

Lecturers and Students' Perception on Learning Dijkstra's Shortest Path Algorithm Through Mobile Devices

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Abstract—In recent years, many studies have been carried out on how to engage and support students in e-learning environments. Portable devices such as Personal Digital Assistants (PDAs), Tablet PCs, mobile phones and other mobile equipment have been used as parts of electronic learning environments to facilitate learning and teaching for both lecturers and students. However, there is still a dearth of study investigating the effects of small screen interfaces on mobile-based learning environments. This study aims to address two objectives: (i) investigate lecturer and student difficulties encountered in teaching-learning process in traditional face-to-face classroom settings, and (ii) to explore lecturer and student perceptions about learning the subject through mobile devices. This paper presents the results of a qualitative study using structured interviews to investigate lecturer and student experiences and perceptions on teaching and learning Dijkstra's shortest path algorithm via mobile devices. The interview insights were then used as inputs to define user requirements for a mobile learning prototype. The findings show that the lecturers and students raised many issues about interactivity and the flexibility of effective learning applications on small screen devices, especially for a technical subject.

Index Terms—Computer network, Dijkstra's shortest path algorithm, mobile devices, perception, small screen interface.

I. INTRODUCTION

In the discipline of computer science, learning computer networks is a core subject for Computer Science undergraduate students. Students usually learn Network Routing Algorithms as a chapter in a computer networking course, in which they learn different types of routing algorithms such as Distance-Vector, Link State (LS) Routing Algorithm and so on (Tanenbaum, 2003; Forouzan & Fegan, 2007). Most computer science lecturers teach link state routing algorithm as part of network routing algorithms. Dijkstra's shortest path algorithm is used to identify and demonstrate the shortest paths between each of the nodes in the network when LS routing algorithm is to route in a network. Apart from learning, a number of Computer Science undergraduate students are also eager to delve further into the topic for doing research. Although electronic learning environments provide some facilities to learn complex concepts indirectly (Drigas, Koukianakis & Pappagerasimou, 2006), students still encounter difficulties in coping with the complex concept of this routing algorithm. More importantly, understanding the technical

terms requires hands-on practice rather than mere theoretical learning.

The use of electronic environments in educational technology started fairly recent to make the learning process easier and increase accessibility of learning and teaching (Sandrasegaran, Cheung, Hossein, Zia & Malwany, 1993; Zele, Hoecke, Lenaerts & Wieme, 2003). Learning via electronic environments, also called e-learning, utilizes electronic and telecommunications technologies for information delivery, especially for educational purposes. With the advent of e-learning, most traditional learning limitations regarding learning times and places are now addressed in e-learning environments (Sandrasegaran, Cheung, Hossein, Zia & Malwany, 1993). Although e-learning technology offers different types of electronic learning environments such as web-based learning environments (WLE) and mobile-based learning environments (MLE), mobile-based learning has recently become an important modality used in e-learning environments (Tong, Yang, Liu & Liu, 2006; Khodabandeh, Afshari & Manian, 2010).

Today, mobile devices, especially touch-based models, have become increasingly used by students. Students presently use different types of different types of mobile devices such as tablet PCs. They often use hand phones to communicate with their friends and family, and also indulge in other tasks such as browsing the Internet, playing games and engaging in different types of mobile applications (Patric, Gao & Wu, 2008). In this regard, mobile technology has been introduced to students as a significant tool to help teach both technical and non-technical subjects (Kuo, Wu, Chang, Chang & Heh, 2007).

Mobile learning technology is commonly regarded as a new generation of communication technology that stimulates the user's interest in learning. On the one hand, educators and researchers are interested in exploring how mobile devices can be used to engage learners to learn and practice subjects more frequently anytime or anywhere, without any special technical requirements (Hentea, 2004; Jun & Zhi-yi, 2010). Although portable devices are viewed as learning tools which enable students to save time and eliminate distance learning limitations (Arreymbi, Agbor & Dastbaz, 2008; Cemal, Dastbaz & Bacon, 2008; Fetaji, 2008b; Ye, Lee & Geng, 2010), the challenge is how a small screen interface (with small and low resolution screen) can be used to learn a technical subject, such as Dijkstra's shortest path algorithm for computer science students, while they are on the move.

