DESIGNING FOR FLEXIBLE LEARNING: DEVELOPING WIRED AND WIRELESS APPLICATIONS

David M. Kennedy[1] and Doug Vogel[2]
[1]Division of Information and Technology Studies, Hong Kong University, Pokfulam Road, Pokfulam, Hong Kong
[2]Department of Information Systems, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong

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Abstract: Mobility is an intrinsic property of learning encompassing spatial, temporal and developmental components. Students' expectations on how and when they learn are creating increasingly heavier demands upon all aspects of their learning and young people, more than any other group, are making mobile devices extensions of their personal space and fundamental to their daily lives. In response, the world is moving very rapidly to engage with the opportunities and flexibility offered by mobile technologies. Educators and developers are faced with the dilemma: do you develop applications for the mobile or the wired environment? In this paper we argue that learning environments will remain combinations of wired and wireless for the foreseeable future. However, not all affordances offered by wired environments are transferable to small mobile devices. In fact, some tasks involving student-generated content are better served by applications that are designed to be entirely mobile. The paper will present initial results and evaluations of five of learning tools with the properties mobility, flexibility and either instructor- or student-generated content.

1 INTRODUCTION

The web has empowered students and instructors with environments that facilitate a wide variety of opportunities for learning and engagement. For example, with appropriate learning design, the web can facilitate engagement with authentic tasks supported by a range of learning resources, and more frequent, meaningful communication with instructors and/or other students in the process of knowledge-building. However, the concept of a fully wired world where students can learn anytime–anywhere is still unrealized and likely to remain that way for some time to come (Vernon, 2006). This is due to:

- limitations in the interoperability of different wireless systems;
- high power requirements of the 802.11 wireless standard, necessitating powerful (heavy) batteries for PDAs and smart phones and concomitant short operating lives;
- lower security than wired links;
- potential interference resulting in frustrated users; and
- cost, since most wireless domains are either password protected (private) or fee-for-service.

Not withstanding these problems a number of countries are choosing wireless connectivity over extensive wired development. However, the educational issue remains the same—providing flexibility of learning opportunities. Students in many developed countries suffer from problems balancing work and study, which limits their on-campus engagement. Thus, student expectations of when and where learning can occur have evolved to include wireless solutions along with wired internet access at home or university.

Mobile devices may well define the next era in computing as such devices create a new paradigm between anytime/anyplace availability (ubiquity) and computing capabilities (functionality).

For example, market trends indicate that sales of notebook computers are currently buoying overall sales of personal computers (PCs), particularly in the developed world, as people move to the convenience of mobile computing (The Register, 2006). Mobile computing devices include a variety of hardware with different functions. They include notebook/laptop computers, personal digital

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assistants (PDAs), mobile telephones, game consoles, mp3 players (e.g., iPod), DVD and/or CD players and digital cameras. Considerable efforts have already been made to utilise the inherent mobility and flexibility for learning of some of these devices (primarily PDAs and mobile phones—small mobile devices). Small mobile devices (SMDs) have been used successfully in business (e.g., Easton, 2002), medicine, (DeHart *et al.*, 2004; Smørdal & Gregory, 2003), nursing (Altmann & Brady, 2005), engineering (Perry & Jacob, 2005), radiology (Boonn & Flanders, 2005), K-12 schools (Johnson & Rudd, 2003) and more recently as a field data-collection and reflection tool (Vogel, Kennedy, Kuan, Kwok & Lai, in press).

In the last two years, many of the functions once associated with separate devices are now being incorporated into a single device called a '*smart phone'* (Zheng & Ni, 2006). The original limitations associated with SMDs (e.g., memory, battery life, connectivity, and CPU speed), are rapidly being overcome in smart phones. Moore's Law suggests that these rapid gains in memory, storage and CPU speed will continue.

