Improving Student Content Retention using a Classroom Response System

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Keywords: Classroom Response System, Content Retention, Student Engagement, Computer Literacy.

Abstract: The most typical uses of a classroom response system are to improve student engagement and to provide opportunities for immediate feedback. For our introductory course in computer science we sought to investigate whether the content and format typically associated with a classroom response system could be adapted from a feedback tool into an approach for improving content retention. We devised an experiment wherein different sections would be presented with complementary sets of questions presented either immediately after the corresponding material (i.e., for feedback) or at the beginning of the following lecture, with the express purpose of reminding and reinforcing material (i.e., to improve content retention). In every case, the participants that encountered an item in the following lecture exhibited relatively better performance on the corresponding items of the final exam. Thus our evidence supports the hypothesis that, with no significant additional investment of preparation or lecture time (beyond that associated with all classroom response systems), questions can be presented in such a way as to engage students while simultaneously improving content retention.

1 INTRODUCTION

Classroom response systems (and particularly those that require only the ubiquitous smart phone with which to interact) present an excellent opportunity for instructors to integrate technology into the classroom in a way that helps facilitate student learning. These systems, exemplified by the practice of posing a question to the class that is answered immediately and anonymously, are known to improve student engagement. Furthermore, these systems offer an opportunity for both students and instructors to receive crucial and immediate feedback about the effectiveness of a lecture.

These express purposes notwithstanding, in this paper we explore the results of an investigation into whether or not classroom response systems can also provide an opportunity for improving content retention through an active (albeit brief) return to previously discussed content, without sacrificing its use as a tool for assessment and improving student engagement.

The remainder of this paper is organized as follows. Section 2 discusses related work in the context of the use of classroom response systems. The course in which our experiment takes place is discussed in Section 3. The experiment design is presented in Section 4, and the results are given in sections 5 and 6. Finally, the paper is concluded in Section 7.

2 CLASSROOM RESPONSE SYSTEM

The feedback provided by a classroom response system can be crucial to both students and instructors. A question on which a particular student under-performs (with respect to the other students in the class) can indicate an area of weakness, and in this way a student's relative performance becomes a discrete opportunity for that student to self-assess his or her current understanding. Furthermore, the immediate and specific nature of the feedback provided by a classroom response system can be contrasted against traditional assessment tools (e.g., quizzes, assignments, etc.) where several topics are often assessed simultaneously and feedback is not immediately available. Additionally, and perhaps more importantly, the feedback provided to instructors allows instructors to adjust the pace of the lecture to match the immediate learning needs of the participating students.

Collier, R. and Kawash, J.
Improving Student Content Retention using a Classroom Response System.
DOI: 10.5220/0006218100170024
In *Proceedings of the 9th International Conference on Computer Supported Education (CSEDU 2017) - Volume 1*, pages 17-24
ISBN: 978-989-758-239-4

Numerous studies ((Boscardin and Penuel, 2012; Moss and Crowley, 2011; Kay and LeSage, 2009; Bruff, 2009; Moredich and Moore, 2007)) have reported that the use of classroom response systems in the classroom can improve student engagement (to the benefit of student learning) and (as noted previously) provide an opportunity for both students and instructors to receive important feedback. Although virtually all surveyed materials reinforce that students are satisfied, on more than one occasion ((Blasco-Arcas et al., 2013; Webb and Carnaghan, 2006)) it has been noted that the studies that report learning improvements might be observing an effect associated with improved interactivity in the classroom, and cannot conclusively demonstrate that the classroom response system is actually required to achieve this effect. This reasonable consideration notwithstanding, the use of classroom response system as a tool to engage students remains largely undisputed. Classroom response systems have also been used to successfully identify students that are struggling (Liao et al., 2016), and Porter et al. showed that performance in classroom response system early in the term was a good predictor of students' outcomes at the end of the term (Porter et al., 2014).

Unfortunately it must also be acknowledged that there is evidence that the adoption of a classroom response system could present a barrier to students (which could, naturally, negatively interfere with knowledge retention). Draper and Brown (2004) reported that some students expressed that the system could actually be a distraction from the learning outcome. Furthermore the review by Kay and Lesage (2009) cited works that discussed the potential for in-class discussions to actually confuse students by exposing students to differing approaches/perspectives. This is, naturally, a potential pitfall for any activity that prompts in-class discussion, and given the numerous reports of the potential advantages associated with classroom response systems, we definitely feel that there is sufficient evidence to motivate the investigation of these systems as a tool for improving content retention.

