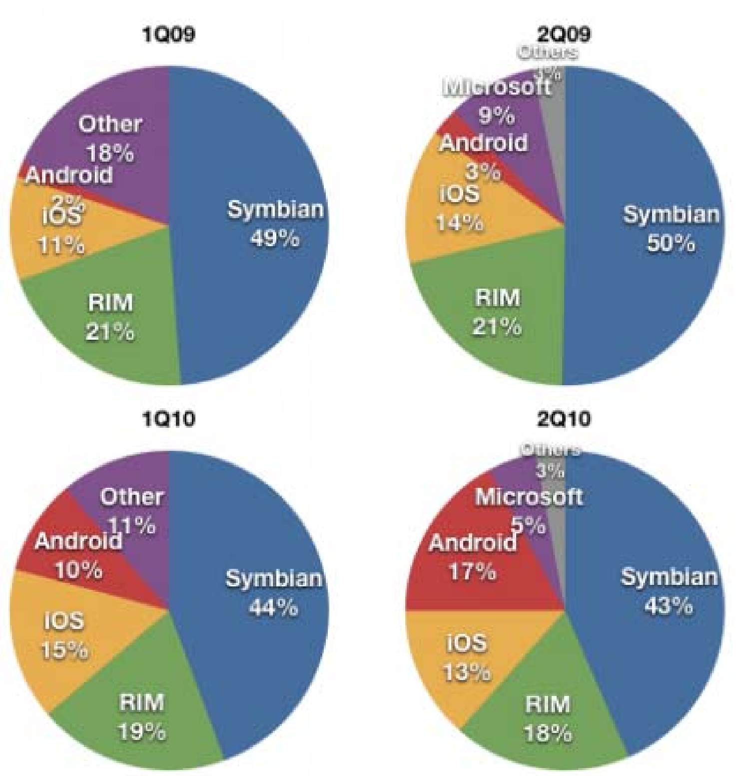


Figure 19: Worldwide Smartphone Sales to End-users from Q1 2009 to Q2 2010*.*

*Note:*

- ‘Other’ includes Symbian devices not sold by Nokia, Microsoft Windows Mobile and various Linux, WebOS
- iOS includes only phones, no iPads, no iPod touch, similarly Android data is based on phone sales.
- Some of these numbers are approximate as they are based on partial data (Canalys does not publish complete share data and some must be interpolated)
- [1]‘Microsoft’ relates to the Windows Mobile OS, as opposed to the forthcoming Windows Phone 7 Series due for release in October 2010.

(Source: Canalys, 2010)

In terms of students’ mobile use within the institution, data profiling visits to the University of Exeter website estimates that around 2% of visits originate from mobile phones – compared to about 1% a year or so ago. This breaks down into about 61% iPhone, 12% Android, 10% iPod touch, 10% iPad, with the remaining users scattered amongst the other mobile devices. Interestingly, there appears to be fewer visits to Exeter servers from RIM and Symbian devices than global ownership data might suggest.

**The Future for Mobile Platforms**

Market statistics detailing the various smartphone operating systems suggest the sector is constantly changing. This is demonstrated by figure 19, which shows the relative popularity of each smartphone platform over 2009-2010. Most notably, this also demonstrates the short amount of time needed for emerging platforms to become more established – for example, Android rose from a 2% market share in Q1 2009 to 17% in Q2 2010, little more than 12 months later.

This composition is likely to continue to evolve over the coming months, both with increased competition over features, and also the introduction of new entrants to the market, such as Microsoft’s Windows Phone 7 Series and the Nokia/Intel-backed MeeGo platform. Such rapidly changing dynamics represent a key technical challenge to maintaining an accessible AR package, as discussed further below.

Whilst Symbian is a clear worldwide market leader in terms of ownership, its dominance has diminished over the past few years as critics suggest that competing platforms have created a more enjoyable user-experience, particularly on touch screen devices which have become more commonplace over the past years. Leading analysts suggest it is too early to identify a clear dominant platform going forward.

All in all, the above data shows the importance of a cross-platform solution in such a dynamic marketplace.  Fortunately, most AR smartphone platforms are available on at least two platforms - an evaluation of popular AR packages can be found below.

### 4.3 AR Software

Both marker-based and markerless applications make use of specialist software to perform AR.  Whilst AR Toolkit traditionally used as a base for marker-based AR applications, some proprietary applications have also been developed for specific uses.  An example of which is Magic Symbol.

