EDUCAUSE CENTER FOR APPLIED RESEARCH

Using Mobile Technology to Enhance Students' Educational Experiences

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EDUCAUSE Center for Applied Research

EDUCAUSE is a nonprofit association whose mission is to advance higher education by promoting the intelligent use of information technology.

The mission of the EDUCAUSE Center for Applied Research is to foster better decision making by conducting and disseminating research and analysis about the role and implications of information technology in higher education. ECAR will systematically address many of the challenges brought more sharply into focus by information technologies.

Using Mobile Technology to Enhance Students' Educational Experiences

Preface

The EDUCAUSE Center for Applied Research (ECAR) produces research to promote effective decisions regarding the selection, development, deployment, management, socialization, and use of information technologies in higher education. ECAR research includes

- research bulletins—short summary analyses of key IT issues;
- research studies—in-depth applied research on complex and consequential technologies and practices;
- case studies—institution-specific reports designed to exemplify important themes, trends, and experiences in the management of IT investments and activities; and
- roadmaps—designed to help senior executives quickly grasp the core of important technology issues.

From its most recent research, ECAR published a comprehensive gathering of information on IT networking in higher education in *Information Technology Networking in Higher Education: Campus Commodity and Competitive Differentiator.*[1] The study uses a multifaceted research methodology to collect and analyze quantitative and qualitative data from approximately 545 senior IT and network administrators.

Literature Review

The study began with a review of the relevant literature on effective IT networking practices and future directions in order to define the study's major themes and create a working set of hypotheses to be tested.

Online Survey

We invited higher education institutions in the United States and Canada that are members of EDUCAUSE (1,477) to participate in an online survey. Senior IT leaders, most of them chief information officers (CIOs) or networking administrators, from 488 institutions responded to the survey. Another 29 institutions that are not EDUCAUSE members asked to be included, generating a total of 517 institutions responding.

Interviews

We conducted telephone interviews to further explore some of the key findings derived in the quantitative research. In support of the study's core analytical chapters, we interviewed 19 individuals representing 13 different institutions. We also interviewed 12 higher education networking leaders about their view of networking's future over the upcoming 5- to 10-year time frame. Finally, we sent e-mail follow-up queries to selected online survey respondents for clarification and further description of some topics. We received responses from 21 individuals.

Case Studies

Researchers conducted this in-depth case study to complement the core study. We assume readers of this case study will also read the primary study, which provides a general context for the individual case study findings. This case, which studies educational applications of mobile technology in The Netherlands, represents a new dimension in ECAR research, as it is our first case study from outside North America. ECAR owes a debt of gratitude to Petra Boezerooy, research policy coodinator, SURF Foundation; Sytze Boschma, ICT advisor, Centre for Educational Training, Assessment, and Research, Vrije Universiteit Amsterdam; Sytze de Bruin, assistant professor, Centre for Geo-Information, Wageningen University and Research; Nils de Reus, researcher, SPINlab, Vrije Universiteit; Mathilde Molendijk, education coordinator, SPINlab, Vrije Universiteit Amsterdam; Patris van Boxel, educational advisor, Centre for Educational Training, Assessment, and Research, Vrije Universiteit Amsterdam; Ron van Lammeren, associate professor, Centre for Geo-Information, Wageningen University and Research; Alfred Wagtendonk, researcher, SPINlab, Vrije Universiteit Amsterdam; Petra Wentzel, educational advisor, Centre for Educational Training, Assessment, and Research, Vrije Universiteit Amsterdam; and other contributing members of the GIPSY and Manolo projects.

Introduction

Information and communications technology (ICT) continues to expand the boundaries of higher education into an "anytime/anywhere" experience. Wireless networks and mobile communications coupled with personal computing devices present new means for students to access classroom information and communicate with peers and teachers, and for faculty members to alter the concept of the classroom. Redefining this educational experience, however, presents new challenges for both educators and IT departments as they determine optimal mixes of technology and pedagogy. The educational goal is not to incorporate technology for technology's sake but to create a meaningful learning experience for the student, and IT departments must support such initiatives accordingly.

A consortium of three Dutch universities—Wageningen University and Research, Radboud University Nijmegen, and Vrije Universiteit Amsterdam—have worked diligently on this issue. Funded by the SURF Foundation, the Dutch higher education and research partnership organization for information communications technology, the consortium has explored flexible uses of technology in and out of the classroom, mainly through the GIPSY project and the Manolo project, discussed in this case study. Their experiences offer guidance and insights for institutions everywhere, and ECAR welcomes our Dutch colleagues' contribution on this important topic.

Mobile Environment Overview

The Netherlands and the United States have similarities and differences in their mobile environments. Both countries are enhancing their technical infrastructures by adding greater bandwidth and service capabilities. There is a big difference, however, in user adoption of mobile technologies. Mobile phone ownership is significantly higher in The Netherlands. This section contextualizes the case study by providing an overview of The Netherlands' mobile service infrastructure and user adoption.

Mobile Service Infrastructure

The Netherlands currently offers 1G, 2G, and 3G services. In 1992, 1G, or Global System for Mobile Communications (GSM) service, first became available in The Netherlands. Four other providers followed shortly afterward. Today KPN, Orange, T-Mobile, Telfort, and Vodafone offer GSM services. GSM is mainly used for voice. Efficient digital coding makes it possible to establish a bandwidth of 11.4 to 22.8 Kbps.

In 2001, Telfort was the first provider in The Netherlands with a national General Packet Radio Service (GPRS, or 2G) network. GPRS adds packet-switching protocols to mobile communication technology. It also uses TCP, which makes GPRS a mobile extension of every other IP network. GPRS costs are assessed per megabit rather than per second, to encourage "always on" mobile service without excessive costs. GPRS offers faster throughput than GSM because the data are sent at the same time using different radio channels. With GPRS, reading and sending e-mails, instant messaging (IM), and browsing the Internet are possible.

