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## Design and Development of Multimedia Learning Objects for Mobile Phones



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### Abstract

This chapter discusses the design and development of a series of prototypes of a multimedia learning object for the mobile phone. It begins with the rationale for this development, and the underlying design and development principles of our learning objects. It then presents the iterative development process that ensued in creating four prototypes for the mobile phone, each of which was refined in light of use and feedback. The design issues and solutions are discussed in the process, documenting the development route that was taken. Student evaluation data is also presented, and this has informed the further development of the prototype. The development sections

are followed by a discussion about the implications of this work, and the chapter concludes with where it is going in the future.

## Introduction

The ability to produce effective multimedia learning applications for technology that is ubiquitous is very appealing. Mobile phones are becoming more technically sophisticated. They can create and play multimedia content; they have larger high quality colour screens; many models can now capture, edit, and play back video, audio, and photographs; many models can also run Flash-based interactive applications (through Flash Lite). They also have greater storage capacity, and networking connectivity with PCs the Internet with Bluetooth and WiFi. Surveys conducted with university students show that they own mobile phones that have multimedia and connectivity capabilities in increasing numbers (Cook et al. 2006). Harnessing the use of these devices for multimedia learning resources which are known to engage and motivate students could be a powerful way of providing learning materials to students who need more flexible learning solutions because of other time demands in their life (Boyle 1997). Specifically, multimedia learning objects can provide multimodal channels that enable students to build up their own knowledge representations of the task in hand. If used in a collaborative way they can help students in identifying the gaps in their own knowledge and hence assist successful task comprehension and performance (Soloway and Norris 2005). Indeed, Nyíri (2002) points to potential enhancement of communication and knowledge that multimedia mobile devices can offer:

Mobile communication is enhanced everyday communication; and just as our everyday conversation is indifferent towards disciplinary boundaries, so, too, is m-learning. Situation-dependent knowledge, the knowledge at which m-learning aims, by its nature transcends disciplines; its organising principles arise from practical tasks; its contents are multisensorial; its elements are linked to each other not just by texts, but also by diagrams, pictures, and maps (p. 124).

Thus our approach to developing mobile multimedia learning objects taps into the desire to communicate and crosses disciplinary boundaries. The organizing principles of our learning objects arise from practical tasks but use multisensorial elements to link the knowledge construction together.

This chapter discusses developmental work being carried out as part of the Centre for Excellence in Teaching and Learning in Reusable Learning Objects (RLO-CETL) at London Metropolitan University. It builds on our

previous work in developing multimedia learning objects for the PC and for the PDA (Bradley, Haynes, and Boyle, 2005a). It explores the next step on the continuum, in designing learning resources for a more ubiquitous and portable device, the mobile phone. An existing web-based learning object on Referencing Books was selected for adaptation for the phone. This was chosen as it was a small and self-contained learning object that could be worked through in a few minutes, and was thus considered suitable for mobile learning, where short, bite-sized resources are most effective. The content development had already been done, and this simplified our task to re-design this content so that it was appropriate for and took advantage of the characteristics of the phone. Our aim is to develop multimedia learning content for mobile phones which is interactive, highly visual, engaging, and effective for the learner, using Flash Lite for authoring and delivery (Flash Lite is a version of Flash for mobile phones). Such learning objects can easily be used by the student whenever they have the desire or opportunity to engage in some learning, wherever they are, taking advantage of this “always there, always on” technology.

This chapter outlines the underlying design and development principles of our learning objects, and then presents the iterative development process that ensued in creating four prototypes for the mobile phone, each of which was refined in light of use and feedback. The design issues and solutions are discussed in the process, documenting the development route that was taken. The third prototype was evaluated with students, and some of their feedback is included. This led to the development of a fourth prototype that rectifies some of the issues that the students raised. The process has been lengthy (spanning about ten months), involving many tests and the creation of different design options. This is illustrated with examples from each of the prototypes, along with references to useful sources of help and information that were used to inform the work. The development sections are followed by a discussion about the implications of this work, and the chapter concludes with where it is going in the future.

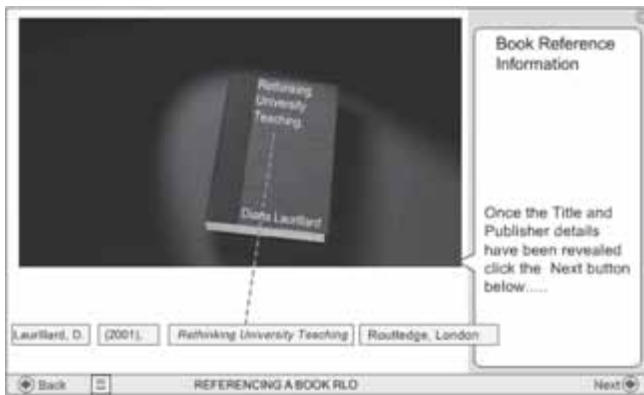
### **The PC-based Study Skills Reusable Learning Objects**

The team has designed and evaluated a suite of high quality, interactive, multimedia Reusable Learning Objects (RLOs) for learning study skills. The suite of learning materials developed for the project included RLOs on how to reference a book, a journal, and a website. They were all designed to encourage first year students to actually have a go at referencing their work. The whole approach to these objects was mapped out after a significant

student observation (in a participative design session) that students don't reference their work "because they [the students] think that tutors will think they don't know enough ... and it will lower their grades."

