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PRE- HEALTH STUDENTS' PERCEPTIONS OF BRING YOUR OWN DEVICE (BYOD) CLICKERS IN AN INTRODUCTORY BIOLOGY COURSE

(Research Article)

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Abstract

The use of clickers in the lecture classroom has increased in recent years. Clickers have been widely used to improve teaching effectiveness in various lecture classroom settings. Most introductory biology courses are taught using direct instruction. One of the ways that students may be engaged in the lecture classrooms is by using a clicker. Clickers have been linked to several positive outcomes for students. Although clickers have been used in several prior studies, few studies have explicitly focused on BYOD clickers (smartphones, tablets, laptops). This study examined pre-health students' perceptions of using BYOD clickers to promote active learning in an introductory biology course at a Midwestern private college. The findings suggest that all students have positive perceptions about using BYOD clickers in the introductory biology lecture. The BYOD clickers can be used to foster best practices to improve classroom experiences and perceptions, and engage all students in biology and other STEM courses. Moreover, having a more equitable classroom environment that utilizes clickers might provide opportunities for these first-generation students to overcome challenges.

Keywords: clickers; student perceptions, introductory biology courses; BYOD

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1. Introduction

Researchers refer to clickers using several names like electronic voting systems, classroom response systems, student response systems (SRS), audience response systems, personal response systems, and interactive response systems are clickers (Oigara and Keengwe, 2013; Han and Finkelstein, 2013). Clickers have been used in the classroom for over 50 years, whereas earlier clickers used infrared technology, which were then replaced by radio frequency-enabled devices (Abrahamson, 2006; Klein, 2009). Recently clickers have taken many forms, including wireless devices, and web-based programs, like TopHat TM response systems, which provide similar benefits to clickers with increased functionality (Tophatmonocle Corp, 2017). Today, contemporary clickers, available through providers like Top Hat, allow students to use their mobile devices (smartphone, tablet, laptop, and Chromebook) to respond to questions that the instructor posts within a PowerPoint as part of daily lectures or as a review from previous lectures (Tophatmonocle Corp, 2017). The increased ownership by students of smartphones and faster wireless data connections gave rise to the Bring Your Own Device (BYOD). The BYOD technology has gained popularity as a flexible and more cost-effective way for instructors to engage with students in the classroom and improve learning outcomes (Chen et al.,2020).

The Top Hat clickers provide student's anonymous responses that are collected via the software portal, where they are immediately analyzed, and a histogram shows the responses' distribution among the answer choices and is visually displayed in real time for reflection or discussion (Caldwell, 2007; Keough, 2012; Emenike and Holme, 2012; Richardson et al., 2015; Stowell, 2015). The Top Hat allows the implementation of various question types, multiple-choice, multiple-response, fill-in-the-blank, matching, ordering, free-text response, and hot-spot (click-on-target) picture questions (Ma et al., 2018; Tophatmonocle Corp, 2017).

Incorporating active learning strategies like clickers in the classroom has been found to generally improve student performance outcomes with respect to exam scores and withdrawal rate compared to direct instruction lectures (Naibert et al., 2022). Moreover, clickers assess student learning to provide the instructor with real-time feedback and promote participation and engagement essential in active learning (Judson and Sawada, 2002; Ma et al., 2018; Bauer, 2020). Therefore, the instructor can instantly decide if a topic needs to be reviewed or if the lecture can proceed, while the students can self-reflect on their understanding of the concept just covered (Caldwell, 2007; Ma et al., 2018; Bauer, 2020). Clickers have also been used for formative and summative assessments. In formative assessment, clickers are used to determine student understanding of concepts without grades to identify misconceptions and the instructor can alter the course of classroom instruction (Fies and Marshall, 2006; Nikou, and Economides, 2018). In summative assessment, clickers assess student understanding of concepts with assigned grades to identify misconceptions and alter the course of classroom instruction (Kay and Lesage, 2009; Caldwell, 2007). Some instructors suggest linking clickers to grade incentives causes students to take it more seriously (Hake, 1998; Morales, 2011).

