Exploring the Use of Cellular Phones for Pervasive eLearning*

Bernd J. Krämer and Georg Ströhlein
FernUniversität in Hagen
Faculty of Electrical and Computer Engineering
58084 Hagen, Germany
{bernd.kraemer, georg.stroehlein}@fernuni-hagen.de

Abstract

The wireless Internet stretches the concept of self-paced learning towards anywhere-anytime learning. It supports the seamless continuation of interaction with learning resources and services even when a student is away from the desktop PC. There is, however, much doubt about the use of omnipresent ICT devices like cellular phones for pedagogically valuable learning settings. In a recently concluded EU project we have examined the potential of such devices for learning by developing a Java-based application, called Histobrick. It supports spontaneous short study phases while students are on the move and particularly aims to provide a ubiquitous tool for examining and deepening a student's knowledge about statistic distributions and their most important characteristic numbers. The pedagogy behind Histobrick is inspired by recent ideas about learning in constructivist settings and the findings of game-based learning. The paper sketches the rationale behind Histobrick, discusses some technical challenges we met, presents the final solution, and reports on a first evaluation we performed with a small sample of students.

1. Motivation

FernUniversität's educational mission is higher education off campus serving distant students who prefer to study anywhere and anytime as they are working professionals, need to take care of their family or have other reasons to avoid physical presence in classrooms. Specially designed textbooks including self-assessment tests and other pedagogically inspired elements enabled the traditional form of distance learning. These paper-based learning resources were supplemented by tutoring and assessment services relying on classical communication technologies like snail mail, fax, phone or email. Face-to-face events are typically rare and short. They take place, for instance, during exams, seminars or lab sessions.

The advent of the World Wide Web offered new options to extend traditional means of distance and campus education towards online distance learning and blended learning styles, respectively. Web-based and offline learning with digital media, briefly: e-learning, provide new options to involve remote students actively in (cooperative) learning and research tasks. Learning on the move with mobile devices stretches the concept of anywhere-anytime learning even further by use of the wireless Internet and other wireless communication facilities. It also supports the seamless continuation of interaction when the learner is away from the desktop PC [1].

As more than 78% of our students own a cellular phone, this and other projects at FernUniversität set out to explore ways that enable students to use idle periods, such as travel time with public transportation or waiting time before a meeting, for learning. The major challenge is to design pedagogically valuable learning objects, training activities and support services for use with small mobile ICT devices that are omnipresent in a student's daily life [8]. In principle, a range of educational services could be provided for students on the move. They include:

- provision of learning content,
- maintenance of personal and administrative data,
- tutoring and consulting,
- communication and collaboration,
- performance of exercises and self-assessment tests,
- remote access to virtual and physical laboratories,
- access to the university library and
- a range of location based services.

*This work was financially supported by the EU under contract numbers 2003-IRL/03/B/F/PP-153111 and EC-US U8041.

The focus of this project was on the design of content and learning activities that support spontaneous short learning phases and may attract the student's attention even under noisy conditions. Their design was influenced by the experiences of a preceding mobile learning project in which we had developed a short course entitled ”Introduction to descriptive statistics”. The evaluation of this learning resource revealed that students wouldn't want to read through long texts on a mobile phone but rather preferred short and concise summaries or comments to supplement online courseware designed for use on desktop PCs or printing. Students also opposed to long download-times due to the high costs they still generate today.

Histobrick, the game-like application on descriptive statistics we report on here was therefore developed under the assumption that

- students use their mobile device particularly for spontaneous, short study phases;
- mobile devices are typically used for repetition, for examination preparation or for quickly looking up details when knowledge gaps are detected in the process of testing the learning progress;
- deep learning has taken place before accessing mobile versions of learning materials, i.e., students have a basic understanding of the learning content they deal with on the mobile device.

The learning application was further inspired by recent ideas about learning in constructivist settings [3] and the findings of game-based learning [4, 5]. The latter tries to help learners build stronger intuitions for domain concepts based on perceptual experiences in a virtual environment.

