Int. J. Engng Ed. Vol. 24, No. 1, pp. 115–126, 2008
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Student Profile Transformation between Desktop PCs and Mobile Phones*

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To meet the learning needs of various types of students, various adaptivity features are being implemented in computer-based learning systems to personalize education for every student. Recent developments in mobile technology have made the computer-based learning systems also accessible through mobile devices such as mobile phones. It is, therefore, becoming necessary that the students can also receive personalized learning through mobile devices. This research looks into various student preferences on different devices and how these preferences change when students move from one device to another to access learning content. Two surveys have been conducted in this research to investigate difference in various preferences of students while using personal computers (PCs) and mobile phones. A prototype computer-based educational system, accessible both from PCs and mobile phones, was also developed for this study to provide real experience of both type of interaction to the participants of the surveys. A student profile template is then designed on the basis of survey findings, which resulted in the student profile transformation framework. The framework is the first step towards content development guidelines to serve students on different types of learning devices.

Keywords: adaptivity; learning styles; mobile learning; profile transformation; user model

INTRODUCTION

AVAILABILITY OF HIGH BANDWIDTH infrastructures, such as GPRS, 3G and UMTS networks, and the increasing number of mobile phone subscribers make mobile internet applications more and more prevailing in our daily life. One important emerging mobile internet application is mobile learning [1]. Empowered by wireless communications, e-business can become m-business (Mobile Business), which will reach the users more effectively and enable instant access to business-critical information and communications [2]. Similarly, e-learning can be extended to m-learning (Mobile Learning) with the assistance of wireless technologies. Several attempts have already been made to develop mobile learning systems [3, 4, 5].

To meet the learning needs of various types of students, mobile learning systems need to deploy adaptive approaches to suit the content presentation and delivery to individual students. However, the way people use mobile devices is rather different from how they use desktop personal computers (PCs). It is likely that students change their behaviour between PC and mobile devices and therefore, student attitudes to PCs will not always be applicable in mobile environments. Even if we only consider the mobile environment, there are still various mobile devices with completely different capabilities, such as ordinary mobile phones and smart phones, which could influence students' learning behaviour. Thus, there are situations where the information in the student model would need to be modified under different learning environments using different types of learning devices, even for the same student.

Student modelling is already an established field of research where information pieces are collected from students to create their profiles. Learning systems can then draw on information in student profiles to provide adapted learning experience for the needs of different individuals. However, most of the student models that exist nowadays are primarily developed for PCs [6, 7]. With the pickup of m-Learning, it is projected that the focus of the student modelling community will also cover mobile student models.

ADAPTIVE HYPERMEDIA AND STUDENT MODELLING

Adaptive hypermedia technologies have been used in education for at least a decade, and many Web-based adaptive educational systems are currently in existence [9, 10]. These systems moni-

* Accepted 5 November 2007

tor the progress made by the students during their interaction with the system and store this information in the student model. The information gathered through student modelling typically includes both the characteristics of the students and any other necessary data to ensure the effectiveness of adaptation [11].

Brusilovsky [12] divided the information within the student model into two major groups: domain specific information and domain independent information, based on the relationships with the subject domain. Brusilovsky identified that the two types of information are both student-related. It has to be pointed out that additional categories are needed to more accurately provide adaptivity and to cater for the diversity raised by the emergence of m-learning. Accordingly, some recent works (such as [11, 13, 14]) have suggested that information such as usage data and environment data should be considered in addition to student-related data. A more comprehensive student model should therefore include the following:

- Student data: (1) domain dependent: for example, prior knowledge about the domain, record of learning behaviour (number of lectures taken, number of times help asked, frequency of mistakes made while solving problems, reaction/answering time while solving problems, and so on), and record of evaluation/assessment, (2) domain independent: for example, learning goals, cognitive aptitudes, measures for motivation state, preference, interest, learning style, individual traits, background and experience, factual and historic data, and demography.
- Usage data: data about how the student interacts with the educational system. It may be domain dependent or domain independent.
- Environment data: the data about hardware, software and bandwidth that the student uses.

Although many researchers agree on the importance of modelling and using individual traits or preferences [15, 16, 17], there is little agreement on which features can and should be used, and how to use them. In this research, we attempted to observe the student profile transformation between desktop PC and mobile phones by investigating the possible changes in personal features of student and to find out what would be the useful information that could be transformed between these two types of devices. Felder-Silverman Learning Styles Theory [8, 18] is used to identify learning preferences.

FELDER-SILVERMAN LEARNING STYLES THEORY

Each individual has his/her unique way of learning. Learning styles are students' cognitive, affective and psychological behaviour that can be used as relatively stable indicators of how students' perceive, interact with and respond to their learning environment [19], or briefly, students' 'characteristic ways of taking in and processing information' [20]. Learning styles greatly affect the learning process and, therefore, the outcome [21]. When the instructional styles do not match the student's preferred learning styles, the student will be disturbed by the mismatch, which will reduce learning effectiveness, although sometimes the students should also be given opportunities to practice their less preferred learning styles to develop skills associated with those learning styles [22].