It should be noted that a number of reviews (Boscardin and Penuel, 2012; Kay and LeSage, 2009; Judson and Sawada, 2002) have noted that much of the research into the benefits and drawbacks associated with the use of classroom response systems has been qualitative and/or anecdotal, and that there are relatively few studies using control groups and quantitative analyses. The authors believe this study to be among the first to offer a quantitative assessment of the use of classroom responses systems as a tool to improve content retention (as opposed to a tool explicitly used for improving engagement or providing student feedback). It should, however, be specifically noted that the approach described by Brewer (2004) in the biology faculty at the University of Montana noted that although response system questions were presented to students during the class in which the materials were presented, correct answers would not be revealed to the students until the following class. Although this practice could conceivably improve retention as well, the express purpose of using the response system was described in that study to be feedback (for both the instructors and students), not an improvement to retention. Similarly, Caldwell (2007) does not mention retention specifically but does describe a "review at the end of a lecture" - this could also conceivably improve retention if these questions pertained to the beginning of a particularly lengthy lecture.

It should also be emphasized that our paper is concerned only with the potential applications of classroom response systems to the problem of content retention; although several other studies have looked at classroom response systems for the retention of students in computer science programs, this is not directly related to the problem of content retention. Porter, Simon, Kinnunen, and Zazkis (2013 & 2010), for instance, indicated that they used clickers as one of the best practices for student retention, but it is not clear how this class response system is used and how it is affecting content or knowledge retention. Furthermore, unlike Tew and Dorn (2013), we do not aim to develop general instruments for assessment. Our approach is ad-hoc with the specific objective of determining if there is measurable evidence that a class response system can help improve retention of content and knowledge by students.

A related issue for which there have been several studies (albeit with conflicting results) concerns whether or not the use of classroom response systems can improve student performances on final exams. Diana Cukierman suggested that studying the effect of a classroom response system on outcomes such as final exam scores may be infeasible (Cukierman, 2015) and an experiment by Robert Vinaja that used recorded lectures, videos, electronic material, and a classroom response system did not demonstrate an impact of these practices on grade performance (Vinaja, 2014). Contrarily, Simon et al. demonstrated in a CS0 course that peer instructed subjects outperformed those who are traditionally instructed (Simon et al., 2013), and Daniel Zingaro confirmed this finding but in a CS1 context (Zingaro, 2014). Zingaro et al. went further to show that students who learn in class retain the learned knowledge better than students who did not learn in class (Zingaro and Porter, 2015). Steven Huss-Lederman similarly reported on a 2-year experiment in which first year students showed better learning gains as a result of using a classroom response system, but there was a drop in these gains in the second year (Huss-Lederman, 2016). In comparison, our work starts from the thesis that classroom response system possibly have an effect on knowledge retention (and, by extension, on final exam scores). Our aim was to quantify this observation in a first-year computer science course and in contrast with the aforementioned studies, the driving question of our research is when and how classroom response questions can be effective in improving learning outcomes. Specifically, we compared two groups which both used the same classroom response system and similar question banks - it was the only the order in which these questions were delivered that differed.

3 COURSE DETAILS AND OBJECTIVES

The course within which this experiment was conducted was CPSC203, Introduction to Problem Solving Using Application Software.) This was a first year computer literacy course at the University of Calgary designed specifically for students not working towards a major in computer science. Consequently, this course did not assume students have any foundation of computer science knowledge upon which to build (although a basic level of familiarity with the use of a personal computer was assumed). Most of the students in attendance are undergraduate students enrolled in a course from the schools of business, management, and/or social science, but students from the natural sciences, communications, and other disciplines also register for this course on a regular basis. The course is taught in a traditional lecture-style format, with content delivered over 13 weeks through a combination of lectures (75 minutes, twice a week) and tutorials (100 minutes weekly).

As the principle learning outcome for this course is to impart an introduction to many of the fundamental areas of the computer science discipline, the course features a particularly broad range of topics. After the initial weeks of the course, during which some very basic introductory materials are presented alongside a discussion of research design fundamentals, the remainder of the course could be logically divided into three“modules”. Figure 1 is a diagrammatic representation of the topics of the course, presented to students during the first (i.e., introductory) lecture to demonstrate the interconnectedness and dependencies of the topics to follow. The arrows indicate topic dependence.

