A Study of User Interface Design Principles and Requirements for Developing a Mobile Learning Prototype

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Abstract-This paper describes a study of User Interface Design (UID) principles and requirements by utilizing mobile device as an instrument for Mobile learning purpose. Thus, methods for designing and developing a learning prototype that are compatible with small screen interfaces and limited capabilities of mobile devices are planned to ensure the learners are able to grasp the concepts of a mobile learning prototype. We also highlight ARCS learning design strategy, which is appropriate for a mobile-based learning application. The mobile learning prototype was developed using Adobe Flash CS5 for learning Dijkstra's shortest path algorithm as a technical subject on a touch-screen iPhone 4, operated on iPhone Operating System (iOS). We present discussions on the UID principles and guidelines used for designing and developing the mobile-based learning prototype. Finally, a survey was conducted to evaluate the usability of this prototype among 20 Computer Science undergraduate students who had previously studied or are still taking the subject. The findings show that the learners perceived the mobile application as usable and the application has contained UI principles and requirements.

Keywords—small screen interface, user interface design principles and requirements, mobile devices, mobile learning prototype, Dijkstra's shortest path algorithm.

I. INTRODUCTION

In Computer Science (CS) discipline, learning Computer Networks is a core subject for CS undergraduate students. The students have to learn Network Routing Algorithms as a chapter in this subject. They generally learn different types of routing algorithms such as Distance-Vector routing, Link State (LS) routing and so on [1], [2]. CS lecturers usually train LS routing algorithm as part of the network routing algorithms. Dijkstra is used to identify and demonstrate the shortest paths between each node in the network when LS routing is to route in a network. Hence, Dijkstra is taught as the shortest path algorithm as part of the Link State Routing. Meanwhile, a number of Computer Science (CS) undergraduate students are eager to do some research on the routing algorithm. Although electronic learning environments provide some facilities to learn complex concepts indirectly, CS students still encounter difficulties to cope with the complex concept of this routing algorithm [3]. Moreover, understanding technical terms requires hands-on practice rather than mere theoretical learning.

Nowadays, prevalence of mobile devices has become a necessity for students' life. We can see a huge number of students use different types of mobile devices such as PDAs, Tablet PCs and mobile phones. They often use the mobile devices to communicate with friends and families, connect to the Internet, play games and applications. As regards, mobile technology has also been introduced to students as a tool for learning technical and non-technical subjects.

Mobile learning technology has been regarded as the new generation of communication technology to stimulate and maintain learner's motivation [4]. Educators and researchers are also interested to use the technology to engage learners to practice frequently and learn anytime, anywhere without any special technical requirements [5]. Portable devices are identified as learning tools, which are able to save time and eliminate distance learning limitation. The challenge now is how a small-screen interface can maintain as an interactive learning and usable tool for Computer Science students to learn a technical subject such as Link State routing algorithms and Dijkstra's shortest path algorithm while they are on the move. There is also a challenge of adapting a technical subject on a mobile platform, especially in such a constraint user interface design. [4] also identify that it is important to motivate learners with usable content delivery in a learning process. As a result, we need to consider designing usable content delivery with good quality of service delivery and system functionality for learning a technical subject on a mobile platform [4],[6],[7],[8].

According to the **first author's experience** during his study at Bachelor of Computer Software Engineering, the researcher noticed that majority of his course mates faced difficulties to grasp the concept of routing algorithms, especially LS routing, Dijkstra shortest path algorithm and how the algorithms worked in a network. We think that the students can solve this problem via more practice and learning the subject in a more interesting way. On the other hand, from the perspective of mobile user interface design, interactive learning for a technical subject suffers usability issue. Designing instruction of Dijkstra's shortest path algorithm on a mobile platform can be an uphill challenge because of adapting content of the technical subject on small screen interfaces [5],[7],[15].

This paper aims to study the User Interface Design (UID) principles and requirements for developing a mobile learning prototype on iPhone platform. The followings are the objectives of this paper:

1) To identify the suitable design strategy to motivate and encourage learners to learn about Dijkstra's shortest path algorithm on a mobile platform;

2) To develop a Flash-based mobile learning prototype based on User Interface Design principles and requirements;

3) To examine the usability level of mobile learning prototype for learning Dijkstra's shortest path algorithm.