Additionally, a number of key players are emerging in the development of markerless AR applications for mobile computing devices and particularly smartphones: Layar; Wikitude and Junaio.  These applications run across a variety of popular smartphone platforms including Symbian, iOS and Android. Such applications can be compared to standard internet browsers as they provide an interface to access and interpret AR data.

#### AR Toolkit

*Platforms: Principally Windows/Linux/MacOS.*
*Some development for iOS/Android/Symbian S60*

First developed in 1999, AR Toolkit is an open-source marker-based tool that allows for the creation of augmented reality applications that can overlay 3D computer graphics onto real world markers.  Video tracking capabilities are used in order to calculate the real camera position and orientation relative to square physical markers in real time.  Overall, the toolkit is a well-used and impressive resource, which responds well in real-time.  More recently, there have been attempts to adapt the software for the iOS, Android and Symbian series 60 platforms, as shown in figure 20.

#### Magic Symbol

*No supported mobile platforms*

Another market-based system is offered by Inition, who have developed commercial solutions as part of marketing and advertising campaigns using static hardware (fixed cameras and plasma/projection screens).  The implementation is similarly responsive compared to ARToolkit, albeit this software does not appear to be available on mobile devices at present.  Real-world applications of this software have included use with the BBC Merlin series, as seen in figures 9 and 10.

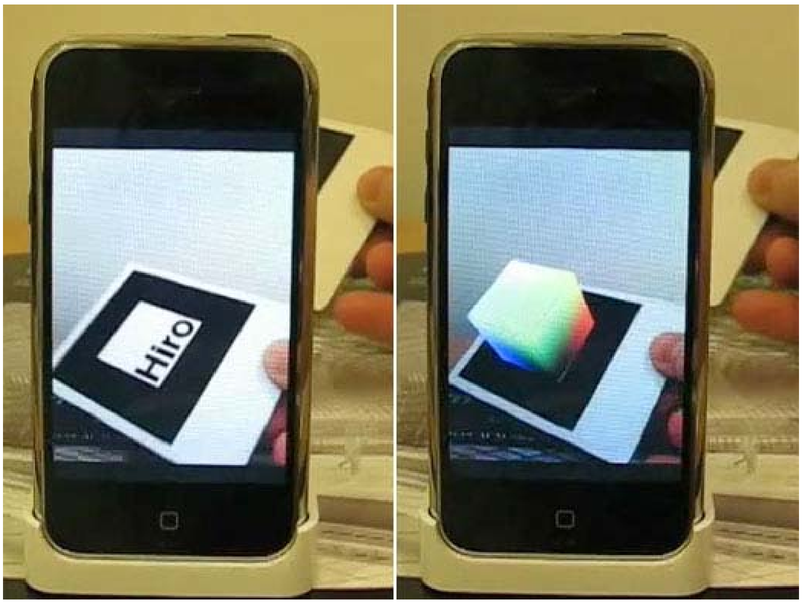


Figure 20: AR Toolkit for iPhone
Source: Technabob (2010)

**Layar**
*Platforms: Android/iOS/Bada        1,000 available layars claimed (July 2010)*

Layar is a markerless system which works by using a combination of the mobile phone's camera, compass and GPS data to identify the user's location and field of view, retrieves data based on those geographical coordinates and overlays that data over the camera view.  By 2011, Layar claims that its application will be pre-installed on 75 percent of phone shipped around the world.

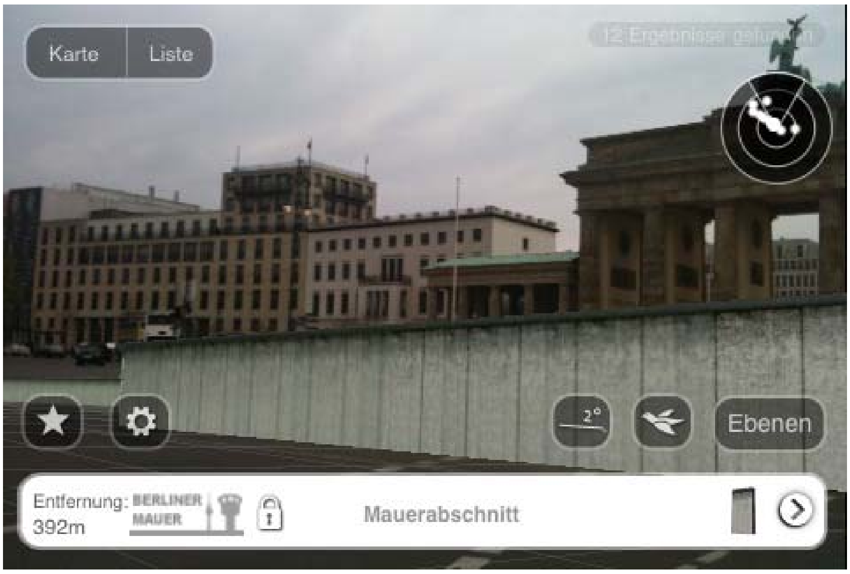


Figure 21: *Berliner Mauer* application of Layer uses 3D objects to recreate a historical landmark.

