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Improved Academic Performance and Student Perceptions of Learning Through Use of a Cell Phone-Based Personal Response System

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Abstract: Personal response systems, such as clickers, have been widely used to improve the effectiveness of teaching in various classroom settings. Although hand-held clicker response systems have been the subject of multiple prior studies, few studies have focused on the use of cell phone-based personal response system (CPPRS) specifically. This study explores students' academic performance and their perceptions of learning through the use of a CPPRS (TopHat) in an undergraduate Food Science class. In this study, students did not use the CPPRS during the first half of the semester-long course, but did during the second half. When CPPRS was used, students responded to 2 multiple-choice questions at 3 points during the class, (a) at the beginning of class, (b) in the middle of the class, and (c) at the end of the class. Student performance was measured by correctness rates on eight 10-item multiple choice quizzes, 4 quizzes each covering the class content that was delivered with compared with without CPPRS. A survey was conducted at the end of the semester asking ($n = 28$) students' perceptions of CPPRS. The average correctness rate for quizzes covering content delivered with CPPRS (85% $\pm$ 9%) was significantly higher than for content delivered without CPPRS (82% $\pm$ 10%) ($P = 0.016$). In addition, students perceived that CPPRS was easy to use (5.04 $\pm$ 0.58 on a 1 to 6 scale with 1 being strongly disagree and 6 being strongly agree) and positively impacted their learning (4.52 $\pm$ 0.99 using the same scale). When used correctly, CPPRS can facilitate student learning in lectures.

Keywords: engagement, personal response system, phone, student perception, student performance

Introduction

In Food Science education, it is important to create instructional environments (classrooms) where students are actively involved and engaged in order to foster student learning. The paradigm for undergraduate education has shifted from faculty passively transferring knowledge to students to a student-centered learning environment where active learners are more engaged in the learning process (Barr and Tagg 1995). This paradigm shift toward increased student engagement in undergraduate education is increasingly reflected in Food Science programs.

Active learning strategies, such as the use of attention-grabbing headlines for lecture material, effective use of stories, and in-class activities increase student engagement and interest in Food Science classes (Harris and others 2015). Engaging students through integrating real world context in Food Science Education has also improved students' understanding of complex concepts, increases knowledge gain, and significantly changes behavioral intentions with regards to Food Safety (Alberts and Stevenson 2017).

Classroom response systems, such as "clickers," have been widely used to improve the effectiveness of teaching and learning by fostering students' active involvement and engagement in various classroom settings (Sevian and Robinson 2011). Clickers can fully engage students in the classroom, allow instructors to evaluate students' understanding of (or misconceptions of) material in real-time, and help instructors to identify students who may require additional assistance (Judson and Sawada 2002). The effectiveness of clickers can be explained by a constructivist approach which supports the concept that clickers may improve student outcomes by providing opportunities for experiential learning in a classroom setting (Savery 2006; Schmidt and others 2007; Strobel and Van Barneveld 2009; English and Kitsantas 2013).

Despite the advantages of clickers, their disadvantages are not negligible. The additional cost of clickers themselves and user frustration due to common technical problems associated with clickers limit the willingness of some institutions and instructors to incorporate their use into classes (Blasco-Arcas and others 2013). Moreover, instructors must invest additional time and effort to adopt and integrate clickers into the teaching and learning process

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during class. Nonetheless, the use of clickers is often well received by students. Students generally enjoy using clickers in class and believe that it helps them to become more active and engaged learners (Gauci and others 2009). Multiple studies have observed improvement in student performance (higher grades) with the use of clickers (Uhari and others 2003; Poirier and Feldman 2007; Morling and others 2008). However, the impact of clickers on students' cognitive learning outcomes and academic performance varies depending upon how these devices or applications are used (Hunsu and others 2016). Therefore, proper implementation of clickers is essential to achieve the desired impact (Freeman and others 2014). Furthermore, differences may exist between impacts of cell phone based personal response systems (CPPRS) as opposed to clickers for students' academic performance, however those differences have not been systematically evaluated.