Several studies have shown that clickers have been incorporated in large and small lecture courses in science, technology, engineering, and mathematics (STEM) to improve teaching effectiveness (Kay and Lesage, 2009; Caldwell, 2007; Smith et al., 2011; Bauer, 2020; Chambers, 2020). Most of these studies show that students have positive perceptions of using clickers in their classrooms (Judson and Sawada, 2002; Caldwell, 2007; Durbin and Durbin, 2006). However, our review of the literature reveals an absence of baseline studies that have examined students' perceptions of using clickers in a medium-sized (~ 65 students) introductory biology lecture course for pre-health professions (Pre-Dentistry, Pre-Medicine, Pre-Optometry, Pre-Pharmacy, Pre-Pharmacy, Pre-Physician Assistants, and Pre- Veterinary). Moreover, despite the evidence about the positive impact of clickers in the classroom, these studies have several limitations that recommend caution in generalizing their findings. Such limitations include studies of a typical students (MacGeorge et al., 2008; Klein, 2009; Fitch 2004; Latessa and Mouw, 2005; Maguire and Maguire, 2012). Some studies have been conducted with students using clicker technologies that are considerably more traditional than those currently available (MacGeorge et al., 2008; Herr 1994; Horowitz 1988). Another issue is the lack of data collection instruments that have reliability and validity (MacGeorge et al., 2008; Klein, 2009; DeVellis, 2003). Finally, the inconsistent labeling of clickers makes it challenging to locate and stay current with the latest research (Kay and Lesage, 2009; Chambers, 2020).

Researchers have shown that students in introductory science, technology, engineering, and math (STEM) lectures are not engaged because most faculty (83%) in these gateway classrooms teach using direct instruction methods (Barnes et al., 2007; Chung et al., 2006; Herreid, 2010; Prensky, 2001a; Bauer, 2020). However, faculty teaching large gateway STEM lecture courses have been shown to adopt clickers readily; around 21% of these faculty regularly use clickers in their courses (Niemeyer and Zewail-Foote, 2018). In large STEM gateway courses, clickers have been shown to improve exam scores and decrease failure rates for students (Caldwell, 2007; Niemeyer and Zewail-Foote, 2018) enhance classroom interaction and active learning (Gauci et al., 2009; Gachago et al., 2011; Guthrie and Carlin 2004; Duncan 2006; Niemeyer and Zewail-Foote, 2018), critical thinking (Mollborn and Hoekstra 2010; Niemeyer and Zewail-Foote, 2018), peer interaction and cooperation (Crouch and Mazur 2001; English and Kitsantas 2013; Niemeyer & Zewail-Foote, 2018), real-time assessment and feedback (Greer and Heaney 2004; Bauer, 2020), conceptual application (Hoekstra 2008; Bauer, 2020), and transform the social and emotional environment of the classroom (Stowell and Nelson 2007; Hoekstra 2008; Tomkin et al., 2019; Bauer, 2020). Since the use of clickers in college, undergraduate STEM gateway courses have been continually increasing (Emenike and Holme, 2012; Gachago et al., 2011); it is important to examine how this pedagogy may differentially affect the perceptions of students within this gateway STEM courses. Given that these science classrooms include diverse students (eg, students from different races, ethnicities, genders, and worldviews), how do these groups experience clickers differently (Chambers, 2020). Although clickers have been widely adopted (Gibbons et al.,

2017; Niemeyer and Zewail-Foote, 2018), very little is known about the effects of clickers on first year pre-health students ((Kay & LeSage, 2009; Chambers, 2020: Hood, 2020).

Some of the challenges faced by these students may be improved by incorporating active learning practices like clickers into these gateway courses. Researchers claim that active learning may enhance students' sense of belonging, mitigate a competitive atmosphere prevalent in large lecture classes, provide more opportunities for students to practice metacognitive skills instead of rote memorization, and enhance academic self-efficacy (Hood et al., 2020). Therefore, this study aims to assess first year pre-health students' perceptions of using BYOD clickers to review what they had covered in the prior lecture in a medium-sized introductory biology lecture classroom. Based on this aim, the research questions have been determined as follows:

1.What are students' self-reported perspectives of using clickers in an introductory general biology lecture?
2. What positive reasons do students give for using clickers in an introductory general biology lecture?
3. What negative reasons do students give for using clickers in an introductory general biology lecture?

