MRS: Automated Assessment of Interactive Classroom Exercises

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ABSTRACT

Classroom formative assessment augmented with timely and frequent feedback has become one of the most prominent teaching practices in education research. On the context of Computer Science (CS) courses that expose students to the functionality and dynamic aspects of various algorithms, traditionally, students are evaluated by exploring in-class paper-based exercises. In these exercises, they simulate the steps of an algorithm by drawing several instances of a diagram. This traditional approach is time consuming, is inherently difficult for students to express the dynamics of an algorithm, does not allow timely feedback, and restricts the number of exercises that students can practice and receive feedback on. Mobile Response System (MRS) is a software environment that facilitates in-class exercises and their real-time assessment using mobile devices and therefore focuses on addressing many of the above-mentioned problems. In this paper, we present results of eight semester-long studies using MRS in two of the required CS courses at Winston-Salem State University (WSSU). Our experimental evaluation shows the educational benefits of the proposed approach in terms of enhanced student retention of covered concepts, reduced failing rate, and increased student engagement and satisfaction.

KEYWORDS

Interactive learning environments; Mobile learning; Real-time assessment; Algorithm visualization.

1. INTRODUCTION

Since the pivotal work of Black and William [1], classroom formative assessment has become one of the most important teaching practices in education research. Bell & Cowie [2] defined it as the repeated use of assessment-based information to recognize and respond to students' needs to enhance learning. Many studies [3, 4] found the classroom formative assessment extremely effective when it is augmented with timely feedback. According to them, a timely and frequent feedback informs students about their current comprehensions and competencies, their progression toward learning, and assist and encourages students to take the next learning step [4].

In CS education, understanding the functionality and dynamic aspects of an algorithm is a crucial skill that every student should be proficient at. Traditionally, these concepts are hard for many students to comprehend as they are abstract and mathematical in nature. Therefore, careful consideration must be given to the methods that are used to assess the student understandings of these concepts in the classrooms. Usually, instructor evaluates the student comprehension of the algorithmic process by offering them paper-based exercises to solve, where they demonstrate their proficiency by drawing several instances of a diagram to simulate operations of an algorithm. While drawing these static images can aid students to mentally conceptualize the abstract phenomena described by an algorithm, it is very hard to simulate and comprehend dynamically evolving algorithms in terms of few diagrams. Moreover, it is time consuming and difficult to draw separate instance of a diagram to reflect each and every step of an algorithm, therefore often student tends to combine several operations of an algorithm (in many occasions by erasing the result of the previous stage with the result of the current stage) in a single instance of a diagram. This shortcut process often generates mistakes and confusions and impedes students' learning process. Time consuming nature of many of these practice exercises also implies that the manual grading can take several weeks for students to receive feedback on their works. As the class sizes grow, this in-class assessment model quickly becomes unsustainable and fails to offer any benefit. Even for a small class size and/or with substantial amount of grading resources (e.g. TAs), only a finite set of exercises can be made available to the students where they can receive feedback. Limited number of graded exercises also prohibits students from evaluating their understanding on a broad range of challenging tasks with various orders of difficulties. However, this exposure is very important in order to stimulate students' cognitive conflicts and engage them in higher-level thinking process.

The MRS [5, 6] project emphasizes on addressing the above-mentioned shortcomings of the in-class assessment model that traditionally instructors employ while teaching algorithms to the CS students. In particular, MRS framework facilitates in-class proficiency exercises and their real-time assessments using mobile devices. We argue that as mobile devices are becoming more pervasive and are being used profusely by students, it will be intuitive for them to perform visual and interactive exercises in their preferred devices. MRS is therefore designed as client server software that allows the instructor to dynamically intervene the students with carefully designed exercise Apps,

SIGCSE '18, February 21–24, 2018, Baltimore, MD, USA

ACM ISBN 978-1-4503-5103-4/18/02…$15.00
https://doi.org/10.1145/3159450.3159607

synchronized with the lecture material, in their mobile devices. Students are able to actively interact with the graphical representation of the exercise while recognizing the effect of their dynamic interactions visually at different stages of the algorithm and send their solutions back to the server computer. MRS then facilitates grading of the exercise automatically by comparing the student made sequence of interactions with the model sequence of interactions. Since MRS software automatically administers the delivery, time keeping and grading of these exercise Apps, instructor could use them more frequently in the classroom and learners could actively participate in more exercises where they can receive feedback. The overall aim of this mobile-based, visual, and interactive exercise is to activate students cognitively in understanding these harder concepts by making the learning processes more explicit and responsive to them. MRS accomplishes this aim in a novel way, by providing App-based visualization exercises, whereas other such systems provide web-based exercises.

