Mobile Computing Program Curriculum —Design and Implementation

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***Abstract*—Mobile computing is revolutionizing the way computers are used. By looking at all of the entities in mobile computing (mobile users, mobile contents, and mobile devices), it forces us to consider a new curriculum design and teaching strategy to teach computing courses to students. Our unique mobile computing curriculum design focuses on given students an in-depth knowledge of comprehensive mobile computing development techniques. This is achieved by not only integrating mobile concepts into a few specific undergraduate traditional computing courses but across the curriculum [13]. This paper presents a new curriculum design that reflects nowadays existing mobile computing technologies. Some of the courses are lab intensive where students experiment with various mobile devices to develop and deploy applications. Also, the paper reports the teaching strategies, feedback, and challenges.**

Keywords- Mobile Computing Curriculum; Computer Science; Teaching Mobile Computing; Portable Devices; Mobile Development;

I. INTRODUCTION

Internationally, mobile computing is on the cutting edge of business software. Accessing information ”anywhere” and ”anytime” has been a driving force for the increasing growth in web and internet technologies, wireless communications, and mobile computing devices. According to Brahima Sanou, Director of the ITU[4]'s Telecommunication Development Bureau, Near-ubiquitous mobile penetration makes mobile computing devices the ideal platform for service delivery in developing countries [1]. This is due to the widespread use of mobile computing devices. Many universities in the world started offering a few mobile computing courses [3][21]. This enables computing schools' graduates to be familiar with mobile computing concepts that are essential within the rapidly changing environment of mobile computing, so that students can pursue a related career or further relevant academic study [13].

Mobile computing is interdisciplinary in nature and the name originated from two words mobile and computing [4] [7][8]. The word mobile refers to mobility of users, contents, and devices, while the word computing is any goal-oriented activities demanding algorithmic processes. Moreover, the area of mobile computing is the merger of computing and communication with the aim of providing seamless and ubiquitous computing environment for mobile users. This “mobile shift” in computing poses fundamental challenges for virtually every curriculum designer, and calls into question most established assumptions about how to implement a curriculum to provide a broad based educational experience of mobile computing to students that reflects todays existing computing technologies rather than improving traditional computing courses in the fields of computer science and computer engineering [5][6]. This paper is the author's attempt to design a new curriculum and teaching strategies of mobile computing program with new mindset that reflects newly emerged theories, techniques and paradigms relevant to mobile computing.

Therefore, the paper is organized as follows: Section 2 gives an overview of the current state of the art and summarizes the paper. Section 3 present previously published papers on mobile computing curriculum and survey of selected universities offering some courses on mobile computing. Section 4 introduces the program framework that contains our goal and philosophy of the program and descriptions of the courses and topics covered. Section 5 presents the teaching strategy for the new curriculum. Section 6 describes several challenges in designing the curriculum and teaching strategy of our program. Section 7 presents the results and feedback. Section 8 concludes the paper and gives possible future work.

II. STATE OF THE ART

Recent years have shown that computing is moving towards an increasingly mobile computing environment with wireless laptops, smart phones, handheld computers and even wireless printers and digital cameras. All of these devices need to be programmed to interact correctly, increasing the demand for these programming and design skills. This demand prompted many universities in the world to introduce mobile computing courses to their undergraduate computer science and computer engineering students. By scanning the literature, we can see that mobile computing courses are only taught as introductory CS and CE courses. For example,

- **In computer science curricula**, the courses introduce the student to mobile software development. The courses focus on building mobile native and web applications [2].
- **In computer engineering curricula**, the courses focus on introduction of mobile and wireless networks.

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However, increasing number of universities has started new mobile computing undergraduate programs leading to bachelor degrees in computer science and engineering with specialization in mobile computing.

- **In computer science curricula**, the programs emphasize on topics which require specialized knowledge from only one particular aspect of mobile software development. For example, interface design issues, multimedia, or graphics design for mobile devices [20].
- **In computer engineering curricula**, the programs focus on mobile communications systems or embedded systems within the context of mobile devices.