2. Method

The clicker used during this study was a web-based platform called Top Hat (Tophatmonocle Corp, 2017). It connects to the students' mobile devices, such as smartphones, laptops, and tablets. The Top Hat platform does not require students to purchase clickers. Instead, they buy a license to use the software on their mobile devices. The price was $20 per student for four months. In addition to clicker questions, the software can host all lecture materials, including presentations, text documents, and videos. Therefore, it is possible to quickly set up questions, move them within presentations if needed, and administer lectures entirely out of the Top Hat platform. Because a grade book function was included, each session had a unique Join Code. The instructor enabled Geofencing for each session to ensure that only students who were physically in attendance could participate. A student roster was linked from the Blackboard learning management system to the Top Hat platform, which enabled various functions such as summative assessments, segmentation of questions, targeted item analysis, attendance tracking, and certain gradebook items to sync at the discretion of the instructor. The Top Hat software allowed questions to be delivered multiple ways: during lectures, assigned homework, or for review.

At the beginning of the course, the professor explained to the students that clicker questions would be used for summative assessment. Students were allowed to discuss the questions with their peers. The instructor also demonstrated how to use the clickers and posted a video from the Top Hat website on how to use clickers on the Blackboard course site.

Throughout the course, the instructor used 5-10 clicker questions at the end of each chapter covered that allowed students to focus their attention and provide feedback on their comprehension of the material covered. The questions were conceptual and focused on the chapter's key concepts (Woelk, 2008; Beatty et al., 2006). The questions were primarily taken from the Macmillan supplemental materials supplied within the textbook and test bank, and the course instructor designed some. The clicker questions were administered directly following the end of the chapter that had been covered. The students responded to questions using their own devices; various question types were utilized, multiple-choice and multiple-answer format, fill-in-the-blank, sorting/matching, free-response, and hot-spot (click-on-target) questions. When a question was presented, students had 2-3 minutes to discuss possible answers to the question with their immediate neighbors, come to a conclusion, and individually submit their answers. Afterward, the correct answer was displayed and explained by the instructor.

We implemented clickers into one section with a total of 64 students of our second-semester general biology course for undergraduate pre-health majors. The course section was taught by one of the researchers. The instructor used various pedagogical techniques in addition to the clicker, including group work, lecture, and facilitated discussion. The percentage of clicker questions answered correctly accounted for 5% of the student's total grades. Students were required to register their clickers in the first week of classes, and throughout the semester, the clickers were used on average in two of the three 50 min lectures each week about (17 times. during the semester). The questions consisted of five to ten questions, with multiple choice, multiple answers, fill-in-the-blank, sorting/matching, free-response, hot-spot (click-on-target) questions, and true/false questions that covered the lecture content. The software registered a response when each student voted, and a histogram summarizing student responses was then displayed in real-time to the class along with the correct answer. If the histogram indicated incorrect student responses to the clicker question, the instructor followed up with further discussion on the topic. The responses were anonymous during the class session, but the individual answers were stored for later viewing by the instructor. The instructor compiled clicker scores for participation over the course of the semester and found that 72% of all clicker questions were answered correctly. A convenience sample (Creswell, 2014) was recruited from an appropriate course at a private Midwestern university, providing a rich mixture of students (Marshall and Rossman, 2014).

Human Subjects Institutional Review Board (HSIRB) approval was obtained. All the students were given one week to take the online clicker survey at the end of the semester. Students were informed that participating in the survey was anonymous and had no possible influence on their final course grades. A 14-item Likert scale survey was used to collect students' perceptions of clicker usage. The items were selected from two prior studies regarding students' perception of clicker usage (Graham et al., 2010). The clicker survey items were based on a 5-point scale, 5 = strongly agree (SA); 4 = agree (A); 3 = neither agree nor

disagree (N); disagree (D)= 2, and strongly disagree (SD)= 1. Two additional open-ended questions were asked to obtain qualitative narrative comments about the strengths and weaknesses of using clickers.

3. Results

The results are presented under each related research question in the following.

R1: What are students' self-reported perspectives of using clickets in an introductory general biology lecture?