With RLOs we place pedagogy at the heart of our concerns, and focus on the need to deal with different types of users (students and teachers). Team Enhanced Creativity (TEC) is an approach to the design of RLOs developed by our team (Cook et al. 2006b; Holley et al. 2007; Smith et al. 2007). Our approach is partly based on Boyle's (2003) notion of decoupling and cohesion. Internally cohesive means the RLO meets a single learning objective and decoupled means that it has no link-outs to external resources. It is also heavily influenced by notions of user-centered and participative design (Norman and Draper 1986). The TEC approach feeds into the wider RLO-CETL Development Methodology (Boyle et al. 2006). TEC enables teaching staff, multimedia developers, and students to become involved in an iterative and highly creative process of reusable learning object design, implementation, evaluation, and reuse. The starting point of the design process is that a number of designs are storyboarded and prototyped. These prototypes are then thoroughly tested for the next iteration of design. One of the main design considerations is to ensure that all the navigation content and controls are easily accessible without overcrowding the interface or overloading the user. Adobe Flash is used for the software development of all our RLOs because it enables the design and development of rich interactive multimedia applications.

Each of the referencing RLOs has a number of sections that are intended to be used in sequential order on the first occasion. However, on subsequent visits the menu system can be utilized to allow users to access sections according to their learning need or indeed what they consider to be the most useful sections at that moment in time. Each RLO starts with a visual splash screen. This proved popular as a means of drawing in the audience. Next is a section that highlights the reasons why the user should reference their work. This was designed to be as simple as possible as it was the first page and, again, the emphasis was not to overload the user. The next section is a tutorial on how to create a reference from either a book, journal, or website. A screen shot from the Referencing Books RLO is shown in Figure 1. This is typical of a guide section, which contains a number of small steps (a tutorial) that allow the user to deconstruct the learning process at their own pace. This is followed by a reference checklist and the final reference list with the newly constructed reference dynamically loaded into place.



**FIGURE 1** A screen from the Referencing Books RLO PC version

The RLOs all conclude with a set of activities to test your knowledge. They have been designed to achieve scaffolding and interactivity by the incorporation of questions, based on presented information that the learner is required to answer. Students are thus scaffolded (Wood et al. 1976; Holley et al. 2007; Smith et al. 2007) into a deeper appreciation of fundamental concepts that may be further developed via a blended learning approach to teaching. The first activity is a set of multiple choice questions, where answers are met with feedback that indicates whether the answer is right or wrong, gives the correct answer, and any additional tips relating to the particular question. The second activity involves the student creating a reference from clicking on given components to assemble them in the correct order. If they do not get it right first time, they are suggested to try again. If they get it wrong a second time, they are recommended to go through the resource again to improve their understanding. In this way the RLOs are designed to allow individuals to construct knowledge by working to solve realistic problems. They can also be used at a later stage for revision or refreshing the memory of a particular concept without having to work through the same problems.

### **The Development Process for the Mobile Phone**

We started developing learning objects for the mobile phone by adapting the RLO on Referencing Books. We chose to develop for popular Nokia series 60 phones (N70 and then N91), which can run Flash Lite 2 (the latest version at the time). This helped us to see what is feasible and effective on the mobile phone. It meant we could research the development and design issues involved, and find solutions without needing to become involved in

the wider technical issues inherent in developing applications that will work on a range of phones with different technical specifications and operating systems. This section describes the iterative development process that ensued, from initial research and testing on the mobile platform to the development of the three prototype versions that were created before conducting student evaluation.

### Initial Concerns

We were aware that designing for mobile devices is very different to designing for desktops (Baird and Whitear 2006), and we had some initial concerns about how the nature of the mobile phone might compromise the design of our RLO. Compared with a desktop PC, the Nokia N70 phone screen is small:  $176 \times 208$  pixels, about the size of a matchbox. Input devices are limited: there is no keyboard, mouse, stylus, or touch screen. Input and selection has to be controlled by the phone's keypad. The N70 phone has two soft keys at the top left and right, directly under the screen, a five-way scroll key with navigation buttons in four directions (up, down, left, right) and a selection button in the centre, and a grid of alphanumeric keys. Figure 2 shows the available keys on the Nokia N70 phone.



**FIGURE 2** The Nokia N70 phone and keypad and the opening screen of Referencing Books

We anticipated further issues in transferring the content of the existing learning object to the mobile phone. Changing the content and structure might be necessary which could compromise the pedagogic integrity of the original learning object. We also had concerns about the ability and performance of Flash Lite on the mobile. Could the mobile phone play the media used in

existing learning objects? Could it dynamically load media (as the movie is playing) such as XML text, video, and MP3 audio?

