Developing Interactive Classroom Exercises for use with Mobile Devices to Enhance Class Engagement and Problem-solving Skills*

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***Abstract*—A recent Pew research center study of mobile device usage revealed that, African American and Latinos are the most active users of the Internet from mobile devices. The study also revealed that minority cell phone owners take advantage of a much greater range of their phone's features compared with people of other ethnicities. At Winston Salem State University (WSSU), it is common for students to multi-task and use their mobile devices while in class for studying, or performing other activities. This paper reports our ongoing experiences running a National Science Foundation (NSF) - sponsored targeted Infusion Project (TIP) in Computer Science Department that aims to leverage this situation by developing a mobile classroom response system (MRS) to allow students solve interactive problems in their mobile devices in order to improve their class engagement and problem solving skills. By allowing them to solve problems in their preferred devices, the project expects to create a friendly learning environment where the students want to retain, be active and skillful.**

Keywords—Mobile Application, Interactive Exercises, Active Learning, Problem Solving, Evidence-based Teaching.

I. Introduction

Recent statistics indicates that although being about one third of U.S. populations, only 10.3% of bachelor's degrees in computer science are granted to underrepresented and minority population [1]. It is also reported that minority students express the desire to go into CS and other STEM major at the same rate as students with other ethnicities, however more minorities switch to another major after being enrolled to a STEM program [2, 3]. Similar crisis is being experienced at the CS department of Winston-Salem State University (WSSU), an HBCU (Historically Black Colleges and Universities), in terms of students beginning with CS/IT as their major and then dropping out or changing their majors. A major proportion of the student who choose to stay in computing field also encounter significant learning barriers which prohibits active participation and persistence in learning. Many of our CS undergraduates are first generation college students in their families and lack of direction and proper guidance from their families typically cause an obstacle to perseverance in learning. Additionally, many of them have a low sense of self-efficacy regarding the mathematical, programming and technical aspect, which prevents them from actively participating in the classroom environment.

Researchers at Rochester Institute of Technology have reported that their use of a technology-rich learning environment in several undergraduate engineering-technology courses has improved learning and decreased withdrawals from, or failing grades in, the courses [4]. Boston University [5] adopted tablet-based problem solving exercises in their freshman mathematics class and reported noticeable increase in student attendance and course completion. Many other approaches [6, 7, 8] also reported enhanced educational experiences when technology such as mobile devices has been adopted in the classroom for students to participate and solve problems.

2010 Pew study of mobile device usage [9] revealed that African American and Latinos are the most active users of the Internet from mobile devices. The study also revealed that minority cell phone owners take advantage of a much greater range of their phones' features compared with other ethnicities. At WSSU, it is common for students to multi-task and use their mobile devices while in class, studying, or performing other activities.

Inspired by the Pew study and the reported impact of utilizing technology-rich class environment at other institutions, our project aims to design, develop and incorporate a Mobile Classroom Response System (MRS) in order to enhance student's engagement, active learning and problem solving skills at WSSU. By using mobile devices, we expect shy students to interact anonymously and participate in class discussions. By asynchronously prompting students with interactive problems related to the lecture material in their mobile computing devices, we expect students to maintain more focus on the course content being presented and ultimately to learn and retain information better.

The rest of the paper is organized as follows: Section II details the proposed intervention along with its activities, the expected outcomes and significances. Section III describes the implementation and current status.

II. The Intervention

A. Tecahing Model

In order to achieve our goal of maximizing class engagement and active participation, we utilized a feedback-driven and evidence-based teaching methodology. In our model, the faculty dynamically prompts student with interactive exercises related to the lecture material in their mobile computing devices. The interactive exercises are

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broadcasted from a question bank located at MRS server. In an interactive exercise, students have to develop the answer following a set of steps guided by a particular algorithm or process. In each step, students have to make key choices that will have impact on the next step of the interaction. During these interaction steps, students can go back and forth and see the impact of their different choices. Interactive exercises can be offered as solving a whole problem from bottom-up or top-down or solving certain steps of a particular problem in order to give students different perspective on the problem and assess their problem solving skills. Once the student traverses each of the steps or the allotted time for the exercise expires, the results of their interactions performed at each step are then sent back to the MRS server as the student response. The MRS software automatically handles the grading of the exercises, by comparing the student made sequence of steps with the correct sequence of steps for a particular problem and immediately provides feedback to the students. After grading, MRS also makes the grading statistics and student submissions available for the faculty to view and share with the students. By using MRS software, students can also send anonymous feedback/questions to faculty and vote on questions that faculty will choose to discuss at the end of the class. There are many classroom response systems (CRS) are available to enhance student learning, however the proposed system aims to deal with multi-step interactive exercises instead of true/false or multiple choice exercises handled by most CRS [10].