Our previous works [5, 6] focused on exploring the design, development and deployment of MRS software environment and exercise Apps and evaluated its effectiveness within a single CS course where students' short-term knowledge acquisition and satisfaction were measured immediately after the MRS-enabled classroom interventions. We found significant evidence that MRS is effective in increasing student understanding of difficult concepts [5] and with MRS it is possible for the instructor to offer more hands-on-activities with increasing order of difficulties to the students during the class time [6]. We then extended MRS intervention to two of the required CS courses (one sophomore and one junior level course) at WSSU and studied MRS's effectiveness in students' long-time knowledge retention, perception of learning and perception of engagement for eight semesters. This paper summarizes the student-generated evidence of the strong and weak points of our interventions and also discusses some of the appealing and challenging aspects from an instructor's perspective.

2. MRS SYSTEM FEATURES

In MRS, the server component hosts questions, manages users, and maintains communication and synchronization, and the client component executes in learner's mobile devices and allows them to login to the system and facilitates interactive exercises. In current MRS implementation, the server has been developed in Java and the client has been developed in Android. MRS allows the instructor to import the interactive exercises (IE) within MRS and to broadcast them to students' mobile devices. When the MRS client receives a new exercise from the server, the corresponding App that renders the given exercise is executed, which allows student interaction with the App. The App then captures learner interaction at every stage (screen) and sends it back to the server for grading. When the server receives all answers back, it uses the corresponding server-side grading component in order to grade learner submissions and creates grading and other statistics.

In each of the IE Apps, students are required to work on a visual representation of a problem and to develop the answer following a set of steps guided by a particular algorithm or process. In each step, students make key choices (for example clicking the table or array indices for selection or swap, selecting from a drop-down menu, selecting a tree node or an edge of a graph etc.) that impact their next step of interaction. Table 1 lists the IE Apps that are utilized in this study along with their visualization and course information.

Table 1. Interactive Exercise (IE) Apps Details

App	Visual Representation	Which Course?
Interactive matching	Clickable 2-D array	Sophomore
Analytical answering	Free writing & word cloud	Sophomore
Truth Table formation	Clickable 2-D array	Sophomore
K-map simplification	Clickable 2-D array	Sophomore
Bubble Sorting	Clickable 1-D array	Junior
Selection Sorting	Clickable 1-D array	Junior
Prim's minimum spanning tree	Clickable logical graph and dynamic table	Junior
Dijkstra's single source shortest path	Clickable logical graph and dynamic table	Junior

The design and development of the MRS system and IEs are out of scope of this paper and interested readers are advised to explore MRS website [7] for downloadable modules and publications [5, 6] to learn more. However, following is a brief description of the important features of MRS, so that readers can gain a good idea about the intervention.

1. MRS supports immediate and automated grading of the interactive exercises. Once all answers are submitted, the server grades them and each student receives an email containing their grade for that exercise, the visual representation of the correct answer, and a visual representation of their submitted answer. The email is preferred as delivery method as screen captures can be attached and the information can be secured for future references. Immediate grading allows the students to obtain faster and frequent feedbacks that reinforce their learning and help them to identify misconceptions and problem areas.
2. MRS provides anonymous and summative grading statistics of the class which is calculated and projected instantly for the instructor to share with the students after each grading session. This instant visualization of class grade distribution allows the instructor to have real-time evidence of students' comprehension of covered lecture materials on a particular class and also helps instructor to identify the concepts that need to be repeated or reinforced. Students are also able to assess their progress toward learning the concept and to compare it with their peers in the class. Along with the grading statistics, MRS also analyzes a wealth of students' mobile device usage and interactions data (i.e. button clicks, time spent, navigation behavior etc.), anonymizes and summarizes them, and makes them available for immediate visualization. This summarized information allows instructor to better understand and interpret student mental model and attitudes during problem solving.
3. MRS also supports in-class anonymous communication, where students can send anonymous question/feedback to the instructor and additionally can vote on existing pool of questions (submitted by other students) that instructor may choose to review and answer at the end of the class.
4. MRS supports multi-step interactive exercises that typically spans into many screens, where students can transition between screens by utilizing "Next" and "Back" button. Pressing "Next" button will lead to a screen where students can see the results of their interactions in the previous screen reflected on the graphical representation of the problem, on the other hand, pressing "Back" button will undo all previous interactions. It is therefore possible to start the exercise from a clean slate by utilizing "Back" button multiple times.