II. LITERATURE REVIEW

For developing a mobile based learning application, it does not matter what type of mobile platform is chosen by the developer [10],[11]. Identifying the best design strategy to stimulate and support learner's motivation is the most important fact that the developer should consider [9],[14]. On one hand, developing the content of a subject based on a mobile platform, a motivational design strategy needs to be included in the mobile-based learning application. ARCS (Attention, Relevance, Confidence and Satisfaction) motivational design strategy was chosen due to its suitability of design strategies for mobile-based learning applications [9].

A. ARCS Design Strategy

In 1987, Keller ARCS provided ARCS model as a motivational design strategy to make the learning environment attractive for learners, which is relevant to their interests and leaning goals, leading them to have confidence and satisfaction [9]. Keller's ARCS model is a four dimensional design strategies to motivate learners to learn more in order to obtain their learning goals. These four dimensions are: Attention, Relevance, Confidence and Satisfaction [9]:

1) Attention: stimulating and maintaining learner's interest in learning process.

2) Relevance: making a relation between instructional system and content with learner's goals.

3) Confidence: controlling the system should offer to the learners (learning application); learner's feeling and expectancy are the other measurements for this design strategy.

4) Satisfaction: satisfying learners from learning process and obtained experiences via positive and constructive feedback, unexpected rewards and positive outcomes.

B. Design Arguments

Seong [10] and Grasso & Roselli [11] presented two attributes that should be considered in developing a mobile-based learning application. In this case, learners and usability of the application are the two points highlighted by the researchers [10],[11].

a. Learners

Learner (or user) is the most important attribute that need to be evaluated by the developer before further developing a mobile-based learning application. Thus, developers should examine learners' characteristics in terms of age, gender, and the level of education and their familiarity with the mobile devices. These terms can help designers and developers to be aware of the user's attitudes and the expectations of a mobile-based learning application. Evaluating the learners before further development is significant so that it helps learners to use the application at ease. Otherwise, any complex methods of using and interacting with a mobile learning application will make learning difficulties for the learners [10],[11].

b. Usability

Usability is an attribute to define the quality of user interface design and interaction of an application. Usability can be measured by the quality of learners' experience during the interactions with the interface of an application [12]. The advantages of usability are: (i) reducing the time and cost of training, (ii) reducing the errors that the user encounters them during interaction with the system, (iii) increasing learning performance and users' satisfaction, and (iv) improving quality of interface interaction [7]. Thus, a set of design principles should be followed to provide an acceptable mobile-based learning application in terms of usability level. We also took account of the user interface limitations of a mobile-based learning application such as small screen size, poor resolution, limited storage facility and lower processing capacity [5],[13],[14]. As a result, the interface must be designed in a simple way without any complexity; size of output file must be reduced as much as possible and the application must not involve high processing capacity.

As mentioned before, a set of User Interface Design (UID) principles is considered for designing and developing a mobile-based learning application [15]:

1) Navigation should be simple and clear from a page to any particular section. In short, the navigation should be consistent throughout all pages in an application.

2) Complex navigation needs to be avoided by the developer on the application.

3) Reduce scrolling frequently.

4) Application should be user-friendly and allowed learners to understand how the application works in a few minutes.

5) Similar actions and information need to be located in similar positions. For instance, similar buttons must be found in similar positions for the whole pages of the application.

6) Flexibility of the display is the significant property for usability of interface design.

7) Providing necessary information. Unnecessary information confuses the learners and decreases their performance.

8) Decreasing textual information and increasing information which is provided in graphical and animated format to minimize learners' cognitive load and motivate them to learn.

9) User control of the learning application should be allowed by the learners.

Nowadays, many mobile applications are developed to learn academic subjects. Although there are some considerable research on mobile-based learning applications, there is still lack of research: (i) to examine the effectiveness of user interface design and Human Computer Interaction (HCI) in instructional applications based on mobile platforms, (ii) to figure out the impacts of surrounding environment on learning process when users learn the

subject through mobile devices [5],[7],[15]. Regarding these issues, there are two recommendations to increase the research on effectiveness of user interface design, HCI and surrounding environment in a mobile-based learning application. The first recommendation is to apply user interface design principles and research on human-computer interaction to make the user interaction ease-of-use for the users. The second recommendation is to use popular and common mobile devices for mobile-based learning application. In this study, iPhone 4 is used as a popular mobile device for learning purpose among the learners to improve their learning interest on the application rather than focus on the device and environment [11], [15].