However, for design purposes SMDs present a different user interface—stylus-driven interactions and handwriting recognition rather than the keyboard and mouse associated with desktop/ notebook computers (D/Ns). In the applications described below, considerable effort has been made to provide:

- *flexibility* of potential use;
- *alternate, but similar interfaces* for wired or wireless devices; and
- *one-stop authoring* of content for both domains.

It is the latter that the authors believe will 'make or break' uptake of these ubiquitous technologies in the broader educational environment.

2 MOBILITY AND FLEXIBILITY FOR LEARNING: THE NEW PARADIGM?

Mobility is an intrinsic property of learning, encompassing spatial (university, workplace, home), temporal (days, evenings, weekends) and developmental (the learning needs/ life skills of individuals which change depending upon age, interest or employment) components. Student expectations on how and when they learn are creating increasingly heavier demands upon all aspects of their learning and young people, more than any other group, are making the devices extensions of their personal space fundamental to their daily lives (Sharples, Taylor & Vavoula, 2005); Vavoula and Sharples, 2002). Figure 1 (after Naismith, Lonsdale, Vavoula & Sharples, 2005, p. 7) is a diagrammatic representation of this view.

In Figure 1 the horizontal arrow indicates increasing mobility of people (right to left), while the vertical arrow indicates increasing mobility of the device.

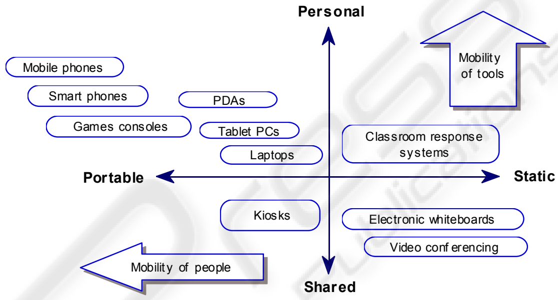


Figure 1: Classification of mobile technologies.

The learning tools described in this paper may be associated with the top left quadrant, where people and devices are highly mobile. In considering how to design applications for both mLearning and wired access, a number of key factors need to be addressed. Zheng & Ni (2006, p. 473) suggested that the main elements that need to be addressed in moving from the D/N to an SMD are:

- context, where the functional design accounts for screen size, processor speed, and educational needs;
- content, resources that can be presented, annotated, queried and answered using the input devices(s);
- community, allowing students to share information (text, SMS and images) via Bluetooth and WiFi;
- communication, using all of the possible input methods, text recognition, keyboard, stylus;
- customisation, so that students have the facility to tailor the device to personal needs; and
- connection, via a variety of methods, to support students moving from wireless to wired environments.

In practice this often means a decrease in functionality or a change in design features when moving from the D/N to SMDs, but this is not the always the case. In applications that recognise mobility as an intrinsic element needed for learning (e.g., field studies, professional practice or engagement outside the classroom), the D/N application may not be suitable. The current developments seek to:

1. develop and research the use of a range of tools for both web and mobile platforms;
2. develop or select software that enables academics to easily publish activities/tasks to the web and/or personal digital assistants (PDAs) or smart phones simultaneously;
3. develop a common set of icons for common tasks (e.g., save, upload, download, log-in, check answer, hints, information) consistent for each mobile application; and
4. provide pedagogical advice and support (with examples) for developing content suitable for eLearning (web-based and mLearning).

In this research a number of applications have been redesigned to provide greater flexibility for student learning by providing access and engagement in the mobile form. The five examples are discussed below.

Interactive Graphing Object (IGO): Many concepts are best represented by graphs, where more than two variables can be represented. Many key concepts in science, business and medical sciences are best understood using graphs (Kremer, 1998; Kennedy, 2004; Kozma, 2000). The Interactive Graphing Object (IGO) was originally developed for the web (Kennedy, 2004) but was adapted for mobile devices to increase the flexibility of learning available for students. The IGO supports onscreen sketching and curve fitting (Kennedy, Vogel & Xu, 2004). The IGO authoring environment also supports web authoring and publishing to either fixed or mobile devices.