In this work, the Felder-Silverman Learning Styles Theory [8, 18] has been selected for three reasons:

1) Its Index of Learning Style (ILS) questionnaire provides a convenient approach to establish the dominant learning style of each student [22].
2) The results of ILS can be linked easily to adaptive environments [23].
3) It is found to be the most appropriate and feasible theory to be implemented in hypermedia courseware [21].

The Felder-Silverman Learning Styles Theory categorizes an individual's learning style preferences by a sliding scale of five dimensions: sensing-intuitive, visual-verbal, inductive-deductive, active-reflective and sequential-global [8, 18]. In 2002, the inductive-deductive dimension was deleted from the theory for pedagogical reasons. Based on the descriptions of the four dimensions of learning styles, a questionnaire, called Index of Learning Styles (ILS), has been developed [22]. Its aim is to help learners identify their own learning styles. The questionnaire consists of 44 questions, each with two possible answers, 'a' or 'b'. Each of the four learning style dimensions is associated with 11 questions. To analyse the questionnaire results, all 'a' responses are counted for the dimension and a score is obtained. The score will then be an integer ranging from 0 to 11, determining the student's level of preference on that dimension. For example, on the active-reflective dimension, the scores can be explained as follows [22]:

- **0 or 1:** strong preference for reflective learning;
- **2 or 3:** moderate preference for reflective learning;
- **4 or 5:** mild preference for reflective learning;
- **6 or 7:** mild preference for active learning;
- **8 or 9:** moderate preference for active learning;
- **10 or 11:** strong preferences for active learning.

One important thing about the above scoring scale is that the four dimensions are continua not either/or categories. A student's preference for one or the other pole of a dimension may be mild, moderate or strong [22]. In learning systems, each of the four learning style dimensions need to be considered as a set of preferences for the presentation of learning content where student preferences are treated as particular levels on the learning style dimension scales. The implementation of the Felder-Silverman learning style theory then requires identification of various pedagogical strategies that suit each category of learning style dimension. For example, requirements for Active/Reflective dimension are as follows [21, 23, 24]:

- Requirements for Active:
  - Study in groups
  - Discussing
  - Explaining
  - Guessing possible questions and answering them with other students
  - Finding ways to do something with learning concepts
  - Brainstorming
  - Experimentation
- Requirements for Reflective:
  - Thinking about quietly before going ahead
  - Stopping periodically to review what has been learnt
  - Stopping periodically to think possible questions
  - Stopping periodically to think possible applications
  - Writing short summaries
  - Watching and listening.

These requirements provide a link between the learning style dimensions and some of the educational contents presentation methods, e.g. pictures for visual and text for verbal on the visual/verbal dimension. Subsequently, a set of content presentation preferences can be identified for each learning style dimension. The following list shows some typical content presentation preferences for various learning style categories:

Active:	Providing discussion area
	Providing practice exercises after a section
Reflective:	Think before going ahead
	Writing summaries
Sensing:	Example first, followed by the exposition
	Providing standard solutions
Intuitive:	Only principles and theories are presented
	Providing new solutions
Visual:	More picture, graphs, diagram
	Animation and video demonstration
Verbal:	Text
	Audio
Sequential:	Step by step presenting material
	Presenting the contents only within current topic area
Global:	Showing a dropdown list for jumping to anywhere in the course
	Providing other related contents outside the current topic area.

Certainly, this list does not include all possible content presentation preferences for each learning style category. However, by analysing these typical preferences in different environments, such as desktop PC and mobile phone, it is possible to find out the changes of learning style preference level on each dimension. To identify these changes, a survey-based approach is used in this research for two types of devices: desktop PC and mobile phone. The questions in the surveys align closely with the Index of Learning Styles (ILS). Students are asked various content presentation preferences separately on desktop PC and mobile phone, and the differences in responses on different devices identify changes in their learning style preferences levels.

The approach adopted in this research maps the eleven grade scale proposed by Felder-Silverman into a three level scale. For the four learning style dimensions, a combination of up to twelve possible learning styles can be formed [25]. The student's learning style preferences can be either sided or balanced on each dimension.

TWO QUESTIONNAIRE-BASED SURVEYS

To investigate the influence of different environments on learning style preferences of students, two surveys were conducted. The first survey was carried out simultaneously in New Zealand and Taiwan. A total of 210 students completed a questionnaire aimed at eliciting their preferred learning styles, preferences for some common learning activities and multimedia elements on desktop PC and on mobile phone. The analysis of the responses from students was expected to provide two broad findings:

1) Which preferences of students do not seem to change on different devices and hence could be transferred automatically between different systems when a student moves from one device to another?
2) Are there any patterns that could be detected for those preferences that do change from one device to another?

The above two findings would then provide basis for designing a student profile transformation framework over different devices.