Table 1 presents the results from questions within our clicker survey, answered on a Likert-style scale ranging from 5 strongly agree (SA) to 1 strongly disagree (SD). Our data indicate that our students found the clickers easy to use (mean = 4.03; 86% agreed). Furthermore, student respondents agreed that they like how clickers give instant feedback (mean = 4.18; 78% agreed). The students indicated that they chose their answers carefully (mean = 4.03; 78%). Students also agreed that clicker usage helped them to gauge my understanding of class content (mean= 3.86; 71%). The students indicated that clicker usage is a good way of helping me maintain concentration in class (mean =3.90; 71%). Our students also agreed that answering clicker questions encourages them to be more engaged in the classroom process (mean = 4.04; 76%). Students agreed that clicker usage helped them participate in class (mean =4.02; 80%). Finally, students indicated that clicker usage helped motivate them to be more prepared for class (mean = 3.80; 73%).

Table 1. Mean Response Scores to Survey Questions about Clicker Use

	Question	SA/A	Mean	SD
1	I like the way clickers give instant feedback.	78%	4.18	1.01
2	Clicker usage helped motivate me to be more prepared for class.	73%	3.80	1.10
3	Clicker usage helped me to gauge my understanding of class content.	71%	3.86	1.17
4	Discussion of the clicker answers helps me to clarify my knowledge about the subject	67%	3.76	1.18
5	Being able to answer anonymously is important to me.	68%	3.96	1.03
6	Clicker usage is a good way of helping me maintain concentration in class	71%	3.90	1.12
7	Clickers help me to do better on quizzes and exams.	61%	3.76	1.21
8	Clicker questions encourage me to be more engaged in the classroom process.	76%	4.04	0.98
9	Clicker usage helped me participate in class.	80%	4.02	1.05
10	Clicker usage helped make the learning experience more enjoyable.	59%	3.76	1.11
11	Given two class sections that are the same in all other respects, I would take the one that uses the clicker	61%	3.63	1.13
12	Overall, I have enjoyed using clickers.	67%	3.73	1.04
13	I found the clickers easy to use.	86%	4.33	0.74
14	I choose my answer to each clicker question carefully.	78%	4.14	0.89

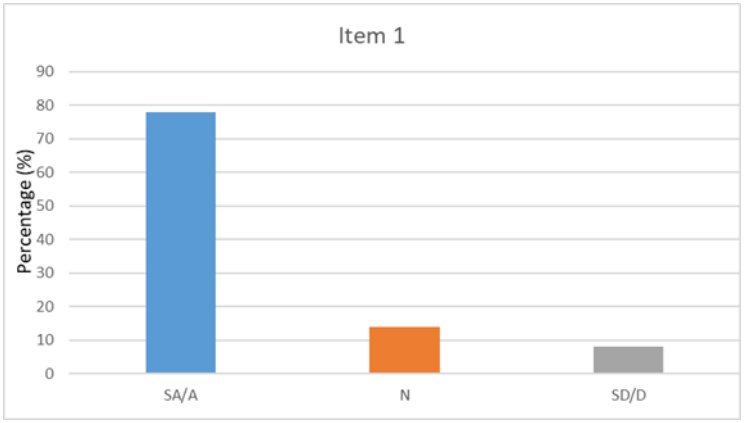

Figure 1. Student responses to Item 1 I like the way clickers give instant feedback?

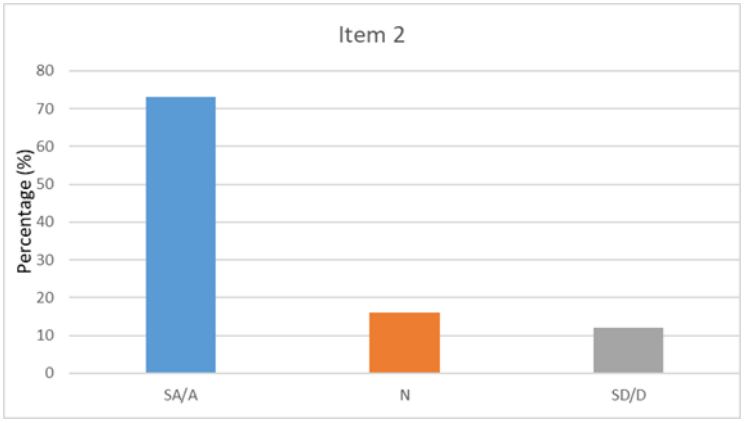

Figure 2. Student responses to Item 2 Clicker usage helped motivate me to be more prepared for class?