**Wikitude**
*Platforms: iOS/Android/Symbian S60/Bada*

Whilst Layar is an all-in-one solution, Wikitude offers three distinct product strands: Wikitude World Browser; Wikitude.me; and the Wikitude API. The *Wikitude World Browser* functions similarly to Layar to display a camera view overlaid with additional information, linking the devices' geographical and axis position to a dataset.

*Wikitude.me* allows users to users to embed POI, which is then viewable though the aforementioned browser. Finally, the *Wikitude API feature* enables developers to build and adapt the technology for their own applications. Current examples include 'geocaching' games – a type of hide and seek involving use of GPS locational data to find augmented reality objects in the real world. Of the three platforms surveyed, Wikitude provides an AR platform across the widest variety of mobile operating systems.

**Junaio**
*Platforms: iOS/Android*

Junaio® is a mobile augmented reality platform allowing users and developers to create content channels in the real world. Developed claim it is "the world's most advanced AR browser" (Junaio, 2010a). Users can flip through channels for public viewing, travel or games and see digital information displayed around by simply pointing the phone. The Android version includes image and object recognition, thus mixing marker-based and markerless AR methods.

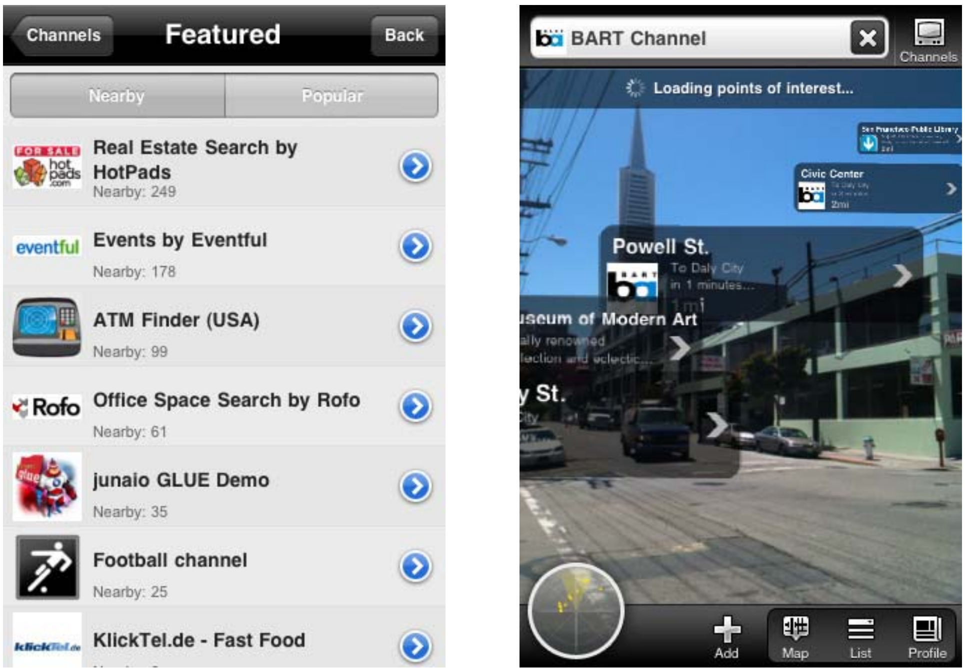


Figure 22: Junaio Application as seen on the iPhone

## 5. Technical Considerations

Successful and user-friendly implementation of a suitable AR platform within this project must also take into account a number of technical challenges associated with smartphones and portable computer devices:

- **Fast moving and innovative sector**
  As demonstrated by the market statistics above, smartphone use is growing, yet the relative use of specific platforms remains fluid. Furthermore, the trend for end-consumers to typically renew their devices every 18-24 months implies even current users will re-evaluate their choice of platform within the short-term.