However, we were confident that we would be able to resolve the concerns we had, having tackled similar issues in developing learning objects for the PDA. To address them we took three simultaneous steps. Firstly, we took time to learn Flash Lite. We began by following the practical guidelines in the Macromedia Flash Lite 2 Content Development Kit (CDK) (Adobe website A), and searching for and learning from online tutorials, forums, and developers' blogs (see the reference list for URLs). We carried out functional tests, and soon became confident that Flash Lite 2 would be able to handle the required media components and that we could achieve the desired levels of functionality and performance on the mobile phone. We discovered, for example, that in order to load assets dynamically, file formats would commonly need to be changed. Text could be loaded in an XML format, graphics were most effective when converted to PNG format, video to 3GP (a format specifically developed for mobiles), and that audio could remain in an MP3 format. We found that free software is available for converting video files into the 3GP format, such as the Nokia Multimedia Converter 2.0 (Forum Nokia website). Adobe has produced a useful document "Optimization tips and tricks for Flash Lite 2," with sections on optimizing multimedia assets and animation performance (Duran 2006). We also learned that Flash Lite can be made to interact with the phone. The two soft keys accept commands. The five-way scroll key could be used to shift "focus" between buttons on a screen. For example, pressing the down navigation key will move focus to the next button below the one with the current focus. The centre key could then be used to select and activate the button. Extensive tests confirmed that Flash Lite 2 supports ActionScript 2. This meant that much of the existing functionality, for example the original self-test multiple choice questions with feedback, could be ported to the mobile.

Secondly, we looked at other Flash Lite examples to identify emerging conventions and design trends. Examples of Flash Lite movies are available from the Adobe Flash Lite Exchange (Adobe website B), and are discussed in the Nokia white paper, "Flash Lite for S60 – An Emerging Global Ecosystem" (Nokia 2006a) and the Nokia "Flash Lite: Visual Guide" (Nokia 2006b), which has tips on emerging Flash Lite solutions. Although many of the Flash Lite movies available at the time were games, they pointed to trends in screen and interface design, navigational techniques, and interactive functionality which were helpful. We found with regards to the two soft keys for example, that the left key is often used for options or home to take the user back to the start of the application, and the right key often has a quit or exit function.

Thirdly, we developed a set of design templates for the component parts of the object and assembled a code library of Flash Lite 2 ActionScript functions. This code library was a combination of found third-party scripts that were reused or adapted and home grown scripts, and included many functions for commonly used procedures; for example, to manage navigation sequences, button focus, and the loading of external assets. Many of these functions were added to the Flash Lite template as the code library expanded, and it gradually became more robust, and streamlined the development process of the prototype movies. Both the template and code library were created to save time during the development of this and future learning objects as they enabled common object features and functionalities to be reused.

### **The Development of Prototype 1**

Following this initial period of research, we moved into the development of a first working prototype, during which time many key design decisions were made. We wanted to retain the structure, modularity and the linear page structure of the original learning object in the Flash Lite prototype. The first step therefore was to thoroughly analyze the existing PC-based learning object and decide how the content and pedagogic approach could most effectively be adapted to the mobile phone, and just as importantly, be effective for use in mobile situations.

### **Rethinking Problems**

In many areas the learning object content and the interactive devices used within it needed rethinking for the mobile phone. We had learnt from our work in designing learning objects for the PDA that smaller screen sizes are not necessarily a design constraint (Bradley et al. 2005a). You just have to rethink any problems that arise, consider available options, and find creative solutions. One example of this was the use of text in the existing learning object. We decided to replace lengthy pieces of text usually used for instructions and explanations with short audio clips. This substitution of text with audio not only alleviates screen overcrowding, but is easier for people to assimilate in mobile situations. Our research has also shown that some students find it easier to learn from audio (Bradley et al. 2005b).

A detailed storyboard was developed, that showed how each of the content screens would be adapted. The storyboard contained the wording for all the text elements to be included, which were often edited and simplified from the existing text for the mobile. It also contained the scripts for the audio clips that would replace the lengthy text-based instructions and explanations,

and these were recorded on an MP3 player so that they could be quickly incorporated as guide tracks into the Flash movie as authoring began.

The next design decisions tackled the issues of methods for user interaction, user navigational controls, and the design of the user interface, and these were incorporated as test content screens were developed. Different solutions for user navigation and interaction were required for the mobile version, controlled solely by the keys on the phone. For user interaction, a two-step “focus and select” method was adopted for the user to be able to click on or activate on-screen buttons. This meant that first the user had to give a button focus by navigating to it, whereupon it would become highlighted, and then use the select key to activate it. This approach was used for both interactive on-screen buttons and content elements, and for navigation from one screen to another. Screen to screen navigation was controlled by two arrow-shaped buttons. To enable additional user control of the resource, conventional commands were assigned to the two soft keys: the left was used as the Home key, and the right as the Quit key to close the learning object.

