# Application of Learning Styles Adaptivity in Mobile Learning Environments

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## ABSTRACT

Availability of advanced mobile technologies, such as high bandwidth infrastructure, wireless technologies, and handheld devices, have started to extend e-learning towards mobile learning (m-learning) (Sharples, 2000). This phenomenon fits well with the new paradigm "anytime, anywhere computing" (Lehner and Nösekabel, 2002). However, the development of m-learning is still at rather early stage and many issues have yet to be resolved. One of these issues is the potential of individualization of learning process for the learners.

This paper explores how to improve learning process by adapting course content presentation to student learning styles in multi-platform environments such as PC and PDA. A framework has been developed to comprehensively model student's learning styles and present the appropriate subject matter, including the content, format, media type, and so on, to suit individual student. The work is based on the Felder-Silverman Learning Style Theory. The framework uses traditional web-based intelligent tutorial architecture, with two additional components: 'learning style analysis module' and 'access device analysis module'. The learning style analysis module takes care of modeling student learning style and communicates with student model, whereas the access device analysis module identifies the access device profile and provides the information to tutorial module. The tutorial module creates the suitable content, based on the student model (including individual learning styles) and access device profile, and presents to the student.

Based on the framework, a prototype for the domain of PHP programming course has been developed. With this system, students are able to learning PHP programming with course content that matches their own learning style and the device used to access the content. A formative evaluation is planned to assess the student satisfaction, learning efficiency, and effectiveness of the system while providing various presentations of the same content to different users on different devices.

## INTRODUCTION

Availability of advanced mobile technologies, such as high bandwidth infrastructure, wireless technologies, and handheld devices, have started to extend e-learning towards mobile learning (m-learning) (Sharples, 2000). This phenomenon fits well with the new paradigm "anytime, anywhere computing" (Lehner and Nösekabel, 2002). However, the development of m-learning is still at rather early stage and many issues have yet to be resolved. One of these issues is the potential of individualization of learning process for the learners.

In past decades, researchers from different disciplines have intended to define and classify learning styles that help teacher to improve their individualized teaching. There are many learning style theories used today and the learning style theories have been applied in educational environment widely. For example, the Theory into Practice Database (TIP, 2003) provides 50 major theories of learning and instruction, such as Kolb's learning style theory (Kolb and Fry, 1975; Kolb, 1984), Gardner's Multiple Intelligences Theory (Gardner, 1993), Felder-Silverman Learning Style Theory (Felder and Silverman, 1988; Felder, 1993), Litzinger and Osif Theory of Learning Styles (Litzinger, B. Osif, 1993), Myers-Briggs Type Indicator (MBTI) (Briggs and Myers, 1977; Myers and McCaulley, 1985). In recent years, researchers have started to undertake the learning styles in computer based educational systems, and there are a few existing systems that have the ability to adapt to student or user's learning style (Carver, et al., 1999; Carver, et al., 1996; Specht and Oppermann, 1998; Gilbert and Han, 1999; Gilbert. and Han, 1999a; Gilbert and Han, 2002; Paredes and Rodriguez, 2002). Currently, many researchers agree on the importance of modelling and using leaning styles, however there is little agreement in aspects of learning style are worth modelling, and what can be done differently for users with different styles (Brusilovsky, 2001). Moreover, the relationships between leaning styles and possible interface settings are still an unclear area (Brusilovsky, 2001).

This paper explores how to improve learning process by adapting course content presentation to student learning styles in multi-platform environments such as PC and PDA. A framework has been developed to comprehensively model student's learning styles and present the appropriate subject matter, including the content, format, media type, and so on, to suit individual student by their learning styles and access devices. Based on the framework, a prototype for the domain of PHP programming course has been developed to demonstrate the ideas.

The paper is organized as following. Section 2 reviews the Felder-Silverman learning style theory used by the project; section 3 overviews the application of

learning styles in adaptive learning systems; Section 4 discusses the high-level architecture of the system.