The motivation for this work is the first author's experiences during his studies in the Bachelor of Computer Software Engineering Program, where he observed most of his course mates having difficulties in grasping the concept of routing algorithms, in particular Dijkstra's shortest path algorithm. From this researcher's point of view, students can solve this problem through frequent practice on this subject in a more interesting way. From the perspective of interface design, interactive learning for a technical subject somehow suffers from usability issues. Instructional designing of Dijkstra's shortest path algorithm on a mobile platform can be a challenge because of difficulties related to adapting its content on small screen interfaces. Thus, this paper aims to investigate the difficulties computers science students and their lecturers encounter when learning and teaching this topic, and explore their perceptions about learning via small screen devices.

II. LITERATURE REVIEW AND RELATED WORK

Portable devices such as mobile phones, PDAs, notebooks and tablet PCs are used to assist the learning process, overcoming the limitations of time and location. Mobile-based learning is flexible, dynamic and easy to use in ubiquitous learning environments. Furthermore, mobile devices can offer ways of learning that are not possible in traditional classrooms or other types of electronic learning technologies (Tan & Liu, 2004; Patric, Gao & Wu, 2008).

Most researchers mention that they have faced some restrictions with regards to instructional design, development and implementations, in part, due to small screen interfaces (Ye, Lee & Geng, 2010). Small screen size, poor resolution, limited storage capacity and limited processing capacity are the main difficulties that researchers face when developing mobile applications (Fetaji, 2008c; Ye, Lee & Geng, 2010).

Despite the above mentioned challenges, researchers and experts on mobile learning technology have reported many positive impacts of learning via small screen devices. It is believed that mobile technology provides opportunities for learners to learn in an indirect and unconscious manner. Expanding the scope of electronic learning environments and environmental awareness are the two significant issues which researchers report are favored by mobile technology. They highlight that content delivery via mobile devices can motivate learners to grasp the concept of learned subjects (Fetaji, 2008c; Ye, Lee & Geng, 2010).

An example of a mobile-based interactive application was developed in Taiwan by Tan & Liu (2004). It consists of a mobile learning server and mobile learning tools to assist elementary school learning English. The application is able to maintain the learner's interest, enhance learning assessment and teach instruction for indoor and outdoor learning activities. In this system, students can connect to the network using their mobile devices, PDAs or notebooks, and download course content. The result of the project indicates that the second part of each lesson, which was presented in a mobile-based format, had a greater impact than the traditional format of content delivery. At the end of the project, the researchers used questionnaires to gauge levels of satisfaction among the learners of learning English via portable devices (Tan & Liu, 2004).

Fetaji (2008b) states that mobile learning can provide students more activities and practices in their fields of study. Fetaji considers how interfaces can be designed to

be more usable and suitable for users working with learning applications. Fetaji used a questionnaire to identify the quality of user interface attributes. The study revealed the limitations of using mobile technology on mobile devices such as small screen size, processors, different brands of mobile devices, etc. Fetaji also discovered that some lecturers are hesitant to use mobile devices for instructional purposes. They think mobile devices can be used to cheat and allow other illegitimate activities (Fetaji, 200b; Fetaji, 2008c).

Although there is considerable existing research that investigates the capabilities of small screen devices such as mobile phones in learning and teaching environments, there is still a lack of research to examine the lecturers and learners' ideas about whether it is suitable to practice technical subjects (Fetaji, 2008a), there is still a need to design and develop instructional applications based on their feedback and opinions. According to Seong (2006), user perception is the most important attribute that needs to be evaluated by the developer before creating a learning application based on mobile devices. Thus, researchers and developers should examine learner characteristics in terms of age, gender, nationality and the level of education, as well as their familiarity with mobile devices. Understanding learner characteristics before development is required to help learners better use the application. Difficult mobile learning applications that are complicated will dissuade learners from using them (Seong, 2006). As a result, we are interested in investigating lecturer and student perceptions about learning a technical subject delivered on small screen devices.