2. Development Context

Small portable devices like cellular phones pose some technical and pedagogical challenges that need to be addressed when judging their suitability for learning in higher education settings.

2.1. Learning Conditions and Technical Constraints

Technical constraints include:

- The small screen limits the amount and type of media and navigation elements that can be displayed.
- The lack of input devices like mouse, keyboard or stylus pen slow down text input speed and reduce the device's usability with respect to man-machine interaction.
- Limitations in device-to-device interaction diminish collaboration options.
- Not every type of media or learning scenario is applicable under all circumstances (e.g., practicing a foreign language course with audio output in a bus).
- There is a higher degree of heterogeneity in hard- and software and the software is frequently not fully compliant with standards.

When trying to identify areas in which mobile devices might add value to one's learning experience, we have to keep in mind that students in developed countries usually have access to a desktop PC-like or laptop on a daily basis. Therefore, developing content or services for small mobile devices seems only meaningful if this content is not already provided by other means.

In the design of Histobrick we were guided by the following recommendations we drew from our previous project [7] and a decent literature study:

- design mainly for off-line usage to minimize connection costs;
- design for single-hand operation to minimize the impact of bumpy conditions during transportation;
- restrict the presentation area to fit entirely on the screen of cellular phones;
- provide interactive learning objects in a platform independent programming language;
- use a game-like scenario to capture a student's attention even in distracting environments;
- support shallow learning and focus on exercises that may reinforce previously learned knowledge.

2.2. Knowledge Domain and Pedagogy

Practitioners in applied statistics are usually concerned with calculating a small set of characteristic numbers from large data samples. Ideally, these characteristic numbers should be used as a foundation to base a decision on which more sophisticated methods can be applied for further investigation. The two most basic and important characteristic numbers are the *measure of location* and the *measure of spread* of a data set. The measure of location indicates where many of the data are found and the measure of spread describes how crowded the data are around the measure of location. Histograms are often used to visualize such data sets; in its graphical variant each bar depicts the amount of data values found for some set of data value classes.

The concept of using few characteristic numbers instead of the large data set works well when dealing with data

Proceedings of the Fourth Annual IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOMW'06)
0-7695-2520-2/06 $20.00 © 2006 IEEE

sets whose histogram is bell-shaped. Unfortunately, experience of many educators in the subject of applied statistics shows that students trust the calculations of statistical software way too much and therefore omit to check the quality of their result by looking at the corresponding histogram. This is especially dangerous if only the mean is calculated as measure of location. But exactly this happens nearly all the time. Hence we decided to provide students with an application giving them a chance to learn in which cases they should not simply trust calculated measures of location.

2.3. Implementation Technology

The task of designing applications for handheld devices suffers from the obstacle that the provision of cellular phones with base software is rather inhomogeneous. International (software) standards can help developers to decide what kind of content and services to consider in a mobile learning scenario. Basically, three different technologies can be used to implement interactive applications for use on cellular phones: Microsoft .Net or C++ for the actual OS platform of the cellular phone, and J2ME (Java 2 Micro Edition) for a subset of mobile devices. We decided to rely on J2ME because it enables a client-based solution. A server-based solution is affected by occasionally intermittent or slow connections that may occur, e.g., in buildings or underground transportation, while an application running largely independently on a client is not. The client-based solution also takes into account the students' cost argument (long connection periods imply high running costs).

The J2ME platform comes with two main components: the Connected Limited Device Configuration (CLDC) handling all hardware related aspects and the Mobile Information Device Profile (MIDP) handling all interfaces to the user. J2ME is specifically designed for devices with a memory in the kilobyte range. Due to this space limitation only a very small fraction of the J2SE classes are contained in J2ME. Additional J2ME classes are provided, however, to support the special screens (LCDUI) and permanent memory (RMS) of mobile devices.