The first of these modules introduces both set theory and graph theory before discussing the application of these principles to problem-solving (e.g. traffic light scheduling). During some previous offerings of this course these topics are followed by several short introductory computer programming lectures, but these lectures were not presented as part of the course offerings discussed in this paper.

The module that follows introduces both propositional and predicate logic before exploring the fundamentals of relational database management systems. These topics (i.e., classical logic and database management) are then brought together for the introduction of structured query language.

The final module provides a brief introduction to the principles of computer networking and security (e.g., encryption and authentication with public-key cryptography. Although these topics are somewhat independent of the previous materials, they do broaden the knowledge base to ensure that students are able to remember, understand, and apply many core computer science topics.

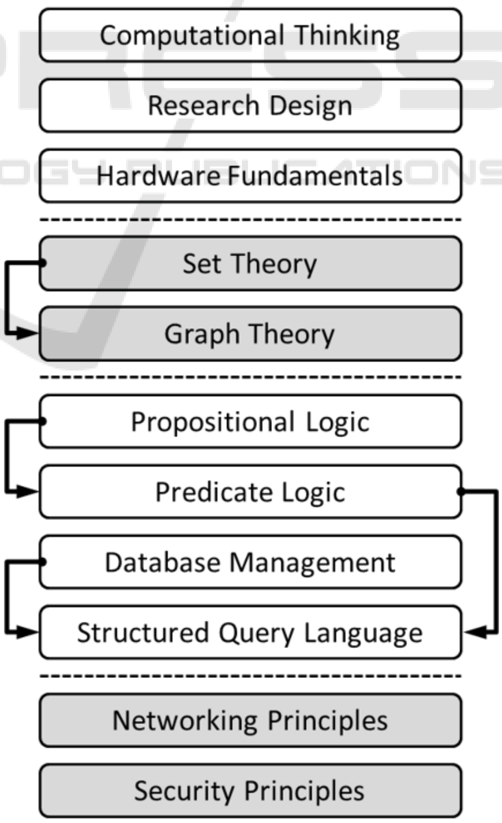

Figure 1: Topics and Dependencies.

4 EXPERIMENTAL DESIGN

At the time of this investigation, the use of a classroom response system in CPSC203 has been standard operating procedure since 2010. Although these systems are widely recognized to encourage student engagement while allowing instructors to assess the degree to which the current material is being absorbed, it might be possible to improve the benefit to the students by using these systems to revisit and reinforce content discussed in a prior lecture. Notwithstanding the fact that it is necessary to ask students about the content that has been presented over the last few minutes to determine if they have absorbed the material and/or created adequate study notes, asking questions pertaining to content that is still fresh in the minds of the students (i.e., in either working or intermediate-term memory) might do very little to aid students in storing the material into long-term memory.

The fall semester of 2014 afforded a unique opportunity for a controlled experiment on the effectiveness of the Tophat classroom response system for improving content retention; the two sections were taught by the same instructor, in (nearly) synchronous 75-minute lectures, with shared assignments, quizzes, and examinations. The two weekly lectures for each section were also taught on the same days (Tuesdays and Thursdays) with the most significant observable differences (at the time the experiment was designed) being that one section would receive its lectures starting at 9:30 AM and would contain roughly half as many students as the other, which would receive its lectures starting at 12:30 PM. From this point these two sections will be referred to as the early section (or the early group) and the late section (or the late group), respectively.

The performance discrepancy that might be attributed to the differing lecture times notwithstanding, a Kolmogorov-Smirnov test was used to determine if there were any statistically significant differences between the scores on the portion of the final exam pertaining to this investigation. This nonparametric test, applied to the final exam scores of the 26 participants that made up the sample from the early section and the 46 participants that made up the sample from the late section, did not indicate a statistically significant difference in their respective final exam performances (D-value of 0.1378 and p-value of 0.898).

For this experiment, a collection of 54 questions was developed for the period of 14 lectures during which the Tophat classroom response system would be in use. Additionally, a minor variation on each of these 54 questions was also developed to ensure that the late section would never receive an identical question to one that had already been asked of the early section. The course was designed such that four questions would be posed to each section during each lecture (except during the first lecture, which would feature only two). The four questions associated with each lecture would be divided (at random) into complementary sets A and B (of two questions each) - the early sample would be asked the questions from set A immediately after the material was presented and the questions from set B at the beginning of the following class, while the late section would be assigned the reverse.