In the first survey, most of the 210 participants were current university students, either undergraduate or postgraduate. For those who were not students, they all had learning experience in tertiary institutions, i.e. they were at least undergraduate qualification holders. 158 participants (75%) had postgraduate qualifications and the rest 52 participants (25%) were at undergraduate level. Their majors were versatile, ranging from information sciences, business studies, accounting, art design and medical administration to foreign language studies. Their experience of having been a tertiary student, whether at present or in the past, was valuable for this survey because they would represent the young and mature student population that the computer-based educational systems are supposed to reach.

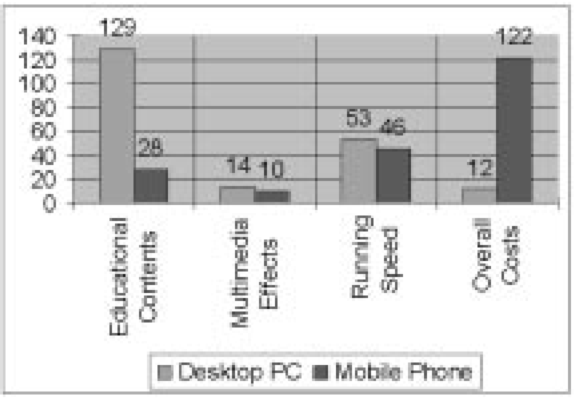

Fig. 1. Comparison between students' preferences for desktop PC and mobile phone.

The students were first asked about their most important concern when using a computer-based educational system on desktop PCs. Most students (61.43%) answered 'Educational Content'. However, when the same question was asked for the educational system on a mobile phone, the majority (58.10%) were more worried about 'Overall Cost'. Only 28 participants (13.33%) selected 'Educational Content'. A comparison among various responses by the students for both desktop PC and mobile phone (Fig. 1) revealed that the concerns for overall costs on mobile phone surpassed every other preference by a very significant difference.

There seem to be at least three possible reasons for concerns regarding costs on mobile phones. First of all, most obviously, the usage fees for mobile phone Internet connections are still too high, even when the price of mobile phones has gone down a lot in recent years. During the survey, we found that most participants had, for a long time, already established a link between mobile phones and high costs in their minds. Their first response to mobile educational applications was that it must be very expensive to use. Second, users already had an alternative cheaper way to use computer-based educational applications, i.e. desktop PC with wired Internet connection. It is very easy to get a desktop PC to access the Internet today in many places with more affordable costs and faster connection rates. The third reason is that there are not many Internet applications usable on mobile phones at present, particularly educational applications, and therefore the benefits of such applications are not as clear as the cost issue. The survey results revealed that many participants had not seen any educational applications on mobile phones and therefore could not really provide a well-informed opinion about them.

Analysis of other questions asked in the survey indicated that participants believed that with the help of mobile phones, learning can take place in many locations outside the campus. Another important finding that confirmed our underlying assumption was that most students' preferences for learning activities and multimedia effects were quite different on desktop PCs and mobile phones, whereas most students' learning style preferences remained the same for both devices.

Since the first survey results were more focused on mobile phone cost issues, a second survey was conducted with the aim of getting more educational perspectives from the participants. The questionnaire for the second survey was designed more specifically to investigate the links between students' preference changes and learning contexts.

Because many participants had not had any experience with mobile educational systems, it was important first to provide them with hands-on experience of such systems. Therefore, a demonstrational education system prototype was developed that students could use on both desktop PC and mobile phone in order to see the actual differences. To alleviate mobile phone cost-related concerns, it was made very clear to the students that there was no mobile connection cost involved in the survey because each mobile phone was connected to the Internet via a desktop PC by Internet sharing.

The demonstration system was developed using Microsoft ASP.net technology in such a way that the students could access it via both desktop PC and mobile phone. The presentation of educational contents was controlled by preference settings in the student profile. By adjusting preference settings on desktop PC and mobile phone, students could choose their most preferred presentation styles for the educational contents provided in the demonstration system. Figure 2 shows the system on desktop PC, Treo 600 mobile phone and Openwave simulator.

A total of 20 students participated in the second survey. They were all tertiary students in New Zealand, whose majors included science, business, psychology and design. The participants were selected on a random basis from various courses in the way that they represented a wider student community. Before filling out the second survey questionnaire, they were first asked to use the demonstration system.

Findings from the second survey can be summarized as follows:

- Most participants (80%) selected 'screen size' as the most influential attribute for their preference changes from one type of device to another, whereas 'web browser' was selected as the most influential attribute by the least number of participants (5%).
- All participants indicated that they would like their preference changes to be updated on every device they use to access the computer-based learning system. The majority of participants (55%) indicated that the synchronization of student profiles on desktop PC and on mobile phone should be done by the system automatically and immediately. Furthermore, most participants (85%) preferred that the default