As mentioned earlier, this study aims to identify the issues and challenges faced by computer science students and the lecturers for learning and teaching Dijkstra's shortest path algorithm. We investigate their perceptions on learning Dijkstra's shortest path algorithm based on small screen devices with a lower resolution and limited processing capability. This paper aims to explore the lecturers and student perceptions and experiences about the current methods of teaching and learning a specific technical subject, including difficulties they faced and their opinions of learning a technical subject via mobile devices. The objectives of the study are addressed below:

- 1) To explore the opinions and issues faced by the learners, in particular any difficulties for them to cope with the concept of Dijkstra's shortest path algorithm in the current face-to-face classroom scenario.
- 2) To measure the lecturers' experiences about teaching the subject in the current face-to-face classroom situation.
- 3) To investigate the lecturers' perceptions about learning Dijkstra's shortest path algorithm via mobile devices.
- 4) To elicit the learners' opinions about the feasibility of learning and practicing technical subject matter through small screen devices.

III. RESEARCH METHODOLOGY

This study employs a qualitative research method using structured interviews (Kumar, 2011; Creswell, 2009) with students and lecturers to identify their issues and difficulties in learning and teaching the subject (Dijkstra's shortest path algorithm). The data collection via interview is subjective data, mainly in text-based descriptions. For

instance, we acquire user feedback and comments from the students about the problems they faced in understanding the concept of the subject, as well as lecturer problems related to teaching and delivering content in the classrooms. The study draws conclusions of student and lecturer perceptions on the topic, by providing suggestions about learning the subject via mobile devices. In terms of sample selection, we use a snowballing technique by approaching all the lecturers who are teaching subjects related to computer network. Only 8 out of 10 lecturers from Faculty of Information Technology (FIT) responded and were willing to participate in the interview session. For the student sampling, we approached the lecturers who agreed to participate in our interview to introduce us to their students in their computer network classes.

In short, the respondents of the interview consist of 8 lecturers (6 males and 2 female) from Faculty of Information Technology (FIT) and 21 Computer Science Undergraduate students (9 males and 12 females). The first group of respondents includes 4 senior lecturers with PhD degree and 4 lecturers with Master degree in the fields of Computer Science or Information Technology. The lecturers are experts in teaching Computer Networks subject to Computer Science undergraduate students. They generally have appropriate knowledge in the respective field of study. Apart from this, all lecturers taught the subject and have experience doing research in the field.

The second group of the respondents is Computer Science students, who have either passed the Computer Networks subject, or are still currently studying the subject. All the 21 students fall under 18-23 age groups. Among the 21 students, 12 students are in the first half of their period of study (6 students are currently studying in third semester and the other 6 students are in their first semester). 9 out of 21 students are in second half of their undergraduate studies (6 students are currently studying in fifth semester and 3 student is in sixth semester). Generally, they had learned knowledge about the Computer Network subject and other related technical subjects. Apart from this, all the 21 students have worked with some learning applications before. They are also familiar with learning technologies, which are used by the lecturers as one of their teaching methods for information delivery (Biello, 2005; Morrison, Ross and Kemp, 2004; Alessi and Trolip, 2001; Mahadevan, 2009).

IV. PROCEDURE

During the interview, some guided questions were prepared. We used simple and everyday language for the interview. The interview questions consist of open-ended and close-ended questions. Any ambiguous questions, which contain more than one meaning and leading questions to dictate an answer, or a specific answer to the respondents were avoided (Kumar, 2011; Creswell, 2009). In this regards, careful consideration was taken about the quality of collected data regarding the number of interviews, quality of interviewers and quality of interactions (Kumar, 2011). We acquired feedback and also comments from the Faculty of Information Technology (FIT) lecturers and computer science undergraduate students.

The interview questions in this study are targeted towards lecturers and undergraduate students. The first type of interview questions is designed for lecturers with the objective of better understanding their perceptions and experiences in teaching computer networks, especially

routing algorithms. The second type of interview questions is designed to understand whether the computer science students having any difficulties in grasping the concepts of the subject, as well as any issues the students encounter in practicing and learning the subject.