  This market dynamic is compounded by the fast-moving development of the platforms themselves. New operating systems such as Microsoft's Windows Phone 7 Series (release due October 2010) and the Nokia/Intel-backed MeeGo platform (further phones due early 2011) suggest potential for the market to become further fragmented.

  Similarly, software updates to existing AR applications (for example, Layar, Wikitude and others, as reviewed below) can change the user-experience. For example, a recent Layar update changed the default view upon launch from camera view to a list of points, which some have argued is less user-intuitive.

- **Battery life**
  One of the main complaints from owners of smartphones made by all manufacturers is the lack of battery life. Even with just moderate use, users should expect to recharge devices at least every 24 hours. Particular services that can severely battery life include obtaining geolocational data as well as screen use, both an inherent result of using an AR package.

- **Use of LCD screens in sunlight**
  Smartphones and other mobile devices typically use Liquid Crystal Displays (LCD) or variants of Light Emitting Diode technologies (AMOLED) to display visual output. Both technologies struggle to remain legible in bright outdoor conditions, such as direct sunlight. Increasing screen brightness can help alleviate this problem, although with a further adverse impact on battery life.

- **Network connection speeds, reliability & desire to use data package**
  Mobile devices utilise 2G/3G data networks to receive data content, of which the AR package is intended to be based. The explosion in UK smartphone ownership and associated data usage has left some networks struggling to cope. Responding to this, mobile networks have phased out the unlimited data offerings that were commonplace in the market even six

months ago, preferring a data cap of around 500MB-1GB per month if data is included. This AR package is expected to feature high quality multi-media content which has an associated data footprint, yet end-users desire to access this content over the cellular network cannot be assumed.

An alternative to data transfer over the cellular network is the use of Wi-Fi, which most current smartphones feature. Whilst the University of Exeter's Wi-Fi network has extensive, even if not complete campus coverage, not all intended users of the AR package can be assumed to have access. This is most relevant to the external audience since there is no reason for them to have a university IT account. Some smartphones disable Wi-Fi capability whilst the screen is not in use as an attempt to conserve battery power. Reconnection to the University Wi-Fi network requires re-entering user credentials in the mobile browser, which may also detracts from the user-experience, as users may potentially have to switch between the AR package and the mobile browser when at each point the screen is reactivated.

- **Reliability of locational data over the campus**
  Smartphones typically rely on the GPS satellite system to compute their geographical position to a best accuracy of +/- 10 metres. Whilst GPS is a worldwide system, it is known to be less accurate, even non-existent in some circumstances, due to problems obtaining the sufficient signal reception required to communicate with a minimum number of satellites required to determine a precise location. Such problems are particularly prevalent inside buildings, but also possible to a lesser extent in other areas where a clear view of the sky is inhibited, for example wooded areas. This problem is compounded by the lower quality GPS chipsets found in low-end phones, as opposed to dedicated GPS devices.

  Fortunately some platforms, such as Android, supplement satellite data with information from wireless networks to improve both accuracy and reliability. Examples include use of triangulation from mobile phone masts and use of nearby pre-mapped Wi-Fi networks. Whilst this adds an extra dataset, and denotes 'A' for 'Assisted' in the A-GPS specification found with many devices, it can sometimes lead to further reliability problems – especially if solely mast data is used as this is rarely accurate to more than 1km!

### 5.1 Limitations of Current Platforms

#### User Interface design

A key challenge of any computer system is to design a suitable and usable interface. Any large database of entries must be easy for users to navigate. Within the *Unlocking the Hidden Curriculum* project, a specific example could be envisaged whereby students seek a particular species within the campus environment amongst. How could this user easily identify and navigate to the species required? An obvious solution would be to provide a search facility within the POIs

Although not strictly an augmented reality application, Google Sky Map provides a good example of an interface whereby specific POIs (planets, stars and constellations) can be easily searched and located, as demonstrated in figure 23.