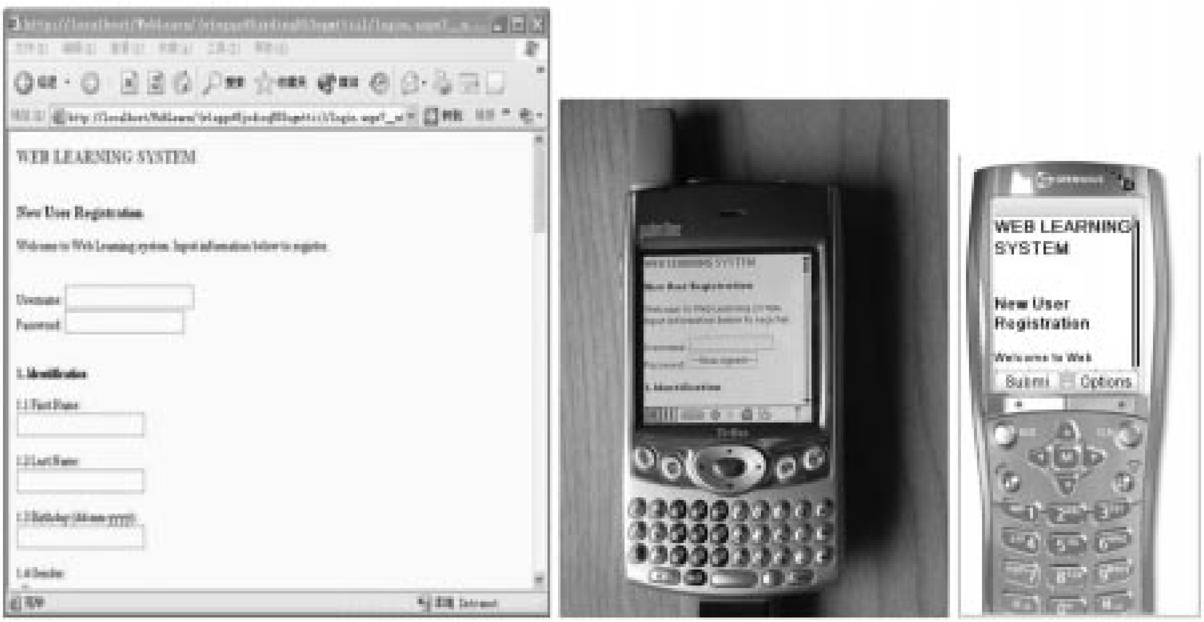

Fig. 2. Demo system on desktop PC, Treo 600 and Openwave simulator.

learning preference settings on mobile phone should be the same as on desktop PC, and vice versa.

- More than half of the survey participants (55%) believed that their learning preferences will be different in different locations. However, there were still 20% participants who believed that learning preferences will not change according to various locations.
- When asked whether they would be willing to change their learning preferences if the device they are using does not fully support their preferred format of learning contents, participants provided mixed reactions. Most participants (40%) indicated that they will not change their preferences when their mobile phone capabilities are too limited to provide the preferred contents. Some participants (25%) indicated that they may even stop learning on mobile phone if that is the case. However, there were still a considerable percentage of participants (35%) who would be willing to adjust their preferences to get supported contents on mobile phone.

STUDENT PROFILE TEMPLATE

To be able to construct a computer-based learning system that is adaptive in both desktop PC and mobile phone environments, a student profile needs to be designed that can automatically reflect the possible students' preference differences in both environments. Therefore, we should first decide what kinds of information should be included in a student profile for effective adaptation.

Although there are no significant attempts available in the literature in this area to the best of our knowledge, the Mobile Learning Metadata (MLM) schema [25] provides an initial attempt in formalizing a student model in mobile learning. The MLM schema has tried to expand the existing IEEE Learning Object Metadata (IEEE LOM) [27] and IMS Learner Information Profile standards [28] for educational systems to support mobile learning. The MLM schema consists of three top level categories, which are used to describe learning resource, learners themselves and context state of learning environment respectively. The category that describes learner contains two sub-categories: Learner Profile, which is about the learner and their preferences; and Learner Model, which is about learner's knowledge and learning history [26].

The student profile template of our research is different from the Learner Profile in MLM schema. The student profile template includes all the three top level categories of the MLM schema, namely learner, learning resource and context. These three categories are named as Student Identity, Learning Resource and Learning Context in the template. However, our research is focused on students' preference changes from one device to another. In order to highlight the preference changes in more detail and to ease future extension of the template, the student profile template puts students' preferences in separate categories instead of including all types of preferences in the learner category. The Learner Model part of MLM (containing learner knowledge and learning history) is not included in the student profile template. The student profile template only focuses on students preferences and does not include learner's competence related information. The other two categories, Learning Resource and Learning Context, are relatively simple compared to MLM schema. This is because our research is focused on students' personal features rather than the learning resource, and it is investigating only two learning contexts: device and location.