In the above universities, the approaches of mobile computing courses taught in the CS and CE curricula are either introductory or intensively focused on one particular area of mobile computing. Our approach differs from existing mobile computing curricula by avoiding too much specialized knowledge from one particular area of mobile computing. The goal of our suggested mobile computing curriculum is to provide students with various courses of computing such as software development, cloud computing, security, multimedia, wireless communication, database, virtual communities, operating systems, human-computer interaction, and game graphics design within the context of heterogeneous mobile devices.

III. BACKGROUND

The ACM/IEEE Computer Science Curriculum 2013[17] lists Mobile Computing as an elective course under the "Platform-Based Development (PBD)" Body of Knowledge and as an core 1 tier 2 topic under several" Knowledge Areas such as "Human-Computer Interaction (HCI)", "Networking and Communication (NC)", and "Social Issues and Professional Practice (SP)". Also, the ACM/IEEE Computer Engineering Curriculum 2004[18] lists Embedded Systems as a Body of Knowledge and also lists Wireless and Mobile Computing under "Computer Networks" Body of Knowledge. The ACM/IEEE Curriculum concluded that it is important for both computer engineering and computer science undergraduate students to be familiar to the concepts of Mobile Computing.

Recently, many papers have been published related to teaching and curriculum of mobile computing. Those papers are as follows:

- Instructors sharing their own teaching strategy of mobile computing class [11][13][14].
- Instructors sharing their mobile computing concepts into the course's topics [12][15][16][20].

A study conducted on selected universities offering a study of mobile computing course(s)**.** From the survey, it can be seen that universities are using five models to integrate mobile computing into their computer science and engineering curricula [19]:

1. Offering undergraduate courses on mobile computing.
2. Offering graduate courses on mobile computing.
3. Integrating mobile computing concepts into their traditional courses.
4. Combining model 1, 2, and 3.
5. Offering mobile computing as an area of research to their graduate students.

Model 1 is used by several universities such as Stanford University, University of Maryland, and Zhejiang University. The majority of universities that have graduate programs are using model 2. Some universities are using Model 3 and integrating mobile computing concepts as topics in their existing courses, as seen by the University of Guelph. The University of Bridgeport, Carnegie Melon University, and Massachusetts Institute of Technology are employing Model 5. Furthermore, an increasingly number of universities such as Middlesex University, Carleton University, Oxford Brooks University, Webster University, and Newcastle University started using a more aggressive approach by offer mobile computing program leading to BSc degree specializing in mobile computing.

In a relevant issue, mobile devices have become attractive learning devices for education. Almost every university student uses a mobile device for both personal and academic reasons [22].

Mobile learning (m-learning) is more flexible, interactive, involving more contact, communication, and collaboration with people than e-learning. Given this environment, we believe that the value of using mobile technologies to support teaching and learning lies in integrating mobile technologies with the current e-learning environments in which the university has made major investments. A project is started to capitalize on these enormous array of mobile devices to promote communication, collaboration and learning. This project is aimed to investigate the development of the Mobile Assistant and Registrar System (MARS) using Cloud Services for the Faculty of Information Technology at the University of Tripoli. The MARS project started with an idea crossed the mind of the author. MARS attempts to alleviate the hassles that students face when registering courses using the existing simple on-line registration system. MARS provides several assistance and course registration services to students, staff, and faculty members through mobile devices.

The project development phases are divided into several smaller projects. A Student task is to choose a MARS project and implemented on a semester or a year long project as part of his/her Mini Project or Senior Project. This collaboration with students and faculty members can help the Faculty of Information Technology enhance classroom activities and learning, as well as administrative functions by integrating mobile technologies with its e-learning environments.