In 2004, Universal Mobile Telecommunications System (UMTS, or 3G) became available in February from Vodafone and in June from KPN. It can reach 384 Kbps and therefore makes using video phones, watching streaming video, downloading music, and getting broadband Internet access possible. UMTS can be used on both mobile phones and computers. For the latter, this means that The Netherlands can soon become one broadband wireless campus. With roaming technologies, easy on-the-go connections with local wireless networks can be established, bringing down the considerable costs for users. One disadvantage is that the bandwidth that can be achieved depends on the number of users: the more users, the lower the bandwidth. Although promised, television quality will hardly be reached with a UMTS network. A 4G network that will bring necessary bandwidth for television and video applications is currently under development. The first 4G network is expected within 10 years.

Mobile Service Adoption

Mobile telephone ownership is far more prevalent in Europe than in the United States. For example, by the end of 2003, 82 percent, or 13.3 million people, will use a mobile phone in The Netherlands, compared with 54 percent in the United States.[2] A 2004 trend report by the Ministry of Economic Affairs on the use of networks and ICT infrastructure reveals a 10.6 percent growth in mobile connections in 2003 in The Netherlands, compared with 10.7 percent annual growth in the United States.

Mobile phone ownership in The Netherlands is quite high among young people. IPM KidWise showed that children aged 8 and younger hardly ever have a mobile phone, but 79 percent of 10-year-old children do have one.[3] When children reach 14 years of age, 98 percent are in some way mobile connected. Our own research[4] showed that all 16- to 22-year-old young adults have a mobile phone.

Given this high ownership rate, it is surprising that schools and universities rarely use the mobile phone as an educational tool. When we consider the use of the Internet, which developed roughly in the same period and with a comparable huge impact in daily life and in education, this is even more surprising. In The Netherlands, some small initiatives exist in which short message service (SMS) text messages are used to inform students about schedule changes or exam results. Sometimes parents get an SMS to inform them that their child is not at school. Also, one project aims to use SMS for mass lectures. Students can ask the presenter questions or reply to questions from the presenter. The presenter can view the incoming replies immediately and respond to them. But in general, these initiatives are small and incomparable to the impact of digital learning environments such as WebCT and Blackboard.

Mobile and Wireless Learning Definitions

Technological developments in the field of mobile and wireless learning evolve so quickly that to prevent confusion we must clearly define both learning types. Frequent redefinition will surely be necessary to keep up with the technological changes. We believe that within a reasonable time frame (10 to 20 years), wireless and mobile learning will completely overlap, creating one global mobile campus. Table 1 delineates the differences between mobile and wireless learning as discussed here.

Organizational Background

To develop effective educational applications of mobile technology, since 2002 the SURF Foundation[5] has sponsored activities at three institutions: Wageningen University and Research, Radboud University Nijmegen, and Vrije Universiteit Amsterdam.

SURF Foundation

SURF is an ICT partnership organization for all Dutch universities (including universities of higher education). Although all educational institutions pursue their own policies with regard to academic and research activities and compete with one another, they nevertheless cooperate closely on an advanced ICT infrastructure. SURF consolidates all educationally supportive processes in which the emphasis lies on the user—that is, students, teachers, researchers, or supporters. This strategy's key concepts include innovation, standardization, integration, knowledge sharing, economies of scale, and cooperation on ICT facilities. As in the United States, ICT has penetrated deeply into the institutions' primary processes, such as research, organization, and education. Correspondingly, SURF has three platforms, each with its own areas of focus: ICT and research, ICT and organization, and ICT and education.

The Three Partner Universities

The three partner universities—Wageningen University and Research, Radboud University Nijmegen, and Vrije Universiteit Amsterdam—have worked together to investigate educational applications of mobility.

- Wageningen University and Research (WUR) has 7,400 employees and more than 8,500 students. The research institutes and university work together closely in five areas of expertise: agrotechnology and food, animal, environmental, plant, and social sciences. Important research themes currently include food safety and the "green" environment. Parts of its

Table 1. Mobile and Wireless Learning Definitions

Feature	Mobile Learning	Wireless Learning
Device size	Handheld: mobile phone, Smartphone, or PDA phone edition	Handheld: Laptop, tablet
Screen size	Very small (mobile phone) to a maximum of 480 x 640 pixels. More common for a PDA is 240 x 320 pixels	"Normal" screen size, 10 to 15 inches
Connectivity	(Inter)national networks such as GSM, GPRS, or UMTS	Local (campus) networks, such as WiFi
Coverage	The Netherlands	Campus

campuses have wireless access points.

- Radboud University Nijmegen has eight faculties (schools or colleges) and enrolls more than 16,000 students in approximately 90 study programs (about 40 bachelor's and more than 50 master's programs).
- The Vrije Universiteit (VU) Amsterdam has teaching facilities for more than 16,000 students. The ICT department supports academics to develop technological solutions to educational problems. The VU campus will have full wireless access for students and staff by March 2005.

All institutions have strong GIS (geographic information systems) departments, where research focuses on how to collect and interpret geographical data. Students can obtain M.Sc. or Ph.D. degrees.

The GIPSY Project

In 2002, SURF founded the GIPSY (Geo-Information for Integrating Personal Learning Environments) project to develop a more flexible and location-based way of learning. One of GIPSY's main objectives was to explore the wireless-supported learning environment. As described elsewhere,[6] this environment consisted of two courses in which students used wireless devices. The project concluded in December 2003.

Figure 1 shows the project's three main stages. GIPSY researchers first conducted focus groups with students, which in turn influenced development of the project's two courses: Introduction to Geo-Information Science, and Integration for Environmental Policy. The decision to create two courses was deliberate. The geo-information basics course focused mainly on wireless learning forms to support individual learning activities, whereas Integration for Environmental Policy focused more on group learning processes and wireless facilities' role in such education. The second course also tried to integrate desktop work and practical fieldwork in a cyclic procedure: students made field trips, on the basis of project planning, to collect geo-referenced data and materials. Directed by the outcome of team discussions, students then processed the data, analyzed the materials, and rechecked the results, preferably again in the field.