The results of two surveys indicate that there are differences in students' learning activities preferences, multimedia preferences and learning preferences on different devices and these differences are influenced by various mobile device capabilities. Therefore, in addition to the three top level categories that are adopted from MLM schema (Learner Identification, Learning Resource and Learning Context), the student profile template also includes three additional top level categories to describe the students' learning activities preferences, multimedia preferences and learning preferences. The complete student profile template is included in Appendix 1. These top level categories of the student profile can be summarized as follows:

- *Learner identification*: This is used to identify one student from others. It includes a unique User ID, a password supplied by the user to prevent any unauthorized access, name, date of birth, gender, address, email, and phone number. Their main function here is to provide more detailed personal information, which could be used for contact purpose, and also for students' feedback on the learning system or for other educational purposes, such as learning material delivery.
- *Learning Resource:* This provides details of what the student is going to learn. It includes subject area, learning objectives, date when the computer-based learning started, date when the computer-based learning should be completed and percentage that indicates how much learning material has been completed.
- *Learning Context:* This describes the contexts in which a student is learning. It includes the details of the device that the student is using and the location where the computer-based learning is carried out (only available when the device is set to mobile because desktop PC is assumed to be fixed).
- *Learning Activities:* The two surveys in this research indicated that only certain types of learning activities are preferred by the students on certain types of devices. Thus, the students should provide their learning activities preferences for an educational system to personalize the availability of various learning activities on suitable devices. This category, therefore, includes six common learning activities: Preview, Learn, Check Notices, Discuss, Review and Assignment.
- *Multimedia Preference:* Survey results indicated that it is possible for a student to prefer all the multimedia effects in the educational system on a desktop PC while restricting media preferences in the educational system on a mobile phone. This means students' multimedia preference will change on different devices. Therefore, students should provide their multimedia preferences in the student profile so that the system can adapt to different devices. Therefore, five basic types of multimedia preferences are included in the student profile: video, sound, animation, image and text. These five multimedia effects are very popular components on typical web pages, thus they are potential candidates to be integrated into a computer-based educational system.
- *Learning Preference:* Each student has his or her own 'characteristic ways of taking in and processing information' [20], which is based on student's learning styles. Therefore, this category includes students' learning styles. However, it is not adequate to predict student behaviour solely based on the student's level on learning style dimensions [22]. Therefore, this category contains eight questions to relate a student's learning style preferences with certain educational content presentation methods by referring to the Index of Learning Styles (ILS) questionnaire (Felder & Soloman, n.d.). To distinguish these eight questions from learning style preferences, they are named learning preferences. Appendix 1 contains the complete student profile template, including these eight questions.

The student profile template, based on the two surveys, elicits useful knowledge about what kind of information should be included in the profile and how environmental factors, such as device capability and location, would influence students' preference settings. Based on this information, the resulting student profile transformation framework aims to transform student profile between desktop PC and mobile phone by considering the influences of environmental factors, such as mobile phone capability and location, on students' preferences.

STUDENT PROFILE TRANSFORMATION FRAMEWORK

Although it is clear that students' preferences are influenced by device capability and location, these influences are very different for different students. Some students are very easily influenced by these two factors and will change their preferences easily whereas others do not find these two factors significant enough to change their original preference settings. Moreover, the changes that will take place in a student's preferences are not always the same for every student. Therefore, in order to achieve successful student profile transformation, it is necessary for the system to identify the connection between students' preference changes and device capability and location.

First of all, a device profile is needed to record all the capability differences of the accessing devices. Students make preference changes because there are differences between the capabilities of their current and previous devices. In the second survey, students were given 12 device capabilities to choose from along with a request that they suggest any additional capabilities, but no new device capability was suggested by the students. Therefore, the device profile for the framework has the following 12 device capabilities:

- Screen Size
- Colour Display
- Screen Resolution
- Audio Quality
- Video Quality
- Input Method
- Battery Time
- Memory Size
- Operating System
- Web Browser
- Internet Connection Speed
- Processor Speed.

Second, the capabilities that make the students change their preference settings should be identified by the computer-based learning system. They are called the influential capacities. Results of the two surveys indicated that the influences of the device capabilities on students are quite different. When a student makes any preference changes on a certain accessing device, he or she will be the only one who knows the best what made him or her to change the preferences. Therefore, the influential capacities can be indicated by the students at the time they make preference changes on different devices. In the student profile transformation framework, students' preference changes are connected with a subset of the above mentioned 12 device capabilities, named as Preference-Change related Device Capabilities (PCDCs). When the PCDCs in previous accessing device are the same as the corresponding capabilities in the current accessing device, the same preference change could be applied to that student's profile for the current device.

For example, when using a previous accessing device, a student changes his or her 'Image' preference to 'False' and selects 'Screen Size' and 'Internet Connection Speed' as the PCDCs. Suppose the 'Screen Size' is 128*128 and 'Internet Connection Speed' is 56 Kbps in a previous accessing device. If the student is now using a device that has the same capabilities, that is, 128*128 Screen Size and 56 Kbps Internet Connection Speed, then the student should also change his or her 'Image' preference to 'False', which could be done by the system automatically.

However, the automatic preference changes update should not occur only at the time when the current accessing device has the same capabilities as a previous accessing device. If those PCDCs are not the same as the current and previous devices, automatic preference change update should be triggered. The relationships between the PCDCs in the current device ($PCDC_{cur}$) and the PCDC in previous device ($PCDC_{pre}$) can be classified in three types:

1) The $PCDC_{cur}$ is better than the $PCDC_{pre}$, which will be symbolized as ">" in this article;
2) The $PCDC_{cur}$ is the same as the $PCDC_{pre}$, which will be symbolized as "=" in this article;
3) The $PCDC_{cur}$ is worse than the $PCDC_{pre,}$ which will be symbolized as "<" in this article.