CPPRS, such as TopHat^{TM}, are purported to provide similar benefits to clickers with increased functionality (TopHat 2017). In addition to responding to multiple choice or true/false questions, CPPRSs allow the use of free-response queries, and interactive functions that make use of maps, graphics, and images. Many CPPRSs can be installed on smartphones as well as other Internet-connected devices like laptops or tablet computers, thus students do not typically need to purchase additional hardware to use CPPRS. Smartphones have permeated the academic environment, especially classrooms (Ali and others 2012). When used properly in the classroom, smartphones can contribute to improved academic performance (Gikas and Grant 2013). However, when misused, smartphones cause distraction and can even enable student misconduct (Tindell and Bohlander 2012).

Clickers have been used in in Food Science courses to engage students and promote active learning (Intemann 2006). Recently, Shaw et al. demonstrated that incorporating clickers into a short course on Hazard Analysis Critical Control Points (HACCP) improved the pass rate of the course (Shaw and others 2015). However, the effectiveness of using CPPRS in Food Science higher education has not been systematically evaluated and a better understanding of students' perceptions of CPPRS used in Food Science education would provide useful insight into the potential for application of such tools. To address this gap, our study aimed to evaluate the impact of using CPPRS on academic performance and students' perceptions of learning in an upper-level undergraduate Food Science course.

Materials and Methods

Overview

The study was conducted in an upper level undergraduate Food Science/Horticulture (cross-listed) course in Fall 2016 at a Southeastern land-grant university. In this study, students did not use the CPPRS (TopHat) during the first half of the semester-long course, but did in the second half of the course. Student performance was measured by the correctness rates on four 10-item multiple choice quizzes covering the class content in which (1) they used TopHat (4 quizzes), and (2) did not use the TopHat (4 quizzes). A survey was conducted at the end of the semester to assess students' perceptions of using TopHat.

Course structure and participants

Students enrolled ($n = 52$) in "Wines and Vines" class in Fall 2016 at a Southeastern land-grant university participated in this study. "Wines and Vines" is a 3 credit hour upper-level undergraduate course designed to help students develop a working knowledge of world wine styles and growing regions, basic principles of grape and wine production, wine appreciation, and sensory evaluation of wine. Two 75-min lectures were offered by the same instructor each week over a 16-wk period (1 academic semester). Because of the requirement to learn and practice sensory evaluation of wine, all students enrolled in this course must be at least 21 y of age by the beginning of the semester. The experimental classroom represented a balance between constructivist and "traditional" didactic lecture styles. A didactic lecture style was used to provide background and factual information. Sensory evaluation of wine with associated class debates and discussion provided opportunities for experiential learning and skill development.

Procedures

Academic performance. Over the course of 1 semester, 22 lectures covering subject matter of relatively consistent type and level of difficulty were delivered. TopHat was not used in the first half of the semester (11 lectures), but was used in the last half of the semester (11 lectures). Lecture structure was consistent throughout the semester. In the second half of the semester, TopHat was used during 3 distinct episodes in each lecture period. Questions were designed to test the students' comprehension of the class content. The TopHat questions were incorporated into the lectures without interrupting the natural flow of the lecture. Two review questions (multiple choice) were asked during the first episode (1 to 10 min) of the class. Two formative questions (non-multiple choice) were asked during the second episode (20 to 30 min) of the class. Two closure questions (multiple choice) reviewing the same day's lecture content were asked during the third episode (40 to 50 min). The students were given adequate time to respond to the question and were instructed to respond independently, without discussing questions with classmates. One minute was allotted to answer each question. Additional time was allowed upon request; however, all participant responses were generally entered in much less than 1 min. The instructor explained the correct answers for all items at the conclusion of each of the 3 question periods. Prior to the delivery of lecture material with TopHat, students were instructed to install the application and watch a demo video to learn and practice the application. Typically, TopHat requires a subscription fee, however for the purposes of this experiment, the student subscriptions were purchased by the University's Center for Teaching and Learning. Students were incentivized to use TopHat in class by the opportunity to earn course credit for entering correct responses to the in-class exercises. Out of a total of 1004 points possible throughout the semester, 144 points could be earned by answering in-class questions using TopHat. Of these 144 points, half could be earned for simply entering a response (participation), and the other half could be earned by entering the correct response (correctness).