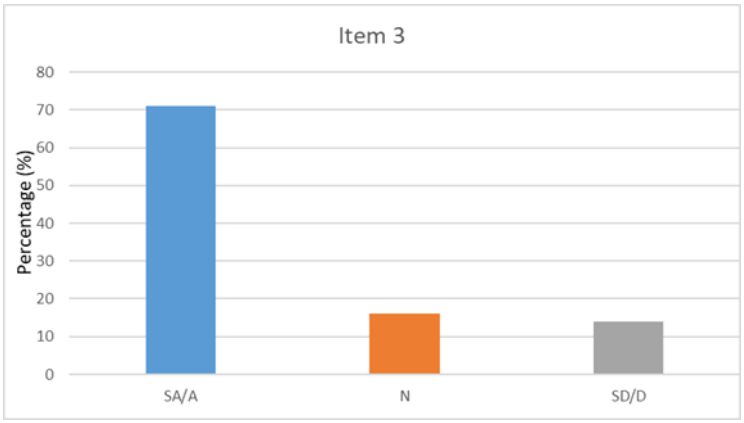

Figure 3. Student responses to Item 3 Clicker usage helped me to gauge my understanding of class content?

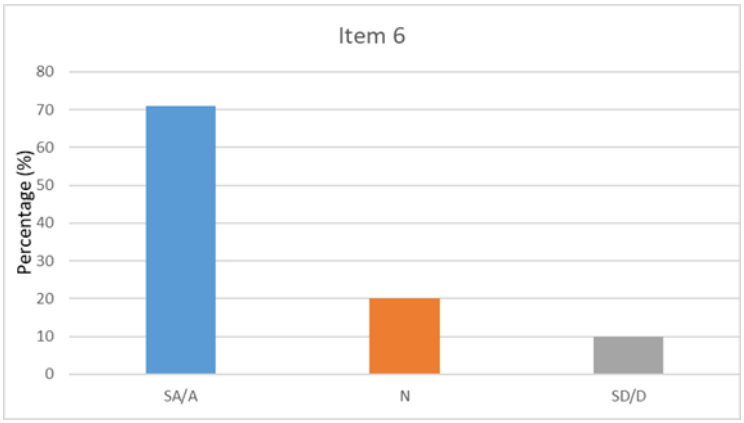

Figure 4. Student responses to Item 6 Clicker usage is a good way of helping me maintain concentration in class?

Figure 5. Student responses to Item 8 Clicker questions encourage me to be more engaged in the classroom process?

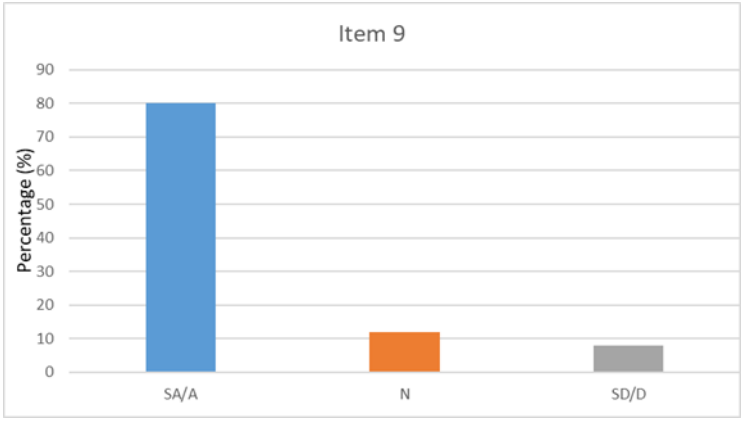

Figure 6. Student responses to Item 9 Clicker usage helped me participate in class?