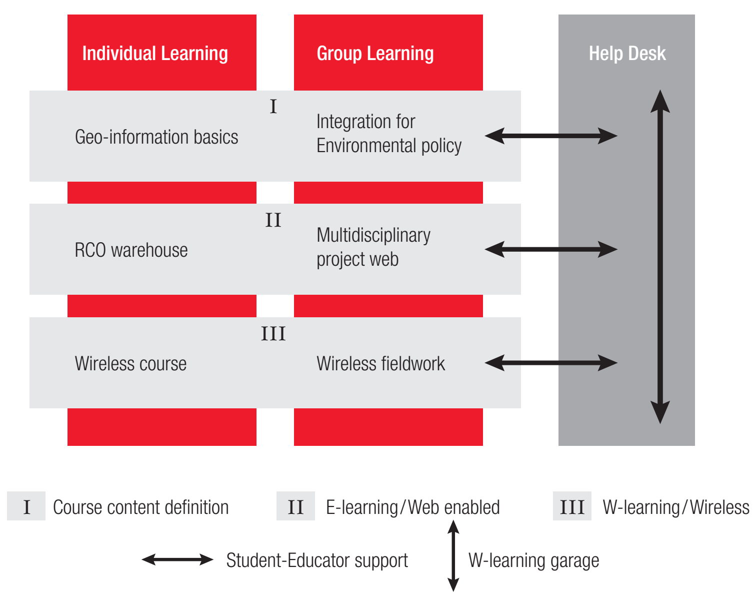

Figure 1. GIPSY Project Stages (Horizontal) and Products (Vertical)

This section discusses the GIPSY project in further detail and covers students' initial assessment of mobile technology during focus groups, their subsequent experiences in the two GIPSY project courses, and their post-GIPSY project fieldwork experience. Finally, students discuss their impressions of using PDA-based course materials.

Student Focus-Group Sessions

In the GIPSY project's first phase, 35 high school and university students aged 16 to 22 participated in a series of focus group interviews to discuss wireless devices' possible applications in education. During the first part of the sessions, participants were interviewed about their current use of mobile phones, palmtops, personal computers, and laptops for both private and educational purposes. Then they were asked to try the state-of-the-art XDA, a first-generation Pocket PC phone edition that connects to the O2 (a European mobile communication service provider) GPRS network, and to reflect on the functionalities and the user-friendliness of fully online devices in the context of their studies and/or fieldwork. Finally, students were asked to evaluate customized educational software applications on the XDA, such as assessment and geographic mapping software (ArcPad).

The focus group sessions show that all students are experienced mobile phone and computer users. They use these technologies daily and with great ease. Receiving calls is the most important feature of mobile phones for this age group, since it is cost free. Making a phone call is expensive, so sending an instant message is the preferred communication method. Expenses are watched closely, because the average amount this age group can and wants to spend on mobile communications is 10 euros per month (about U.S.$13). For this reason, most interviewees prefer a prepaid service plan, which makes it clear when the budgeted allowance for that month's mobile communication has been spent. Some students explain, "With prepaid you can easily monitor your amount," and "When your amount is finished, you cannot make any more phone calls, but people can still reach you." Mobile phones are not used for educational reasons, but only privately.

Adoption of advanced features is not currently popular. State-of-the-art mobile phones let users connect to the Internet. One student tried this once, thinking it might be useful "on holiday, to read the weather forecast." But this functionality is also expensive and for that reason not very popular at the moment. When thinking of functions that would add value to the mobile phone, students agreed on four points:

- lower the costs of mobile communication services,
- improve the battery's operational life span,
- add a function to read e-mail, and
- add a *useful* keyboard.

All participants had a PC at home; only three did not have Internet access. Only two high school students and three university students had a laptop computer. For the other students, laptop ownership was not a big advantage, since wireless connections were not yet available and all institutional departments had a sufficient number of desktop computers. Computers were used for sending e-mail, finding information, and downloading music. Especially important and widely used was MSN Messenger, although no student ever used it to chat with a teacher.

During the sessions' second part we provided the interviewees with an XDA. Several small tasks had to be performed: for example, send an e-mail, use Internet Explorer, work with Pocket Word and Pocket Excel, and watch a film trailer. Tasks also included some specific educational exercises: a self-test with Questionmark Perception and data entry with the GIS application ArcPad.

During this phase, we observed four stages in students' reactions to the XDA's possibilities:

- Stage 1: Students typically expressed excitement about the product itself. Some initial reactions included, "It works …" or "You get used to it quickly" or "The quality of the screen is pretty good."
- Stage 2: Initially, students tried familiar applications on the XDA: the Internet, MSN, and Hotmail.
- Stage 3: As students gained familiarity, they experimented with its new applications. Reactions included, "You can really read a book, wow!" and "This one also has a dictionary" and "Cool, [we can] watch a movie while on the train."
- Stage 4: Finally, students began to reflect on its value and utility. Comments included, "For what can I really use it?" and "What is the value for the money?" and "Not a very speedy connection."

On the basis of the discussions, we distilled the following technical advantages and disadvantages, also outlined in Table 2. High school students liked the idea of mobile self-tests, whereas university students felt the XDA would be more suited for high school educational applications.

To evaluate the GIS tasks, we asked the students to imagine using the XDA during a fieldwork trip. They were supplied with a GPS and ArcPad, a pocket version of GIS mapping software. The students could enter new measurements and access the database for immediate data validation. They were convinced that this application and technology would offer added value to their fieldwork. Their discussion focused mainly on weight and size versus usability. They concluded that the small size and low weight are a big advantage during fieldwork. This is more important than possible software and screen size limitations. The functionalities that ArcPad offers suffice to provide an excellent addition to fieldwork.