Students took 8 quizzes throughout the semester, the first 4 covering content delivered without the use of TopHat, and the last 4 covering content delivered using TopHat.

All quizzes were announced at the beginning of the semester. Each quiz consisted of 10 multiple-choice questions: 6 intended to assess lower-order learning (Remembering, Understanding, and Applying) as defined by Bloom's taxonomy, and 4 intended to assess higher-order learning outcomes (Analyzing, Evaluating, and Creating). It was hypothesized that the use of TopHat would improve factual recall of lower order information as well as encourage critical thinking and expansion of knowledge and skills. To limit bias, all multiple-choice quiz items included 4 possible answer choices, which never included "all of the above" or "none of the above." Answer choices were listed alphabetically for each quiz

Table 1–Mean ± standard deviation of correctness rates on items designed to assess: lower- and higher-order of thinking, content delivered with/without TopHat, and all items/all content. Voluntary responses were received from $N = 39$ students, representing 75% of the total class enrollment of $N = 52$

Correctness rates*	Content delivered without TopHat	Content delivered with TopHat	All content
Lower-order questions	0.85 ± 0.10	0.88 ± 0.08	0.87 ± 0.08
Higher-order questions	0.77 ± 0.13	0.79 ± 0.12	0.78 ± 0.12
All questions	0.82 ± 0.10	0.85 ± 0.09	0.83 ± 0.10

*Note: The 2 main effect pairwise comparisons and 3 of the 4 simple effect pairwise comparisons were statistically significantly different ($p \leq 0.01$). The simple effect pairwise comparison of higher-order/without TopHat compared with higher-order/with TopHat was not statistically significantly different ($p = 0.20$).

Table 2–Survey results summarizing students' perceptions of using TopHat. Voluntary responses were received from $N = 28$ students, representing 54% of the total class enrollment of $N = 52$. Response options and values were: strongly agree (6), agree (5), somewhat agree (4), somewhat disagree (3), disagree (2), and strongly disagree (1)

Survey questions	Average score ± standard deviation
Theme 1: Impact of TopHat use on learning	**4.52 ± 0.99**
Using TopHat improved my learning.	4.46 ± 1.20
Using TopHat made me think more during class.	4.82 ± 1.02
Using TopHat increased my focus on the class.	4.29 ± 1.15
Theme 2: Ease of use	**5.04 ± 0.58**
Using TopHat was easy.	5.18 ± 0.82
Using TopHat was common sense.	4.93 ± 0.60
Using TopHat was straightforward.	5.00 ± 0.77

item. Students were allowed 12 min to take each in-class quiz. Printed copied of the quizzes were provided to students in class, and we observed that 12 min was an adequate amount of time for all students to complete the quizzes.

At the end of the semester, the researcher (not the instructor) announced the recruitment statement (Appendix A) in class and distributed Informed Consent forms (Appendix B) to students. The recruitment statement described the basics of the study (for example, who is involved, the nature of the research, anonymity and confidentiality). Signed consent was voluntary, and indicated students' agreement that the PI/Co-PIs may access and analyze their quiz scores for research purposes. No personally identifying student data was attached to the quiz score data set. Thirty-nine students (75% of the total class enrollment of $n = 52$ students) consented to allow their quiz scores to be included in this study ($n = 39$, 25 females and 14 males).

Statistical analysis. This study employed a 2 × 2 factorial design. Mean correctness rates ± standard deviation are presented in Table 1 for (1) quiz items covering content delivered with compared with without TopHat, (2) items designed to assess lower compared with higher order thinking, and (3) the overall quiz scores. Significance of the 2 main effects (TopHat use and lower-compared with higher-order quiz items) and their interactions was determined using repeated measures (within subjects) analysis of variance with a Greenhouse-Geisser adjustment. Significance was defined as $P < 0.05$. This analysis was conducted using IBM SPSS Statistics (IBM Corporation, Armonk, N.Y., U.S.A.). Effect size was calculated (Cohen's d) for both main effects and interactions using means, standard deviation and the correlation between the 2 means. The effect size is defined as large when the Cohen's d value is 0.8, medium when the value is 0.5, and small when the value is 0.2.