We first interviewed 8 lecturers who have either taught or a presently teacher the course on computer networks to the computer science undergraduate students. Before each interview started, we explained the purpose of the interview and gave provided explanations about the study. A consent form was presented to obtain permission from the respondents agreeing to voluntary participate in the interview. We used audio-taped and note-taking to record the respondents' answers and recommendations. The answers were then analyzed and a conclusion was drawn to provide lecturers' recommendations, perceptions and expectations about the topic.

We interviewed 21 computer science undergraduate students, all of whom had previously studied the subject or were at that time were studying the subject of computer networks. The students' knowledge of computer networks had been pre-screened by the researcher before each interview was conducted. This was done through the FIT lecturers' suggestions for the interview. The researcher also referred to the semester they were currently studying in the computer networks course and the scores of the exercise, assignments and general exams. The researcher first briefed persons participating in the interview of the students to get their responses and points of view, according to the questions and recommendations. Their answers were then analyzed concerning the difficulties they faced in the face-to-face classrooms and their perceptions on learning the subject delivered on mobile devices.

From this interview, we intended to obtain student feedback and comments on learning in the computer network course and opinions on learning the technical subject via mobile devices with a lower resolution. To structure the interview, a set of pre-determined questions were prepared for the students. The questions included questions about their study major, their interests in about computer networks and any difficulties they encountered coping with the concept of algorithms. The questions also attempted to discover the technologies used by the FIT lecturers, whether they were effective in motivating them to practice and improve their knowledge of the subject itself. Furthermore, questions concerning the use of other types of technologies and the degree to which they effectively delivered information, proved to be feasible for practice without constraints in time and location, and their opinions about learning via mobile devices.

The respondents were prompted to express any issues and difficulties they faced in current face-to-face classroom assignments and lab practices, the current e-learning technologies that were used, teaching methods employed by lecturers, and the interactive instructional systems that students were currently exposed to. They provided useful opinions and essential content, principles and practices for the mobile-based learning prototype. For instance, the 21 computer science undergraduate students consisted of juniors and senior students of the FIT (Faculty of Information Technology). They provided some feedback about their difficulties in coping with the concept of the subject in the classrooms along with their perceptions about learning and practicing the technical subject while using handheld or small screen devices.

V. INTERVIEW FINDINGS

A. Interviews with Lecturers

During the interview, we prompted some guided questions to the FIT lecturers in order to gauge feedback in subjective comments. The questions were designed with different considerations, including their teaching experience, current technology use in their courses and their perception about using mobile devices for information delivery.

The first part of the interview questions covered the lecturer's experiences on the subject. For instance, "*Which chapter (chapters) of the course titled Computer Networks is the most difficult to teach?*" In the lecturers' opinions, teaching the topic of signals and signal transmissions is the most difficult chapter to teach because there is still lack of technologies and tools available for lab practice. Apart from this, network security and physical layers are the two most difficult topics to teach from the lecturers' points of views. From the FIT lecturers' responses, we derived that there are some existing tools to teach some complex topics, but the tools are generally expensive and pricey, which limit their potential use in the classroom. As a result, the difficulty of comprehending a particular topic is due to insufficient tools, software and applications to assist students to grasp the complex concept. In turn, this is complicated furthermore by inadequate lab practice for students. In addition, one of the lecturers believed each chapter of the subject can be considered difficult to teach students. The difficulty of teaching a subject or a chapter on the subject of computer networks depends on each individual student and the level of his/her knowledge on different topics of the subject. To the lecturers, routing algorithms can be difficult to teach some students, especially those who do not have knowledge about algorithms in general and, more specifically, routing algorithms.

The next question asked was "*Do you teach Dijkstra's shortest path algorithm in the Link State routing as part of the Computer Routing Algorithms chapter?*" This question is deemed significant because we wanted to find out whether the FIT lecturers teach the technical subject or just merely their research interests. All 8 lecturers expressed they teach the specific topic, and 6 out of 8 lecturers also expressed they do further research in the field of computer networking.

The second part of the interview questions was designed to identify the technologies used by the lecturers. The information gathered reveals that all of the 8 lecturers use the same teaching activities, which include assignments, quizzes, practice and exams. The technology used to teach is mainly Microsoft PowerPoint to deliver content. Additionally, Cisco software such as Cisco Packet Tracer and Cisco System were also used to show the students how a network works, including data transfer, packet analysis, routing transactions, and connections between nodes, routers, etc.