As a clarifying example, if the four questions associated with the nth lecture of the course were designated q1, q2, q3, and q4, the early section could be asked questions q2 and q3, immediately after the material had been presented, and questions q1 and q4 at the beginning of the n+1th lecture. The late section, on the other hand, would be asked variations on questions q1 and q4 immediately after the material had been presented and questions q2 and q3 at the beginning of the n+1th lecture.

In this way, both classes answered 27 questions immediately after the material was presented (allowing for the traditional role of the classroom response system as an engagement/assessment tool) and 27 questions on the following class (wherein the classroom response system questions become an opportunity for students to revisit the material that had been presented during a previous lecture).

5 "MULTIPLE CHOICE" ITEM RESULTS

For the early group, within which there were 26 participants, the average participation level was 73.18% (standard deviation 27.16; with 0% and 100% indicating participants that did not answer any of the class response system questions and answered every question, respectively). For the late group, within which there were 46 participants, the average participation level was 72.48% (standard deviation 24.85). As there was a substantial difference between the number of students in each group and a lack of normality in the data, the nonparametric Kolmogorov-Smirnov test was used to determine if there were any statistically significant differences between the corresponding participation levels. With a calculated D-value (for the maximum difference between the distributions) of 0.1288 and a very large p-value of 0.929, the null hypothesis (that both samples come from a population with the same distribution) cannot be rejected. It is, thus, not unreasonable to conclude that both groups were equally willing to participate (or, more precisely, the difference in participation levels was not considered statistically significant).

A simple performance assessment (with respect to the classroom response system questions only) can be derived for each participant as the fraction of the questions answered by the participant that were, in fact, answered correctly. In the early group the average performance was 70.66% (standard deviation 13.74) while in the late group the average performance was 66.95% (standard deviation 13.54). Once again the Kolmogorov-Smirnov test was used to determine if there were any statistically significant differences (since the data sets were not normally distributed) but with a D-value of 0.2533 and a p-value of 0.218, the null hypothesis that both samples came from the same distribution cannot be rejected. It is not unreasonable to interpret, from this, that neither of the participant groups was able to outperform the other. This is a welcome result considering that both groups received exactly the same number of questions for both the engagement and retention questions.

Having established that it would not be unreasonable to compare each of the groups on specific questions (to assess the degree to which specific questions can improve retention), four of the twenty multiple choice questions and one of the eight short answer questions from the final exams were designed such that they would both reflect and resemble classroom response system questions encountered by the class. Although this is unarguably a rather small sample from which to draw conclusions, it is important to recognize that the typical classroom response system question (i.e., designed to improve student engagement and provide an opportunity for feedback) is not necessarily a suitable question for a summative assessment tool like a final exam.

It should be noted that virtually all of the material from the final exam was accompanied by at least one related classroom response system question (with the exception of one multiple choice question and one short answer question that addressed material covered in the first three weeks, before the classroom response system came into use). Nevertheless it must also be noted that most of the corresponding final exam questions did not resemble their classroom response system counterparts. Consequently the authors feel that the most generalizable conclusions will be drawn from the observed performance differences (between students that encountered the corresponding classroom response question during the same lecture as the material vs. the following lecture) for those exam questions where the parallels to the corresponding classroom response questions were undeniable.

Two of the four multiple choice final exam questions pertained directly to structured query language (SQL). The former (denoted MCQ1) requested that the students select the correct "where" clause to produce a specific result, while the latter (denoted MCQ2) presented a SQL query and requested the students provide the number of rows that would be returned. Of the group of students that encountered MCQ1 during the same lecture as the corresponding material (i.e., the lecture on the construction of "Where" clauses), 38.5% answered the classroom response system question correctly and 57.7% answered the corresponding final exam question correctly. If this is contrasted against the group of students that encountered MCQ1 during the following lecture (i.e., at least 48 hours later), only 32.6% answered the classroom response system question correctly but 60.9% answered the final exam question correctly. A simple summary of these results would observe that the group of students that received the classroom response system question in the following lecture did "better" on the final exam question, even though their performance on the classroom response question was worse than the other group. This result is depicted in Figure 2.