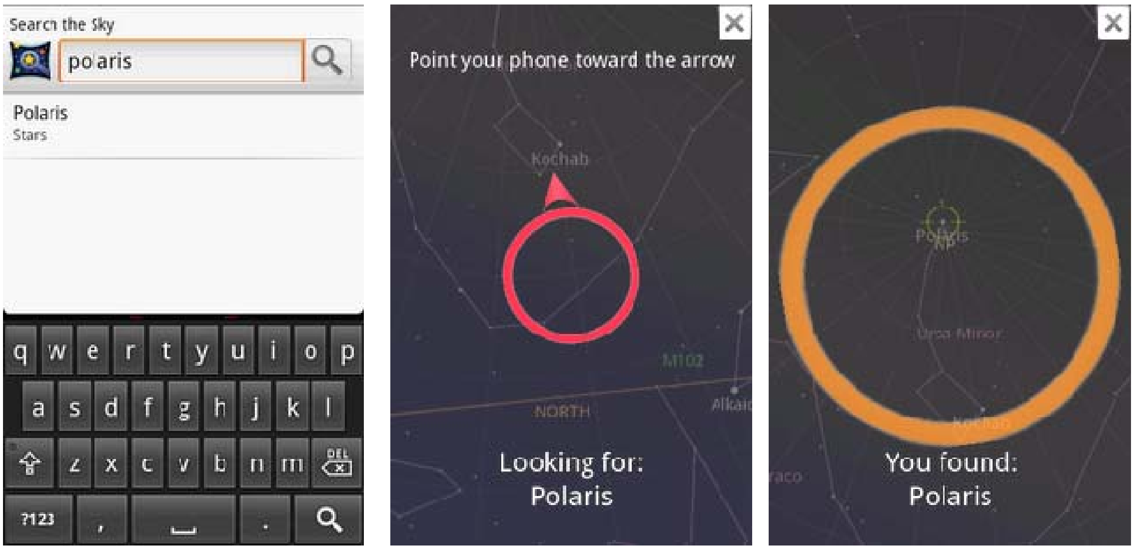


Figure 23: Example of Search Feature within Google Sky Map.

While most browsers feature the ability to search layers/worlds to view within the browser – it seems that of the AR browsers surveyed – only Wikitude offers the option to search for POIs within layers/worlds themselves. However, search results do not appear to be well integrated to the application itself, as it seems there is currently no facility to switch back to the camera view and navigate to a given search result.

## 6. Choosing an Augmented Reality System

Table B shows a comparison of available AR software, based both on marker-based and markerless technologies. Each of the surveyed software has its own strengths and weaknesses, with differences most distinct in ability to handle multimedia content.

The technical knowledge required to construct such a system is also an important factor in choosing a system.  Whilst some software requires a basic knowledge, other solutions – most notably AR Toolkit and Magic Symbol – would require significant development expertise for them to function on a mobile platform.

In the content of the *Unlocking the Hidden Curriculum* project, a solely marker based solution not seen as ideal due to the size of the sample areas and the potential difficulty of finding specific markers over a wide habitat area. Additionally, physical markers require maintenance in the medium term, otherwise an incomplete could affect the user experience.  Such upkeep places additional work on campus maintenance resources.

With these factors in mind, and given the challenges associated with developing solely marker-based software for mobile platforms, it is suggested that markerless applications are preferred.  This leaves a choice to be made between: Wikitude, Layar and Junaio.

In evaluating these platforms, popularity and existing user-base of mobile browsers are important considerations, as well as functionality and usability. Whilst Junaio appears to be the most advanced browser in terms of functionality, there is no evidence that it is pre-installed on handsets.  On the other hand, Layar currently offers slightly less features and requires more technical competence to construct, yet it seems that the application is already pre-installed on a significant number of handsets.  Wikitude offers more limited, yet still important functionality, it requires basic technical knowledge and it is also the only application that is available on Symbian devices.

Taking into account these considerations, the best solution may be to create access points to the database for as many platforms as possible, in this case: Layar, Wikitude and Junaio.  Indeed, integrating the dataset into all three software platforms also covers three significant operating systems: iOS, Android and Symbian as well as the smaller Bada platform.  In terms of market penetration, this accounts for at least 72% of smartphones based on recent sales figures.

Working across a number of software platforms also offers the additional benefit of ‘future-proofing’ the application to a greater extent.  In such a dynamic market environment, it is difficult to identify future trends. Thus being enabled on the widest possible range of platforms improves longevity, whilst also offering greater flexibility to adapt to new developments as part of a wider community linked to each of the software applications.  Similarly, such integration also offers potential to make use of any future improvements and new features within the software applications themselves.