The lecturers were also asked the question, "*Which other technologies can be used to assist them to teach the Dijkstra's shortest path algorithm as part of the Link State routing algorithms or in Network Routing Algorithms?*" The purpose of this question was to obtain lecturers' opinions about other type of technologies they felt could be used to assist them teach the technical subject. The 8 lecturers disagreed as to how useful mobile devices are in helping students to learn the technical subject. In terms of

increasing student learning and study performance, they generally do not consider using mobile phones to teach the subject. However, they mentioned that the small screen interface on a mobile platform is useful if the learning application on mobile devices is interactive, allowing instant communication with a server to connect with other users and share knowledge among the lecturers and their peers. In addition, they also mentioned that applications possessing graphics, animations and other types of multimedia elements are useful to help students' self-study, especially with regards to hands-on practice for the technical subject.

B. Interview with Students

In the interviews with 21 computer science undergraduate students, the researchers wished to discover:

- 1) Basic information about the respondents' academic status, their thoughts about the subject and, in particular, the topic of Network Routing Algorithms.
- 2) The technologies used by their lecturers to teach the subject and evaluate. Any other technology used to motivate them to practice and enhance their study performance.
- 3) Their difficulties (if any) that students encounter with the concept of the subject, especially routing algorithms.
- 4) Their opinions about any types of technologies that can be used to motivate them for hands-on practice.

During this interview, some guided questions prompted interviewees from a general topic (network routing algorithms) to the main point of interest, Dijkstra's shortest path algorithm. From the feedback gathered, all 21 students except one expressed "*I have learned Network Routing Algorithms as a chapter of the computer network course*". 15 of the 21 students agree with the sentence, "*Network Routing Algorithms is a difficult chapter to learn in the computer networks course*". 18 of the 21 students also mentioned they had learned Dijkstra's shortest path algorithm in Link State routing algorithms as part of the chapter on network routing.

The students were then asked, "*What are the types of technologies used by your lecturer to deliver the information to you in learning network routing algorithms?*" The question was included to identify the technologies used by the lecturers at Multimedia University to deliver information for their exercises and lab practices. The responses given were consistent with the lecturers that Microsoft PowerPoint was used to deliver instruction, while Cisco Packet Tracer was used for assignments, quizzes and lab practices.

The question, "*Which technologies can be used to motivate you to better learn Dijkstra's shortest path algorithm in the link state routing or other types of network routing algorithms?*" was formulated to obtain student perceptions and expectations about any other technologies that they perceive as useful for their learning. The students generally answered that the technologies actually being used (Cisco software, for example) is useful in showing them how a network works, network topology, how data transfers in a network, and so on. 6 out of 21 students were generally satisfied about the Cisco network technology used by their lecturers in terms of helping them enhance their knowledge of routing algorithms via lab practice. Having said this, 9 students mentioned that although

the Cisco software helped motivate them to practice the subject, the software is quite difficult to work with, especially when there is lack of access for frequent practice. From the students' points of view, hands-on practical and interactive learning applications can be helpful to improve their learning.

VI. DISCUSSIONS

From the lecturers' points of view, the answers demonstrate they generally disagree about using mobile devices, especially mobile phones for learning Dijkstra's shortest path algorithm in the link state routing algorithms. Apart from learning and delivering the information to students, when asked, "*In your opinion, which teaching and learning strategy can be used to deliver usable and meaningful content on mobile platforms?*", they suggested that tablet PCs with larger screen interfaces and higher storage and processing capacity are better devices for students to practice and communicate with each other or with their lecturers. All lecturers believed using Tablet PCs help improve hands-on practice and interactive training as compared to mobile phones. Apart from this, they also mentioned that using multimedia elements such as graphics and animations are useful in helping students grasp the complex concept of computer networks course and routing algorithms, in general. The characteristics of interactivity and practical software with immediate feedback are other suggestions recommended by the lecturers.

