An Evidence Based Learning and Teaching Strategy for Computer Science Classrooms and its Extension into a Mobile Classroom Response System*

M. Muztaba Fuad[1], Debzani Deb[1] and James Etim[2]

[1]Department of Computer Science
{fuadmo, debd}@wssu.edu
[2]Department of Education
etimj@wssu.edu
Winston-Salem State University
Winston-Salem, NC 27110, USA

***Abstract*—Evidence-based instructional practices were incorporated in class, which gave immediate indication on student's problem solving skills and class participation information. This pedagogy showed positive results and broader acceptance by students in several semesters of intervention. Significant usage of mobile devices during class motivates the extension of this pedagogical approach of asynchronous problem solving using mobile devices. We believe that use of such devices in the classroom for solving interactive problems will enhance student's abilities to solve problems by using their preferred interaction mode. This paper presents the results of the evidence based pedagogy and development of a mobile classroom response system that extends this pedagogy to help student solve interactive problems in their mobile devices to improve their class engagement and problem solving skills.**

***Keywords*-Mobile application, evidence based learning, active learning.**

I. Introduction

To improve student learning in the Science, Technology, Engineering and Mathematics (STEM) disciplines, traditional pedagogical approaches are not enough to transfer critical knowledge to students. One of the major reasons for low retention rate in STEM filed here in the USA might be related to how we teach and how we assess student learning. A closed loop, feedback driven evidence based teaching and learning technique has to be devised and implemented in our classes to improve active learning and student retention rates in the STEM discipline.

A. Need for evidence-based learning

Lecturing is one of the most widespread forms of classroom instruction delivery technique. A fundamental problem of traditional lectures is that, although they are 60 to 75 minutes long, students only have an attention span of 20 minutes [1]. This problem is exacerbated in recent years by the proliferation of mobile computing devices in the classroom. Having such a computing device allow the students to swerve their concentration into something other than what the class is covering. Even if the students do that during a fraction of the class, they might miss key aspect of the lecture that will later hamper their problem solving skills. In such a class setting, quizzes and exams are one of the most effective ways to assess student learning. However, since such quizzes and exams are administered sparsely across the semester; it is extremely difficult to synchronize content coverage and student learning. By administering only such quizzes and exams in a course, faculty might not fully gauge student learning and have any chance to improve student learning during the semester. The goal of the pedagogy presented in this paper is to keep student enthusiastically participate in class discussion, actively take notes and keep more concentration in lecturing so that their learning ability and problem solving skills are improved.

II. Strategy used

Over the past couple of years, evidence based teaching and learning methods are brought into focus from the experience gained in clinical psychology and their use of Evidence Based Practices [1]. Different authors [3]-[4] have discussed the advantages of using such evidence-based methods for teaching and learning in academia. As with any evidence-based methods, the strategy presented in this paper is based on constant monitoring of outcomes from assessment and resulting continuous improvement of the applied method. In our strategy, short quizzes were introduced at the end of every class, which gave immediate evidence on student learning. Each short quiz spanned 10 minutes and administered at the end of a 60-minute lecture and a 5-minute break/discussion time (Total class time was 75-minute). Each short quiz asked questions (1 or 2 analytic /reasoning questions) from the content covered in the first 60 minutes of the class. That way, faculty can make sure that students understand the content covered in that class. This also allows the faculty to see whether anything from that class have to be repeated to reinforce the learning. These quizzes were administered as open notes. That also served another important purpose: since students know that there will be an open note quiz at the end, they concentrate more in lectures, actively participate in class discussion and critically take notes. So, beginning of each class, discussion about the short quiz of the previous class was performed to have a closed loop-learning model and to keep the class in-sync with the content covered. This way, evidence of students being struggling with any specific topic comes in forefront right away and faculty can take appropriate steps to mitigate the problem in its infancy. To alleviate student

*Supported by National Science Foundation grant #1332531

trepidation about having a bad quiz grade at the end of the class, 1 or 2 of the short quizzes, on which student did poorly are dropped from calculation. Short quizzes only contributed a portion of the course's total assessment along with exams, assignments, labs and group projects. Although there are divided opinions [6]-[8] on quiz-based assessment, we modified it in a way that it is evidence based and it does not harass students in the class.