In section 5, the design and implementation of a prototype are discussed. Section 6 concludes this work.

## LEARNING STYLE AND FELDER-SILVERMAN LEARNING STYLE THEORY

A learning style is defined as the unique collection of individual skills and preferences that affect how a student perceives, gathers, and process learning materials (Johnson and Orwig, 1998). Each individual has his/her unique way of learning. Learning style greatly affects the learning process, and therefore the outcome (Carver and Howard, 1999; Vincent and Ross, 2001). In past decades, the leaning style area has been developed advanced. Numerous learning style theories have been applied in educational practices, e.g. Kolb's learning style theory (Kolb and Fry, 1975; Kolb, 1984), Gardner's Multiple Intelligences Theory (Gardner, 1993), Felder-Silverman Learning Style Theory (Felder and Silverman, 1988; Felder, 1993).

From the existing learning style theory, the Felder-Silverman Learning Style Theory is chosen to be implemented in this project. The reasons to choose this learning style theory are:

- Its Index of Learning Style (ILS) questionnaire (Felder and Soloman, 2003) provides a convenient and practical approach to establish the dominant learning style of each student.
- The results of ILS can be linked easily to adaptive environments **(**Paredes and Rodriguez, 2002).
- It is most appropriate and feasible to be implemented for hypermedia courseware (Carver and Howard, 1999).

This theory categorizes an individual's preferred learning style by a sliding scale of five dimensions: *sensing-intuitive, visual-verbal, inductive-deductive, active-reflective* and *sequential-global* (Felder and Silverman, 1988; Felder, 1993). Currently, the inductive-deductive dimension has been deleted from the previous theory, because of pedagogical reasons. As shown in table 1, this theory defines student's learning styles by basing on a sliding scale of five dimensions: sensing-intuitive, visual-verbal, active-reflective and sequential-global.

| Definition | Dimension | | Definitions |
|---|---|---|---|
| Do it | Active | Reflective | Think about it |
| Learn facts | Sensing | Intuitive | Learning concepts |
| Require Pictures | Visual | Verbal | Require reading or lecture |
| Step by step | Sequential | Global | Big picture |

*Table1: Felder's learning dimensions (Carver, et al., 1999)*

From these dimension descriptions of learning styles, a questionnaire – Index of Learning Styles, is developed by Felder and Soloman (Felder and Soloman, 2003). The aim of the ILS questionnaire is to help learners to identify their own dominant learning styles. Currently, the questionnaire consists of 44 questions that each comes with two possible answers, a or b. All question are classified correspond to four pairs in the Felder and Silverman Learning Style theory. The results of questionnaire are explained as follows:

- If your score on a scale is 1-3, you have a mild preference for one or the other dimension but you are essentially well balanced. (For example, a 3a in the ACT/REF category indicates a mild preference for active learning.).
- If your score on a scale is 5-7, you have a moderate preference for one dimension of the scale and will learn more easily in a teaching environment which favours that dimension.
- If your score on a scale is 9-11, you have a strong preference for one dimension of the scale. You may have real difficulty learning in an environment which does not support that preference.

## EXISTING EDUCATIONAL SYSTEMS IMPLEMENTED LEARNING STYLES

Since mid 90's, a few educational hypermedia systems, which model student's learning styles, have been developed. The system developed by Carver et al. (Carver, et al., 1999; Carver, et al., 1996) relates learning styles based on Felder-Silverman Learning Style Theory to course components, e.g. slides, hypertext, media clips. According to student's learning style, the system presents a list of course components with links by order, and student can explore the course by click the links.

Arthur system (Gilbert and Han, 1999; Gilbert. and Han, 1999a; Gilbert and Han, 2002 ) assumes four leaning styles: auditory, visual, tactile or a combination of these styles, and there is respective course material for each style. When student

first time enter the system, the course content is delivered to student randomly. Then the system monitors student's learning process and base on student's evaluation to update student's learning styles (auditory, visual, tactile or a combination of them). According to student's latest learning styles, the system provides the suitable course content. The learning styles supported by the system are not based on any educational learning style theory, so its learning styles are more or less like preference.