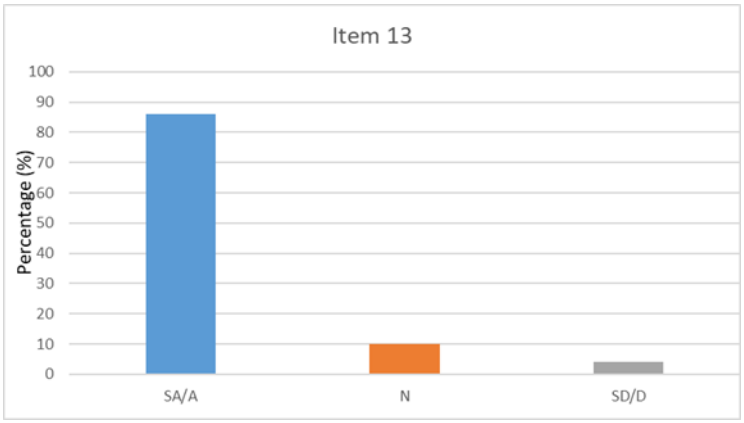

Figure 7. Student responses to Item 13 I found the clickers easy to use?

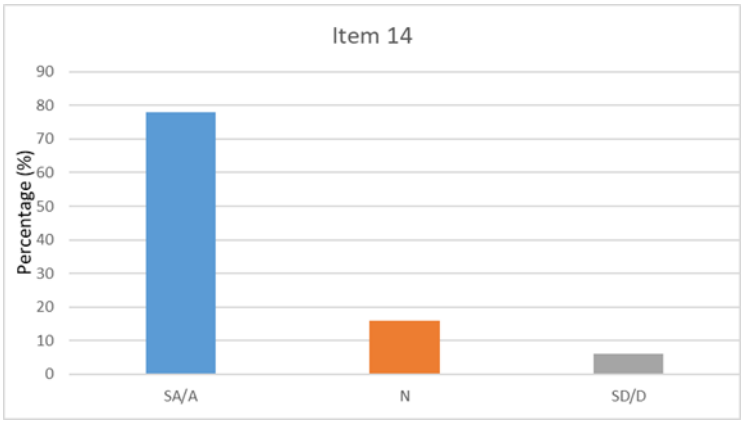

Figure 8. Student responses to Item 14 I choose my answer to each clicker question carefully?

R2: What positive reasons do students give for using clickers in an introductory general biology lecture?

Anonymous written student responses were also overwhelmingly positive (51% of students answered) regarding implementing an electronic response system into our introductory biology course. Three themes emerged from the analysis: understanding lecture material, being more engaged, and answering questions anonymously.

Understanding lecture material

The following quotes describe the participant's experience:

P35: "I liked using the clickers as a way to help me learn about the lecture. I enjoyed how they were for participation rather than correctness because that made me actually think rather than think am I going to get this right or wrong."

P40: "Using clickers helps reinforce to me what material I still need to review a bit more to gain a better understanding!"

P42: "It helped clarify content that I did not understand and allow me to know which content to review."

More engaged

The following quotes describe the participant's experience

P1: "I am able to look back and review the questions I had, it is very interactive and allows students to be more intervened/interactive."

P9: "the clickers helped me stay engaged in class."

Answer anonymously

The following quotes describe the participant's experience

P35: "Allows students to answer questions anonymously and allows them to see right answers."

P50: "Using clickers is a great way to stay anonymous while also participating in class lectures."

R3: What negative reasons do students give for using clickers in an introductory general biology lecture?

Three themes emerged from the analysis: another app, cost, and technological issues.

Another app

The following quotes describe the participant's experience

P31: "Not necessary, we can always use worksheets or the other assignments as usual. Clicker questions just gave us another app to use, without being especially different or nice."

Cost

The following quotes describe the participant's experience

P47: "Only weakness of the clicker questions would be that it's an additional payment that you had to get for the class."

P42: "The price. Even with a discount, the cost out-weighs the benefits. Other applications such as Google Forms serves a similar purpose that can track attendance and be used to answer questions without charging a fee."

Technological issues

The following quotes describe the participant's experience

P4: "I had issues one time with my clicker questions, but I contacted TopHat support and they were able to fix it."