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IV. PROGRAM FRAMEWORK

Our suggested mobile computing program curriculum focuses on building an in-depth knowledge of advanced mobile computing and development techniques. Because basic mainstream computing skills and knowledge are still required by academia and industry, our curriculum is divided into two components. The two components are defined as follows:

TABLE I. SHOWS COURSES OF THE CC.

Introduction of Computing	Introduction to Programming	Operating System	Foundations of Database
Data Structure & Algorithms	Computer Organization	Computer Networks	Problem Solving Techniques
Basics of Information Security	Software Engineering	Internet Development	Discrete Mathematics
Object Oriented Programming	System Analysis		

- **Computing Component (CC).** It contains courses drawn from computing-related disciplines such as mathematics, statistics, physics, and computing. In the area of computing, students are required to take some traditional courses in area of computer science and computer engineering. The CC courses are listed in TABLE I.
- **Mobile Computing Component (MCC).** All mobile computing-related courses are placed in this component. The MCC courses are listed in TABLE II and TABLE III.

With both CC and MCC are defined. Why is it necessary to split the curriculum into two components, namely, CC and MCC? The answer to that is in the very real differences between the two. MCC is, to an extent, CC, but CC is not necessarily MCC. What this means is CC is not just a single discipline but it is a family of disciplines and therefore meets the definition of CC. In addition, CC may or may not incorporate mobile devices in its educational content and as such may or may not meet the definition of MCC. In many ways, CC acts as a pillar to MCC. The courses in MCC have one or more prerequisite courses from CC designed to ensure adequate preparation for courses in a sequence. This strategy allow students to gain broad knowledge of computing-related disciplines covered in CC, and then gain advance knowledge of mobile computing-related discipline covered in MCC. For example, foundation of database course in CC is a prerequisite to mobile database course in MCC, and operating system course in CC is a prerequisite to mobile operating system course in MCC, and so on.

TABLE II. THIRD YEAR COURSES IN MCC.

Course Number	Course Name	Course Content
ITMC 311 (L P)	**Mobile Applications**	C#, Objective-C, and Java Mobile Applications programming foundation.
ITMC 312 (L P)	**Personal Area Networks**	Concepts, Architecture, Design, Performance Evaluation, Protocols, and Applications.
ITMC 313 (L P)	**Mobile Operating Systems**	Using Architectures of (Android, iOS, Windows).
ITMC 321 (L P)	**Mobile Interaction Design**	User Behavior, Interacting with Information, and Theoretical Models of Movement and Perception.
ITMC 322 (L P)	**Heterogeneous and Mobile Databases**	Extensively discusses Multi-Database Systems (MDBS) and Mobile Data Access Systems (MDAS)
ITMC 323 (L P)	**Principle of Wireless and Mobile Networks**	Introduction to Mobile and Wireless Networks.
ITMC 324 (L P)	**Application Development with Java ME**	J2ME using the following Models: Web Applications using Mobile Client Frameworks, and Native Applications using appropriate SDKs.

The advantages of our suggested mobile computing program curriculum can be summarized as follows.

- Allows students to gain fundamental knowledge and skills of computing-related disciplines by taking courses in CC. Then, students enhance and apply their transferable knowledge and skills in courses taken in MCC.
- Varieties of text books available that teach the fundamentals of computing such as programming, database, networking, and computer architectures. This variety of text books might not be available in the area of mobile computing, while those acquired knowledge will be useful in leaning the courses in the MCC.
- It simplifies teaching.

In this curriculum, MCC contains elective courses in which students can select five courses. These courses may emphasize on topics relevant to mobile computing area. Examples of elective courses are the following courses:

- ARM Microprocessor
- Programming Paradigms

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- Mobile Commerce
- Topics in Compilers Construction
- Mobile 3D Graphics
- Parallel and Distributed Computing
- Mobile Game Developments
- Topics in Mobile Computing
- Faculty Free Elective

As an interdisciplinary curriculum, non-technical schools and institutions across the university can contribute to the curriculum by creating specialized elective components (SECs). For example, the School of Arts and Media may integrate a SEC (Media Design) in this curriculum by choosing five specialized electives courses from its school. As a result, students will have a unique opportunity to take selected classes from other programs as part of their degree.