Tatoes: Tatoes is an XML-based application that converts the highly successful quiz-generation software Hot Potatoes (available free to educational institutions from http://hotpot.uvic.ca/) to a form that functions on a Pocket PC. Authoring is done on a PC and the Tatoes software converts the files (multiple-choice, fill-in-the-gap, ordered lists, matching exercises) to run on any device with the Windows .NET mobile platform installed. An instructor creates a series of questions using Hot Potatoes publishes them to the web or mobile form.

Crossword puzzle: The Crossword tool is part of the Tatoes environment. While generally focusing on knowledge-type questions, it has been popular with students in the mobile form, as they can undertake the exercise when away from any network, wired or wireless.

Build-a-PC tool: The student is required to select from a range of computer components to build a desktop computer system appropriate for specific people in an organisation. Students must make decisions based upon the position held, responsibility level and budget available. Extensive feedback is provided about their decisions.

In each of these examples, instructors author once and publish to the internet and/or mobile devices with one click.

Phototate: This software utilises the camera feature found in smart phones and PDAs. Students may capture images, annotate the image with a pen tool, and add audio content to the final saved file.

In Tables 1 and 2 the differences between the web and mobile forms are shown using screen captures from the online and mobile versions of the same application (except for Phototate).

The first four tools have been used with two cohorts of first-year information systems students (totalling 1,600 students) at the City University of Hong Kong (CityU), while Phototate has been piloted on a field trip to Norway by third-year science students at CityU.

3 DESIGNING FOR FIXED AND WIRELESS DEVICES

Development of the mobile applications has been undertaken since 2004. In Figure 2, a framework showing the software developed as part of this project is presented in relation to mobility (horizontal axis) and content creation, instructor or student (vertical axis). In the majority of institutions of higher education, applications have been developed from the premise that connection to computing environments will be at fixed locations using a D/N computer (e.g., university, schools, home, computer laboratories and internet cafes).