A. Course Information

The course used in this study was a sophomore year major course that was offered in both Fall and Spring semesters. This course introduces students to digital electronics and the foundation of computers. Data about student demographics, enrolled credit and work hours were also collected and analyzed to see whether there is any relationship with the outcome of the study. There was no discernable pattern with the results seen in Section III Although most of the students were sophomore with certain age range, there were also small number of non-traditional and transfer students in the class.

III. Effectiveness of the New Strategy

This strategy was intervened in two semesters and compared with the data of past two semesters when this strategy was not utilized. First, student's reaction on course evaluation survey questions was examined. This survey is administered by the office of Institutional Planning, Assessment, and Research of the university to assess every class. Specifically three of the survey questions were examined to show student's perception about the short quizzes. Table 1 shows the data from the survey (on a scale of 5). Overall, students' responses were positive than before the short quizzes were implemented. Specifically, students get faster and frequent feedbacks that reinforced their learning. The class grades were also compared as shown in Table 2, which shows a stark difference. Student grades were up and fewer students were failing the course.

TABLE 1. COURSE EVALUATION SURVEY DATA

Question in the Survey	With intervention	Without intervention
Gave quizzes, tests etc. that reflected the objectives of the course.	4.93	4.69
Provided students with useful feedback on tests, projects, and assignments.	4.85	4.34
Throughout the semester, provided students with feedback regarding their academic performance in the course.	4.83	4.55

TABLE 2. STUDENT GRADE INFORMATION

Grade	With intervention	Without intervention
A	37.5%	26%
B	23%	21.5%
C	23.5%	25.5%
Less than C	16%	27%

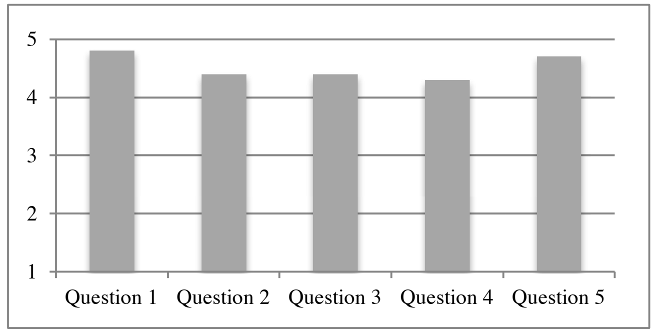


Figure 1. Survey results.

After receiving such encouraging signs of student improvement and engagement, we administered a survey the following semester that is more geared towards getting student's impression about the use of short quiz in the class. We specifically asked 5 questions to gauge student impression as listed below:

Question 1: Short quizzes gave me faster feedback to understand my learning abilities.

Question 2: Short quizzes challenged me to go beyond simple memorization of facts.

Question 3: Short quizzes encouraged me to apply course related knowledge and skills to solve problems.

Question 4: I prefer courses, which have short quizzes to assess student learning.

Question 5: Grading scheme (lowest 1 or 2 short quizzes are dropped) for short quiz is fair.

Student gave answers to the questions using a *likert* scale, where 5 meant "Strongly Agree" and 1 meant "Strongly Disagree" with 3 being "Neutral". Figure 1 shows the average of the student responses for each questions and it is evident that student had a strongly positive impression of the new teaching and learning strategy used in the class.

IV. Why and How to Extend This Model?

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 [9]. Boston University [10] adopted tablet-based problem solving exercises in their freshman mathematics class and reported noticeable increase in student attendance and course completion. Many other approaches [11]-[12] also reported enhanced educational experiences when technology such as mobile devices has been adopted in the classroom.

2010 Pew study of mobile device usage [13] 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 Winston-Salem State University, which is predominately a minority university, it is common for students to multi-task and use their mobile devices while in class, studying, or performing other activities. The effect of such behavior when mobile devices are used for learning purposes is not well understood and there are proponents who think of them as quite disruptive [14]-[15]. We believe that use of such devices in the classroom for solving interactive problems will enhance student's abilities to engage and complete tasks in their preferred interaction mode. Inspired by the Pew study and the reported impact of utilizing technology-rich class environment at other institutions, we extended the model by developing a Mobile Classroom Response System (MRS) and incorporating it in the undergraduate education of a primarily African American student population to enhance student's engagement, active learning and problem solving skills. By using mobile devices, we expect shy students to interact anonymously and participate in class discussions. By 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 findings presented in Section III encouraged us to extend this model by scattering the questions of the short quiz across the class while synchronizing with the content covered.