On the basis of the focus group sessions, we concluded that for "normal" educational settings the XDA

- is an advanced and cool device;
- can do many things, but nothing really well (not *the* "educational killer application");
- is good for "quick checking" of e-mail, schedules, exam results, opinion collecting in class;
- is not suitable for lengthy use (reading, writing);
- generates some interest for e-books;

Table 2. The XDA's Advantages and Disadvantages

Advantages	Disadvantages
Check e-mail everywhere, easy to use and read, could replace SMS	Connections are slow, typing is slow, keyboard necessary, limited storage
Use Internet wherever you are, MSN always online	Left-to-right scrolling, Web sites too big to see effectively on small screen
E-books, useful for making notes, highlighting passages	Pocket Word, Pocket Excel are very limited editions
Easy to use	Costs are too high
All-in-one agenda, mail, Internet, contacts	Risk of theft, rain, mud, breakability, and so on
Screen size	Screen size
Good-quality screen	No integrated camera, GPS

- is a lightweight extension of but doesn't replace the PC in any way;
- generates some interest among high school students for 10-minute self-tests; and
- has a problem when it comes to battery use.

When using the XDA for fieldwork,

- students were very satisfied,
- there were few technical problems,
- ArcPad proved a useful application for data entry,
- it was not extensively tested in rain and mud,
- battery life is poor—only four hours, and
- screen size versus portability was important.

These conclusions mean that the research projects' focus will revolve mainly around the use and design of mobile fieldwork.

GIPSY Course: Introduction to Geo-Information Science

This introductory course offers students basic information on main concepts, main technology, and the impact on society of geo-information science by means of the geo-information cycle. This cycle consists of describing, analyzing, and realizing real-world features and processes via spatial data and information. Main concepts are based on the notion of models (conceptual, formal, and technical); geographical attributes (thematical, geometrical, and temporal); geo-reference; geo-data-structures; and methods and techniques (such as algorithms) to realize the geo-information cycle (capture, storage, query, process, transform, and visualize). Examples are given to apply the geo-information cycle to research projects of different spatially oriented environmental sciences.

The course contains lectures, Arc-view training, a group assignment to determine the location best suited for a vineyard, and three self-assessments. These individual tests were offered both in a wired Blackboard environment and on the PDA phone edition using the Questionmark Perception database.

The intent of self-assessment within the course Introduction to Geo-Information Science was to give students the opportunity to check their knowledge level and give information on subjects they hadn't yet mastered. The assessment is based on different size chunks: questions, correct and incorrect answers to these questions, and a structure tree of these questions related to the structure tree of the learning objectives and learning objects.

For the mobile version of the self-assessment, the questions and related answers are stored in a Questionmark Perception database; for the wired version, the questions are stored as Blackboard data sets. Because Blackboard Unplugged, a portable version of Blackboard, was still under development, the project team had to develop the mobile application. The application offers students an assessment tree containing the modules they have to master. As soon as the student selects a module, the PDA phone edition connects to the Questionmark server. Much as in a normal wired online testing routine, the student sees the questions and can answer them. When a question is answered, the answer is sent back to the server and checked. The result, score, possible feedback, and reference to related learning objects are sent back to the student's device. The learning objects are offered as downloadable PDF files in the wired version of the asesement.

Five students used the mobile assessment opportunity on a PDA phone edition, and three of these five students did the self-assessment on public buses or trains. The five students who used the PDA phone edition were not really satisfied with the connection stability and communication speed (maximum of 256 bps) and complained that they had to scroll too much (both horizontally and vertically) to view information. The students who did the self-assessment on public transport used a maximum of 9.72 MB of data transmission for this test.

GIPSY Course: Integration for Environmental Policy

Integration for Environmental Policy is a master's course that offers students the opportunity to gain further knowledge on geoinformatics and remote sensing. The course is offered to a wide range of students from different educational backgrounds and countries. It extends and integrates some state-of-the-art topics in the field of geo-information science, including imaging spectroscopy and geo-visualization. Fieldwork is a major part of the course, where students work in small groups to solve one of many cases using mobile techniques and ArcPad software. They write a report on their findings and also give a presentation in the field.

The GIPSY project selected this course to gain further expertise in mobile learning in relation to group learning processes. Furthermore, this course tries to integrate desktop work and practical fieldwork in a cyclic manner. On the basis of project planning, students make field trips to collect geo-referenced data and materials. Directed by the outcome of team discussions, students process the data, analyze materials, and check the results again in the field.

We gave the multidisciplinary student teams different PDAs (PDA phone edition, iPAQ, Loox), all with mobile phone connectivity and GPS. Furthermore, ArcPad software and some ArcPad scripts were installed on the devices. The students were trained to use the device, the software, and the scripts. The geo-data used in the project were provided via a Web-based project environment (QuickPlace) and used by the student teams during the fieldwork.

Thirteen groups (64 students) worked full time during four weeks. Each group had a different case to work on. Eleven teams developed an application to collect location-based field data. Two teams developed location-based services (see Figure 2). These applications support navigation through a certain area. To check the geo-data, the students navigated by ArcPad with GPS to the real-world phenomenon and determined whether it existed as a geo-database object. If not, a new object would be stored in the database. The students developed different information nodes on the route that provided information (sound, text, and pictures) about that point in the environment. When the application user followed the route and reached a node's influence sector, the fact data popped up on the PDA phone edition.

The GIPSY project found that during the fieldwork the students couldn't read and work with the QuickPlace project Web site because QuickPlace produces large scripting files and the GPRS uses small-bandwidth transmission. Also, the Pocket PC's Internet Explorer version couldn't parse the ActiveX and JavaScripts that are part of the scripting.

The PDA phone editions were almost exclusively used for ArcPad and ArcPad applications. Rarely, the students used them as mobile phones and as PCs to run Pocket Word and Excel. The students found the devices easy to work with because they're similar to the normal computers they're used to.