Adaptive Courseware Environment (ACE) (Specht and Oppermann, 1998) provides certain mechanism to adapt to student's learning styles. When a student starts to use a new courseware, the student are asked for their learning strategies, such as learning by example, reading texts, or learning by doing. Based on the learning model, the domain model and the pedagogical model, the presentation component selects appropriate learning units and generates individual hypermedia documents for student. In strict learning style theory in education, its supporting learning styles may be classified into student preference.

The Web-based system created by Paredes and Rodríguez (2002) uses Felder-Silverman Learning Style Theory and Index of Learning Styles to assess student's learning styles. Then the assessment result is used to automatically adapt Web-based educational systems' content sequencing for student. However, the system only supports two dimensions of four dimensions in the Felder-Silverman Learning Style Theory.

Different systems have various ways to collect student's learning styles, such as interview, questionnaire, and monitor student's behaviour. However, an important point that has to be kept in mind is to get a useful student's learning style actually is a psychological test process that specially designed, and not by a simple interview (Brusilovsky, 2001).

All of these systems are PC based systems. They do not support the mobile environments, which are emerging very fast and need to be further explored. The aim of the paper is to explore how to support individual study in mobile environments.

## THE HIGH-LEVEL ARCHITECTURE OF THE SYSTEM

The high-level architecture uses traditional web-based intelligent tutorial architecture, with two additional components: 'learning style analysis module' and 'access device analysis module'. (figure1).

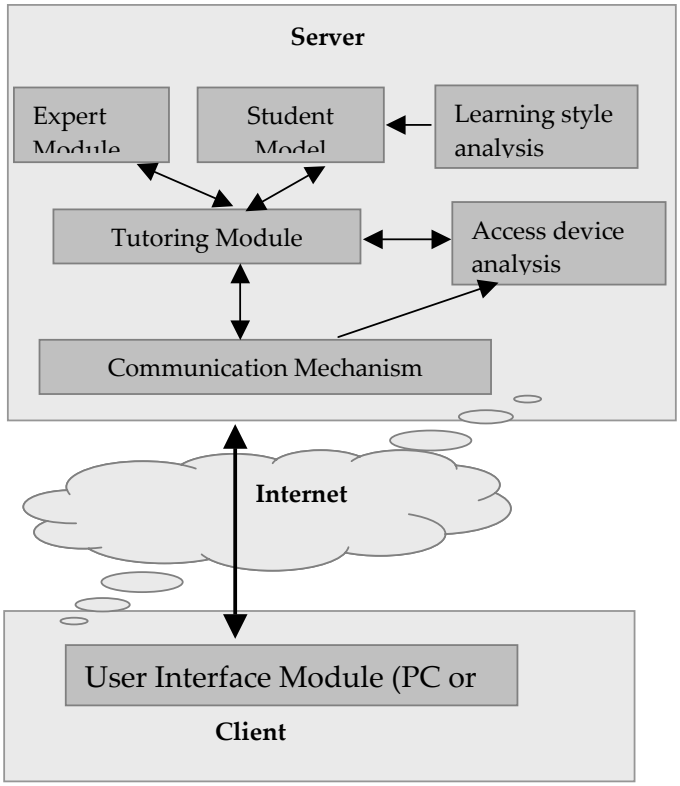

Figure 1: the high level architecture of the prototype

The learning style analysis module takes care of modeling student learning style and communicates with student model, whereas the access device analysis module identifies the access device profile and provides the information to tutorial module. The tutorial module creates the suitable content, based on the student model (including individual learning styles) and access device profile, and presents to the student.

## TOWARD THE PROTOTYPE

This section discusses how to implement the prototype based on the above architecture.

### Adaptation in mobile learning environments

The adaptation in mobile learning environments implicates that it has to consider the individual learner and the access device. In the prototype, the access devices are PC or PDA.