The above model allows the faculty to have real-time evidence of students' comprehension of covered lecture materials on a particular class and also helps faculty to identify the concepts that need to be repeated or reinforced. By utilizing MRS software, faculty is also able to instantly capture screens from student submissions and discuss on those screens if context-sensitive feedback is needed to provide. On the other hand, this approach allows the students to obtain immediate and frequent feedbacks that reinforce their learning and helps them to identify problem areas. The active interaction with a problem via multiple steps while going back and forth and seeing the consequence of their choices at each step is expected to enhance students' analytical and problem solving capabilities.

B. Proposed Activities

The proposed project includes four distinct activities: 1) development of the MRS software, 2) development of interactive problem solving course modules and corresponding rubrics that can utilize the MRS software, 3) deployment of the software and course modules in target classes at WSSU, and 4) assessment and documentation of progress toward our goal and performing continuous improvement. The purpose of the MRS software is to provide a collaborating and responsive environment where students can solve their problems in an interactive way and communicate their solutions with the instructor and the instructor can communicate questions, answers, feedback and student performance data with the students. The developed MRS software and corresponding course modules will be deployed in one sophomore (Introduction to Hardware Organization) and one junior (Analysis of Algorithms) course, which are required courses for both CS and IT majors and involve use of mathematics and problem solving. A comprehensive evaluation framework will be utilized for assessment and evidence-based continuous improvement. The project team includes a faculty from Education to formulate and execute evaluation and assessment and an external evaluator to review, assess and guide the project evaluation towards achieving the desired goals.

C. Expected Outcomes

We expect that the adaptation of MRS in the classroom will increase student engagement and active learning. Also, students will improve their problem solving capabilities and therefore be prepared better to enter the computing workforce or graduate study. By incorporating mobile devices in learning and classroom interaction, Computer Science department at WSSU is also expected to increase its effectiveness to attract and retain students.

D. Significance to the Education Community

This research is expected to enhance the understanding of developing an interactive mobile response system and how to use mobile devices in the classroom to improve student's class interaction and problem solving skills. The successful execution of this project will advance research and the knowledge of mobile device usage in CS classrooms and more importantly the way it impact teaching strategy and student learning at WSSU and other institutions. The work seeks to explore the transformative power of the adoption of mobile technology in classroom environment to improve educational experiences.

It is expected that this project will invigorate interest in Computer Science among students through exposure to the technology-rich learning environment. By enhancing student learning and problem solving abilities, it is also expected that this project will improve the quality and quantity of underrepresented minority students in STEM workforce or graduate study. The instructional software system, course modules and study results will be disseminated through websites, publications and presentations and other institutions can effectively incorporate them in their undergraduate CS curriculum. The project will also enrich the teaching strategies of educators of minority-serving and other institutions by including a diverse set of active learning components.

III. Implementation

A. MRS Design and Architecture

The MRS software is designed as a client-server application and Fig. 1 depicts its overall structure. In this design, MRS clients can be diverse set of computing devices as long as they have the developed client app installed in them to interact in the class. The MRS server (or the faculty computer) broadcasts the questions, collect student submissions, and manage the submissions for display and for grade calculation purposes. The server is the secure entity in this software architecture, which holds the databases for questions, and their corresponding answers and grading rubrics. It also has the required data analysis component to tabulate student submissions and produce easy to interpret reports and graphs. The server also keeps track of every user in the system with their credentials and privileges and can incorporate student user information from the corresponding course shell of a course management system such as BlackBoard, Moodle etc. The server constantly monitors whether students wants to initiate a feedback/question/voting session from their mobile devices and handles the request appropriately. Currently, we are using Android based mobile devices for client and Java for the server. During deployment students can use their own device (has to register first and install client App) or they can use tablets (supported by the grant) that are readily available and equipped with client App.