There is another important difference between cellular phones and other mobile or stationary computing devices: Cellular phones can only run one application at a time, while the other devices can run several applications simultaneously. This allows a student who may have got stuck in the interaction with a learning task to suspend it for a while and contact a tutor or peer through a chat, an email or other means of collaboration before resuming the learning task. Hence, to allow students to share her experience or problems with co-students or a tutor, the mobile learning application needs to embed a mechanism for sending and receiving short messages from within the application.

J2ME applications, called MIDlets, are developed and tested on a PC before they are deployed to real phones. During development two files are generated for each MIDlet: a Java Application Descriptor (JAD) file, which is a text file providing important information on the core application file. The latter is a Java Archive (JAR). The Java source file is compiled and pre-verified on the development computer as mobile devices lack the computational power and memory to perform this task. It is also useful to use a so-called obfuscator before deployment to save memory by replacing the usually long class names by abbreviations.

The MIDP 2.0 standard provides some advanced means of event processing and screen control. It was thus decided to use the combination of CLDC 1.0 and MIDP 2.0 as the minimum requirement for Histobrick. The first affordable phone on the German market compliant to these standards was the Sagem MyX-7 in 2003. Today, a whole range of cellular phones from different vendors satisfies this standard and is able to run our application.

3. Design of the HistoBrick MIDlet

HistoBrick aims to provide students with a tool they can use to learn about the relationship between distributions, visualized by histograms comprising 8 classes and the characteristic numbers of the distributions, i.e., their measures of location and spread. The students' task is to construct a histogram whose characteristic numbers meet given target values as closely as possible.

Once downloaded and started, the HistoBrick MIDlet shows an introductory 'splash' screen and then a page on which the desired language can be selected (currently English and German). After language selection the main menu appears from which all important features can be accessed. The 'new', 'load' and 'set game' entries start a game with different preconditions: 'new' means randomly chosen initial values, 'load' continues a previously saved game, and 'set' allows for manually chosen initial values.

During a game, a small square representing a 'brick' slowly falls down from top of the screen. The gaming student's task is to move falling 'bricks' into a proper slot at the bottom of the screen by pressing the appropriate phone keys in such a manner that after 50 bricks the characteristic numbers of the distribution created agrees as closely as possible with the target values. Figure. 1 shows a game situation in which 20 out of 50 bricks have been sorted into the histogram slots. Target and actual characteristic numbers, which are visualized graphically below the slots in Fig. 1 and which may change with every new brick, largely agree in the current play situation.

Due to the limited computational power of CLDC 1.0 enabled devices (no native support for fractional numbers) the pedagogic aim of demonstrating different measures of location and spread for the same distribution had to be given

Proceedings of the Fourth Annual IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOMW'06)

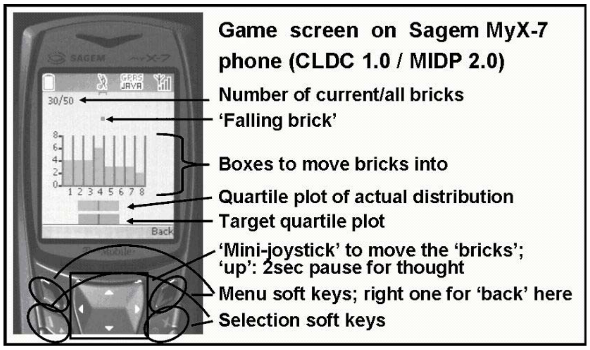

Figure 1. Annotated game screen and control keys of the Sagem MyX-7 phone

up. The currently deployed version of the HistoBrick only displays the median as measure of location together with the first and third quartile as measures of spread, i.e., a so-called quartile-plot.

4. Testing Histobrick on Different Devices

When the off-line features of the MIDlet were first tried out on the Sagem MyX-7 in April 2004, we were highly satisfied with the high level of agreement between the appearance and functionality of the MIDlet in the PC emulator of SUN's IDE and on the real phone. The MIDlet could be successfully downloaded from WML and HTML formatted pages on the web.