V. TEACHING STRATEGY

The teaching strategy for the new curriculum is enable student to gain theoretical and practical skills of the entities in mobile computing (mobile contents, mobile communications, and mobile devices), and not only how to design, develop, and then test mobile applications on various mobile devices. As shown in TABLE II and TABLE III, some courses are tagged with two letters "L" or/and "P". The letter "L" indicates that the course requires supervised lab. While, the Letter "P" indicates that the course require mini project. The project can be a group project. Except for ITMC 324 course, programming languages and mobile platforms used in this curriculum is not glued into a particular language or device. This will give student an opportunity to learn application development running various environments such as Android, Windows, and iOS. To elaborate further on course content and teaching strategy, some selected courses in MCC are discussed below:

ITMC 311 Mobile Applications:

Prerequisite courses: Object oriented programming course, problem solving course, and data structure and algorithms course. Since a student entering this course has a basic knowledge of programming in a particular language, object-oriented concepts, and problem solving skills, this course covers the principles of mobile analysis, design, and development concepts using various languages such as C#, Java, and Objective-C running on iOS, Android, and Windows. This way a student is focused on mobile application development at the same time exposed to various languages and platforms. At the end of this course, student has experienced mobile developments using different tools, languages, and platforms.

ITMC 324 Application Development with Java ME

Prerequisite courses: Mobile applications course. This course covers advance mobile applications development using J2ME mobile application programming for mobile platforms using the following models: Web applications using mobile client frameworks, and native applications using appropriate SDKs.

TABLE III. FORTH YEAR COURSES IN MCC.

Course Number	Course Name	Course Content
ITMC 411 L P	**Security in Mobile Computing**	Mobile computing. security and privacy from the prospective of (mobile interaction, mobile application, wireless communication)
ITMC 413 L P	**Social Networking**	Architectural Principles for Heterogeneous Social Networking Platforms, Social Concepts, Agent-Based Computing, and Information Exchanged between Community Members.
ITMC 421 P	**Fundamentals Ubiquitous Computing**	The visions of Ubiquitous Computing and some of its applications, such as Location, and Context Awareness in Ubiquitous Computing.
ITMC 422 L P	**Cloud Computing and Mobile Applications**	Cloud Computing Services and Infrastructures (Virtualization, plus Developments of Mobile Apps that interacts with the Cloud.
ITMC 423 L P	**Mobile Multimedia**	The Creation, Delivery and Analysis of Multimedia Content in Systems with Mobile Devices

ITMC 411 Security in Mobile Computing

Prerequisite courses: Mobile applications course, principle of wireless and mobile networks course, and mobile interaction design course. Topics covered are select from multidisciplinary: Mobile interaction (Principles of usability, security, and privacy; Methodologies for evaluating usable security; security and usability analysis Phishing and Risk; Knowledge-based authentication; Biometric and alternative authentication; Security and privacy; Usable security software design principles; Human-in-the-loop design framework; Security indicators and warnings; Usable security for security administrators). Mobile application (Mobile Platforms, mobile services). mobile communication systems (Mobile cellular telephony. Wireless internet; Mobile ad hoc; Sensor networks).

ITMC 422 Cloud Computing and Mobile Applications

Prerequisite courses: Heterogeneous and mobile databases course, and social networking course. Topics covered: Cloud computing services and infrastructures; development tools; fundamental tradeoffs and algorithms and

applications. iOS, Windows, and Android programming to develop mobile applications with backend storage, and computing components running on the cloud; Accessing cloud services with mobile devices; Extending mobile applications with cloud processing and resources; Extending cloud services with the collective power of mobile devices; Partitioning of service functions between mobile devices and clouds; Data management for mobile cloud.
Next, a discussion of assignments, exams, labs, mini projects, and senior projects is presented.