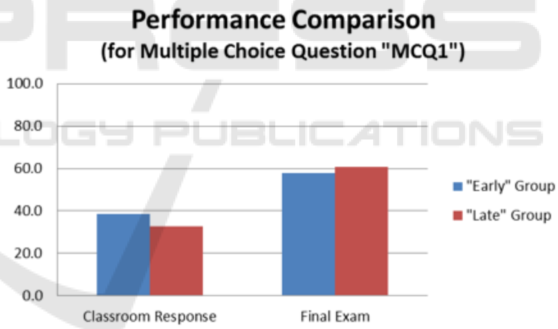

Figure 2: Performance on an application level question.

Of the group of students that encountered MCQ2 during the same lecture as the corresponding material (i.e., the lecture on Cartesian products and join operations), 58.7% answered the classroom response system question correctly and 41.3% answered the corresponding final exam question correctly. Of the other group, on the other hand, 69.2% answered the classroom response system question correctly and 61.5% answered the final exam question correctly. As with MCQ1, the students that received the classroom response system question in the following lecture did "better" on the final exam. It may, however, be worth noting that this same group performed "better" on the classroom response system question as well. This result is depicted in Figure 3.

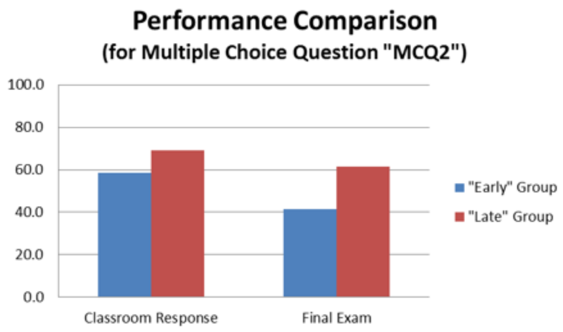

Figure 3: Performance on an application level question.

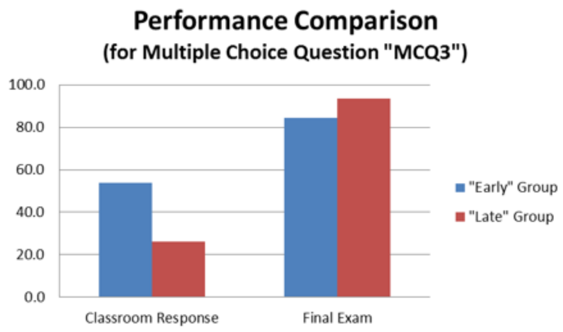

Figure 4: Performance on an application level question.

The other two of the four multiple choice final exam questions considered for this investigation pertained to networking. Using the terminology from the cognitive domain of Bloom's taxonomy (Bloom, 1956), where the structured query language questions discussed previously could be said to assess at the application level, these networking questions would be best categorized as assessment tools for the knowledge and comprehension levels (respectively). The former (denoted MCQ3) pertained to the differences between user datagram protocol (UDP) and transmission control protocol (TCP) and the latter (denoted MCQ4) pertained to the POST and GET operations of the hypertext transfer protocol (HTTP). Of the group of students that encountered MCQ3 during the same lecture as the corresponding material, 53.8% answered the classroom response system question correctly and 84.6% answered the corresponding final exam question correctly. For the sample that encountered the classroom response question during the following lecture, 26.1% answered the classroom response system question correctly and 93.5% answered the corresponding final exam question correctly. In spite of the very significant difference in performance on the classroom response question itself (with only 26.1% of the late sample answered the classroom response question correctly), once again the final exam question results indicate that the group of students that received the classroom response system question in the following lecture did "better" on the final exam. This result is depicted in Figure 4.

Of the group of students that encountered MCQ4 during the same lecture as the corresponding material, 53.8% answered the classroom response system question correctly and 88.5% answered the corresponding final exam question correctly. When this is contrasted against the results from the late group, the familiar pattern was evident; 37.0% of the late group answered the classroom response question correctly but 91.3% answered the final exam question correctly. This result is depicted in Figure 5.

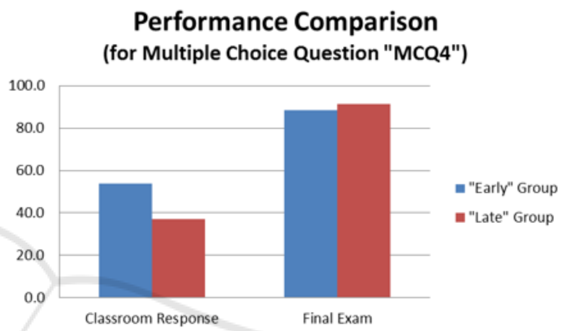

Figure 5: Performance on an application level question.