III. METHODOLOGY

C. Research Design

In designing and developing the mobile-based learning prototype and testing the level of usability, there are several principles for designing the user interface and interaction. The researchers are to implement the UID principles and guidelines in the design and development process. After the prototype was developed, a usability questionnaire was used to evaluate the usability of the prototype among 20 Computer Science undergraduate students as the first round of study. For collecting and identifying the usability level of application, learners need to fill up the survey and answer to the questions. The survey questions were adapted from Purdue Usability Testing Questionnaire [15],[16].

We investigate the level of usability by evaluating the User Interface Design, which include consistency, flexibility, learnability, minimal action, minimal memory load and user guidance. The learners need to rate each question from 1 to 7 likert scale (1=bad, 7=good). Data were collected and evaluated by the researchers to show the final results of the survey, which indicates the usability level of the learning application [15],[16],[17].

D. Software and Technical Approach

In designing and developing the mobile-based learning prototype, there are two (2) applications used: (i) Adobe Flash CS5 as the main software for animations and movie clips creating, .IPA output files (for iOS-based devices), and Action Script 3 program writing, (ii) Adobe Photoshop CS5 to design the background of each content page, colors of buttons and so on.

a. Rationale of Software Use

As described, the software which was used for this mobile prototype is Adobe Flash CS5 and it was created in mobile platform environment for iPhone 4. We used Adobe Photoshop CS5 for designing and modifying all the original still movie clips, images for the prototype. Adobe Flash CS5 is employed because the environment of Adobe Flash enables the developers to create different movie clips and merge them simultaneously. Furthermore, Flash programming allows easy user control of the learning application by the learners. It is also easy to make special effects developing an interactive learning prototype in Adobe Flash environment. The navigation and almost all the interactive facilities were made by Adobe Flash CS5 using

Action Script 3. Using Flash programming also enables the developer to introduce mobile devices as a usable tool for Computer Science students to learn a technical subject such as Dijkstra's shortest path algorithm while they are on the move.

b. Design Idea and Development Environment

The user first access to an introductory page and is allowed to choose a desirable button. Each button shows an action that each router has to perform while working on the network. Once an action is chosen, s/he will be directed to the main page of the specific action. Each Main page presents basic information about the action and also a main menu at this particular stage. We ensure the page is friendly, colorful and simple. Main page contains a simple animation to encourage learners to learn about the routing path; in addition to 4 buttons are presented so that learners can get access to all steps of learning. There is also a textual context to describe the action for students via some simple sentences. Users can choose the buttons for any of the 4 learning steps i.e. learning the action, viewing an example for testing and practicing the action to evaluate them. The design also allows students to have full control of the mobile device and lessons. After touching the button, the page will change to a new content page. Based on the step chosen, part of the learning or content practice will be presented in a proportionate form and the user can trigger further interactions with the learning content. Keeping the user active for learning is the researchers' main concern.

Furthermore, the learning prototype has been developed on the basis of design structure as shown in Figure 1. Each sub-topic under the main topic (Link Sate Routing Algorithm) was shown as a button at Intro page of the prototype. In this mobile prototype, the only active button that can be chosen by the users is "Identify Shortest Path".
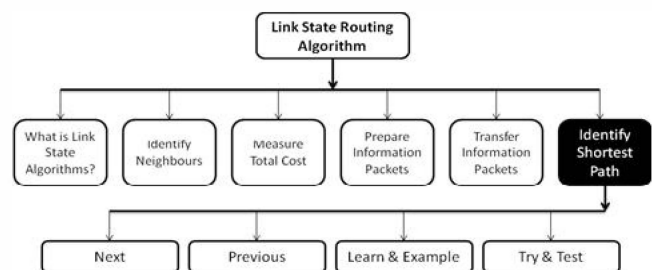

Figure 1. Structure of the prototype.