P7: "There were times where the clicker questions were only available on the professor's board, which made it hard to see at times, especially when content was small and descriptive."

P19: "For the questions to click on the picture, it marks me wrong when i get a little bit off from the designated space."

4. Discussion

This study assessed first year pre-health students' perceptions of using a BYOD in a second-semester introductory biology course with a series of questions at the end of each chapter covered.

Overall, the students had generally positive perceptions of using clickers in a medium-sized undergraduate general biology course. Similarly, several studies have reported that students had positive perceptions of clickers in large and small lecture courses (Addisonet al., 2009; Caldwell, 2007; Bauer, 2020; Deslauriers et al., 2011; Smith et al., 2011). In this study, students reported that clicker questions encouraged them to be more engaged in the classroom process. Previous studies have shown that students are more interested or engaged in lecture concepts presented and discussed using clickers (Cadwell, 2007; Maguire and Maguire, 2012; Chambers, 2020; Bauer, 2020). Researchers believe that students are more engaged and actively involved in the learning process as they might have fun using a clicker device and observing their colleagues' answers (Cadwell, 2007; Maguire and Maguire, 2012; Chambers, 2020; Bauer, 2020). Students indicated that clickers were easy to use. Other studies reported similar benefits, indicating that clickers were easy to learn and use (Cadwell, 2007; Maguire and Maguire, 2012; Chambers, 2020; Bauer, 2020). Kegouh, 2012 indicated that students exposed to clickers find the technology easy to use whether they have been exposed to clickers for a short or an extended period. Clickers do not require a steep learning curve.

Students reported that clickers resulted in increased participation in class. Researchers have shown that clickers can promote increased participation in the classroom because more students are likely to participate due to the anonymity associated with each response (Draper et al., 2002; Buyukkurt and Cassidy, 2012). Anonymity allows all students to participate in the learning process without fear of being judged by their peers or the instructor. (Cadwell, 2007; Klein, 2009; Chambers, 2020; Niemeyer and Zewail-Foote, 2018; Jones, 2008). In an ideal

scenario, shy students who regularly respond correctly will develop confidence and eventually feel more comfortable participating in class discussions (King and Joshi. 2008; Cadwell, 2007; Klein, 2009; Chambers, 2020; Niemeyer and Zewail-Foote, 2018). Moreover, several researchers indicate that using clickers increases student participation when compared to classrooms where clickers are not used (Caldwell, 2007; Klein, 2009). Students reported that using clickers enabled them to have real-time responses. Several studies have shown that the use of clickers offers real-time feedback for students and instructors on how well concepts are understood (Cadwell, 2007; Klein, 2009; Chambers, 2020; Niemeyer and Zewail-Foote, 2018). This can help the instructors to modify their explanation or mode of teaching quickly; students can also assess and discuss their understanding with their peers (Vega, 2013; Oigara and Keengwe, 2013).

Students reported that clickers helped motivate them to be more prepared for class and gauge their understanding of class content. Johnson and Lillis (2010) indicated that using a clicker in a microbiology module improved student motivation and attention. Students indicated that clickers helped them learn the material more effectively, stay focused, and verify their understanding. Johnson (2005) argues that using clickers in the classroom encourages student discussion of the material covered in class to gauge their level of understanding and promotes an effective learning class experience (Oigara and Keengwe, 2013). The pedagogical benefit of clickers, most commonly mentioned by the students, is enhanced student attention and concentration during lectures (Peftitsis and Mavroudi, 2022). In a previous study, the lecture sessions that utilized the clicker began with students completing review questions over the material they had read before attending class. Students indicated that this served as a powerful motivator for class preparation. Moreover, students indicated that it enabled them to understand what was important in the assigned homework and the material they were learning (MacGeorge et al., 2008). Students have reported that they feel more comfortable participating in classes that utilize clickers than those that do not (Eastman, 2007; Eastman et al., 2009, 2011). With more chances to participate and interact in class, students tend to have increased attention during lectures (Draper and Brown, 2004; Klein, 2009; Cadwell, 2007; Chamber, 2020).