- Adaptation to student' learning styles: The framework is able to adapt to individual student learning style by providing a default learning style adaptation and individual learning style adaptation.

    - The default learning style adaptation: the system populates student learning style with a default learning style if student selects not to take the learning style assessment process. Based on validation of Felder-Soloman's Index of Leaning Styles that more students are active, sensing, sequential, and visual than reflective, intuitive, verbal and global(Van Zwanenberg, et al., 2001; Zywno, 2003), the default learning style is active/sensing/sequential/visual.
    - The individual learning style adaptation: the system recommends student take the learning style assessment before starting the course. Therefore, it is able to adapt the course to student's individual learning style.

The system provides the questionnaire of Index of Learning Style that student can take to assess their individual learning style. From the explanation of the results of Index of Learning Style questionnaire, there are three possible degrees of preference for each element in the four dimensions: mild, moderate, and strong preference. In the case of there is a mild preference for one dimension that means not necessary to adapt to it, the system signs a default preference for it (table 1) based on the validation result (Van Zwanenberg, et al., 2001; Zywno, 2003).

| Dimensions | Default preference |
|---|---|
| Mild active or reflective | Active |
| Mild sensing or intuitive | Sensing |
| Mild visual or verbal | Visual |
| Mild sequential or global | Sequential |

*Table 2: default preferences for mild preferences of learning style dimensions*

- Adaptation to student' access devices: for the demonstration purpose, the framework is able to adapt to PC based and PDA. When a device accesses the system, the access device analysis module will identify the type of devices automatically, and provides the device information to tutorial module. Based on the student's learning style and his/her access device, the system will present the course content accordingly.

**The control flows in the system**

From the figure 1, the control flows in the initial accessing the system are: a) after a student logs into the system successfully, it provides two options

(default learning style and take the learning style assessment) for the student. b) If the student selects the default style, the system populates the student learning style in student model with the default style (active/sensing/visual/sequential). Otherwise, the system provides the Index of Learning Style questionnaire for the student. After the student finishes the questions and submits the answers, the system analyses the student's learning style and populates his/her student model.

From then, the tutoring module will combine the student's leaning style information and the information of access device provided by access device analysis module, and serve the student with course content according to his/her learning style and access device.

**Classification of student learning styles and their implementation rules**

Based on Felder-Silverman Learning Style Theory, classification of student learning styles and their implementation rules are defined.

Because the system signs corresponding default preferences for those mild preferences of leaning style dimensions and treats the moderate and strong preference as the same, there are 16 types of combination of leaning style dimensions. They are:

- active/sensing/visual/sequential
- active/sensing/visual/global
- active/sensing/verbal/sequential
- active/sensing/verbal/global
- active/intuitive/visual/sequential
- active/intuitive/visual/global
- active/intuitive/verbal/sequential
- active/intuitive/verbal/global
- reflective/sensing/visual/sequential
- reflective/sensing/visual/global
- reflective/sensing/verbal/sequential
- reflective/sensing/verbal/global
- reflective/intuitive/visual/sequential
- reflective/intuitive/visual/global
- reflective/intuitive/verbal/sequential
- reflective/intuitive/verbal/global

These different types of learning styles are respectively implemented by the combination of the following 8 elements. The implementation rules for each element are discussed as follows.

- Active: study in groups to discussing, guess possible question and answer them, find ways to do something with learning concepts
  - Providing discussion area
  - Reminding student to guess several possible questions
- Reflective: think about quietly before going ahead; stop periodically to review what have been learning, writing summaries
  - Think before going ahead
  - Stop periodically to review what have been learning
  - Writing summaries
- Sensing: facts, example following by the exposition, hand-on work, practical material
  - Example first and following by the exposition
  - Hand-on work, such as practicing in the applying environment
- Intuitive**:** abstract, concept, theory, exposition before example
  - exposition first and following by the example
  - more concept and abstract
- Visual: picture, graphs, diagram, flow chart, schematics, demonstration, concepts map, color notes, slides with multimedia
  - More picture, graphs, diagram
  - Animation demonstration
  - Color important concepts
- Verbal: text, and audio
  - text
  - audio
- Sequential: Step by step logically to present material, outline the material in order
  - Step by step to present material
  - Constrict links
- Global: Large picture before detail, large jump, context of the subject
  - Give big picture of the course
  - Provide all the links

16 types of learning styles and their corresponding implementation rules have been finalized. In the next section, the design and implementation of the prototype are presented in details.