The user interface design can be seen in Figure 3 below. On each screen a horizontal bar at the top housed the name of the learning object. A bar at the bottom of the screen provided navigation controls and orientation information. On the left and right were the labels for the two soft keys, Home and Quit. In the middle was the screen number and its position within the resource (e.g., two of six), and the navigation controls to move forwards and backwards through the resource (two simple arrow buttons). Directly above the bottom bar was the title for the screen or section, along with an audio icon to play the introductory audio clip. The audio icon was given focus on entering the screen (highlighted in green as in Figure 3), as the first thing we wanted the user to do was to listen to this audio introduction. Navigation within the content of a screen thus began at the bottom, with the user moving upwards to access other content elements. In part this was because of the interface design of the PC-based learning object, which also had the orientation and navigational controls at the bottom of the screen, and was retained for the mobile version. Because the screen orientation information was at the bottom, it seemed natural to place the screen title there too, and the audio icon as well. From there, if there was other content to access on the screen, as there is in the example in Figure 3, the user would move upwards, using the up navigation key. A deep red colour scheme was chosen for the orientation and navigation bars and for the headings. Elements on the top and bottom bars were white. This colour scheme was chosen in an effort to provide strong contrasting colours to improve readability on the phone’s screen, especially important when devices are used outdoors.



**FIGURE 3** The test your knowledge Why Reference? screen in Prototype 1

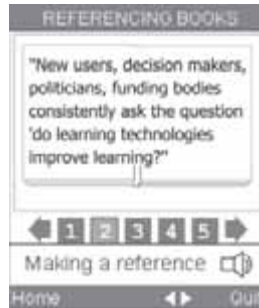
### Creative Adaptations

A number of key adaptations were made from the original learning object as the development of the mobile prototype progressed. One example is the “Why Reference?” screen (see Figure 3). The original used text keywords that were clicked on to reveal a text-based explanation. This would be difficult to transfer to the mobile, as it would require an easy method of selecting the text keyword, and then enough space on the screen to be able to display the text explanation. Our solution was to retain the mood of the original by keeping the text keywords, each of which can be given focus and then selected to play an audio explanation of it.

Another technique used to avoid overcrowding on the screen, was to divide content into smaller bite-sized chunks, so it was “split over a number of screens” (Baird and Whitear 2006) than are found in the existing learning object. For example, questions and feedback are on separate screens in the quiz at the end of the learning object.

The “Making a Reference” section of the original learning object has a series of 3D animations over a number of screens that explain the process. For the mobile this was adapted into a step-through series of simple animations with audio commentaries (see Figure 4). To navigate through the steps the user has a sub-menu row of square numbered buttons. The navigation design in this section was influenced by the Making Coffee step-through animation (Flash Lite: Visual Guide v1.1, Nokia 2006b).

The self-test activities at the end of the object also needed adaptation, in particular the second activity which required the user to click on components to assemble a reference in the correct order. This would be difficult to reproduce on the mobile, and it was felt that the activity could effectively be tested in



**FIGURE 4** The Making a reference section from Prototype 1

another format. The two activities were therefore combined into a quiz, containing six multiple choice questions with answers and feedback. Scores were also added to the mobile version at the end, which actually led to an enhancement over the original version. This type of multiple choice assessment task is perfect for the mobile phone, as questions can be answered easily and quickly without the need for complicated user input, and the presentation format fits effectively within the dimensions and portrait orientation of the mobile screen.

## The Development of Prototype 2

The first prototype was tested with peers (the multimedia development team and colleagues), and they did not like the navigation system. The two-step process of navigation between screens wasn't thought to be intuitive, and was slow to use, as the user first had to navigate to the button to give it focus, and then press the select key to activate it. The "click investment" required slowed the user down (DotMobi Mobile Web Developer's Guide 2007). Users found that it was not easy to use the learning object with one hand, and that it needed the attention of a dexterous user.

Finding a better method was influenced by the tutorials loaded onto the Nokia N91 mobile phone (we purchased some N91 phones part-way through this development work). In these tutorials, horizontal screen to screen navigation uses only the left or right navigation keys on the phone, and follows the observation made by Ulm that "all mobile navigation is linear" (Ulm 2005).

A revised design attempted to simplify the navigation process, and used the left and right navigation keys to navigate between screens. Only a single action was needed to the right key to advance a screen or to the left key to go back. As well as being easy to use, this also reserved the up and down navigation keys for vertical navigation within the content of a screen.

At this stage we did not change the design of the user interface. We did however experiment with different colour schemes. The aim was to visualize a number of contrasting colour schemes, and see how this affected clarity and legibility on the mobile screen. The main interface elements were changed to what was considered by the designer to be a more widely acceptable blue colour scheme.