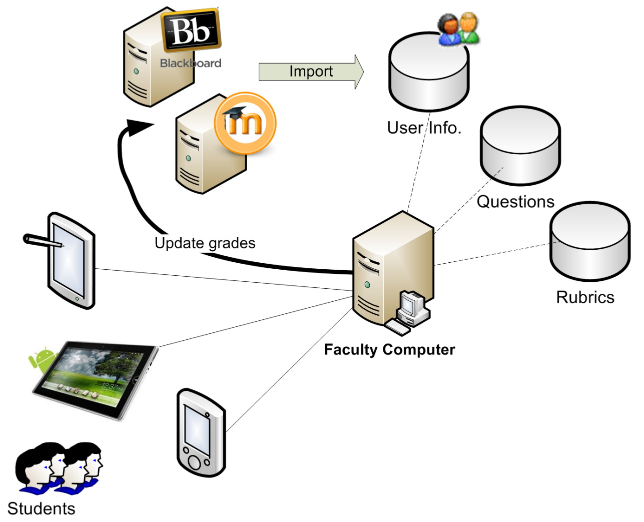


Fig. 1. MRS system organization.

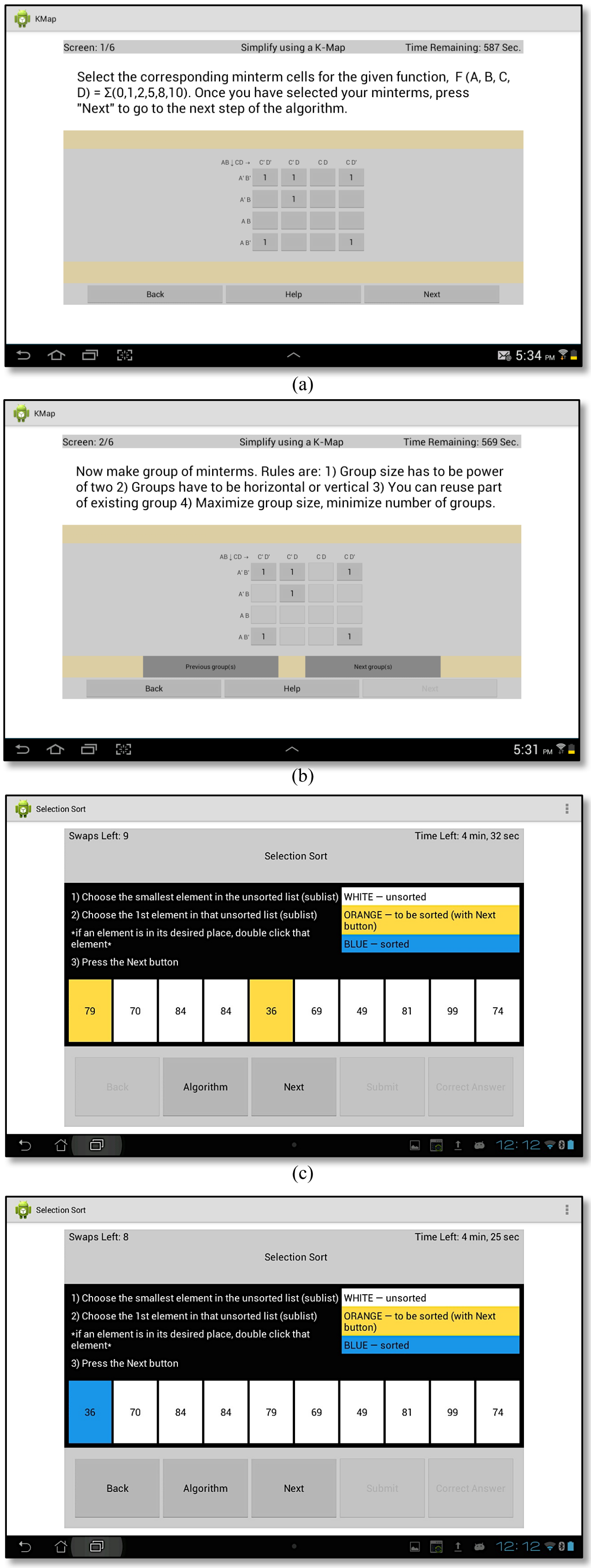
B. *Interactive Exercises*

Instead of merely watching the faculty lecturing on a topic, the proposed pedagogy aims to use frequent interactive exercises during class period to get students to respond and interact with information in a non-passive way and to get them to construct and modify virtual artifacts while providing them immediate feedback based on their interactions. The interactive exercises are designed as dynamic entities rather than static entities to support greater diversity and to allow students to practice with different variations of a problem. The exercises are therefore parameterized, where parameters are populated with randomly generated values to create different instance of a problem.

Developing fully interactive exercises is time-consuming, as the developer has to consider various scenarios that can arise because of different ways a student may choose to interact and various feedbacks that the computerized application needs to provide in those scenarios. Our goal is to develop exercises to support three to five key concepts in each of the selected courses. Fig. 2(a) and 2(b) shows intermediate screens of the exercise that was developed for assessing the student understanding of Karnaugh map (K-map) simplification algorithm in the Hardware Organization course. Fig. 2(c) and 2(d) showing the transition screens of an exercise developed to assess the comprehension of Selection Sorting Algorithm in the Analysis of Algorithm course.

C. *Assesment of Student Submissions*

Integrated and effective assessment of interactive exercises is another major goal of this study. Few researches support integrated assessment of interactive exercises such as TRAKLA [11], JHAVE [12] and OpenDSA[13]. However, they are built for a different platform and utilized technologies such as HTML and Javascript in their



(d)
Fig. 2. Intermediate screens for developed Interactive exercises.

implementations. There are issues that must be addressed in order to an effective assessment system including:

1. How often to intervene students with exercises during a 75 minutes class period?

2. How to effectively assess student submissions? Interactive exercises typically have multiple steps and each step has "what happen next" scenario that the student needs to determine. The assessment therefore needs to be based on number of correct steps, not on one single final answer. For a particular randomly generated problem instance, correct sequence of steps need to be generated and saved at MRS server to compare with student made sequence of steps. Much effort is needed in order to create and organize correct sequence of steps for a problem instance and effectively utilizing them during assessment.