Battery charging is an important issue for using PDAs in fieldwork. The four-hour average life span seemed too short for intensive use in fieldwork. Durability is another theme: students thought the devices could be easily damaged during fieldwork, but that was not the case. Nearly all handhelds performed without any damage or failure.

Students prefer the PDAs during fieldwork, especially because of their portability, weight, and functionality compared with bigger laptops. They would like bigger screens, but when this results in a heavier device, students turn to the PDA again. Students think it's important during fieldwork to keep an eye on the environment; observing what happens around you is fieldwork's main goal. Analyses vrije Universiteit amsterdam — Katholieke Universiteit Nijmegen — WAGENINGEN UNIVERSITY

Archaeological walk guided by a PDA

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Problem

Nijmegen is from Romen origin therefore a lot of indications of the Roman period can be found in the city of Nijmegen. An argaeological walk is mapped out along the Roman archaeological sites on the Hunerberg and the Kops Plateau, strarting at the museum "Het Valkhof".

Most of the indications of the Roman period are almost invisible. To make the walk more clear and attractive a guide by means of a PDA (personal digital assistant) is wanted.

Personal Digital Assistant.

Building the application

The application is build in ArcPAD Studio and you can run the application in the ArcPAD program. It is possible to put all the desired functions in the application.

The application

- Different layers: Geomorphology, Height, Top10 Vector, hotspots, hidden spots.
- Pop-up information at every hotspot
- Pop-up information during walking at hidden spots
- Hyperlinks for extra information
- GPS for navigating
- User can choose its own route

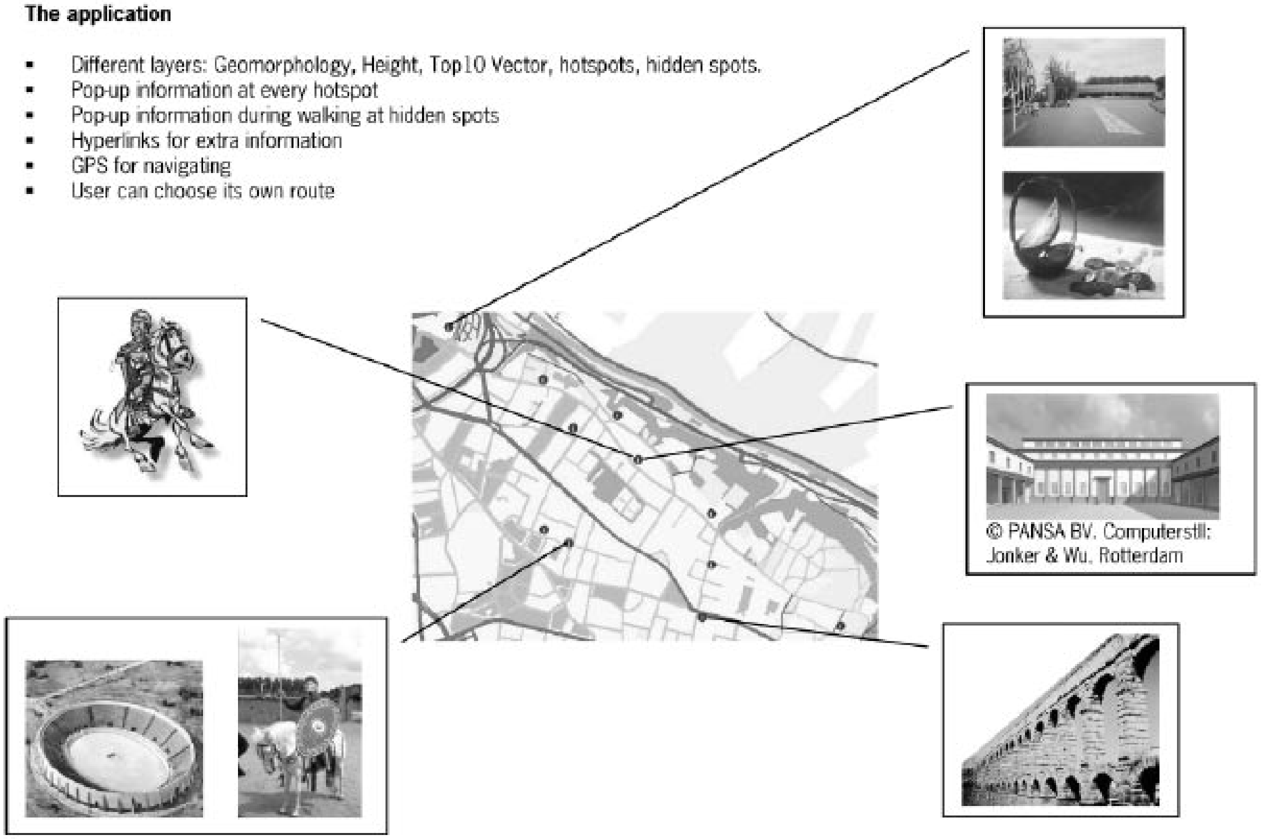

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Figure 2. Example of Student Location-Based Services

of the measurements almost always take place at the university or at least at a desktop computer available at the fieldwork location. The requirements placed on the "fieldwork computing device" are therefore less demanding, and PDAs will almost always suffice.

Post-GIPSY Fieldwork: Archaeology Fieldwork in Southern Italy

VU's archaeology division asked the GIPSY project to participate in updating their archaeology fieldwork in southern Italy. Major aims included developing and testing a computer-supported fieldwork method and mobile learning components for the course. During the fieldwork in 2004, a computer-supported fieldwork method was introduced. First, observations were made, and other ideas were generated on the basis of these themes. New ideas couldn't be implemented immediately but will be during the 2005 fieldwork.

The archaeological fieldwork seeks to learn more about the domestic and colonial history of a former Greek colony in Italy. Materials found in the field are collected and analyzed. The archaeology division is looking for a way to electronically administer their findings on the spot so that they can locate the findings more exactly and use them immediately for further analysis. Normally, the findings would be marked on a paper map and then digitized. The expectation was that state-of-the-art mobile and GPS technology would make immediate data-entry possible.