5. In order to support unlimited practice and graded exercises, the interactive exercise Apps are designed to accept inputs as parameters, where parameters can be populated with either randomly generated values or instructor generated values to create many different variations of a problem. An exercise definition is stored as an XML file and contains exercise parameters such as problem components, time to answer, special instructions etc., which are used to render the corresponding App in the client device. The file additionally contains different rubric and grading parameters such as correct answers, grading weights, etc. to support server-side automated grading. Therefore, creating a new exercise instance (with input data and grading rubrics) does not involve changing any programming code. More importantly, one single exercise definition file can contain many problem instances and importing that file into MRS server allows the instructor to prompt the students with as many practice and graded exercises as the class time permits.
6. MRS uses step-wise grading and students can receive partial credit for partially correct answer. Checkpoints are utilized in the client devices to monitor students' interaction throughout the exercise. The system then formulates a sequence of interactions as student submission and compares them with the model sequence at the server to determine how much of the exercise was answered correctly. This grading methodology obligates students to correctly follow all intermediate algorithmic steps rather than guessing the final answer.

3. EXPERIMENTAL EVALUATION

We postulate that students' increased engagement with the mobile-friendly, interactive and instant-feedback nature of MRS, as well as visually seeing the consequence of their interactions in different stages of a multi-step problem, while going back and forth, will allow the students to comprehend and retain the subject material better. We are also interested to explore MRS's impact on various levels of students, students' open-ended feedbacks and instructors' perspective regarding the strengths and limitations of using MRS. Our Research Questions (RQs) are as follows:

1. RQ1 - Are the students using MRS become more engaged, retain concepts better, and enjoy enhanced learning than the non-intervened students?
2. RQ2 - Is there any notable difference between how the intervention impact CS sophomore vs. junior students?
3. RQ3 - What feedback do students from the intervened group provide regarding their experience?
4. RQ4 - What do the instructors, willing to deploy MRS in their classroom, need to consider?

3.1 The Study Setting

The MRS software and associated IE Apps were deployed in two courses during the period of Spring 2015 (S15) to Spring 2017 (S17) semesters with a total of 97 students being intervened. One course, entitled as, "Intro. to Computer Hardware Organization" (CSC 2320, offered with MRS during S15-S17 semesters) is a sophomore level course and the other is a junior level course, "Analysis of Algorithms" (CSC 3331, offered with MRS at S15, S16 and S17 semesters). Both courses focus on concepts involving functional dynamics whereas the junior (algorithm) course emphasizes on a large number of such topics.

Before MRS, both courses were taught with lectures, paper-based in-class assessment exercises, take-home assignments, midterm and final exams. During the intervened semesters, the paper-based in-class assessment was replaced with MRS-based IEs where students had a chance to practice some IEs before participating in multiple graded exercises while progressively being exposed to higher-order problems. For comparison, student performance data gathered during the F13 (N:11) and S14 (N:17) offerings of the sophomore course and the S13 (N:19) and S14 (N:11) offerings of the junior course were utilized as baseline data. The same instructor taught all offerings of a particular course and the course setting and teaching practices have been consistently maintained both before and during the MRS interventions. Table 2 shows some course and participant related information. In an effort to diminish the impact of confounding variables such as size, display and appearance of mobile devices, each student was provided with an identical Samsung tablet in the classrooms while performing IE Apps.