Figure 5 shows the “Reference Checklist” screen from the second prototype, and the revised colour scheme. The checklist acts as a reinforcement of what was covered previously, namely how to construct a reference for a book to include in a reference list. The audio clip explains the process step by step, and is accompanied with animations that visually illustrate each piece of information or component that makes up the reference. Thus the component being described in the audio is simultaneously highlighted on the screen, in this example the second component, the date of publication. Beneath the numbered components, the book reference is constructed, and scrolls across the screen from right to left in real time with the audio clip. This scrolling technique was adopted as a solution to not being able to display a complete book reference clearly and legibly across the width of the screen.

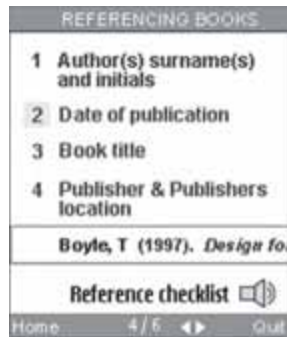


Figure 5: The reference checklist screen from Prototype 2

### The Development of Prototype 3

Feedback from a further round of tests by peer users confirmed that the simple one-step navigation technique adopted to move between screens had greatly improved usability. As a result the navigation process was less confusing, and allowed “the user to interact without thinking too much about it” (Lettau 2005). Users found it was more intuitive to use the navigation keys on the phone to go right or left (forward or backward) through the

object. It also improved one-handed device operation as you didn't have to concentrate so hard on the navigation process.

However, users highlighted that there were problems with the navigation of the step-through "Making a Reference" sequence, particularly now that the screen to screen navigation had been changed. It was criticized for not being obvious and for being slow, so a better, more intuitive and usable solution was sought.

It was decided to adopt a simplified sub-menu, which would use a small button in the form of a page with a number in its centre. Once the graphic button has focus, the up or down keys on the phone will increase or decrease this number, from 1 through to 5. The centre key when pressed loads that numbered section of the animation, together with its accompanying audio file. Text-based instructions to use the up and down keys were added at the bottom of the screen, next to the audio icon. The resulting overall interface and sub-navigation system for the "Making a Reference" sequence can be seen in Figure 6 below, which shows Part 3 of the sequence. On the bar at the bottom of the screen the two arrows pointing left and right have been retained from previous versions to indicate to users that there is horizontal, linear navigation, and that navigation between screens is done by pressing the navigation keys to the left or right.



**FIGURE 6** Step 3 in the making a reference sequence from Prototype 3

With the completion of the third prototype, we felt that we had reached a stage where the overall design of the learning object, the user interface and the navigation system were sufficiently refined and effective. The next stage was to evaluate the prototype with students, to get their valuable feedback, and to confirm if our design was effective for them.

### **Student evaluation of the third prototype**

The refined third prototype was evaluated with students to get their feedback. We particularly wanted their views on the mobile learning object, and to know if they found it easy to use and navigate through it. We also wanted to get their views more generally on mobile learning and on learning materials for mobile phones. Evaluation was conducted in three separate sessions, and involved seven students. Each was given a Nokia N91 mobile phone with the learning object pre-installed, and they were asked to work through it and make any comments they had as they did so. They were only given a short briefing that told them what they were going to be looking at and how to use the keys on the mobile phone to navigate and select and execute actions. They were not given any instructions on how to navigate through the learning object, as this was one of the main functionalities that we wanted to test to see if our design was intuitive and easy to learn how to use. Afterwards they completed a short questionnaire, and this was followed by an informal discussion about their experiences.

All the students owned a mobile phone, so they could not be described as novice mobile users. There were five females and two males, and they represented a broad age range, with one student between 18-20, three between 21-25, one between 26-30, and two between 36-45.

The first question they were asked was what they thought about the Referencing Books resource, and all the feedback was very positive. One described it as “refreshing,” two said it was “a very useful tool,” two said it was “helpful,” three mentioned that it was “concise,” and one commented that it “could have contained more in-depth information.” One of the students said, “I think it’s a really useful tool – referencing is important and often overlooked. It’s clear, concise, and easy to use. I wish I had this in my first degree.”

In terms of usability, they all thought that the object was easy to use, with four rating it “very easy” and three rating it “easy” (ratings were on a 3-point scale, from “very easy” to “not easy”). We specifically asked if they had any problems navigating through the object, to test their views on the navigational system we had chosen. One said, “no not really once you’re familiar with your phone,” and another said, “occasionally unsure when a section had come to an end.” Another said it “took a while to work out how to go backwards.” However, none of the students reported significant navigational problems, with most saying that once they had become familiar with what they had to do, they were fine, “because it’s really short and organised in that way, if you do make a mistake and mess up where you

want to be you can get back to where you were really quickly.” One student did, however, raise an important usability issue. “After playing the audio on each page I naturally felt compelled to scroll down, instead of up... I think it’s natural that I want to scroll down first.” None of the students raised concerns about the size of the learning object on the mobile phone, or had problems reading or understanding the text or interface elements. Two students did comment that the Nokia N91 phones were quite large and chunky compared to some phones, and wondered what the experience would be like on a phone with a smaller screen.