A. Related Works

Although 'clickers' were used to increase class interaction in variety of disciplines, in different settings and during a substantial period of time [16]-[17], it has several disadvantages [18]-[19] that make it difficult to use in classrooms. Different studies [20]-[21] have found the benefits of using mobile devices in classrooms and in recent years, there has been a plethora of work [22]-[24] performed to incorporate mobile devices in classrooms. Since students rely on their computing devices (cell phones, tablets etc.) for all sorts of communication, they usually keep those devices on hand and we can use those to enhance the class experience and minimize the problems with 'clickers'. There are also several commercial products [25]-[27] for different mobile platforms that provide similar functionalities.

In summary, there are three distinct differences between MRS and other similar works. First, MRS facilitates interactive problem solving. In Science courses, students need to actively solve problems by interacting with the problem in a hands-on approach. Only by using multiple-choice or true-false questions, students will not be fully able to synthesize a problem and develop their critical thinking skills. Presenting the problem as interactive entities will allow the students to actively play with the problem via different steps to solve it and as a result of it we can potentially improve student's critical thinking and problem solving skills. Second, MRS is user friendly and completely transparent so that faculty and students (who are less savvy in technology) can use the system with ease and without any headache. Use of self-configuration and self-management primitives used in other research areas will facilitate that. Finally, the system is open sourced and free for anyone to use. Anyone interested in using the system can try the system and can modify the system to suit their needs.

B. Interactive problem and grading rubric

Course modules that illustrate various interactive problem-solving activities are critical for successful deployment of the MRS. In that regard, one sophomore level hardware organization course (offered in both semesters) and one junior level algorithm course (offered in Spring semester) is selected, which will be used to assess the system and for which several interactive problems are being developed so that students will be able to interact with them using the client application. These courses are a good candidate for testing the system because they assess mathematics and problem solving skills and we can incorporate several kinds of interactions during the class to enhance these skills.

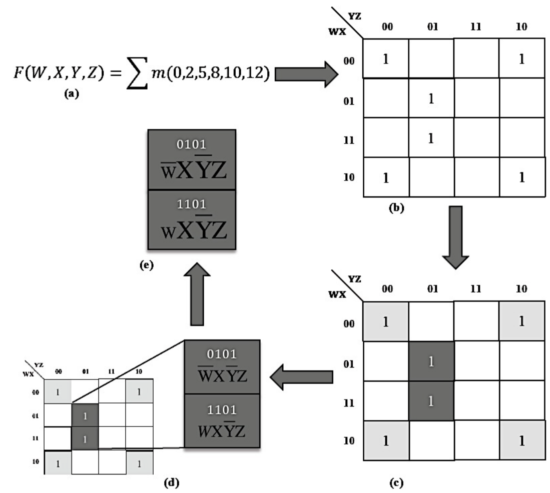


Figure 2. Sample interactive problem.

Figure 2 shows step-by-step process of a sample problem that students will solve by interacting with it in their mobile device. This simple problem is illustrating how we are going to test whether a student understood Karnaugh map (K-map) simplification algorithm and can follow the steps to solve a particular problem. Students are presented with the sum-of-minterm expression (Figure 2(a)), from which, they have to map it (Figure 2(b)) to the corresponding K-map. The K-map will be rendered in the software and students can select cells corresponding to the equation. This will test, whether students learned how the map is laid out and what every cell points to. Once this step is finished, students will make groups with the cell following the minimization algorithm (Figure 2(c)). Students can select any cell and each group made will take a different color to distinguish it from other groups. This will test whether student understands different characteristics of making groups. Next, students will interact with each group (Figure 2(d)) and have to select variables (Figure 2(e)) following the minimization algorithm. This will test whether students fully comprehend the minimization algorithm. During these interaction steps, students can go back and forth and change their answer. This will allow them to see what is the affect of different selection on the result and how every piece fits together. Problems can be started bottom up or at the middle to give students different perspective on the problem and assess their problem solving skills. Each problem has a rubric that not only grade correct answers but also partial answers to gauge student's problem solving skills and thinking models.