Table 2: Course-wise MRS Intervention Information

	Junior			Sophomore				
	S15	S16	S17	S15	F15	S16	F16	S17
#Students	18	19	14	14	8	8	5	11
#IE Apps	2	3	3	2	3	4	4	3
#Graded IE	4	10	7	3	8	10	13	10

3.2 Study Design

In a typical intervened class of 75 minutes, the instructor spent the first 30 minutes to convey a lecture covering a specific concept and problem-solving exercises related to that concept by utilizing slides and whiteboards. In the next 15 minutes, students applied their understanding of the concept by practicing some IEs, followed by completing the first graded IE (same paper-based exercise was offered to the control group), which is similar to the already lectured examples in terms of the degree of difficulty. As all students received instant email with their answers and correct answer after completing the first graded IE, instructor then spent the next 5 minutes pointing out the mistakes and clarifying the concepts more. The next 10 minutes were spent by the students solving a second graded IE, which is of higher order of difficulty than the examples and exercises covered previously. The following 5 minutes were spent by the instructor to reinforce the topic and correct student misconceptions (if any). Students spent the last 10 minutes of the class performing a difficult graded IE that required critical thinking and involved unfolding scenarios that were not explicitly taught before. It should be noted that this is a tentative outline of activities and there is room for flexibility (e.g. having two or four graded exercises instead of three) depending on the difficulty of the lectured concept, student comprehension level and amount of questions that they have, and other class logistics.

3.3 Metrics

In order to measure students' retention of knowledge in the long term, we utilized the final course grade as evaluation metric. The graded MRS-based class exercises contribute toward 10%-15% of the total course grade. However, student's long-term knowledge acquisition is further tested on the same topics during the midterm and final exam and each of these exams contributed 15% to 20% toward the total course grade. In addition to that, course failing rates are also considered as a measure of knowledge retention.

To assess student engagement and perception of the MRS environment and its overall effectiveness, an anonymous experience survey (Table 3) was offered to the learners only after they completed all MRS related in-class activities. The students gave their opinion about eight statements using a Likert scale of four values (Strongly Agree, Agree, Disagree and Strongly Disagree), with an agreement scale ranging from strongly agree (4) to strongly disagree (1). The survey questions were then grouped into thematic categories of *perception of learning* and *perception of engagement*. In order to ensure that students are actually looking at the content of the survey, not just "clicking through", the survey was designed to contain both positive and negative questions. Additionally, the survey includes following two open-ended questions.

1. Tell us about the MRS features that you found to be most useful.
2. What would you suggest in order to improve MRS environment or your experience?

Table 3. Thematic Categories of Student Survey Questions

Questions about Students' Perception of Learning
Q1. MRS is helpful in understanding concepts such as A, B & C.
Q2. MRS helps in visualizing the steps in A, B & C.
Q3. Using MRS did not improve my understanding of A, B & C.
Questions about Students' Perception of Engagement
Q4. I am enjoying this experience.
Q5. I feel competent & confident to solve problems in MRS than in a pen- and paper-based setting.
Q6. The A, B & C Apps are intuitive and easy to use.
Q7. Seeing my grades immediately after taking the exercises is really helpful.
Q8. Learning to use MRS software & related Apps is additional work beyond normal course work.

3.4 Results & Discussions

Final Course Grade: Table 4 shows the descriptive statistics for final course grade (out of 100) attained by the intervened and non-intervened group of students in the junior and the sophomore classes. The results indicate that the average grades attained by the treated groups in both classes are significantly higher than the average scores attained by the non-treated groups. The treated group also performed more uniformly than the control group, which is reflected in its much lower standard deviation value. A two-tailed independent samples t-test assuming unequal sample variances, with 5% significance level, was performed on the final course scores and shows significant differences between groups for both courses. The results also show that the sophomore students were benefitted marginally more than the junior students due to the use of MRS. These results affirmatively answer RQ1 and verify that the students, who are intervened with MRS, learned contents better and had better retention of topics covered over the entire course than the non-intervened group of students. The results further confirm that the MRS impacts different levels of students slightly differently and positively answer RQ2.

Course Failing Rate: Fig. 1 shows the comparison of overall course grade distributions for the junior class during the intervened (S15, S16, S17) and the non-intervened (S13, S14) semesters. On average, 28% of the non-treated group of students received a course failing (D/F) or withdrawal (W) grade, on the other hand, only 9% of treated group of students received the D/F/W grades. Interestingly, although the average percentage of students receiving A or B grades remain the same (59%) in both treated and non-treated semesters, the percentage of students receiving A grade enhanced from 19% to 34% in intervened semesters. This observation indicates that along with reducing course failing and withdrawal rate, MRS intervention was also helpful for average or above average students, who otherwise would receive grade B, however with MRS intervention they were able to enhance their understanding and achieved higher grades.