During the fieldwork in June 2004, the staff and students were each supplied with a PDA (HP-Compaq 5550) with ArcPad software. The survey leader was also equipped with a GPS receiver for quick orientation in the field. The PDA contained aerial photos of the area. Normally, paper copies of photos of the area had to be dragged along. Pointing the PDA at the aerial photo loads a form in which characteristics of the area can be filled in. New findings can thus be marked, including the artifact type. Since the students' survey walks totaled many kilometers per day, the surveys themselves were literally mobile in character.

Unfortunately, because of difficulties with the GPS settings, the fieldwork experienced no improvements in speed and quality of orientation. However, solving this problem is only a matter of time. On the other hand, several benefits emerged. The construction of a GIS database in combination with GPS offers several possibilities for fast orientation when revisiting fields (and retrieving and editing collected data). Also, automatic panning based on GPS position is available, as is the possibility to build location-based GPS services, which can be used for wireless and mobile learning objectives.

Handling the device and the application is easy to learn (approximately one hour), but it is advisable to have technical support close at hand. This weeklong fieldwork exercise showed that operating skills and speeds can improve considerably in one or two days. In the test surveys, approximately 50 units were mapped per day (from approximately 6:30 a.m. to 12:30 p.m.). This pace will probably increase if the conditions (type of fields, number of finds, visibility, and so on) stay the same.

Form input was fast and smooth and can probably go even faster after some small alterations. Uploading data from the handheld to a PC proceeded without problems. Errors in the tables can be edited in Excel or Access, and the improved attribute table can be loaded back to the handheld without problems.

The devices seemed to work well in the hot climate, although they occasionally froze, especially after they hadn't been used for a while. Taking the devices in and out of their cases possibly pressed the buttons on the side, causing the devices to freeze.

A less successful element of the application is the unit drawing facility. Even though a polygon is easily drawn and edited if necessary, it is difficult to draw a unit boundary with sides exactly or approximately 50 meters long, for example, in a square shape bordering exactly or closely the already drawn polygons.

PDA-Based Course Materials

In the initial focus group sessions, students pointed out that they would need to work with a PDA longer in order to provide feedback on the possibilities of their uses in education. So, we supplied five students with PDAs (iPAQ and Loox) for a two-month course, Digital Spacial Data. All course materials (.doc, .pdf, and .bmp formats) available on the Blackboard course site were downloaded to the PDA via its cradle. Care was taken that the tabs on the PDA resembled the tabs on Blackboard so that students could easily find the course materials on both. Students were instructed on how to use the material on both the PDA and Blackboard. During a group interview, students reported on their experiences with the PDA.

In general, the students liked the idea of having all their course information literally at hand, but in daily practice they hardly used the course information on the PDA, for several reasons:

- A printed version of the documents is just as easy or even easier to use. Making notes on the PDAs was nearly impossible because formulas are not recognized and the keyboard is too small.
- The .pdf formatted documents were only readable with a lot of scrolling.
- Using the cradle is difficult, so students couldn't put extra materials on their PDAs.
- Pictures in the .doc versions of the documents were not visible.
- The PDAs had all sorts of technical problems that complicated their use.
- The internal memory was limited and sometimes caused the PDAs to be too slow.

When asked whether they could use PDAs successfully in regular classroom activities, students responded that current PDA versions don't yet offer the same functionalities that small laptop computers or tablet PCs offer. As one student stated, "The PDAs are not yet sophisticated enough." Another student remarked, "Since there is a computer nearly at every corner at the university, I'd prefer to walk to a computer instead of using a PDA." But one student believes "this is an interesting option for use during fieldwork, because of the weight and possibilities."

The Manolo Project

The Manolo project is a follow-up to the GIPSY project, representing the SURF Foundation's and the three universities' next research initiative on mobile education applications. The project name was inspired by Manolo Sanlucar, one of the most intriguing flamenco and Gypsy musicians. His style combines a strong traditional foundation with constant research into innovation and integration with other music domains. Innovation and a strong foundation are inspiring guidelines for this project, which is currently under way, deploying experimental mobile educational applications during 2004 and 2005.

Project Goals

The Manolo project builds on the GIPSY project's experience and focuses on the integration of electronic, wireless, and mobile learning. In digital learning it's becoming increasingly common to distinguish between e-learning, w-learning, and m-learning. Although a variety of other classifications can be used, these terms distinguish between the existing Web-based computer-enabled learning (e-learning), the extension of accessibility through campus-wide wireless networks (w-learning), and the connection of fully mobile users to education using PDAs (m-learning).

The project's core assumption is that in the future students and educators will have much more flexibility in choosing the enabling education environment. Choices will include the traditional face-to-face or classroom sessions along with computer-enabled learning accessible through multiple channels and devices. Education and community resources will be available anywhere, anytime through the fixed Web, the campus wireless network, and students' personal devices. Students will increasingly own the technology for accessing education (portable PC, tablet, PDA, smart phone) as part of their standard personal equipment.

Depending on the context, education and community resources are visible to students in different ways that optimize the fit between context, technology, and education goals. Students on campus have access to the whole portfolio of stored resources through the campus Web. They can access specific communication tools and shared areas through the wireless LAN and portable computers to facilitate workshop and collaborative education, and they can maintain their links to peers, resources, and the community in full mobility through PDAs. Education remains at the center, with technology allowing a more pervasive and flexible environment that adapts to different goals and different circumstances. With these assumptions in mind, the Manolo project's main goals are to

- increase the fit between education type and goal, and the digital environment used to support it, with a view of offering a portfolio of e-, w-, and m-learning courses;
- formalize this knowledge into educational, technological, and organizational blueprints and best practices; and
- use the digital media, and especially w- and m-learning, to facilitate communication and community building in digital learning.