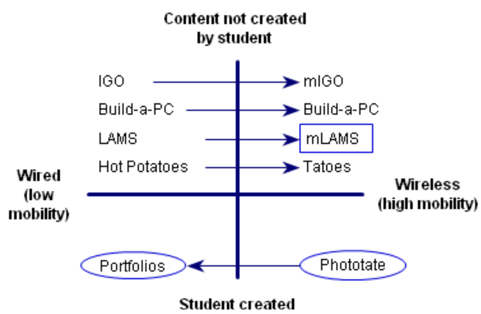
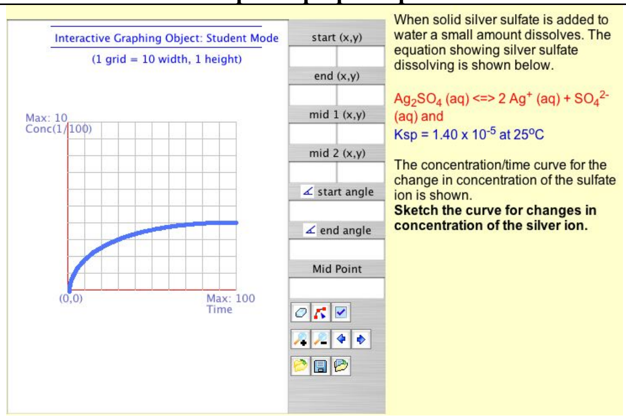
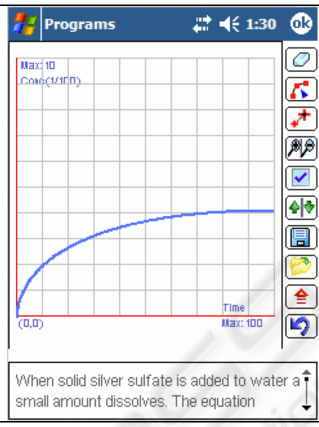
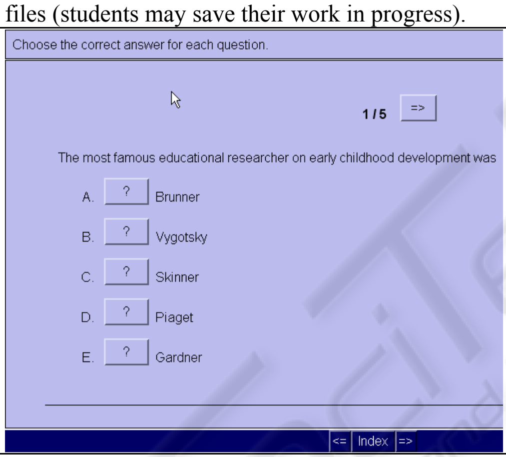
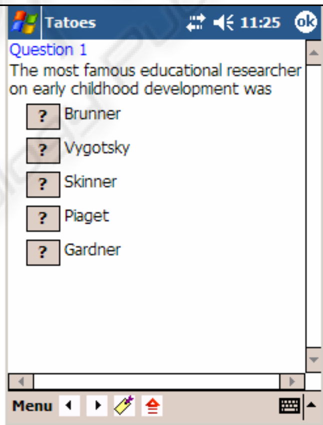
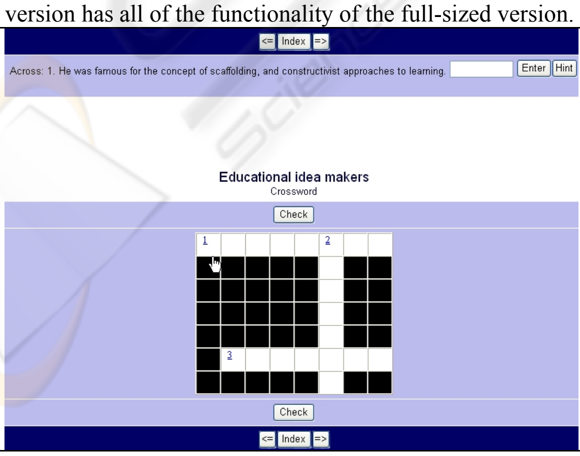
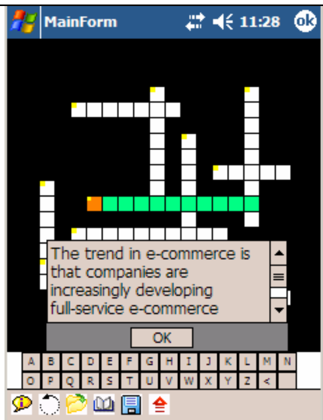


Figure 2: Content creation for applications intended for fixed *and* wireless devices.

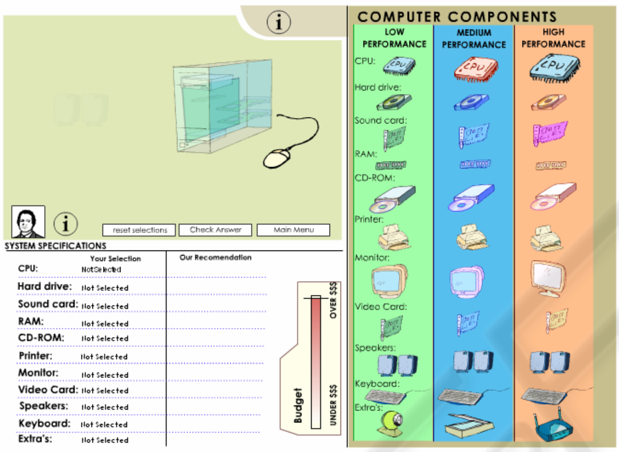
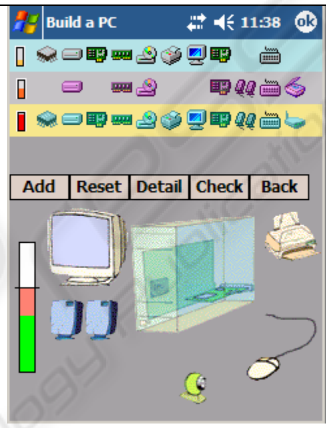
Table 1: Comparing applications, desktop/notebook versus mLearning equivalents (three tools).