Table 4: Descriptive Statistics of Final Course Grade

	Junior Control (N: 30)	Junior Treated (N:51)	Sophomore Control MRS(N:28)	Sophomore Treated (N:46)
Average	71.2	81.30	73	84
Std. Deviation	26.2	15.27	19.1	12.1
F-Test	F = 2.91, p = 0.0004		F = 2.45, p= 0.002	
T-Test	**t = -2.19, p = 0.031**		**t = -2.97, p = 0.004**	

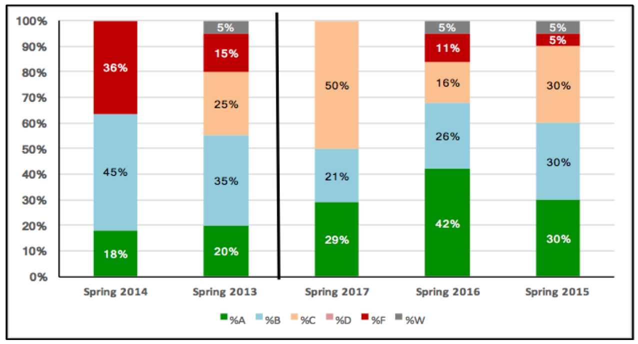

Figure 1: Grade Distributions for the Junior Class

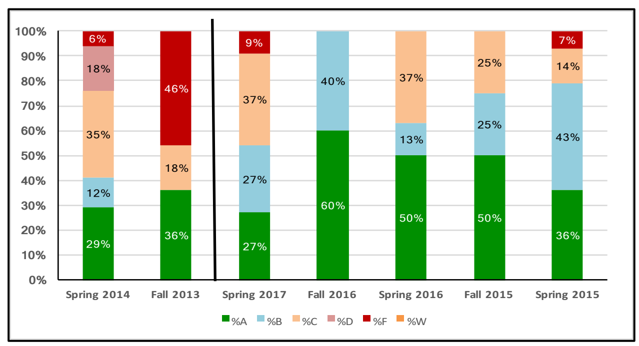

Figure 2: Grade Distributions for the Sophomore Class

Fig. 2 details the grade distributions for the sophomore class during the intervened (S17, F16, S16, F15, S15) and the non-intervened (S14, F13) semesters. Similar to the junior class, MRS intervention helped in reducing D/F/W rates from 35% to 3%. Unlike the junior class, the percentage of student receiving A or B grade enjoyed a substantial enhancement from 39% in non-intervened semesters to 74% in intervened semesters. Similar to the junior class, on average, more students received an A grade in treated semesters (45%) than the non-treated semesters (33%). These results, again, positively confirm both RQ1 and RQ2.

Student Survey: Table 5 shows the descriptive statistics for the student survey results gathered during all intervened semesters and thematically organized into two categories such as *perception of learning* and *perception of engagement*. These results represent a strong student approval of the proposed approach and positively attest RQ1. While considering positive questions (only) for all intervened semesters, students on average reported very high levels agreement on perceived learning and perceived engagement

Table 5: Descriptive Statistics of Student Survey Results.

	Perception of Learning	Perception of Engagement
Junior Class (N: 47)	Mean = 3.76 Stdev = 0.02	Mean = 3.6 Stdev = 0.02
Sophomore class (N: 42)	Mean = 3.71 Stdev = 0.19	Mean = 3.62 Stdev = 0.20