The classification of student learning styles and their implementation rules requested for implementing the Felder and Silverman learning style theory have been identified and discussed. In the following section, the prototype that implements the Felder and Silverman learning style theory is discussed.

**Implementation of the prototype**

The prototype uses the PHP programming tutorials material as course content. Students' profiles including the learning style are stored in a MySQL database. The prototype is developed by using XML technologies, PHP, Apache web server.

To dynamically identify the access device, a simple http header string identification technique is used. Since the PDA is limited at the size of screen and the resource, it is not capable of displaying multimedia as rich as PC. Therefore, two sets of course content are developed for PC based and PDA based.

The figure 2 is the page that student can select the default learning style or taking the leaning style assessment from PCs. If the student selects the course area directly, the system will populate the student model with the default learning style and bring the student to the course content according to the learning style.

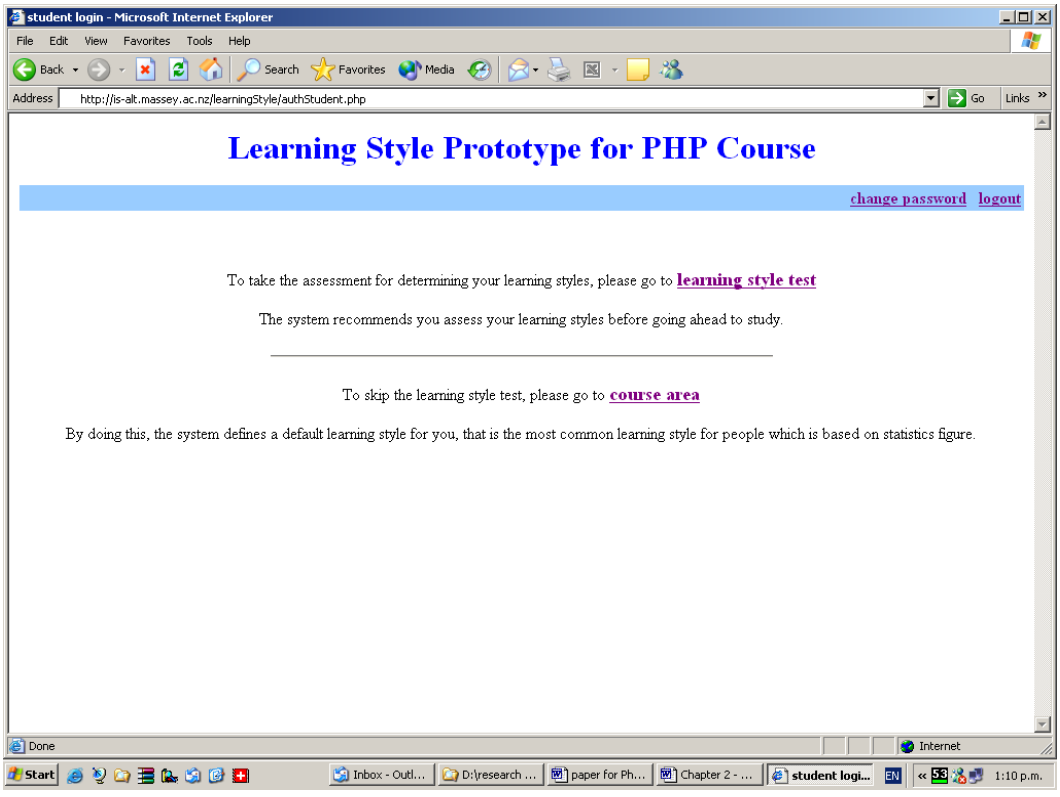


*Figure 2: a screenshot that student can select to go straight to course or take the assessment*

The figure 3 is a lesson for the learning style- active/sensing/visual/sequential. It provides the example at the begging of the lesson (if the lesson has example).