Survey to evaluate student perceptions of learning. At the end of the semester, a survey was conducted to evaluate students' perceptions of TopHat use in class. The survey was delivered using Qualtrics^{TM} (Qualtrics, Provo, Utah, U.S.A.), and a list of the survey questions for this study is provided in Appendix C. The students were asked to take the survey verbally by the researcher (not the instructor) in class, and also via email announcement. The survey was open for 2 wk after the initial announcement. Due to the anonymous nature of the survey, no incentive was offered for completion of the online survey. The survey items addressed students' perceptions and questions following 2 themes were used for this study: (1) the impact of TopHat use on learning and (2) ease of use. Additional questions addressed demographic information. Specific questions grouped by theme are listed in Table 2. Response options and values were: strongly agree (6), agree (5), somewhat agree (4), somewhat disagree (3), disagree (2), and strongly disagree (1). Demographic data of students (age, gender, major, and academic class standing) was also collected at the end of the anonymous voluntary survey. The average score and standard deviation for each item and for each theme were then calculated from the digitized responses (Table 2).

Results and Discussion

Academic performance

The mean ± standard deviation of the correctness rates on the items designed to assess lower- and higher-order of thinking, for quizzes covering content delivered with/without TopHat, and for all quiz items are presented in Table 1.

As expected, students performed better on quiz items designed to assess lower order thinking concepts (0.87 ± 0.08) than on quiz items designed to assess higher order thinking concepts (0.78 ± 0.12), $P < 0.01$. The effect size was large, $d = 0.971$. This finding agrees with our intended design for lower- and higher-order questions in the quiz. Higher-order questions are expected to prove more difficult than the lower-order question as they require more cognitive processing skills. But difficult questions do not necessarily associate testing higher cognitive levels (Lemons and Lemons 2013). Assessments including a combination of items designed to assess both the lower- and higher-order of thinking and learning better facilitate students' learning and ultimately result in higher academic performance (Wilen and Clegg 1986).

Overall, students performed better on the content that was delivered with TopHat (0.85 ± 0.09) than on the content delivered without TopHat (0.82 ± 0.10), $P = 0.016$. The effect size was medium, $d = 0.436$. Furthermore, there were significant interactions of the 2 independent variables in our study (the use of TopHat and higher- compared with lower- order items). Specifically, for the content delivered without TopHat, the correctness rates were better for the lower (0.85 ± 0.10) compared with higher-order (0.77 ± 0.13) quiz items $P < 0.001$. The effect size was medium, $d = 0.600$. Similarly, for the content delivered with TopHat, the correctness rates for the lower (0.88 ± 0.08) and higher-order (0.79 ± 0.12) quiz items were significantly different with $P < 0.001$. The effect size was large, $d = 0.919$. Within all lower-order quiz items, mean correctness rate for content delivered with TopHat (0.88 ± 0.08) were higher than for content delivered without TopHat (0.85 ± 0.1) ($P = 0.016$). The effect size was medium, $d = 0.408$. However, within the higher-order quiz items, mean correctness rate for content delivered with TopHat (0.79 ± 0.12) was not significantly different than for content delivered without TopHat (0.77 ± 0.13), $P = 0.207$. The effect size was small, $d = 0.206$.

By incorporating in-class exercises using TopHat into the lectures, students performed better overall and better on questions designed to assess lower-order thinking. However, in our class, TopHat use did not improve students' performance on quiz items designed to assess higher-order thinking and learning. Our findings generally agree with prior research that clickers can promote students' academic performance by increased student engagement and more interaction between the instructor and the students (Mayer and others 2009).

Students' perceptions of the effect of using TopHat on learning

Survey results from 28 students ($n = 28$) who voluntarily responded to our survey are reported in Table 2. Twenty-one out of 28 students used a cell phone primarily to answer TopHat questions during the lectures, while 7 of 28 responded primarily using laptop computers or tablets. All of the students who participated in the survey own smart phones. There were 6 female and 22 male respondents, ranging from 21 to 26 y of age (mean ± standard deviation for age = 21.8 ± 1.25 y). The majority of respondents were white, with 1 respondent identifying as Hispanic or Latino. Eight respondents were Food Science and Technology majors, 3 Horticulture majors (2 of those were Viticulture minors within the Horticulture major), and the remaining 15 survey respondents were from various majors including General Engineering, Animal and Poultry Sciences, Agribusiness, Accounting, Psychology, Applied Economics, Sociology, Marketing, Biological Sciences, Hospitality and Tourism Management, Computer Engineering, and Electrical Engineering. Thus, a fairly diverse group of majors and genders are represented, but ethnic or age diversity was not observed among our respondents.