But after some of the planned on-line features had been implemented and tried out, the early satisfaction disappeared. It turned out that this phone uses the WAP stack to access the Internet. But when an Internet connection to a page on an HTTP web server is to be established, the phone totally depends on the features of the so-called WAP gateway of the mobile Internet services provider (mISP).

Usually, mISPs offer two different access points; one is for the WAP protocol and the other for the HTTP protocol. It is no problem to access WML as well as HTML pages with the WAP browser of that phone but when the WAP access point is active and an Internet connection is to be established from within J2ME, the WAP gateway delivers 'wrong' WAP header information to the KVM, which then refuses to establish an HTTP connection. Conversely, when the Internet access point was active, the phone could not set up a GPRS connection. Moreover, this change required accessing system menus of the phone, which will likely deter many users from trying it out at all. In the end, the Sagem MyX-7 was found to be unable to establish an HTTP connection from within J2ME at all.

In June 2004 another affordable J2ME enabled phone entered the German market: the Siemens CX65. Moreover, this phone was reported to support even the CLDC 1.1 standard, which meant that calculations involving fractional numbers should be natively supported by J2ME. This turned out to be true and, fortunately, HTTP connections could be established from within J2ME as well. Additionally, the built-in browser was capable of dealing with the HTML elements of the web mail software used by FernUniversität, so that at least the text part of emails could be read. When trying out secure access to that account, it turned out that the WAP gateways of three out of four major German mISPs refused to accept the certificate of the web server of FernUniversität. This drawback will be overcome after all certification authorities of German universities will have joined the certificate hierarchy of the German research network and their certificates will then be known to the world.

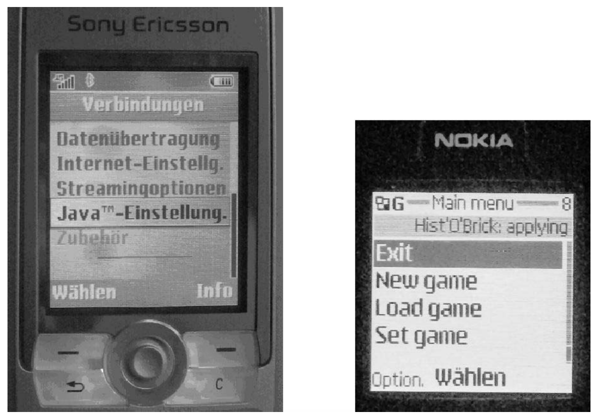

Figure 2. HistoBrick on the Sony Ericsson K700i (left) and Nokia 6230 (right)

In October 2004 we tested Histobrick on a Nokia 6230 and Sony Ericsson K700i. On these phones the unchanged Java code including Histobrick and the communication features worked well. In the system menu of the K700i there is an extra entry to specify an access point for J2ME (see Fig. 2 left), so that there is no need to change this every time when the phone's browser or J2ME is used to access the Internet.

5. Evaluation

While developing and deploying early versions of Histobrick, the findings and opinions of a few mobile learning students, who acted as early test students, were taken into account in the ongoing design process. But it is beyond the scope of the work reported here to evaluate the effect of using Histobrick on students' knowledge of statistics.

Proceedings of the Fourth Annual IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOMW'06)
0-7695-2520-2/06 $20.00 © 2006 IEEE

The technical pre-tests revealed that current mobile phones can not be reliably integrated into current learning management systems. In addition, formal assessment appears to be a task unsuitable for mobile students [6]. Therefore, the focus of the post-test evaluation [2] set out to collect opinions about general and project specific issues in mobile learning. For this purpose a self-administered, web-based questionnaire was used. Student opinions are measured by presenting statements and asking for the level of agreement on the five point bi-polar scale "2: strongly agree", "1: agree", "0: uncertain", "-1: disagree" and "-2: strongly disagree". Where appropriate, the option "not applicable" was included. An open question provided the possibility to add individual comments.