Since the $PCDC_{cur}$ and $PCDC_{pre}$ have to be read from respective device profiles, both previous and current device profiles should be available for getting PCDC values. If the current device is the student's first accessing device, that is, there is no previous device profile, a copy of the current device profile is treated as a previous device profile as default. PCDCs can also be discriminated by defining them as PCDC*mn*, where *n* is the accessing device sequential order and *m* is the preference change sequential order in the *n*th accessing device. Then the conditions for automatic update of device capability related to preference changes can be listed as in Table 1.

It should be noted that in Table 1, the relation $PCDC_{m\ (n-1)} = PCDC_{mn}$ has not been included. The reason is that the same device capabilities will not result in preference changes. Results of the two surveys indicate that different device capabilities will result in students' preference changes. If there are two devices with the same device capabilities, then the students will not set different preferences for the two devices, unless they have been influenced by other environment factors, such as location.

In the second survey, more than half of the participants agreed that their learning preferences tend to change in various locations. Therefore, it is essential to take the influence of locations into consideration for student preference changes. The influence of popular locations for mobile learning was already investigated in the first survey. Each of these locations has its own features and has a different influence on individual student's preferences. Therefore, the student profile transformation framework includes preference settings for locations, called Location Based Preference Changes (LBPCs).

Table 1. Conditions for automatic update of device capability-related preference changes

Current Device = D_n Previous Device = D_{n-1}	Current Device = D_{n+1} Previous Deice = D_n	Automatic Preference Change Update
$PCDC_{m\ (n-1)} < PCDC_{mn}$	$PCDC_{mn} = PCDC_{m(n+1)}$	True
	$PCDC_{mn} > PCDC_{m(n+1)}$	False
$PCDC_{m\ (n-1)} > PCDC_{mn}$	$PCDC_{mn} = PCDC_{m(n+1)}$	True
	$PCDC_{mn} < PCDC_{m(n+1)}$	False

The LBPCs are the preference changes that a student makes for a particular location. Therefore, these preference changes should only be triggered by various locations. The initial LBPCs are set manually by the student. The update method for LBPCs is much simpler compared with the update of preference changes caused by device capabilities. This is because locations are not modelled by their characteristics. Each location is considered as one influential factor for preference changes.

When considering automatic preference change update, it is necessary to first identify whether the cause of the preference change is device capability, location or both, which again should be indicated by the students themselves. By using the conditions in Table 1, the conditions for automatic update of both device capabilities related and location related preference changes can be summarized as in Table 2.

There are still two more factors that may result in student preference changes, namely unsupported preferences and preference conflict. Unsupported preferences result from device incapability. When the device is not able to support a student's preference settings, the device would usually just neglect that preference and do nothing. For example, when a device does not support image, it would usually display a blank screen or an error message. The results of the second survey indicated that most students will continue learning with one of the following strategies for the unsupported preferences: neglect the preference, change to supported preference, or use a replacement preference. For each unsupported preference, the student would select one of the above three options. Once an option is selected, that option can be automatically applied to the same subsequent unsupported preference on other devices.

Preference conflicts are defined as the conflicts among different preferences. For example, if a student selected the preference for visual object (as asked explicitly in the questionnaire) and is identified to be the opposite from the questions regarding learning style (derived implicitly), there will be a preference conflict because both of these preferences draw on the same cognitive function—proficiency to process visual information. The majority of participants in the second survey chose consideration of other preferences in priority. Therefore, as adopted in the survey analysis, 'other preferences first' can be used as the default option, but the student would also be able to choose consideration of learning preference first.

By taking device capabilities, locations, unsupported preference and preference conflict into consideration, Fig. 3 shows the resulting student profile transformation framework for desktop PC and mobile phone.

It is assumed that desktop PCs are of adequate capabilities to fulfil all the student preferences settings. Moreover, it is assumed that the location where the desktop PC is used as an accessing device is fixed. Therefore, in the framework, the device capabilities and location of desktop PC are fixed. In future work, we intend to include various differences found in PCs, such as memory size, CPU power, operating systems, software tools and Internet connection speed. This will extend the framework to include more device capabilities at the high end of the spectrum. For the current work, these differences did not have any significance, particularly when the alternative device in the research was a mobile phone. Consideration of differences between different types of desktop PCs will be important when considering other devices such as personal digital assistants (PDAs), smartphones and tablet PCs.

The student in the framework is expected to have two different student profiles with different preference settings on desktop PC and mobile phone. However, second survey results indicated that most students would initially like to have the same default preference settings on both devices, and then decide whether preference changes are needed. Therefore, in the framework, both learning preferences and other preferences (multimedia preferences and learning activities preferences) have the same default settings after a student sets up his or her first student profile. This means that when the student constructs his or her student profile initially on a desktop PC, the profile on the mobile phone will be the same as default, and vice versa. Only after the student has used the computer-based educational system with these default preferences, could he or she make more practical preference settings, which are called as preference changes in the framework.