The question "*What is the main issue of you having difficulties teaching the concept of Dijkstra's shortest path algorithm in link state routing algorithms?*" was also included in the questionnaire. Several responses were given to this question, including the following: 'technologies which are used for teaching', 'students are having less practice', 'complex concept of the subject', 'time of teaching' and 'others (please explain)'. The lecturers were also given a chance to answer this question from their point of view. All 8 lecturers opined that insufficient practice is the main difficulty related to teaching the concept to their students. On the other hand, this issue can be solved if there are some practical software and learning applications to eliminate time and location constraints. The lecturers felt that this would save resources in terms of teaching, learning, practice and communication between lecturers and students.

From the students' perspective, 15 out of 21 students agreed with the sentence: "*Network Routing Algorithm is a difficult chapter of the Computer Networks course*". The majority of the respondents (18 students) mentioned that they had learned Dijkstra's shortest path algorithm as part of Link State Routing Algorithms. 9 out of 21 students felt they did not have sufficient practice time to fully understand the concept of computer routing algorithms. On the other hand, 12 students said that they had had enough time to practice the subject. However, they expressed having a portable hands-on application at hand could be useful for them to practice anytime and anywhere.

In terms of difficulties related to learning the subject, the answers given by the students showed that the most important problems were the complexity of the concept and insufficient lab practice. 12 of the 21 students responded that the complex concepts of the subject. Of these, 3 students were in sixth, three students in fifth and three students in third semesters, respectively. In other words, senior and junior students with more knowledge

about the subjects enrolled in the Computer Science Program are more concerned about having insufficient time to practice, more than other issue related to learning Dijkstra's shortest path algorithm. In addition, other challenges faced by the students include the types of training technologies used by the lecturers and the inadequate time of training make the subject difficult to learn. Having said this, the difficulties of learning can be somewhat mitigated if there are learning applications which can eliminate time and location limitations for learning and teaching, especially if they can provide hands-on practice.

Student perceptions and feedback generally shows that they prefer using interactive instruments such as mobile devices to practice Dijkstra's shortest path algorithm or other algorithms at a convenient time and location. Given the low resolution capacity and small screen interface of mobile devices, the students do not consider mobile phone very useful as a self-study tool in learning Dijkstra's shortest path algorithm. Although the lecturers have not considered using mobile devices and small screen devices to teach the subject, they mentioned that using mobile learning applications can increase their learning efficiency and help them to do better on evaluations. It is important to learn that any application should be interactive and provide immediate feedback so that students can interact and share knowledge among their peer groups.

VII. CONCLUSION

In conclusion, the lecturers and students in the computer science course have not thought extensively in terms of whether or not mobile devices are suitable for learning and teaching the Dijkstra's shortest path algorithm. They mentioned that although small screen devices can help save time and eliminate location restrictions for students and lecturers to communicate with each other, they still have many limitations such as limited processing capability, low resolutions and high costs to support learning a technical subject.

This study suggests that mobile devices should be considered to better integrate mobile technology into the teaching and learning of technical subjects. In general, it is recommended that "*the learning application should be interactive and provide immediate feedback. It should also allow students to communicate with each other and encourage teamwork. Communicating with a server and using multimedia elements to deliver content is considered more useful and applicable for students to practice more frequently and understand the concept of a subject in an indirect and unconscious manner, thus acquiring greater practice at their convenience*". Based on these recommendations compiled from lecturer and student opinions, a mobile device can be effectively used if given a larger small screen interface on smart phones or tablet PCs. However, tablet PCs are judged to be more useful mobile devices than mobile phones for learning this technical subject.

Applying user and experts opinions and suggestions are very important for providing a design structure for mobile-based learning applications. Observing user perceptions of an m-based learning application and implementing them in the design and development process can increase user performance and their grasp of concepts in technical subjects. A simple navigation and usable interaction design will definitely support learning and motivate learners to learn technical subjects.

Our future study will identify a suitable design structure to motivate and encourage learners to learn about Dijkstra's shortest path algorithm on mobile devices. It will be integrated after comparing its effectiveness in teaching and learning via tablet PC and mobile devices. Furthermore, usability testing will be conducted for the improved application. The application will be tested by computer science lecturers who are familiar with the subject and their students. The application will be compatible with most mobile platforms by using Java programming language.

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