At the time of writing, only a very small sample of 10 students has completed the questionnaire after having downloaded and extensively tried out Histobrick. We cannot judge here whether pure verbal or pure numerical or combined labeling of the scale points leads to a mentally evenly spaced representation of these points, which is theoretically required for numerical calculations like taking the mean of some ratings. Thus, in a first step of exploration, the mean and standard deviation as well as the median and other quartiles are used, the latter ones definitely here being valid measures of location and spread, respectively. In Fig. 3 all the items concerned with attitudes are given as a bar chart depicting the mean of the valid item ratings together with its 95% confidence interval as well as the median together with the first and third quartile. The items are sorted by the mean value.

Mainly due to the small sample size no statistically valid differences between items can be found. The only item the mean of which significantly differs from zero is "pure mobile access acceptable". Exploring the other items on a tentative level, it can be stated that students obviously belief the costs for mobile communication as well as data transfer are too high. Thus they rate them negative, which would support the stated reject of the always-online and pure mobile scenario.

There is a large group of items for which the mean is very close to zero and about which most students are indeed uncertain. This group contains all items concerned with quality, learning objectives, effectiveness and outcomes of mobile learning. The most simple explanation is that most participants in this study did not feel to have enough experience to really state an opinion and therefore have chosen scale points close to "0: uncertain". The group of most positively ranked items with a nearly significant positive mean contains four items, the short forms of which read: "navigation in m-learning course is easy", "additional mobile access increases the flexibility of e-learning", "equipment easy to use", and "effective m-learning requires graphics". This might indicate that we have learned our lesson but

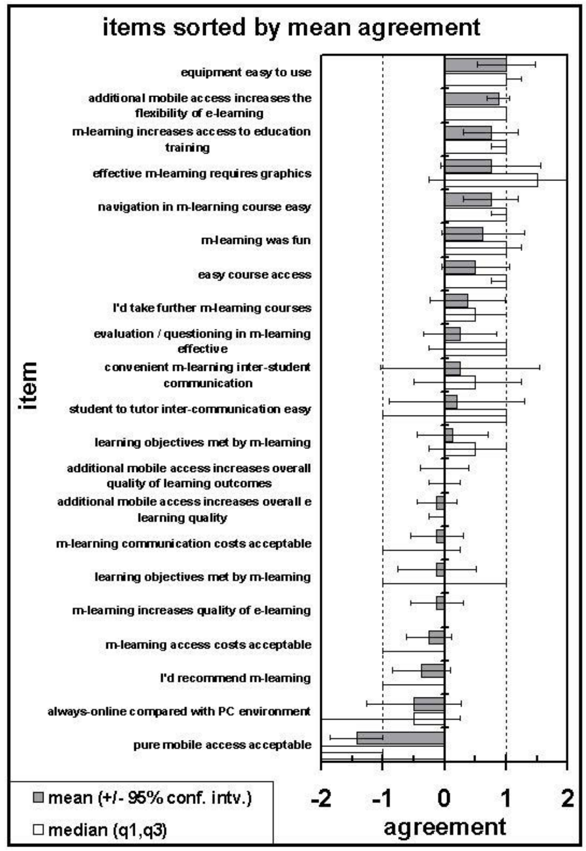

Figure 3. Item ranking according to mean of agreement

exploring the comments does not support this conclusion. Four of ten participants provided an extra comment:

- "Well - I even don't like reading long texts on a PC. I need paper - it's better to read from, I can mark words, can add my remarks. Things get worse with the tiny screen of a cellular phone."
- "I don't think that a cellular phone could improve my learning experience. The menu structures are too complicated and there is not much benefit in the game itself cause it is boring."
- "I personally experience mobile learning quite regularly. I quite often listen to audio books to improve my foreign language skills. My motivation is to use the time that I spend in my car. I think that mobile learning with the help of cellular phones provides interesting opportunities for particular subjects."
- "In my opinion, small courses suitable for mobile

Proceedings of the Fourth Annual IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOMW'06)
0-7695-2520-2/06 $20.00 © 2006 IEEE

download onto laptops or PDAs are a happy medium".