C. MRS System Organization and Function

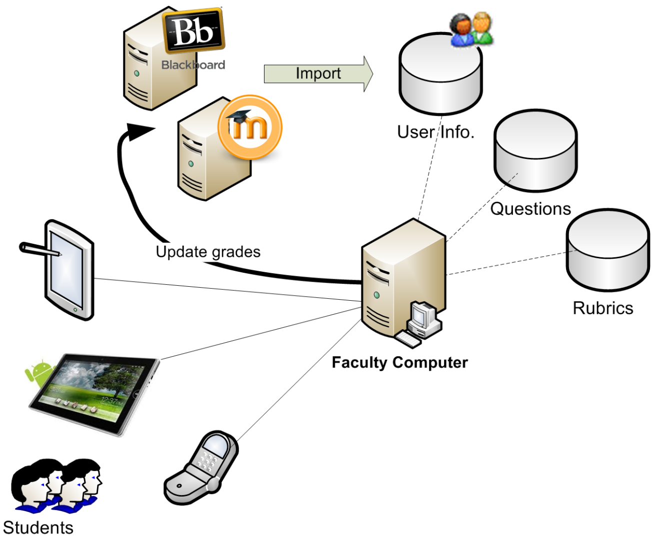
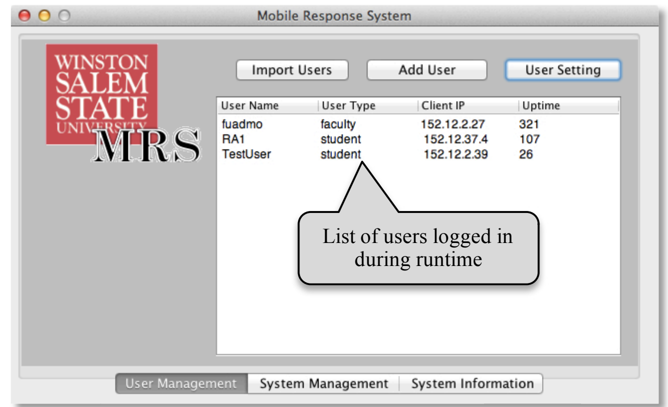
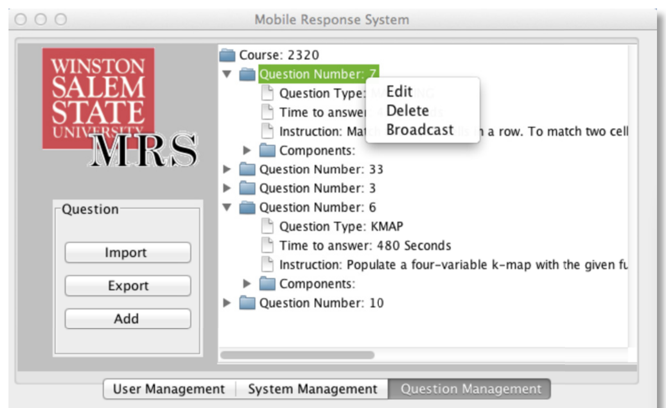


Figure 3. Overall system organization.

The MRS software is designed as a client-server system. Clients can be diverse set of computing devices as long as they have the developed client app in them to interact in the class. Currently, we are using Android based mobile devices for client and Java for the faculty machine (the server). Figure 3 shows the overall system structure. The faculty computer is the secure entity in this software architecture, which holds the databases for questions, answers/rubrics and user information. It also has the required data analysis component to tabulate user responses and produce easy to interpret reports and graphs. Each client has a corresponding client application (app) to receive and respond to questions. Before the start of the class, faculty has to setup in-class interaction (importing student info, questions, their answers/rubrics and setup type of analysis, kind of report etc.) in the faculty computer using a graphical user interface (Figure 4(a)). Once the interaction for the class is setup and the class is in motion, the faculty can use a trigger (mouse click or a designated key in the keyboard) to broadcast a question to students (Figure 4(b)). To facilitate secure and anonymous interaction across the system, user categories with specific system privileges have to be set and maintained. The faculty machine keeps track of every user in the system with their credentials and privileges. One way to facilitate this process is to incorporate the system with campus wide learning management systems, such as BlackBoard or Moodle, so that user information from a course shell can be easily transferred and synchronized.