3. How to effectively visualize overall class performance for the interactive exercises that include multiple stages?

4. How to store student responses (for example, capturing student screens at each stage) in a manner that makes it easy for instructor to share and analyze it? While sharing a particular submission for the purpose of discussion, how to respect respective student's privacy?

5. How to use the results of the assessment to reinforce /repeat concepts or enhance future learning?

While some of the above issues have been resolved (such as #2 and #4) with some preliminary approaches, the others (such as #1, #3, #5) require more investigation and experimentation before an effective choice can be made. As the exercises are being developed and deployed in classes in coming semesters, we hope to gather better understanding of how to resolve/improve them in near future.

D. Evaluation Plan

The primary aspect of this project is the proof-of-concept development of MRS software, interactive exercise modules and their deployments in respective courses. The baseline data are being collected during the last few offerings of the concerned courses and will be utilized in evaluation and comparison. More specifically the following evaluation metrics will be utilized

- Completeness and quality attributes of MRS software.
- Number of interactive exercises developed.
- Student performance data
- Pre-test/Post-test data
- Student survey data
- Faculty observation data
- Adoption of developed material outside of WSSU

E. Current Status

The MRS system is operational now and its scalability, responsiveness and reliability parameters are being tested and so far they all fell within accepted ranges. Currently in the target courses, students are dynamically being prompted with interactive exercises related to the lecture material in their mobile computing devices and the instructors are receiving real-time formative assessment as the students work through the steps of solving the exercises. Preliminary student feedback shows enhanced learning experiences as students maintain more focus on the course content being presented and immediately apply their knowledge to solve problems in an interactive way. The formal pre- and post-tests based assessment will be undertaken starting from Fall, 2014 and at the FIE conference in October, we hope to present the initial assessment data gathered on the intervened cohort of students.

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