On the visual design of the resource, four students used the word “clear” to describe it. Comments included “Uncluttered and clear,” “Basic but efficient,” “Great. Simple and clear,” and “It was clear and easy to follow.” No mention was made about the colour scheme, so we can assume that no-one had concerns with it.

We asked if they would like the university to provide them with resources like this, and the six students that answered the question all said yes. The same six students also said that they would be prepared to use their own mobile phones within their university course. One student commented afterwards that he was already using his mobile and his PDA for learning purposes. Two questions were asked about their attitudes towards using mobile phones for teaching and learning, and the results are shown in Tables 1 and 2 below.

**TABLE 1** How useful would it be to access learning materials via your mobile?

Rating	Extremely important	1	2	3	4	5	Not at all important
N		1	4	1	0		
%		16,7%	66,7%	16,7%	0%	0%	

They all consider it to be important to be able to access learning materials via their mobile, 83 per cent, if you combine the responses to “1” and “2,” although one rated “3” in the middle so could be undecided, and one did not answer the question (see Table 1). We have received a much more positive response to this question from these students than when we asked 101 first-year students the same question in a mobile phone survey a few months earlier, when only 46 per cent thought it was useful to be able to access learning materials on their mobiles, and 29 per cent were undecided, rating “3.” This could be because the students in this evaluation study have

had an opportunity to see and use learning materials on a mobile phone, whereas the others had not, and therefore couldn't visualize the types of learning materials that could be created. This question was pursued in the informal discussions that followed the questionnaire completion by asking if they would have imagined having something on their mobile that they could learn from before being involved in this exercise today. Most of the students answered no, with one saying "No I wouldn't have thought about it but I don't see why not because you can get everything else. I mean, you can get mobile phones which are like PCs and you can carry your entire life in your mobile phone." Another said "I can see so many different uses." A couple of students asked how we intended to make such resources available to students, and this is something that we have not tackled yet.

For the second question, they all thought it was positive if the university contacted them via their mobile phone for learning purposes (again one did not answer the question). The full results are in Table 2. Their responses suggest that students are becoming more open about their personal mobiles being used for learning tasks, and that they do not see this as an infringement upon their personal devices or space.

**TABLE 2** How would you view the university contacting you via your mobile for learning purposes?

Rating	It would be a positive aspect	1	2	3	4	5	It would be a negative aspect
N		2	4	0	0	0	
%		33 %	67 %	0 %	0 %	0 %	

Many of the comments made by students in the informal discussions afterwards reinforce the positive responses given in the questionnaire. Some of these are included in Table 3.

Many of the comments made are very emphatic. One student describes it as "cool," another "brilliant," and one said "I love it." One said "I really enjoyed using it." Two students commented on the potential of the mobile learning object, saying "I think it's got a lot of potential," and "I think it's a great idea."

**TABLE 3** Student comments about the Referencing Books mobile learning object

"I really enjoyed using it."  
"I thought it was great and really handy."  
"I think it's brilliant."  
"I think it's got a lot of potential. I would definitely use it if it was applicable to my course."  
"It's cool."  
"I love it."  
"I think it's something that's really useful."  
"You can go home on the tube or the bus and just read it."  
"I think it's a great idea."  
"I think it's really good."

A frequent topic that was raised by students was the notion of wanting to have learning resources that are convenient for them. Resources that could make use of what was referred to as "dead time," for example, while traveling on the tube (subway), bus, train, or coach to and from university or going home to visit parents, or in any environment where you did not have access to a computer, such as whilst having lunch in a cafe. They like the fact that mobile learning resources have the added advantage that they can be used anywhere, anytime, because they are designed for small devices that are carried everywhere, and can be used whenever its convenient, especially in cramped environments (such as when on public transport as one student noted) and in situations when it would be more difficult to study from bulkier text books or course notes.

### **The Response to Student Evaluation**

Student feedback confirmed that some aspects of the design were not intuitive and could be improved. This led to another development cycle and the creation of Prototype 4.

### **The Development of Prototype 4**

In the light of student feedback, and discussions with colleagues from another multimedia development team, further changes were made to the presentation of content on the screen and navigation through it, the overall interface design, and to the Making a Reference step-through sequence.

The biggest problem with the screen design was that peer users and students did not like navigating through the content within a screen from the bottom upwards. They did not find this intuitive, so this was changed.

This in turn led to changes in the overall interface and screen design. The title of each screen or section was moved to the top horizontal bar and replaced the title of the learning object, which was considered to be superfluous and removed. Because mobile learning objects are likely to be short for completion in just a few minutes, it was considered that it was not necessary to include the title of the object beyond the first screen. At the same time, the audio button was moved to the top bar, next to the title, because as the audio clip introduces each screen, it suited being in the same place. Moving the audio button also benefited the focus order. The audio button has focus when the user enters a screen, and pressing the down navigation key on the phone moves the focus down the button list, resulting in a more straightforward top to bottom focus path. These changes had the effect of freeing up space below the central content area, and made the overall screen design less crowded.