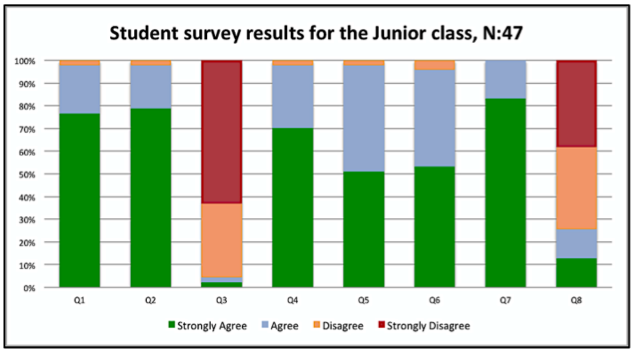

Figure 3: Survey Responses for Junior Class

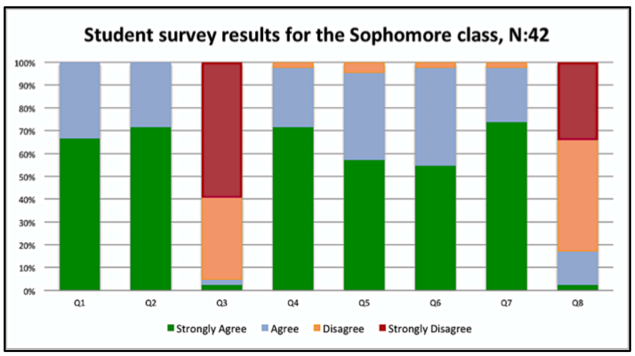

Figure 4: Survey Responses for Sophomore Class

for both classes (Table 5). In order to investigate whether there is any statistically significant difference between the perceptions of students from the junior class and sophomore class, we compared the survey responses by using the Mann-Whitney U Test and the result came out as insignificant. However closer look at the question-wise responses for the junior class (Fig. 3) and the sophomore class (Fig. 4) reveal some interesting phenomenon. It is evident that, all students of the both groups equivocally appreciated the enhanced understanding (Q1) and visualization (Q2), while about 10% more junior students strongly approved them than the sophomore students. In both classes, a small percentage of the students (2% to 5%) did not find MRS to be enjoyable (Q4), preferable over paper-based exercises (Q5), or intuitive and easy to use (Q6). Similar percentage of students (~4%) in both classes also attested that they did not experience enhanced learning after using MRS (Q3). Interestingly, a substantial group of students complained about the additional workload that is involved with MRS (Q8). About 26% of the junior students confirmed that learning to maneuver the exercise Apps are additional work, whereas only 18% of the sophomore students found it to be difficult. As the junior course covers harder concepts and algorithms than the sophomore course, it is possible that a considerable number of students recognized the extra effort.

Students' Comments: The survey also contained two open-ended questions and 95% of the junior students taking the survey generously expressed their perspective in the comments section, where 70% of the sophomore students provided comments. The students' comments for both questions are categorized according to the themes that we observed and their distributions are shown in Table 6 and Table 7. Table 6 reflects that, students' positive attitude toward the visual way of learning and immediate feedback and their appreciation regards to the improved understanding of the difficult concepts arise frequently in their answers. However, junior students admired visual and interactive exercises considerably more than the sophomore students. On the other hand, sophomore students appreciated the detailed email feedback much more than the junior students. The students of the junior class found hands-on-learning and the use of back button more useful than the sophomore students; on the contrary, sophomore students really valued the repeated practice and the support for anonymous question.

Table 6: Response Distribution (%) for Question: "Tell us about the MRS features that you found to be most useful."

Themes	Junior class	Sophomore class
Immediate and automated grading	24%	24%
Visual and interactive exercises	22%	15%
Instant email feedback with correct and submitted answer	10%	18%
Improved understanding	15%	13%
Hands-on-learning	7%	0%
Use of back button	8%	2%
Immediately projected model sequence of interactions after completing the exercise	1%	4%
Immediately projected class-wise grade distribution	1%	6%
Repeated Practice	4%	8%
Better Exam Preparation	4%	2%
Instructors' in-class re-explanation	3%	0%
Anonymous Question	1%	8%

Table 7 reflects the distribution of student-suggested improvements of MRS and is extremely helpful for us to identify the current limitations of MRS and future enhancements. It should be noted that, many of these suggestions are already implemented in the later versions of MRS since their first appearance as comments. For example, currently MRS provides email feedback with correct and submitted answers, which was suggested by a group of students during earlier deployments. There were many App specific suggestions and bug reports and later versions of MRS addressed many of those suggestions successfully. A considerable number of students (especially junior) expressed the desire to receive the grade instantly as part of the App along with the detailed email feedback. Many students of the junior class wanted more algorithmic concepts to be supported my MRS, on the other hand, sophomore students wanted more frequent use of it in the classrooms. Both group of students expressed the desire to see MRS being adopted in the mid-term and final exams and in the other CS/IT classes, which clearly indicates their positive attitude towards it. Many students emphasized on downloading MRS and accessing the practice problems not only in the classrooms, but anytime and anywhere as they wish. Majority of the students suggested that a better, simpler and more appealing interface would benefit them more. A large group of junior students suggested having a "Reset" button in order to start from a clean slate, which would be much easier than pressing back buttons multiple times. The students' comments and suggestions provide a detailed insight for RQ3 and indicate that the students took the time to explore

MRS, found it to be useful and wanted more and better use of it in future. The frequency distributions of respective themes (Table 6 & 7) also suggest that the junior and the sophomore students found different aspects of MRS appealing and their suggestions also vary significantly (RQ2).