The preference changes on the mobile phone are

Table 2. Conditions for automatic update of both device capability-related and location- related preference changes

Cause of preference change	Meeting automatic update conditions in Table 1	Same location	Automatic preference change update
Device capability	True	True or False	True
False	True or False	False	
Location	True or False	True	True
True or False	False	False	
Both device capability & location	True	True	True
False	True or False	False	
True or False	False	False	

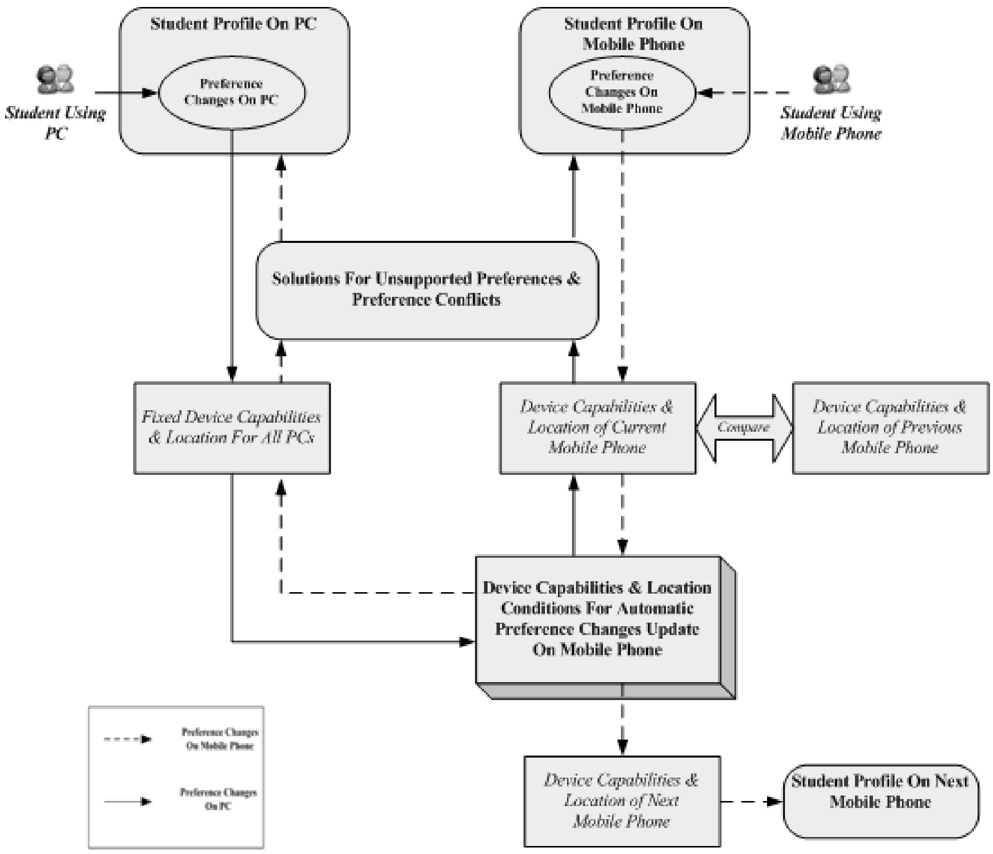

Fig. 3. Student profile transformation framework for desktop PC and mobile phone.

connected with the current device capabilities and locations. Then by comparing current device with previous device, the conditions for automatic update of preference changes can be obtained, as discussed previously. Only after the conditions are met, the same preference changes could be updated on the next device, i.e. desktop PC or another mobile phone. The preference changes on the desktop PC will not be connected with particular device capabilities or locations of the desktop PC, because in the current framework, every desktop PC is assumed to be fixed and have all the capabilities to fulfil all the student's preference settings (particularly when these capabilities are compared with the mobile phone's). However, fixed device capabilities and location are used to decide whether the preference changes on a desktop PC can be automatically updated on a mobile phone.

In the framework, the preference changes on a mobile phone are displayed by broken arrows and the preference changes on desktop PC are displayed by solid arrows. When there is a preference change on a mobile phone, the change is first connected with certain device capabilities and location of the mobile phone. The current mobile phone is compared with a previous mobile phone (if current mobile phone is the first mobile phone that a student uses as accessing device, the previous mobile phone will have the same device capabilities and location) on these preference change-related device capabilities and location to obtain the conditions for automatic preference change update. After this, the desktop PC's capabilities and location are checked against those conditions to see whether these preference changes can be automatically updated on the desktop PC. Those conditions are also used for automatic preference change update on the next mobile phone in the same manner.

If the preference change is made on desktop PC, the fixed PC capabilities and location are compared with the mobile phone capabilities and locations to decide whether the conditions for automatic preference changes are met. If the conditions are met, the preference changes on desktop PC continue to update the student profile on the mobile phone. If the conditions have not been met yet (for example, when the student has not used the mobile phone or has not made any preference changes), the preference change on the desktop PC also passes the condition and continues to update the student profile on the mobile phone.