Assignments
Due diverse areas of MCC courses, the assignment deadlines should be flexible. The instructor needs to remember that some of the students will have to learn some extra material on their own in order to do the assignment.

Exams
Initially, students are expected to do two midterm exams plus final exams. Due to emphasize of hands-on experience, instructor can have one midterm exam instead of two. Marks are split evenly between exams and assignments on one hand and projects and labs on the other hand.

Labs
A mobile computing education requires hands-on experience because you can't give in-depth explanations of many abstract mobile development concepts without practical hardware and software demonstrations. We use two types of labs (supervised and unsupervised) to enhance students' learning. As it stands today, all faculty members owns at least one laptop and mobile devices are now necessary tools in students' daily life. These mobile devices create mobile lab since a classroom can be easily converted into a lab. Also, students are encouraged to use their mobile phones.

Mini Projects
In addition to the assignments, students are required to be organized into teams, of at most two students, to work on semester long projects. Based on the particular course, projects are either hands-on intensive programming or/and survey type projects. The objective is that the students should choose a topic relevant to the course, study it on their own, (with help from the instructors) and will learn about in much more depth that they don't get from the class lectures. Students are required to provide periodic reports of their progress in addition to their final reports and presentations at the end of a semester. Furthermore, some of the term project topics can be chosen by students as their senior projects.

Senior projects
Senior-project students will soon be entering the workforce. Hence, it is important that graduates have full grasp of various aspects of mobile computing, as well as the ability to design and implement mobile systems and services. Senior-projects are a semester long and can be extended to second semester. The senior project must encompass the process of concept creation and development, testing, and debugging of the mobile application. Students will be applying collaborative skills to synthesize ideas and technical skills to create the "app" and conclude the senior project with a presentation of final application design and implementation. As mentioned earlier, senior project can be a continuation of mini project. A maximum of two students can work as team on senior project.

VI. CHALLENGES

The challenges can be view from the following perspectives:

Books perspective: Although, there are several books available that covering various aspects of mobile computing. For instance, textbook for mobile application developments focus only on one particular language and device. In our curriculum, the course "ITMC 311 Mobile Applications" covers the principles of mobile analysis, design and development using various languages such as C#, Java, and Objective-C running on iOS, Android, and Windows. Asking students to buy several books for one course in the MCC is a daunting task. Also, we could not find suitable text book that cover one aspect such as mobile operating system, mobile database, and mobile security that is not a collection of papers published in journals and conference proceedings.

Topics perspective: Mobile computing is a multidisciplinary topic and students are expected to be exposed to various areas. Hence, it becomes important to avoid dealing with topics or emphasizing on topics which requires too much specialized knowledge from one particular area. In our curriculum the course "ITMC 411 Security in Mobile Computing" covers the principles of mobile computing security from three angles, namely, mobile interaction, mobile application, and mobile communication systems. Also, new mobile technologies will continue to emerge, as a result, MCC's courses must adapt to changes and innovations occurred in its area.

Instructors perspective: The instructor should take into account the constant innovation nature of mobile computing for a particular course and adapt the course material and topics accordingly. This implies that the instructor should be ready to add and/or delete some of the initially planned course topics during the semester. This requires the instructor to integrate any emerging trends of mobile computing technology into corresponding course.

VII. RESULTS FEEDBACK

The university curriculum committee originally approved the mobile computing program in the Spring of

2013/2014. The new course "ITMC 311 Mobile Applications" was offered for the first time in fall of 2014/2015 in the software engineering program and internet technology program. The mobile computing program commences to start in Spring 2014/2015 academic year.

Yearly, the faculty hosts the Technology Days event. This event gives staff, faculty, and students an opportunity to learn about technologies on campus and participate in discussions of the current state and future innovations in the Faculty of Information Technology. The mobile computing curriculum was presented and a student questionnaire was conducted in the last day of the event. The students' responses we received were positive. Many students expressed enthusiasm to a great extent to enroll in the new program. Majority of the students stated the importance of gaining practical skills and broad knowledge in mobile computing area in their future career and academic endeavors.