Table 7: Response Distribution (%) for Question: "What would you suggest in order to improve MRS environment or your experience?"

	Junior	Sophomore
Add more concepts to MRS	16%	3%
Use more often in the classroom	6%	14%
Support for downloading the Apps in students' devices and for practicing the Apps anytime, anywhere.	3%	14%
App specific suggestions.	9%	13%
Show correct answer instantly and send it via email for future reference.	0%	3%
Add helpful "tips" in the Apps to steer student toward correct answer.	0%	3%
Port MRS to iOS/Apple device.	0%	6%
Better, simpler and more appealing interface.	17%	13%
Add Stylus to improve interaction.	3%	6%
Use MRS in other CS/IT classes.	3%	6%
Add virtual discussion board to participate in discussion outside of classroom.	0%	6%
Show grade instantly in App after completing the exercise.	15%	3%
Offer MRS-based midterm and final exam.	3%	3%
Fix bugs in the Apps.	3%	6%
Send grade by text message as opening and reading emails takes time.	0%	1%
Have a "Reset" button that will start the App from the beginning.	22%	0%

Instructors' comments: Both instructors appreciated the immediate grading, instant visualization of class grade distribution and App tracking data, anonymous questions, and the support for offering more practice problems to the students. By exploiting MRS, instructors could receive an instant snapshot of her classroom comprehension and could change the pace of the class dynamically such as broadcasting more challenging problems to the students instantly if the students comprehend concepts quicker. However, MRS-based classes need a considerable amount of organization and preparation in terms of updating the tablets with necessary Apps, creating the exercise definition (XML) file etc. At certain times during the junior class, the instructor found out that some students took too long to complete their exercises because of using the back button too many times since they did not understand the concept well enough to make a concrete decision. In those cases, the whole class had to wait for the slower students to complete before receiving their grades. However, the problem only occurs during the first few practices of an exercise and at certain times, instructor had to reduce the amount of allowed time to make the wait shorter for the rest of the class. The real-time "Back Button Usage" statistics provided by MRS also becomes helpful to detect such situations. These comments provide important insight regarding RQ4.

4. RELATED WORKS

TRAKLA2 [8] is the pioneering learning environment that supports algorithm simulation exercises, automatic assessment and visual feedback. JHAVÉ [9] is a java application that renders algorithm visualizations and allows learner explorations by pop-up questions. VisuAlgo [10] is an online collection of visualizations that generates questions for the learners to answer based on the content. OpenDSA [11] and related JSAV [12] supports algorithm visualization and proficiency exercises. However, all of them support content delivery via web browser and therefore utilized technologies such as HTML, Java, JavaScript etc. and none to our knowledge do so via native mobile App like MRS.

5. CONCLUSIONS

This paper presents the results of eight semester-long studies using MRS in two required CS courses at WSSU. More specifically, we studied the student-generated evidence of the strong and weak points of the MRS interventions and explored various research questions around those evidences. Our comparative study based on students' final course grade and course failing rate showed that the intervened group of students had better retention of the topics covered over the entire course and performed significantly better than the non-intervened group. Analysis of survey responses showed very high levels of agreement on perceived learning and perceived engagement. Answers to the open-ended questions revealed the mostly appreciated features of MRS and considerable differences were noticed between junior and sophomore responses. Instructor comments' identified few challenging aspects of deploying MRS in the classrooms Overall, students enjoyed MRS, explored it enough to suggest important improvements and expressed the desire to experience more of it beyond the two intervened courses. In future, the focus will be on making the App interface and IEs simpler and more appealing. We will also work toward extending MRS to support out-of-class practices and activities.

ACKNOWLEDGMENTS

This research was supported by National Science Foundation grant #1332531.

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