It is worthy to note at this point that these results are very intuitive; a classroom response question posed to the class at the beginning of the lecture, but pertaining to content from a previous lecture, is not being used to provide feedback about the immediate learning needs of the classroom. It does, however, stand to reason that such a question is an opportunity to reinforce (and bridge the current lecture with) content from a previous lecture, thereby improving student retention. This would, naturally, be evidenced by a relative performance improvement on the corresponding questions of the final exam

6 "SHORT ANSWER" ITEM RESULTS

The final question posed to the students on the final exam that corresponded directly to a classroom response question previously encountered by the students used the short answer format (i.e., it was neither a multiple-choice question nor was it any other format where prompts or possible answers were provided to the student). This question entailed the creation of a graph that, when subjected to a graph colouring algorithm (n.b., one of the earlier topics on the course) requires the same number of colours as the number of vertices in the graph. Consequently it could be argued that according to the terminology from the cognitive domain of Bloom's taxonomy this question was a synthesis level question.

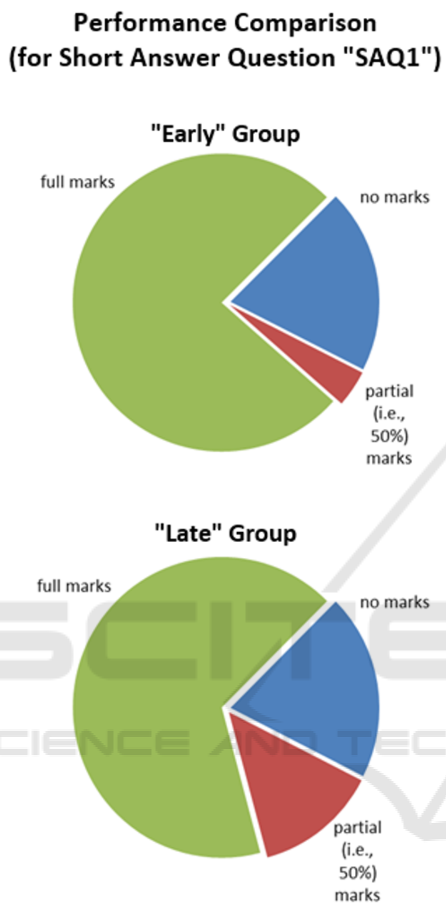

Figure 6: Performance on a synthesis level question.

Both the early and late participate samples (i.e., those that encountered the classroom response question immediately after the material was presented in lecture or at the beginning of the following lecture, respectively) achieved the same performance level (i.e., 50%) on the classroom response question. Nevertheless, the results of the experimental analysis indicated that the average mark achieved (on the corresponding short answer question of the final exam) by the late sample was greater than the average mark achieved by the early sample (78.0% and 73.3%, respectively). Although this is consistent with the previous results, the conclusion must be tempered by the fact that this difference was not found to be statistically significant (according to an unpaired student t-test). The distributions of students (from the early and late samples) that achieved full marks, partial marks, or no marks on the corresponding final exam question is depicted in Figure 6.

7 CONCLUSIONS

As any educator that has employed a classroom response system can attest, the creation of suitable items is a considerable investment of time - both the time required to develop a suitable item and the time consumed in class to present the item, allow the students to formulate and submit a response, and discuss the results. That said, there are well-established benefits to the class if these costs can be incurred, most notably as an approach for improving student engagement and (if the questions are a source of marks for the student) motivate, and as source of immediate feedback for both the students and the instructors. The results of this experiment support the hypothesis that the very same activity can also be used to improve student retention simply by varying when these questions are presented to the student. Questions posed to the students at the beginning of the lecture that follows the lecture where the corresponding materials were introduced are an opportunity for students and instructors to briefly revisit material in a structured activity, and this, in turn, presents an opportunity for students to reinforce knowledge that has passed into long-term memory. It is also worth noting that although this approach does entailing sacrificing the utility of the classroom response question as an approach for acquiring immediate feedback, it does not preclude the other more typical application of these questions as a way of motivating or engaging students.