(a)



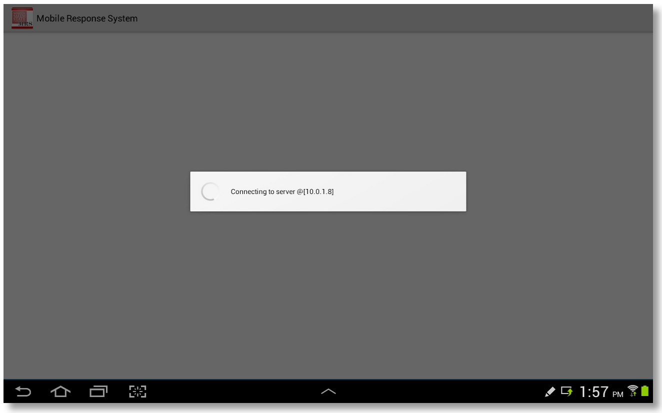
(b)

Figure 4. MRS-Faculty machine at work.

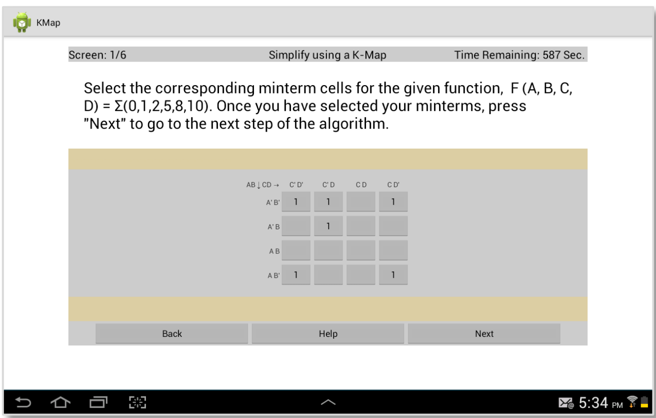
Usually when a user initiates a check-in to the system, the clients first locates the faculty machine (Figure 5) and once a session is established, credentials are validated so that the client can start accepting questions. Once a question is received, the MRS client will invoke the corresponding activity to render the given question. As mentioned earlier, each question will have multiple interactive screens (Figure 5 (a) and (b)), which students can traverse back and fourth. Once the faculty machine receives answers back from all the clients, it does corresponding analysis of the data and displays it accordingly. Currently, several interactive problems are being developed with a planned deployment in Fall of 2014. The underlying system is operational and its scalability, responsiveness and reliability parameters have been tested and they all fell within accepted ranges.

V. CONCLUSIONS

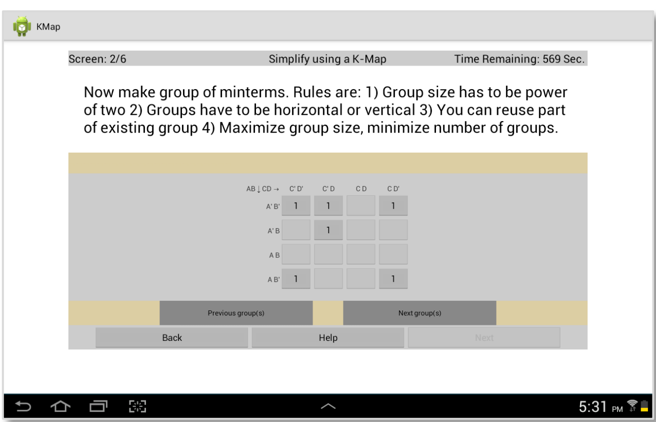
This paper addresses a significant learning barrier experienced at many universities, which is the problem of students' inability to keep engaged and interested in classroom. An evidence based teaching and learning strategy is presented in this paper that received positive



(a)



(b)



(c)

Figure 5. MRS-Client machine at work.

results after implementation in undergraduate classroom. This strategy is extended into the mobile devices and the paper discusses on different aspects of the extension. This research investigates the applicability of using mobile devices in the classroom and incorporation of interactive problem solving using those devices to increase class engagement and active learning for student.