Summarizing, the participant who submitted the first comment seems to be totally reluctant to the concept of mobile learning, the second one obviously is used to play compelling games, the third one can only use audio because the hands are needed for operating the car, and the last person prefers PDAs or laptops over cellular phones.

Unfortunately, it is hard to translate these comments into recommendations for a more general pervasive learning scenario. We do not claim that applications like Histobrick are able to either change a person's general attitude towards a technology or her behavior concerning the use of a specific technology. We support the argument that it should be closely examined where mobile and pervasive technology adds value (from a student's point of view) to existing learning scenarios.

When observing participants playing Histobrick in various environments it always turned out that the idea of capturing students' attention by designing a game-like mobile application worked.

6. Conclusions

With our Histrobrick application we demonstrated that the J2ME platform implemented in modern cellular phones can be utilized to provide students with a highly interactive ubiquitous learning resource. Such phones have enough computational power to let the KVM display convenient real time graphics of intermediate complexity.

First tests with mobile students traveling by bus, tram or train showed that a game-like pedagogic approach is suitable to completely attract a student's attention even in very distracting environments.

The most profound restrictions for that class of mobile devices in learning settings arose from the fact that standard cellular phones cannot run more than one application at a time. This prevents students from conveniently using the built-in communication features of such phones in combination with content offered by educational institutions. To eliminate these restrictions, educational institutions acting as content providers for m-learning have to set up very complex web services or MIDlets supporting communication and collaboration functions from within learning applications.

Some problems may also occur when the built-in software of cellular phones is used to access secure web pages or web pages making use of new HTML elements. These problems are likely to disappear when all phones natively support an HTTP protocol stack and their web browsers are derived from the code of current PC browsers.

There are significant differences between cellular phones on the one hand and smart phones and PDAs on the other hand. Cellular phones usually have small screens, can run only one application at a time and are operated in one hand by pressing keys or pushing a joystick. Smart phones as well as PDAs (and the convergent device class frequently called MDA, which means a PDA with an integrated telephony functionality) have bigger (touch-)screens, support multi-tasking, and are operated using both hands, one for holding the device and the other to hold the stylus needed for the touch-screen. However, as the latter device class is relatively expensive, student's hardly own one.

The primary purpose of the evaluation we performed with a small sample of students was to understand the modalities in using mobile phones in deepening and testing students' knowledge of a particular field of science (here statistics) by means of an edutainment solution. It also served to investigate the students' acceptance of our prototype solution HistoBrick.

References

[1] S. Bull, Y. Cui, A.T. McEvoy, E. Reid, and W. Yang. Roles for Mobile Learner Models. *2nd International Workshop on Wireless and Mobile Technology in Education (WMTE'04).*, IEEE 2004.

[2] J. Calder. Programme Evaluation and Quality: A Comprehensive Guide to Setting up an Evaluation System. Kogan Page, London, 1994.

[3] Dave H. Jonassen. Thinking Technology: Toward a constructivist design model. *Educational Technology*, 34(3): 34-37, 1994

[4] M. Prensky Digital game-based learning, McGraw-Hill, New York, USA, 2000

[5] Kurt D. Squire. Cultural Framing of Computer/Video Games. *Game Studies* 2(1), July 2002 (http://www.gamestudies.org/0102/squire/)

[6] Georg Ströhlein. Mobile learning using mobile phones: hype or tripe?, *E(lectronic)-Learning - Technologiebasiertes Lehren und Lernen* (ELTK'06), Passau, Feb. 2006

[7] Georg Ströhlein and H. Fritsch. Test and Evaluation of a Course Designed for Mobile Learning, ZIFF Papiere 120, FernUniversität in Hagen, Hagen, Germany, 2003

[8] Siobhan Thomas. Pervasive, persuasive eLearning: modeling the pervasive learning space. 3 rd Int'l Conf. On Pervasive Computing and Communications Workshop (PerCom 2005), IEEE 2005.

Proceedings of the Fourth Annual IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOMW'06)
0-7695-2520-2/06 $20.00 © 2006 IEEE