When the preference changes on the desktop PC have passed the conditions and are ready to update the student profile on the mobile phone, or when the preference changes on the mobile phone have passed the conditions and are ready to update the student profile on the desktop PC, all the preference changes need to be checked for possible unsupported preferences and preference conflicts. Any unsupported preferences or preference conflicts need to be resolved before the preference changes update the student profile. This solution is based on the results of the second survey, as presented earlier.

CONCLUSION AND FUTURE WORK

In this research, two surveys were conducted that resulted in the student profile template and student profile transformation framework. Students' preferences on a desktop PC and mobile phone are found to be rather different. The transformation framework relates students' preference changes with contextual factors, such as device capabilities and locations, for learning using mobile phones.

The framework provides a solid step towards providing adaptivity when students change devices to access computer-based learning content. Current research is based on two devices: desktop PC and mobile phone. With emergence of various kinds of devices such as personal digital assistants (PDAs), smartphones, tablet PCs and so on, extensions to the framework could be possible by investigating the device capabilities of the newer devices. Differences in various desktop PCs could also be investigated to accommodate user preferences for the higher end of device capability differences.

Another important contextual factor, location, would require further consideration in future research. For example, if two locations are of the same type (e.g. cafe), both of them are assumed to have the same influences on students' preference changes (e.g. high noise level). However, this is not always true. Environments in the same type of locations may also change. Therefore, it will be better to connect location characteristics rather than location names with students' preference changes. It is similar to the fact that we connect device capabilities rather than device model names with students' preference changes. In addition, whether and how the students' preferences will be different when they are at standstill or mobile in the same location still needs further investigation.

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APPENDIX 1: STUDENT PROFILE TEMPLATE

ATTRIBUTES	DATA TYPE	DESCRIPTION
1. Identification	***Category***	***Detailed personal information about the student himself***
1.1 User ID	Text	Unique text string to identify a student
1.2 Password	Password	Password for the user to login the system
1.2 Name	Text	First name and surname of the student
1.3 Date of Birth	Date	Birthday of the student
1.4 Gender	Text	Gender of the student
1.5 Address	Text	Address of the student
1.6 Email	Text	Email address of the student
1.7 Phone number	Text	Phone number of the student
2. Learning Source	***Category***	***Information about the web course that the student is taking***
2.1 Subject	Text	The subject area of the computer-based learning
2.2 Objectives	Text	The learning objectives for the student
2.3 Start Date	Date	The date when the web-based learning starts
2.4 Due Date	Date	The date when the computer -based learning should be completed
2.5 Current Status	Percentage	A percentage that indicates how many learning materials have been completed
3. Learning Context	***Category***	***Information describing the environment in which the student is learning***
3.1 Device	Text	The device that the student is using
3.2 Location	Text	Indicate the location where the web-based learning is carried out (only available when the device is set to mobile)
4. Learning Activities	***Category***	***Learning activities that the student carries out for the web course***
4.1 Preview	True/False	Decide whether to include course preview activities
4.2 Learn	True/False	Decide whether to include course material learning activities
4.3 Check Notice	True/False	Decide whether to include course notices checking function
4.4 Discuss	True/False	Decide whether to include course related discussion function
4.5 Review	True/False	Decide whether to include course review activities
4.6 Assignment	True/False	Decide whether to include course assignment activities
5. Multimedia Preferences	***Category***	***Common multimedia effects that will be provided by educational systems***
5.1 Video	True/False	Decide whether to provide videos
5.2 Sound	True/False	Decide whether to provide sounds
5.3 Animation	True/False	Decide whether to provide animations
5.4 Image	True/False	Decide whether to provide images
5.5 Text	True/False	Decide whether to provide detailed texts

ATTRIBUTES	DATA TYPE	DESCRIPTION
6. Learning Preferences	***Category***	***The way in which certain contents will be presented in the educational systems***
6.1 I prefer the course contents to be mostly (a) concrete information or (b) abstract concepts.	a/b	Decide whether concrete or abstract information should be provided
6.2 I prefer to (a) master the standard solutions or (b) find out new solutions.	a/b	Decide whether new solutions should be presented in addition to standard ones.
6.3 It is easier to understand the course contents that are explained (a) visually or (b) verbally.	a/b	Decide whether visual or verbal contents should be provided
6.4 I like to read books that (a) have many pictures or (b) contain mostly texts.	a/b	Decide whether pictures should be provided
6.5 I can understand something better (a) after I try it out or (b) after I think it through.	a/b	Decide whether practice exercises or questions should be provided
6.6 I like to (a) study in study groups or (b) study alone.	a/b	Decide whether a discussion area should be provided
6.7 I like to (a) learn course contents step by step or (b) jump to advanced topics when learning.	a/b	Decide whether the links that can jump to anywhere in the computer-based course should be provided
6.8 When learning a new subject, (a) I stay focused on that subject and learn as much about it as I can or (b) I try to connect that subject with related subjects.	a/b	Decide whether provide related subjects

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