Student can enter the group discussion area anytime through the menu – discussion area. The lesson is presented step by step with few links that student can jump. According to the visual, the lesson is presented with picture and highlighting the important concepts.

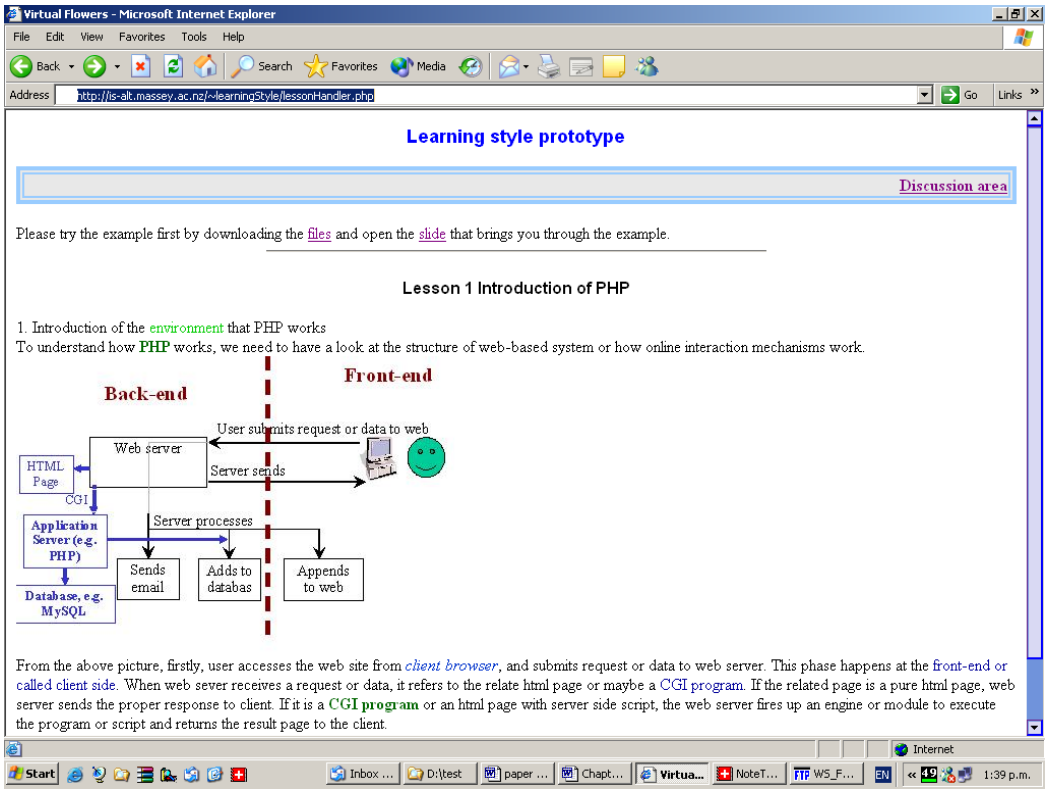

*Figure 3: a screenshot of a lesson for leaning style active/sensing/visual/sequential*

## CONCLUSION

In this paper, we presented a mechanism to fully model student's learning styles and fully adapt the course content to individual learning style, based on the Felder-Silverman learning style theory, and the access device. A prototype for PHP programming course was developed to demonstrate the mechanism. Students can perform study with course content that nicely match their own learning style and their access devices (PC or PDA). By adapting the course content to the student's individual learning style and access device, we expect students are able to learning more efficiently and more effectively.

Next step, we are going to conduct an evaluation on the prototype to assess the learning efficiency and effectiveness of this system.

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