These goals will be achieved by extending the digital education offering to w- and m-learning and integrating it with existing e-learning at the partner universities. The Manolo project will focus on the following questions:

- What educational components will receive the largest growth or benefit from w- and m-learning, and what educational activities are most suitable or unsuitable for certain digital environments?
- Which courses and students would benefit most from this?
- Concerning the known issues in community building and communication for e-learning, what type of communication between students and teachers and among students can be improved or introduced, and what benefits are they supposed to bring?
- How do the educators' and tutors' roles change when we introduce these communication channels?
- How will w- and m-learning impact the education portfolio universities offer?
- What ICT infrastructure provides the most suitable environment for w- and m-learning?
- What support organizations will be needed to provide the necessary level of support to w- and m-learning deployment?
- What is the business model for universities and educational organizations that introduce w- and m-learning? What are the financial implications for organizations and students? What are the implications for the facilities (such as classrooms, meeting rooms, and computer rooms) of institutions that introduce w- and m-learning?

Project Execution

To address these issues, the project will target a select group of courses and provide students with a working e-, w-, and m-learning infrastructure for the entire course or for specific modules. For each course or module, the project will predefine the course's structure and which parts will be supported by e-, w-, and m-learning.

From the infrastructure side, it will integrate (existing) e-, w-, and m-learning ICT infrastructures at Vrije Universiteit (VU) Amsterdam and Wageningen UR (WAU). Courses will be based on existing modules developed for e-, w-, and m-learning. Both infrastructure and materials are mostly available at the partner organizations already, but in a scattered and uncoordinated way. The first goal is therefore to streamline and adapt these pieces to produce an integrated offering of education available through the whole portfolio of e-, w-, and m-learning.

The digital learning environment's back end will be the Blackboard software (standard, Blackboard toGo, and Blackboard Unplugged, detailed in the next section). This base will be extended with multimedia and communication—in particular, Instant Messaging, conference call capabilities, and video communication.

On the basis of existing experience of the partner organizations in the GIPSY project, there is an expectation of the most- and least-suitable digital setup for various education activities and community aspects. For instance, e-learning environments are suitable for storing and delivering entire reading chapters, while large amounts of text are inappropriate for mobile devices. On the other hand, dynamic information and news would lose their immediacy if stored for future use in an e-learning platform and would be best delivered to mobile devices. During the courses, these assumptions will be tested for confirmation or revision. Manolo will assess which parts can be best supported by e-, w-, and m-learning.

Development of Blackboard Unplugged

As noted above, one infrastructural component of the Manolo project is Blackboard Unplugged, the wireless version of Blackboard. At present, a trial version is being developed as the first installation of this type in Europe.

During the GIPSY project some small experiments with Blackboard toGo were conducted. Blackboard toGo, made by ArcStream, is a portable Blackboard version of Blackboard 5 designed for Pocket PC and Palm OS users. Users can connect to Blackboard and have information delivered via a special menu to their mobile devices. The information is outlined to fit the devices' smaller screens, so that only up-down scrolling is needed. The GIPSY project experiments showed that it is very useful to have up-to-date Blackboard information available on the device. All announcements, course content, assignments, and other materials offered as HTML in Blackboard can be displayed on the mobile device. Unfortunately, other functions commonly used in Blackboard can't be displayed, including the discussion board, e-mail functions, group pages, and any materials not offered as HTML. It is a special concern that Blackboard's communication functions aren't available on smaller devices. To us, both information and communication are crucial elements for excellent education, and neither can be left out.

Blackboard toGo is only available for Blackboard Version 5. Since 2003, many institutions in The Netherlands have migrated to Blackboard 6, which means that Blackboard toGo can no longer be used for m-learning opportunities. Neither ArcStream nor Blackboard was willing to develop a Blackboard toGo version for Blackboard 6, so the Manolo project team decided to attempt to develop Blackboard toGo for Blackboard 6. With the SURF Foundation's financial support, programmers developed a first version of Blackboard toGo, now renamed Blackboard Unplugged. This version resembles the original version and can display HTML files on mobile devices. Further programming is being carried out to enable Word documents to be displayed appropriately on small devices. When this part of the software is available, test sessions with students will be executed.

Project Experiments

The Manolo project selected five courses that have potential wireless and m-learning components:

- Biodiversity and Ecological Fieldwork,
- Introduction to Geo-Information Science,
- Field Course: Vegetation Science and Systems Ecology,
- Environmental Science, and
- Academic Master Cluster Environmental Sciences II.

Besides the implementation of Blackboard Unplugged within these five courses, several more specific experiments and tests will be done during 2004 and 2005:

- Use of CropViewer (detailed in the next section) within the ecological fieldwork course. Attempts will be made to further develop CropViewer so that photos, drawings, sounds, and interviews can also be included in the database.
- Systematic use of group messaging during fieldwork. Because students learn from each other and from their teacher, group messaging applications will be tested and implemented in several courses.
- Use of UMTS in remote areas. UMTS is now available in some parts of The Netherlands, and Manolo will test the connection speed and availability in certain areas. The roaming aspect of GPRS is also a facet of this experiment.
- MOVIDA[7] offers the possibility of ascertaining people's real-time location. It might be interesting for teaching staff to know exactly where students are in order to supply them with relevant information.
- Since various voting tools are now available, the Manolo project will test the possibilities in different courses.

CropViewer

One experiment in the Manolo project involves CropViewer, a GIS application thus far used mainly for agricultural applications that lets field-workers visualize a high-resolution satellite map of the fieldwork area on a handheld device. The area displayed on the device is centered on the user's position, determined by GPS. The user can insert a point on the map and associate crop information to it, such as type and description. The information is associated to the entire crop parcel containing the point. Through a wireless connection, each point added is sent to a central server in real time.