A better solution for navigating through the Making a Reference step-through sub-menu was also required. Operating the step-through was still a slow two-step process. Our test users and some of the students had found this problematic. Users suggested making use of the number keys on the mobile to control each step. By clicking a keypad number from 1 to 5, the appropriate step in the animation sequence is played. This was a totally different approach to any of the other navigational techniques we had used to date, and made use of the alphanumeric keys on the keypad of the phone for the first time to navigate to content screens. Instructions on how to navigate through the step-through were included within the introductory audio clip, thus removing the need for textual instructions to be placed on the screen. The revised design is shown in Figure 7.



**FIGURE 7** Step 3 in the making a reference sequence from Prototype 4, showing the revised user interface and sequence navigation

## **Summary of the Key Design Decisions**

To summarize, this fourth prototype has gone through a number of key changes in its iterations, influenced not only by input and feedback from the development team, but also from peer users and from student feedback.

The overall navigation system from screen to screen was simplified, from a two-step “focus and select” process to using the left and right navigation keys on the five-way navigation key to move forward and backward through the object. This has proved to be more intuitive to users, is an easier and simpler process, and improves the ability to use the learning object on a mobile phone with one hand.

The design of the user interface was refined in light of the revised navigation technique, and to improve overall usability and clarity. When the arrows on the bottom bar were used to navigate between screens, it seemed natural to access content on the screen from the bottom upwards, starting with the audio introduction. This did not prove to be intuitive with users, and once navigation through the object was changed to using the left and right navigation keys, there was no reason why you couldn’t navigate downwards through a screen, from top to bottom. The screen title and audio icon were therefore moved to the top bar, and the learning object title was considered to be superfluous and removed.

The navigation of the Making a Reference section has proved to be the most difficult to find a solution to. Having a sub-section is in itself problematic in what is only a short learning object, and maybe the storyboard needs revisiting to break down the content of that sub-section into a series of discrete screens, which would remove the need for an additional navigation system. The current prototype makes use of the alphanumeric keys on the phone to select the appropriate section.

We have found that user interactivity and the use of multimedia have not been compromised in the mobile version. Users still control what they look at, and the pace in which they work through the object. All of the multimedia elements from the original have been retained, except for the 3D animation which was replaced with a 2D cartoon strip type animation. Most of the graphics used in the prototype were deliberately kept simple, so that we could concentrate on the more fundamental design and development challenges. In some places the use of multimedia has enhanced the mobile version, for example the addition of audio commentaries aids understanding, and simple animations can accompany them providing visual illustration.

In this first learning object that we have developed for a mobile phone, how to navigate and execute user interactions using the available keys was

a major challenge. We are confident that we have arrived at an effective navigational system, making use of the available, common device keys. The five-way navigation key is used to move backwards and forwards through the learning object, and up and down through the content elements of individual screens. Number keys on the keypad are used to access numbered screens within the sub-section, and clearly this technique could be more widely utilized, for example to navigate to specific screens or to select parts of content, such as in a numbered list, or a menu.

## Discussion

A significant issue at the beginning of this project was the extent to which the Mobile Learning Objects (MLOs) can retain the pedagogical richness of the original desktop based resources. The original learning objects were developed to tackle a series of pedagogical challenges, such as facilitating learner engagement, and aiding students in dealing with problems of abstraction and complexity. These learning objects for the PC used a number of constructivist principles. They provided, for example, rich interactive visualizations, learner controlled pacing, and used scaffolding to assist learners in the transition to real-life use of knowledge (Boyle 2003; Holley et al. 2007; Smith et al. 2007). Given the constraints of the mobile phone device, a significant question was to what extent this rich functionality could be retained.

The underlying conceptual approach to tackling this problem is based on the idea of Generative Learning Objects or GLOs (Boyle 2006). In this approach the concrete realization of the learning object is separated from its underlying design. The underlying design, or pedagogical pattern, is viewed as providing the true basis for reuse. In this approach the mobility of learning objects is viewed as another presentation level of the same learning object. This work has allowed us to explore the extent to which this approach works. The pedagogical structure of the learning object is represented in the GLO approach as a network of pedagogical choices. This network is independent of any particular concrete realization. Mapping the pedagogical choices to the mobile device thus involves two main considerations.

The first is the transformation of media elements: text, graphics, animations, and so on, so that the presentational richness of the original PC objects can be captured in the mobile devices. The bulk of the chapter has dealt with this issue, and demonstrated that this was largely achieved. The second issue is the extent to which the richness of pedagogical intent of the original can be captured in the mobile version. Do the navigational limitations and small screen size of the device provide significant obstacles to achieving

this pedagogical richness? The feedback from the study points strongly to the ability to capture this pedagogical richness on mobile devices. The navigation system has to be transformed into basically a two-dimensional navigation of page forward and backward, and tab up and tab down the selected screen. However, this provided no major barriers to achieving rich interaction. In fact, work on this and other learning objects has shown that quite rich techniques, such as fading from video to schematic representations, can be achieved quite naturally within this apparently limited navigation structure. A further insight is the extent to which transforming text to speech, especially when mediated through headphones, produces a more intimate feel for the learning objects. This, in fact, enhances the engagement level of the learning objects over and above the PC-based learning objects.