Tool	Desktop or laptop computers	Small mobile devices
IGO/ mIGO		
	A set of icons has been used to simplify the user interface. Input of actual values in the mobile version is no longer available and, in the mobile version, longer questions must be scrolled to read the entire text. However, both versions support complex curve fitting, iterative forms of feedback, zooming, and saving of files (students may save their work in progress).	
Hot Potatoes / Tatoes		
	In moving from the D/N to the SMD some limits on text length are needed to reduce the amount of reading on the SMD and the use of images is problematic. However, for text-based questions the mobile version has all of the functionality of the full-sized version.	
Xword		
	The two versions are almost the same, with a much more efficient use of screen real estate in the mobile form. The major difference is the need for the questions and hints on the mobile version to overlap the crossword, unlike the web version where the clues are at the top of screen.	

The second dimension considers who is responsible for the creation of the content. While the internet has created many opportunities for teaching and learning, and many interactions/tasks can be designed by instructors, the underlying assumption is that the student is the recipient of the content. The major exception to this statement is the use of computer-mediated communication (CMC). Thus far, the use of mobile devices for students to generate content has been limited to text (SMS, email and CMC), digital photographs and video, and data collection using a forms-based interface).

In this project providing tools and resources to enable students to learn at a time most suitable for the student, and simple to use authoring interfaces (PC-based) are seen as primary factors guiding the developments.

Table 2: Comparing applications, desktop/notebook versus mLearning equivalents (two tools).

Tool	Desktop or laptop computers	Small mobile devices
Build-a-PC		
	The two versions are effectively, the same. However, what has changed is the way in which students engage with the task. In the D/N version, students use a drag-and-drop method using a mouse. In addition, the mouse-over of a component produces a description of the item. On the SMD version, the tap-and-click method is used (the object is selected and then added using a tap on the appropriate button, or the student selects 'Detail' to know more about the component).	
Phototate	 Download audio	
	Phototate is software that allows students to collect data in the field or undertake reflective practice. Phototate allows students to annotate the photos taken with a PDA or smart phone with a variety of pen colours and attach an audio file to the annotated image. The composite file may then be uploaded to a Course Management System and the student's ePortfolio for future analysis and reflection. The file on the left is from a science field trip to Norway, uploaded to a webpage. The attached audio file consists of a discussion about nutrient levels versus water clarity between a student and the instructor. On the right is a partially annotated photo of students on a PDA.	

The major expected outcomes are flexibility of learning opportunities. Flexibility incorporates a:

- *connected* mode (at the campus);
- *nomadic* mode (at home or connected to a desktop computer on campus or at home), and
- *disconnected* mode (on public transport, away from wired or wireless connections)

(after Zheng & Ni, 2006)

To date, what has been shown is that the change in interface between the more fully featured web versions of individual applications has not interfered with students who use the mobile form of the tools for self-guided learning. Numerous authors see only problems of security, screen size, battery life and CPU speed; however, we focus on opportunities and flexibility for student learning. In Table 3 these issues perceived as problematic are discussed in light of our experiences and feedback from students. The list of problems is adapted from Csete, Wong, and Vogel (2004), but the improvements in mobile affordances since 2004 have been relentless.

Table 3: Perceived limitations of SMD versus actual experience: Designing for web and mobile applications.