CropView is based on ArcPad and consists of three main components: a mapping component, an entry form, and a storage and exchange component. The mapping component includes the data installed on the PDA and ArcPad's customized mapping functionality for collecting point information. Since the shape of the crop fields can be determined in most cases with the help of the satellite images, crop identification corresponds to adding a point—called a crop point—within a field area and associating crop-attribute information to it. An entry form helps the user determine crop type and add more information. An application made with ArcPad Studio ensures that once a point is added by tapping the map on the screen, the entry form pops up to assist form identification and specification. If in some cases the field boundaries don't match those derived from satellite images, the user can sketch the correct boundary observed in the field by using ArcPad's redline functionality.

When the user taps the screen to place a crop point, an entry form appears showing seven of the most prevalent crops in the fieldwork area. The user can view information in three ways:

- Quick List displays the list of crops, with the most common ones presented first; this list is based on each crop type's frequency in past fieldwork.

- If the observed crop isn't among the top seven, the user can access Full List, which displays a comprehensive list of crops, classified into crop families.
- The View Information tool helps field workers correctly assess crops by providing visual and descriptive information for each. Less experienced field workers can use it to facilitate crop identification. The user can also record comments and text information, or add a picture taken in the field if a wireless camera is available.

Table 3 summarizes the information CropViewer can collect.

The application uses two methods for data storage. First, data collected is locally stored and can be transferred to a central GIS at the end of the fieldwork. To prevent data loss caused by battery failure or technical malfunction of the PDA, the application saves data on a removable memory card instead of using the PDA's internal memory. The second method uses remote data storage. The application lets users send the information collected about each crop point to a remote database through a wireless Internet connection (via GPRS). In this second case, the information is both stored locally and sent remotely. The remote synchronization is optional.

The database on the remote Web server, located on the user organization's premises or hosted by a third party, operates as an input device for a real-time ArcIMS Web mapping service that displays the crop points collected on the background maps. Even though this feature isn't mandatory for this application, it makes possible the exchange of data remotely between different field teams and the office. This allows monitoring of the whole field campaign and permits introducing process optimizations.

Since standard communication facilities such as e-mail or FTP are available on handheld devices, field workers can also use the wireless Internet connection for other purposes, such as consulting colleagues at the office (for example, to send a picture of a crop and get advice on its identification) or exchange logistics information with other field workers.

Although not currently used in an educational setting, CropViewer might prove interesting for fieldwork activities, especially the connection to the remote server. As fieldwork locations typically are remote and involve significant travel time, on-site time must be used effectively. For example, CropViewer lets students immediately compare current results with previous findings. Let's say students engaged in an exercise to learn water quality testing skills are provided with instructions to do the tests and are asked to report on their results. In a normal situation, students do the tests, return to the university, and discover whether their results are correct or incorrect. If the results

Table 3. Information Collected by CropViewer

Automatically Recorded	Entered by Field Worker
▪ Crop point's map coordinates (x, y) ▪ Field worker's GPS coordinates (x, y, z) ▪ GPS data-quality parameters (number of visible satellites, horizontal dilution of precision) ▪ Date and time of point recording ▪ Project year, map sheet, field worker code	▪ Name of crop to be classified: "crop type" code ▪ Comment about the crop to be classified (optional) ▪ Code and file location of picture taken with digital camera (optional)

are incorrect, they must return to the spot and conduct the tests again. In a mobile fieldwork situation, students can do their tests, send the information to a remote server, and compare their results with the information available at this server. They will now see immediately whether their results are correct, and if necessary they can redo the experiment on the spot. This fast feedback improves learning, as the pedagogical view advises correcting mistakes as soon as possible.

Lessons Learned

The GIPSY project has made the first steps to implement, test, and deploy mobile learning. The project has generated technical and education expertise on mobile learning in the specific domain of GIS. Teacher and student panels have extensively evaluated the mobile technologies implemented and have provided positive feedback. The GIPSY project has also highlighted several educational, technological, and organizational effects not yet completely addressed, some of which the Manolo project plans to study further. In particular:

- The technology infrastructure is not yet ready for truly mobile learning. Stability, device availability, and course support problems remain unresolved.
- Personalization is crucial but is not yet sufficiently implemented—not because personalization tools don't exist, but because many courses' monolithic nature makes tailoring educational material to personal preferences difficult.
- Mobile learning works only when its practical use during the course is unmistakable and logical.
- The impact on educators is large, but little guidance exists on how to achieve the best results for mobile learning.
- Clear relationships seem to exist between what constitutes good and bad use of mobile learning. These relationships are not fully spelled out in educational terms.
- Wireless and mobile learning impact logistics, resources, and costs. These impacts must be identified and modeled to provide guidance for future implementations.
- Communication—both teacher–student and student–student—seems to find new channels and opportunities within mobile learning. This positively affects community building but must be streamlined from both the ICT and educational sides.
- The course Web site should be accessible by mobile devices. QuickPlace had serious limitations in this respect (bandwidth, Java) and is therefore not suitable.
- Batteries pose serious limitations to PDAs' usefulness in fieldwork. An average usability of four hours is too short for a normal fieldwork workday.
- PDAs will do an excellent job as "fieldwork computers" in most cases, since in fieldwork weight and size are defining factors.

Further Reading

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Our experience so far has demonstrated that digitizing and publishing existing material on the Web may have limited influence on educational materials' quality and effectiveness if it's not linked to a redesign of the course itself. The early experience with wireless and mobile learning also shows that simply offering the same Web-based digital material through another channel (the wireless device) has negligible added value and renders the whole effort prone to the gadget trap. The mobility dimension changes the relevance of the educational materials' various parts; students' attention span; the focus of their education effort; and their attitude balance toward reading, experimenting, interacting, and communicating. But mobile tools' immediacy also offers new communication opportunities that students—especially the youngest ones—have already adopted. Overall, there is a growing recognition that the weakest spot in computer-based learning remains the communication and community dimension. This concern can find potential answers in wireless and mobile learning.

Endnotes

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