As presented in Table 2, students agreed or somewhat agreed that TopHat positively impacted their learning (mean score for Theme 1 was 4.52 ± 0.99), and they agreed that TopHat was easy to use (mean score for Theme 2 was 5.04 ± 0.58). The student perceptions that TopHat had a positive impact on learning generally align with the quiz score data in that students earned higher scores on the lower-order items when TopHat was used in the delivery of the content evaluated.

Currently, it is a challenge to inhibit the existence and use of smartphones in classrooms due to the ubiquity of multitasking with smartphones in daily life (Armstrong 2014). One strategy for adaptation to pervasive multitasking in the classroom is to turn smartphones into useful learning tools to foster teaching and learning. Our results indicate that having students actively use their phones to participate in an upper-level undergraduate Food Science course can improve academic performance and student perceptions of learning.

Limitations and future directions

Factors extraneous to our study such as holidays and demands from other courses, jobs, etc. could have impacted academic performance along the time course of the semester, in addition to the impact of our treatment. While the difficulty of course content and lecture format were designed to be consistent throughout the semester, different topics were necessarily covered as the semester progressed. Students' personal preference and academic preparation for specific topics is expected to introduce some variation in academic performance. Finally, our course was the first course in the Department of Food Science and Technology at our University to incorporate the use of TopHat in lectures, thus the students were likely new to using TopHat. In the future, it would be appropriate to examine the use of CPPRS across a variety of content areas within Food Science, as well as across various pedagogical approaches. This approach would increase generalizability of the current findings.

Conclusions

TopHat, a CPPRS system, is a useful tool to improve students' academic performance and perceptions of learning in upper-level undergraduate Food Science classes. While improvement in academic performance on lower- order of learning assessment items was observed, improvement in performance on higher-order items was not. With the prevalence of smartphones among students, CPPRSs such as TopHat offer a strategy for turning ubiquitous phones into useful tools that can facilitate a collaborative teaching and learning environment through engagement.

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Appendix A: Recruitment Statement

Script for Announcing the Survey to the Class by the researcher

We have been using cell phones as clickers in this course this semester. We would like to collect some data on your perceptions of the use of cell phones as clicker as part of a research study. We would use these data to present at conferences and write an academic article.

The research is being conducted by

Peter Doolittle, Executive Director of the Center for Instructional Development and Educational Research

Amanda Stewart, your instructor, Assistant Professor of Food Science and Technology

Daniel Steger, graduate student and TA, Food Science and Technology

Sihui Ma, graduate student and TA, Food Science and Technology

Anyone who has been in this class this semester who is at least 18 y of age is eligible to participate in the survey. The survey is online and should only take about 10 minutes to complete. Participation in this survey is voluntary and the results will be anonymous. We will not be linking who you are to your responses.

Whether or not you participate is up to you and your participation, or not, will have no impact on your grade for this course.

If you have any questions, you can ask them now or send me an email at sdaniel3@vt.edu.

Appendix B: Consent Form

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants in Research Projects Involving Human Subjects

Title of Project: Student Distraction Following Cell-Phone-based Personal Response System Use

Investigator(s): Peter Doolittle, pdoo@vt.edu, 231–3954
Amanda Stewart, amanda.stewart@vt.edu, 231–0868

I. Purpose of this Research Project

The purpose of this research study is to explore students' use of cell phone-based personal response systems (i.e., clickers). The classroom learning experience is multifaceted, involving lectures, discussions, and student responses to questions. How do students use cell phones as 'clickers' during class? Do students find their use beneficial to their learning?

The results of this research study will be used to construct academic conference presentations and academic scholarly articles. The research study is open to all students in FST/HORT 3114 Wines and Vines.