IV. RESULTS AND DISCUSSIONS

The prototype has been accomplished using Adobe Flash and Photoshop software for mobile learning prototype on Apple iPhone 4 platform. The researchers are to create mobile-based prototype to support instruction of Dijkstra's algorithm through small screen interfaces and then evaluate the usability level of application among the Computer Science Students. The prototype consists of more than 10 designated pages with the consideration of technical constraints on small screen devices such as compact screen size and poor resolution during the design and development of the learning prototype [5],[13]. The final designed

product has been presented to the students as a mobile-based interactive learning prototype to support their learning activities and practices in the field of study.

The main page brings the users to the content page of learning Dijkestra's shortest path algorithm. For every topic, "Main page" was provided in order for learners to have an overview of the action. The main page consists of 4 buttons addressed by "Learn & Example", "Try & Test", "Previous", "Next" so that learners are able to access to all steps of learning.

A. Discussion on Mobile User Interface Design & Development

As mentioned before, the application implements a design strategy to support interaction among learners working on the learning application. ARCS (Attention, Relevance, Confidence and Satisfaction) model was used as a motivational design strategy to engage the learning environment for learners to boost interest among learning a technical networking subject.

In the design phase, procedural steps help define the learning application requirements. Design guidelines and principles for designing and developing an interactive learning application based on the mobile technology were considered by the researchers. Requirements and UID principles that an application for learning a technical subject based on small screen devices were applied in the design process.

On the basis of identifying motivational learning strategy and UID design principles and guidelines, below are several screen shots of the mobile learning application. Figure 2 shows the Intro page, showing an animation at the top area, which represents a network routing process. The use of animation, colours and texts in an animated format are to gain users' attention. User can directly enter any action that each router has to perform while working on the network by touching the specific button which is dedicated for a specific operation.
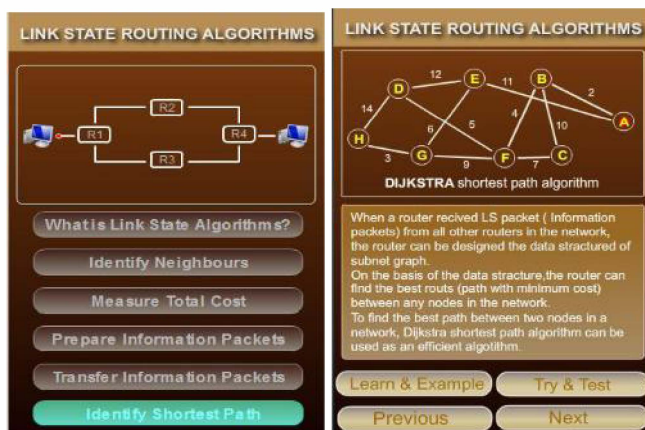

Figure 2. Intro page of a mobile application (left).
Figure 3. Main Content page of Link State Routing Algorithms (Right).

In this prototype, users can access the "*Identify Shortest Path*" page. When the users touch the button, the learning system will bring them into the content page of learning Dijkstra's Shortest Path Algorithm. An eye-capturing effect is presented to capture attention of users at the first time they encounter the application.

In Figure 3, the content page contains an animation at the top screen, descriptions and four (4) active buttons at the bottom page. The description informs the learners about the objective of the learning application. Information about the technical subject is provided to stimulate recall of users' prior knowledge. 4 buttons are contrived as the main entrance buttons that can be chosen by the users. All learning pages are reachable for users via the Content page. The design allows full control of the application traverse through the pages by the users. To adhere to the principle of consistency on the interface, we designed the "Previous" and "Next" buttons in fixed locations that the placement is consistent across the whole application. The "Next" and "Previous" were designed to bring the users to "Intro", or "Learn & Example" pages. Furthermore, similar background colour for the entire application is adhered. When the users interact with a button, there will be a change of colour of the buttons, which are other properties considered by the researcher to ensure consistency across all interfaces. This is consistent with the UID principle no. 5 in section II.b.