**Table B: Comparison of Different AR Software Technologies**

Functionality →

| | **AR Toolkit** | **Magic Symbol** | **Wikitude** | **Layar** | **Junaio** |
|---|---|---|---|---|---|
| Mobile OS Platform/s | Symbian[1] / iOS[2] / Android[3] | Not currently supported | iOS 3.1.3 (3GS) / Android 1.5 / Symbian / Bada | iOS 3.1 (3GS) / Android / Bada | iOS 3.1 (3GS) / Android 1.6 |
| Development stage (mobile version) | Alpha | Release | Release | Release | Release |
| First Launched | 2003 | 2006 | 2008 | 2009 | 2009 |
| User base | Not known | Not known | Not known | 1,000,000 active users[5] Pre-installed on 75% of devices | 10000 – 50000 downloads (Android) |
| App reviewer rating *(out of 5)*:<br>- Android<br>- iOS | N/A | N/A | 4.0<br>2.5 | 4.0<br>2.0 | 3.0<br>3.0 |
| Marker-based / Markerless | Marker-based | Marker-based | Markerless | Markerless | Both |
| 3D Objects | ✓ | ✓ | ✓ | ✓ | ✓ |
| Proximity Object Triggers | × | × | × | ✓ | Think so! |
| Zones as POI | × | × | × | Partial[6] | Partial[7] |
| Audio | × | ✓ | Partial (via attachment parameter[4]) | ✓ | ✓ |
| Video | × | ✓ | Partial (via attachment parameter[4]) | ✓ (not in floaticon, but link to youtube app) | ✓ |
| Standards used | Proprietary | Proprietary | KML / ARML[4] | Proprietary | Proprietary |
| Technical ease | Advanced | Advanced / proprietary | Basic Knowledge | Technical competence required | Basic knowledge |
| Input Method | Varied | Software / webcam | Web / API | API | API / XML |

| | | | | | |
|---|---|---|---|---|---|
| Technical documentation | Good | Poor | Good | Excellent | Good |
| Notes | Requires advanced skills to create mobile version | Requires advanced skills to create mobile version | Opportunity for user-created POIs | Symbian / MeeGo in development[5] | Allows dynamic reaction |

**Notes:**

[1] Source: Open GLES (n.d.)

[2] Source: Technabob (2010)

[3] Source: NyARToolkit (2010)

[4] Source: OpenARML.org (n.d.)

[5] Source: Layar (2010)

[6] Achieved using multiple POIs to create a zone

[7] Using Maxdistance parameter.  Source: Junaio (2010b)

## 7. Glossary

**API** (Application Programming Interface)
*An interface enabled by a software application that enables it to interact with other software.*

**AR** (Augmented Reality)
*Term denoting use of technology to provide additional information about the physical environment.*

**Floaticon**
*A 3-dimensional animated object that is typically overlaid onto a camera view in a markerless augmented reality system. Floaticons can be programmed to display data in a variety of formats including text-based, or audio-visual content.*

**GPS** (Global Positioning System)
*Global navigation system using satellites to gain a precise location at any given point worldwide.*

**Immersive**
*An engrossing total environment usually associated with Virtual reality where complete presence is implied within a simulated (virtual) space.*

**Marker-based AR**
*An Augmented reality system based on responses triggered by a bar code, QR code or 'magic symbol'.*

**Markerless AR**
*An Augmented Reality system based on responses triggered by virtue of the location of the user's smartphone or handheld computing device*

**POI** (Point of Interest)
*A unique feature identified by an Augmented Reality application and represented by a floaticon on the smartphone's viewing screen.*

**Smartphone**
*A mobile phone that offers advanced computing features including the ability to download and run software applications.*

**Tablet**
*A portable personal computer usually equipped with a touch screen and ability to access the internet via a wireless connection.*

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## 9. Appendix 1

### Unlocking the Hidden Curriculum – a JISC-funded Learning and Teaching Innovation Project at the University of Exeter

The project is built around the innovative and creative use of Augmented Reality.

The main campus of the University of Exeter is built on a country estate overlooking the city and surrounding countryside. The campus includes a variety of distinctive habitats and is rich in biodiversity. Students and grounds staff have regularly collected data through their programmes of study and conservation activities but this information and knowledge has hitherto remained hidden from the wider community.

The project will enable the campus to function as a 'living laboratory' and reveal a dynamic landscape of flora and fauna at any time of day or season to a variety of audiences who wish to interact with this unique location. Using Augmented Reality, the campus will be transformed into an accessible learning resource to support the formal and informal curriculum. Scientific data will be presented in a creative way to interpret the living landscape and promote engagement with Education for Sustainable Development (ESD). Visitors to the campus equipped with suitable smartphones will be able to trigger information presented as rich visual and audio media as they explore a variety of habitats and areas of particular interest. This location-specific information appears as an overlay superimposed on a viewing screen fed by the smartphone's built in camera.

Figure 24:Visualisation of Proposed AR Biodiversity System