The survey will provide information regarding students' use of cell phone-based 'clickers' in class, their impact on students' learning, and their contribution to the overall learning environment.

II. Procedures

Should you agree, the survey engagement will involve:

(1) You will be provided in class with a description of the online survey's purposed.
(2) The online survey will address students' use of the cell phone-based 'clickers' and basic demographic information (e.g., age, gender, year at VT).
(3) You will be provided in class with a link to the online survey.
(4) Completion of the online survey will take no longer than 10 minutes.
(5) Completion of the online survey will be anonymous.

III. Risks

The risks of involvement in the survey are minimal and involve only the provision of one's perceptions related to the class and the use of cell phone-based 'clickers.' You may withdraw from the survey at any time and the survey questions will not focus on any potentially embarrassing or dignity threatening topics.

IV. Benefits

Participation in this survey will benefit future teachers, students, and society by clarifying how cell phone-based 'clickers' may be used more effectively in classes. This knowledge will allow teachers to construct more effective learning environments. Finally, no promise or guarantee of benefits has been made to encourage you to participate.

V. Extent of Anonymity and Confidentiality

No identifying information (e.g., name, email) will be collected during the survey and only general demographic will be collected (e.g., age, gender, year at VT). At no time will the researchers release identifiable results of the study to anyone other than individuals working on the project without your written consent.

The Virginia Tech (VT) Institutional Review Board (IRB) may view the study's data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in research.

VI. Compensation

No compensation for participation will be provided.

VII. Freedom to Withdraw

It is important for you to know that you are free to withdraw from this study at any time without penalty. You are free not to answer any questions that you choose or respond to what is being asked of you without penalty.

Please note that there may be circumstances under which the investigator may determine that a subject should not continue as a subject.

Should you withdraw or otherwise discontinue participation, you will be compensated for the portion of the project completed in accordance with the Compensation section of this document.

VIII. Questions or Concerns

Should you have any questions about this study, you may contact one of the research investigators whose contact information is included at the beginning of this document.

Should you have any questions or concerns about the study's conduct or your rights as a research subject, or need to report a research-related injury or event, you may contact the VT IRB Chair, Dr. David M. Moore at moored@vt.edu or (540) 231–4991.

IX. Subject's Consent

I have read the Consent Form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

____ Date_________

Subject signature

____

Subject printed name

(Note: each subject must be provided a copy of this form. In addition, the IRB office may stamp its approval on the consent document(s) you submit and return the stamped version to you for use in consenting subjects; therefore, ensure each consent document you submit is ready to be read and signed by subjects.)

Appendix C: Survey

Welcome to our survey on the Impact of Cell Phone-based Personal Response System Use on Academic Performance. If you are interested, please continue.

For Q1 to Q6 response options and values were: strongly agree (6), agree (5), somewhat agree (4), somewhat disagree (3), disagree (2), and strongly disagree (1).

Q1 Using TopHat improved my learning.
Q2 Using TopHat was easy.
Q3 Using TopHat made me think more during class.
Q4 Using TopHat was common sense.
Q5 Using TopHat increased my focus on the class.
Q6 Using TopHat was straightforward.
Q7 How did you primarily answer the TopHat questions?

- ❑ Cell phone
- ❑ Laptop
- ❑ Other. Please specify: ___________________

Q8 Which of the following best describes your cell phone?

- ❑ Basic phone
- ❑ Smartphone
- ❑ I do not own a phone

Q9 What is your age?

- ❑ 21
- ❑ 22
- ❑ 23
- ❑ 24
- ❑ Other. Please specify: ___________________

Q10 To which gender identity do you most identify?

- ❑ Male
- ❑ Female
- ❑ Transgender
- ❑ Other. Please specify: ___________________

Q11 What is your ethnicity?

- ❑ White
- ❑ Hispanic or Latino
- ❑ Black or African American
- ❑ Native American or American Indian
- ❑ Asian/Pacific Islander
- ❑ Other. Please specify: ___________________

Q12 What is your major/minor?

- ❑ Food Science and Technology Major
- ❑ Horticulture Major
- ❑ Viticulture Minor
- ❑ Other. Please specify: ___________________