The outcome of the study, and our explorations to date, indicate that very rich pedagogical techniques can be achieved on mobile phones. This often requires adaptation at the media level, for example replacing explanatory text with speech. However, these presentation level adaptations do not detract from the pedagogical richness of the learning object, and in some instances, enhance it. MLOs obviously have certain other features, such as the ability to produce situationally-specific learning, which provides opportunities not easily made available on desktop devices. The future for developing pedagogically rich, constructivist learning resources on mobile devices thus looks very promising.

## **Conclusion**

We have reached the stage where we have developed four iterations of a prototype with refinements made at each stage in the light of peer testing and student feedback. We now have a fully functional prototype, and in the process we have researched and tackled a lot of the issues involved in developing multimedia Flash Lite 2 learning objects for Nokia Series 60 phones. Student feedback confirms that multimedia mobile learning objects are desirable, and this work is now developing in a number of parallel strands.

A key issue now is how we can integrate MLOs and students' own mobile phones into campus-based teaching scenarios in a coherent manner. We are already beginning to develop new MLO prototypes in different subject areas, and will conduct more extensive trials on these with students. There are also opportunities to embrace the strengths that the mobile phone can bring to learning, for example in combining multimedia learning content with scenarios for learners to capture and contribute media files (user generated content), dynamically upload content on the move, and communicate with peers and/or tutors. The possibilities for incorporating multimedia learning

resources into sociable learning scenarios on mobile phones is achievable and could be very powerful, and that is one of the directions that we are interested to pursue in the next phase of development.

We also have to investigate and tackle a number of issues associated with how we could make such learning objects available to students. Since we embarked on this work, licensing deals with mobile device manufacturers are making Flash Lite available on more phone models, and in most cases freely, making Flash-based learning objects a more viable proposition. So far we have limited our work to developing solely for Nokia Series 60 phones, and in particular the N70 and N91. There are issues around how content would be presented on phones with different screen display sizes and resolutions (which currently varies widely). We have to determine how we can best package up the learning objects for easy transfer onto the phone (the current prototype consists of one SWF file, and a series of external assets for the audio and text files). And then determine how we could make available the packaged files for users to have on their phone (for example, by providing pre-installed SD or memory cards, or by downloading from the Internet, which is a cheap option if it can be done via WiFi), sending them via Bluetooth, or transferring them via a PC (if students' phones permit this).

Another area we are working towards is streamlining the production process of our learning objects, so that once the creative design phase is over, the Generative Learning Object (GLO) tool can be used to instantiate versions for the Internet, mobile devices and further down the line for ubiquitous devices such as wearables.

Having a refined working prototype has been vital in helping us to get meaningful feedback from students, and has helped them to visualize what the future of mobile learning could look like. Student feedback on this learning object has been extremely positive, and is very encouraging. A high percentage of them (83 per cent) think it would be useful to be able to access learning materials on their mobile. Students can not only see the potential for multimedia MLOs, but they see them as being “cool” and “brilliant.” They can also identify ways in which they would use them, saying that they're “really handy” and “really useful,” and can see the benefits of using them in periods of dead time, when traveling in cramped spaces, and in environments where there is no access to computers. Such comments suggest that multimedia MLOs can engage students into learning, and provide an interesting and enjoyable experience. We are constantly surprised by the positive student reaction towards mobile learning, and the fact that they say the kinds of things that we would be aiming for, summed up by one student who said, “I think it's got a lot of potential. I would definitely use it if it was

applicable to my course.” Such feedback indicates that students are receptive towards multimedia MLOs, and that there is therefore great potential in continuing with this direction in mobile learning, providing that materials are well designed and based on sound pedagogic principles.

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<http://www.biskero.org/>

<http://flash-lite-tutorial.blogspot.com/>

<http://chiaotsu.wordpress.com/>

<http://www.flashmobilegroup.org/>

<http://richardleggett.co.uk/blog/index.php>

<http://www.flashdevices.net/>

<http://www.flashmobilegroup.org/>

<http://justin.everett-church.com/index.php/>

<http://casario.blogs.com/mmworld/>

<http://www.christianhalbach.de/blog/>

<http://www.blueskynorth.com/>

Adobe Mobile and Devices Forums: <http://www.adobe.com/cfusion/webforums/forum/index.cfm?forumid=68>

Nokia Developer Discussion Boards: <http://discussion.forum.nokia.com/forum/index.php>

Yahoo Group: <http://tech.groups.yahoo.com/group/flashlite/>

**Acknowledgments**

The Centre of Excellence in Teaching and Learning in Reusable Learning Objects is funded by the Higher Education Funding Council for England. London Metropolitan University is the lead site, in partnership with the universities of Cambridge and Nottingham.