In "Learn & Example" Page, most of the objects, including 2 main buttons (Next and Previous) and 4 small buttons (Back, Stop, Play and Next) are interactive (Figure 4). In this phase of learning, the application is to present the content and provide learning guidance for the learners via an animation, includes texts and graphics which are changeable during the instruction. There are two types of buttons, which are (i) "Next" and "Previous" buttons. The buttons are to traverse between different pages in the application, and (ii) "Back, Stop, Play and Next" Buttons. These buttons allow learners to control the steps of example which is demonstrated in 7 steps. For instance, when the user touches the "Play" button, an example starts in an animated format and shows how Dijktra's shortest path algorithm chooses the nearest node in a hypothetical network from a source to the destination. The colour of each node, which is programmed by the algorithm, will change slightly from brown colour to white color in each step. Furthermore, each step defines how the algorithm picks the nearest node in a textual format. Learners can stop the animation in each step that they desire by touching the "Stop" button. "Next" and "Back" buttons allow learners to follow the steps gradually. In this design, the researchers are to make the learning easy by: (i) memorizing how to use the interface of application, and (ii) how user can re-use the application after a break.

In Figure 5, 6 and 7, learners can run a test in the "Try & Test" page. The application permits learners to elicit and assess their performance in a motivational way. The learning system will then provide an appropriate feedback, includes number of errors, which is made by the learners during the evaluation and time of test completion by the users.

Figure 5 shows the "Try & Test" page, where users can evaluate their performance in Dijkstra's shortest path algorithm using the same design strategy in "Learn & Example" page. This page also includes two buttons of "Play" and "Stop". When the user touches the "Play" button, the test will start and the "time" window shows the time of testing. The "time" will be showed 180 seconds at the

beginning. It will be reduced from 180 seconds to 0 by the system. When time subsides, and the "**time**" window shows 0, the system automatically brings learner to the last page and shows the number of errors made by the learner. There is also a "previous" button allocated to allow learners to go to the "Learn & Example" page directly.
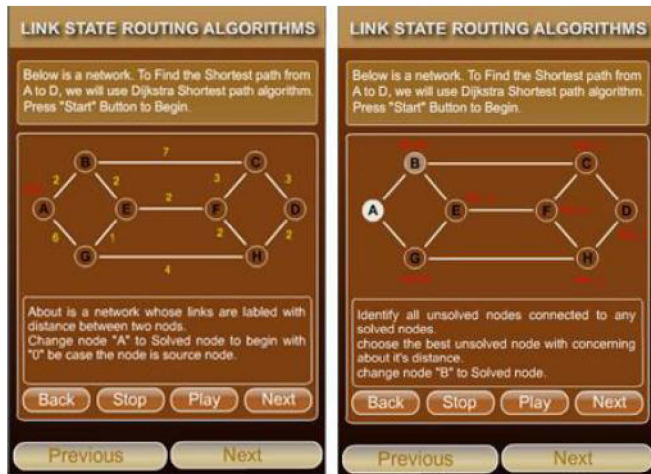

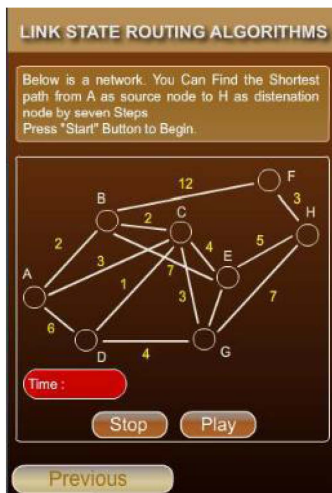Figure 4. "Learn and Example" Content Page.

Figure 5. Try and test page.

When the user touches the "Play" button, the test will start and the "time" window shows running time of a test (Figure 6). The users can touch each node to determine the nearest route from the current node. The test starts from node "A" as a source node to node "H" as the destination node. During the journey, when the user touches each correct node, the colour of the node will change from brown to white colour. This shows the users that the node chosen is correct to reach the destination. During the test, if the user touches a wrong node, a pop-up window appears, and shows a warning message of "*Be careful. This is a wrong node*". At the end of the test performed by the user, the number of wrong nodes is made and the total time will be shown as the system feedback. A "Previous" button also exists to allow learners to go back to the "Learn & Example" page whenever they would like to leave the test.