Perceived inhibitors	Key functional differences: Web/Mobile	Future solution
Small screen size	Current screen size creates overlapping text and/or graphics, especially for the feedback to questions. This has not been an inhibitor to the use of the mobile versions of the content in the minds of the students.	Flexible film display
Non-ergonomic input method	From one perspective, the stylus or onscreen text recognition limits the speed and flexibility of input for an annotation. However, a stylus also allows more flexibility for annotations using Phototate software, and text input has never surfaced as a significant issue (student focus groups).	Voice recognition Projection keyboard Cursive hand-writing recognition improvements
Slow CPU speed	Applications run more slowly than on a desktop computer, but the speed at which all of the applications run is deemed satisfactory by students.	New breed of architecture for faster CPU
Limited memory	The size and power requirements of more powerful CPUs limit what can be placed in mobile devices. This is a limitation only on the most demanding of applications. All of the examples described above operate satisfactorily on PDAs up to two years old. The advent of cheap flash memory has overcome storage issues. Up to 100 Phototate files can be stored on one 512 Mb flash memory card.	Expansion memory card Increase internal RAM capacity
Limited battery span	Extended use is limited by current technology, and this remains a problem, particularly the non-persistence of information with some hardware.	New breeds of lithium batteries or fuel cells
Ever-changing OS	This is a current and likely future problem not resolvable in the short term with many competing systems (e.g., Symbian and Windows mobile).	Open-source OS for mobile devices (e.g., Linux has been run successfully on a smart phone)
Infrastructure compatibility	There is a plethora of wireless standards, some of which require large amounts of power, but also offer increased bandwidth and transfer speeds.	Standards are still being developed to bridge the mobile platform.
Connectivity bandwidth	Current wireless networks have sacrificed speed for access, but this is changing rapidly.	3G mobile capacity and Bluetooth v.1.2 More efficient wireless protocols than currently available

3.1 Brief Summary of Current Evaluation Data

Qualitative and quantitative evaluations have been undertaken with Tatoes, Phototate and build-a-PC and are reported elsewhere (Vogel et al., 2007). The use of the exercises on the PDAs was not mandated so students tended to download exercises more than upload the completed work. However, students who achieved higher levels in the mid-term exam performance were positively correlated with the group that also used the mobile exercises.

The key finding from the tutors (with 416 students participating in various tasks from a cohort of an introductory business course) indicates that students who engaged with the use of mobile devices for learning in and out of the classroom found the experience of using a PDA provided a significantly better set of learning experiences, was fun, and useful for motivation and confidence building. Approximately one quarter of the total student cohort of 1,600 have engaged with all or some of the tools in spite of the voluntary nature of the exercises. While the initial evaluation results were encouraging, there still remains a great deal of work to be done to explore more fully the reasons why students used or did not use the exercises. In particular, the ongoing research seeks to determine why students (almost all) did not use the high quality feedback provided (all incorrect alternatives had a detailed description of why the selection was incorrect) with the Tatoes exercises. The expectation was that students would take the opportunity to explore incorrect alternatives in order to improve their understanding: this was not observed. The current cohort of students are experiencing specific teaching interventions in an attempt to determine if their current approach to learning can be modified, and encourage more students to use the exercises.

4 THE FUTURE

The future may see a paradigm change as mobile devices become more integrated into educational environments (see Table 2). However, for this to occur we need to establish sound pedagogical frameworks based upon experience and research into how students use the tools in practice: what the specific learning needs are, and how more effective feedback, communication and collaboration can be enhanced. Four tools, Tatoes, Crossword, IGO and Build-a-PC, have been designed with the facility for lecturers to provide high quality feedback to students. The use of the Tatoes environment provides limited evidence that writing multiple-choice questions with detailed feedback may encourage some students to not only look for the correct answers to a question, but to spend time examining what makes other distracters wrong. Phototate provides a tool for reflective practice and data generation by students away from traditional classrooms and lecture halls, providing support for more flexible modes of learning.

The focus in the past has been on the perceived limitations of mobile devices, rather than the pedagogical affordances and flexibility offered. The rate of uptake (voluntary) by students has been steady as they take advantage of the:

- the quality of the feedback provided for incorrect distracters and correct answers; and
- flexibility offered by anytime/anyplace learning.

What this project has made clear is that offering students the flexibility of mobile learning options in addition to current wired learning environments is viable now, and not something that educators need to wait for. The key issues are not technological, but pedagogical and institutional.

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