REFERENCES

1. D. Perry, "How The Brain Learns Best", *Instructor Magazine*, 2000, pp. 34-37.
2. A. E. Kazdin, "Evidence-Based Treatment And Practice: New Opportunities To Bridge Clinical Research And Practice, Enhance Knowledge Base, And Improve Patient Care", *American Psychologist*, vol. 63, 2008, pp. 146-159.
3. B. K. Saville, "Using Evidence-Based Teaching Methods to Improve Education", *Excellence in Teaching*, vol. IX, 2010, pp. 48-54.
4. J. Fairweather, "Linking Evidence and Promising Practices in Science, Technology, Engineering, and Mathematics (STEM) Undergraduate Education: A Status Report for The National Academies Research Council Board of Science Education", Washington, DC, 2010.
5. D. Mitchell, "Education that Fits: Review of International Trends in the Education of Students with Special Educational Needs", 2010, http://www.educationcounts.govt.nz/publications/special_education.
6. H. Craft, "Using Pop-Quizzes as an Assessment", 2009, https://suite.io/harvey-craft/2skn2a6.
7. M. Forti, "Pop Quiz: How Can Measurement Improve Student Learning?", Bridgespan Group, March, 2012.
8. G. Everding, "Repeated Test-taking Better for Retention than Repeated Studying", 2006, http://news.wustl.edu/news/Pages/6715.aspx.
9. M. Cometa, "Use of Technology-Rich Learning Environment Reveals Improved Retention Rates", Rochester Uni. of Tech., 2011, http://www.rit.edu/news/story.php?id=48699.
10. C.A. Romney, "Tablet PC Use In Freshman Mathematics Classes Promotes STEM Retention", *Frontiers in Education Conference*, 2011, pp. F1J-1-1-F1J-7.
11. S.E. Kowalski , "InkSurvey Tool: Probing Student Understanding and Encouraging Active Learning with Open-ended Questions and Tablet Technology," *HP Online Speakers series*, October 6, 2006.
12. Z. Avery, M. Castillo, et. al., "Implementing Collaborative Project-Based Learning using the Tablet PC to enhance student learning in engineering and computer science courses", *Frontiers in Education Conference (FIE),* 2010, pp. F1E-1 - F1E-7.
13. A. Smith, "Mobile Access 2010", Pew Internet and American Life Project, 2010.
14. S. W. Campbell, "Perceptions of Mobile Phones in College Classrooms: Ringing, Cheating, and Classroom Policies," *Communication Education*, vol. 55, no. 3 (July 2006), pp. 280–294.
15. W.Hu, "Seeing No Progress, Some Schools Drop Laptops," *New York Times*, May 4, 2007.
16. J. Caldwell, J. Zelkowski, and M. Butler, "Using Personal Response Systems in the Classroom", *WVU Technology Symposium*, April 11, 2006, Morgantown, WV.
17. J. Roschelle, W. R. Penuel, and L. Abrahamson, "Classroom Response and Communication Systems: Research Review and Theory", Presented at the Annual Meeting of the American Educational Research Association, San Diego, CA, 2004.
18. J.E. Caldwell, "Clickers in the Large Classroom: Current Research & Best-Practice Tips", *Life Sciences Education*, vol. 6, no. 1, pp. 9-20.
19. M. Bugeja, "Classroom Clickers and the Cost of Technology", *Chronicle of Higher Education,* December, 2008.
20. L. Mockus, and S. Edel-Malizia, "The Impact of Mobile Access on Motivation: Distance Education Student Perceptions", *17th Annual Sloan Consortium International Conference on Online Learning,* November 9-11, 2011, Orlando, FL.
21. A. Jones, and K. Issroff, "Motivation and Mobile Devices: Exploring the Role of Appropriation and Coping Strategies", *Research in Learning Technology*, vol. 15, no. 3, pp. 247-258.
22. J. Roberts, "Harvesting Fragments of Time", *Mobile learning pilot project*. Technical report, McGraw-Hill.
23. J. R. Young, "Mobile College App: Turning iPhones Into 'Super-Clickers' for Classroom Feedback", *Chronicle of higher education*, December, 2008.
24. H. Ketamo, "Learning for Kindergarten's Mathematics Teaching", *Proc. IEEE International Workshop on Wireless and Mobile Technologies in Education*, Växjö, Sweden, 2002, pp. 167-168.
25. Top Hat Monocle, 2013, https://www.tophatmonocle.com.
26. Socrative, 2013, http://m.socrative.com.
27. E-Clicker, 2013, http://www.bignerdranch.com/apps.