The five items from the final exam (i.e., the four multiple choice questions and one short answer question) used for this experiment were designed such that they would assess (as much as possible) knowledge at several different levels of Bloom's taxonomy while at the same time having a clear and apparent connection to a previously encountered item. Every student in attendance of the lecture (regardless of whether or not they participated in that specific classroom response activity) would have encountered the question (and subsequent discussion), with the only difference being when they encountered it. In all cases, the student sample that encountered the classroom response item in the following lecture exhibited better performance than the student sample that encountered the item immediately after the material had been presented. As noted previously, this is an intuitive and not particularly surprising result, since the item was obviously not being used to generate immediate feedback if it did not accompany the corresponding lecture content. Contrarily, these items, though structurally identical to a traditional classroom response question, were used to improve retention rather than generate feedback. It is encouraging that the use of these retention questions would appear to be correlated with measurable improvements in performance.

It is, however, noteworthy that the results would also seem to suggest (albeit with less certainty) that students do not perform as well on these questions when delivered in the following lecture. This is also a relatively intuitive result, but the impact was measurable and should be considered if classroom response activities are used in part to determine a student's final grade. This makes intuitive sense since students may learn more from early mistakes or failure than they would when they get it right while not fully understanding it.

REFERENCES

Blasco-Arcas, L., Buil, I., Hernandez-Ortega, B., and Sese, F. J. (2013). Using clickers in class. the role of interactivity, active collaborative learning and engagement in learning performance. *Computers & Education*, 62:102–110.

Boscardin, C. and Penuel, W. (2012). Exploring benefits of audience-response systems on learning: a review of the literature. *Academic Psychiatry*, 36(5):401–407.

Bruff, D. (2009). *Teaching with Classroom Response Systems: Creating Active Learning Environments*. Jossey-Bass.

Cukierman, D. (2015). Predicting success in university first year computing science courses: The role of student participation in reflective learning activities and in i-clicker activities. In *Proceedings of the 2015 ACM Conference on Innovation and Technology in Computer Science Education*, ITiCSE '15, pages 248–253, New York, NY, USA. ACM.

Huss-Lederman, S. (2016). The impact on student learning and satisfaction when a cs2 course became interactive (abstract only). In *Proceedings of the 47th ACM Technical Symposium on Computing Science Education*, SIGCSE '16, pages 687–687, New York, NY, USA. ACM.

Judson, E. and Sawada, D. (2002). Learning from past and present: Electronic response systems in college lecture halls. *Journal of Computers in Mathematics and Science Teaching*, 21(2):167–181.

Kay, R. H. and LeSage, A. (2009). Examining the benefits and challenges of using audience response systems: A review of the literature. *Computers & Education*, 53(3):819–827.

Liao, S. N., Zingaro, D., Laurenzano, M. A., Griswold, W. G., and Porter, L. (2016). Lightweight, early identification of at-risk cs1 students. In *Proceedings of the 2016 ACM Conference on International Computing Education Research*, ICER '16, pages 123–131, New York, NY, USA. ACM.

Moredich, C. and Moore, E. (2007). Engaging students through the use of classroom response systems. *Nurse Education*, 32(3):113–116.

Moss, K. and Crowley, M. (2011). Effective learning in science: The use of personal response systems with a wide range of audiences. *Computers & Education*, 56(1):36–43.

Porter, L., Zingaro, D., and Lister, R. (2014). Predicting student success using fine grain clicker data. In *Proceedings of the Tenth Annual Conference on International Computing Education Research*, ICER '14, pages 51–58, New York, NY, USA. ACM.

Simon, B., Parris, J., and Spacco, J. (2013). How we teach impacts student learning: Peer instruction vs. lecture in cs0. In *Proceeding of the 44th ACM Technical Symposium on Computer Science Education*, SIGCSE '13, pages 41–46, New York, NY, USA. ACM.

Vinaja, R. (2014). The use of lecture videos, ebooks, and clickers in computer courses. *J. Comput. Sci. Coll.*, 30(2):23–32.

Webb, A. and Carnaghan, C. (2006). Investigating the effects of group response systems on student satisfaction, learning and engagement in accounting education. *Issues in Accounting Education*, 22(3).

Zingaro, D. (2014). Peer instruction contributes to self-efficacy in cs1. In *Proceedings of the 45th ACM Technical Symposium on Computer Science Education*, SIGCSE '14, pages 373–378, New York, NY, USA. ACM.

Zingaro, D. and Porter, L. (2015). Tracking student learning from class to exam using isomorphic questions. In *Proceedings of the 46th ACM Technical Symposium on Computer Science Education*, SIGCSE '15, pages 356–361, New York, NY, USA. ACM.