At the end of the new course "ITMC 311 Mobile Applications", we asked students to complete evaluation surveys. Ninety percent of the students completed the survey. The following statements represent selected statements of the likert scale survey.

Statement. 1 The instructor presented content in an organized manner.

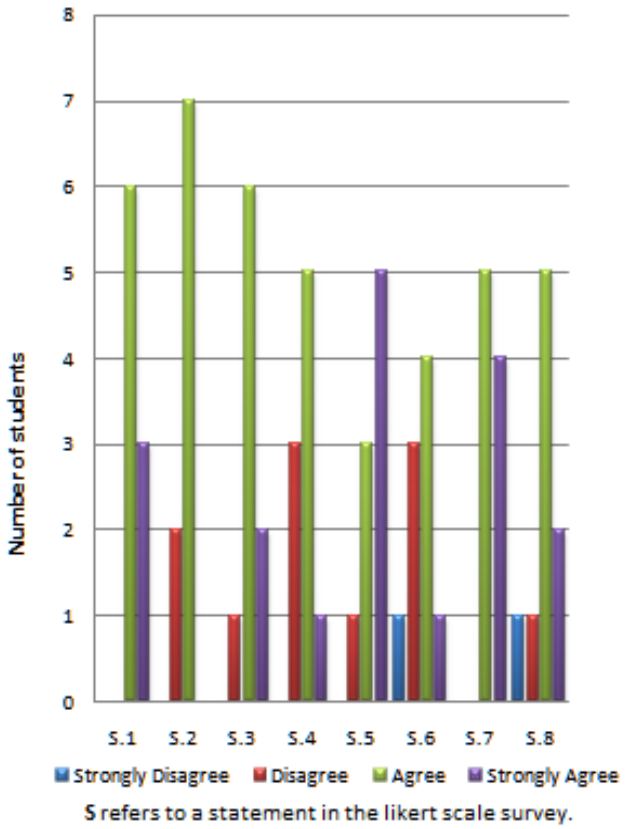

Figure 1. Students Results.

Statement. 2 The instructor presented content in an organized manner.

Statement. 3 The instructor helped me identify resources I needed to carry out the project.

Statement. 4 The course was appropriate for the stated level of the class.

Statement. 5 Course was difficult than what I thought.

Statement. 6 Mobile development was more educational than desktop development.

Statement. 7 I recommend my fellow students to take the course.

Statement. 8 The course encouraged me to develop mobile app in my senior project.

Statement. 9 I prefer to take more courses in mobile application development.

The overall response from students was positive. Figure 1 presents the students' response to the likert scale survey. In the open-ended questions students' responses were positive on how would you rate the overall effectiveness of the instructor's teaching? On the question of what did you like best about this course, most students expressed development of mobile apps on their smart phones. On the question of what did you dislike about this course? The response was marks should be better distributed to reflect the time spent to develop mobile applications. They suggested marks for labs should be higher than written exams. On the question of what was the most challenging aspect in this course, most expressed lack of previous practical programming skills.

VIII. CONCLUSION

We have presented our experience in designing and teaching strategy of an undergraduate level program leading to bachelor of information technology in mobile computing. Our unique mobile computing program covers various aspects of mobility in the area of computing. The curriculum is divided into CC and MCC. In the CC, students required to take courses in diverse set of areas such as mathematics, statistics, physics, and computing. In the MCC, students are required to take several courses in mobile computing area. The constant innovation effecting mobile computing area makes the curriculum in the MCC dynamic. This allows adaptation of innovation occurring in the mobile computing area to be easily adapted into our curriculum.

For future work, we will continue to integrate more area of mobile concepts across our program's curriculum as new technology in mobile computing emerges and changes in mobile paradigm arise.

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