Figure 7 shows the feedback provided by the system. There is a small window, which demonstrates the number of wrong nodes chosen by the user, and also the total time that

the user performs the test. "Previous" button brings user to the "Try & Test" page to re-do the test. Home button takes users to the "Intro" Page to choose another action that each router has to perform while working on a network.
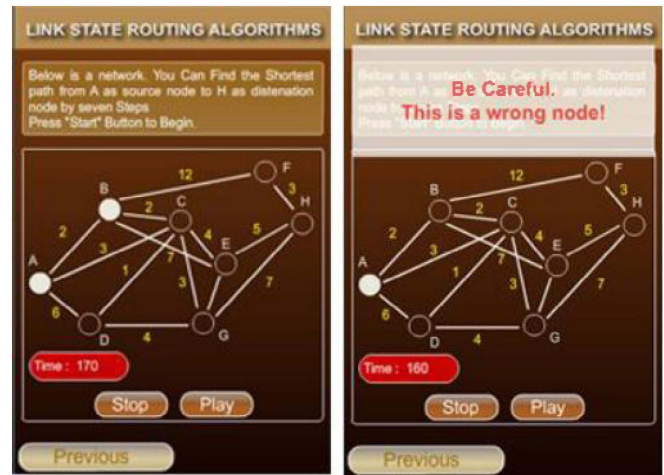

Figure 6. Users running a test.

Figure 7. Test result is shown after a user running the test.

B. Results of Level of Usability

As mentioned in the Methodology section, we aim to test 6 factors of usability during the evaluation: consistency, flexibility, learnability, minimal action, minimal memory load, and user guidance. Figure 8 shows that consistency has obtained the highest score among other factors (5.02). This means all pages of the application designed by the same display and background color. The second highest score (4.50) is minimal action which shows simplicity and clear navigations and interactions from one page to any particular section in the prototype. User guidance is the third factor which gains more than 4 (4.35) from the learners' point of views. This is shown that quality of guidance, feedbacks and the usefulness level of errors and warning massages are provided. Minimal memory load (3.99) is the next factor from the learners' point of views. The terms measured based on students' delay when they worked with the application after a break time. However, learnability only accounts for 3.57, which demonstrates the easiness level of designed application for the users who accomplished the task when they encounter the application at the first time. In addition,

flexibility of the application also scores lower than 4 (3.09) indicates that the defect of application to zoom-in and zoom-out by the users during the interaction with the application.
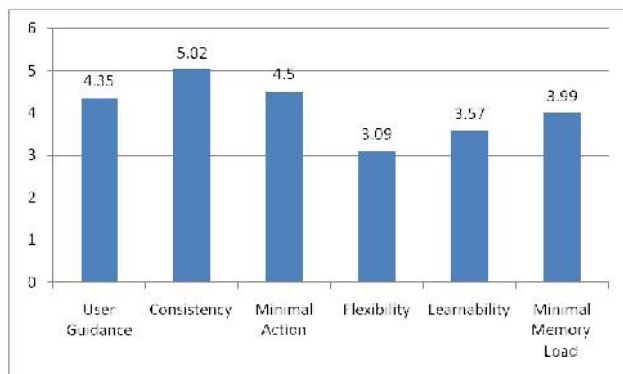

Figure 8. Results of the quality of usability for the mobile application.

The overall score of the usability level shows the acceptance level of usability of the application. The findings indicate that a huge number of the learners agreed that the mobile learning application is adhered to the UI principles and requirements of usability components albeit further improvement is required. Flexibility and learnability of the application were not gained high scores because of the users were not be able to customize the screen size and change the orientation of the prototype; the results shows that the users could not accomplished the task easily when they encounter the application at the first time.

V. CONCLUSIONS

Applying UI Design principles and guidelines are very important for developing a mobile-based learning application. By observing user interface design principles and implementing them in the development process, it can be helpful for users to increase their performance and grasp the concept of the technical subject as described in the application. A simple user interface and usable interaction design will definitely support learning and motivate learners to have interest on learning a technical subject.

For the future works, we will improve the application by including all actions that allow each router to perform for learning and practicing a more comprehensive Link State Routing Algorithms while working on the network. Furthermore, usability testing will be conducted for the improved application. The application will be tested by Computer Science lecturers, whom are familiar with the subject, and students in this field of study. The application will be compatible with other mobile platforms by using Java programming language. A set of questionnaires related to the application will also be provided to the users to evaluate the usability level of application in different mobile platforms such as Tablet PC.

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