Students reported that clickers allowed them to answer questions carefully. This finding is consistent with previous studies that showed students may have taken time to answer the clicker questions since they were assessed on their understanding of prior lecture notes. This allowed the students to evaluate their level of understanding at the end of a lecture session (Cadwell, 2007; Klein, 2009; Chambers, 2020; Niemeyer and Zewail-Foote, 2018). Faculty who use clickers in their classrooms strongly advocate that students who commit to an answer—even if they just guess—are “emotionally” or “psychologically invested” in the question and pay better attention to the discussion that follows (Cadwell, 2007; Beatty, 2004). Students think that the clickers help them listen more intently in class and, therefore, help in better understanding what the instructor teaches. Students also believe clickers prompt them to attend class and deeply process the material (Fitzpatrick Finn and Campisi, 2011).

Summative assessment, or the evaluation of student performance based on grades, has been used extensively with clickers (Fies and Marshall, 2006). Some studies suggest that students are more likely to work on a problem presented during class if clicker-submitted answers are offered credit (Cutts et al., 2004; Caldwell, 2007). In a previous study (Kay, LeSage, and Knaack, 2010), secondary school students did not like using clickers for tests. However, when clickers were used for formative assessment, students were significantly more motivated and cognitively engaged. In our study, students were more engaged and focused when they knew that the clicker questions were used for summative assessment. The student comments highlighting the strengths of the clicker and reiterates the findings of past studies concerning class participation, reinforcement of concepts that help in preparing for exams and quizzes, and instant feedback (Cadwell, 2007; Chambers, 2020; Niemeyer and Zewail-Foote, 2018). The comments regarding the drawbacks of the clickers mainly were technical problems. Similarly, previous studies reported that clickers' main disadvantage is that they did not function properly (Chambers, 2020). This was particularly disappointing for students who were being graded for using clickers (El-Rady, 2006; Sharma et al., 2005; Siau et al., 2006; Cadwell, 2007).

5. Conclusions

Overall, our results demonstrate that first year pre-health students enrolled in this second-semester general biology course favored using BYOD clickers. The students perceived that using clickers helped them participate more and engage in the course. Furthermore, students felt that real-time feedback significantly enhanced their learning. The BYOD clickers can be used to foster active classroom learning, improve classroom experiences and perceptions, and engage all students in biology and other STEM courses. Indeed, active-learning approaches have been reported to improve student attitudes and increase student performance in STEM courses compared to traditional lectures and may serve as a way to engage and retain students in STEM (Cadwell, 2007; Klein, 2009; Chambers, 2020; Niemeyer and Zewail-Foote, 2018). Some of the challenges faced by first-generation students may be improved by incorporating active learning practices like clickers into these gateway courses. Moreover, having a more equitable classroom environment that utilizes clickers might decrease "imposter syndrome" providing opportunities to overcome challenges. There are, however, limitations to our studies. We did not consider individual student differences (age, gender, race), which should be done in later studies. Data were only collected through a self-report survey.

Furthermore, triangulating the data through observations or qualitative interviews would enhance and deepen our understanding of the interaction between students and using clickers. Future studies should use validated and reliable clicker surveys to enable cross-validation of studies. Detailed research studies are lacking on the specific benefits and challenges that influence the use of BYOD clickers. For example, what is engaging about using BYOD clickers in the lecture classroom setting, and is increased interaction superficial or meaningful in learning?

6. Declaration of Conflicting Interests and Ethics

The authors declare no conflict of interest.

References

Abrahamson, L. (2006) 'A brief history of networked classrooms: Effects, cases, pedagogy, and implications', In Audience response systems in higher education: Applications and cases (pp. 1-25). IGI Global.

Addison, S., Wright, A., and Milner, R. (2009) 'Using clickers to improve student engagement and performance in an introductory biochemistry class', Biochemistry and Molecular Biology Education, 37(2), 84-91.

Barnes, K., Marateo, R. C., & Ferris, S. P. (2007). Teaching and learning with the net generation. Innovate: Journal of Online Education, 3(4).

Bauer, C. (2020). Engineering essential attributes of cooperative learning and quality discourse in a large enrollment course by leveraging clicker devices. Journal of College Science Teaching, 49(4), 16-23.

Beatty, I. D., Gerace, W. J., Leonard, W. J., and Dufresne, R. J. (2006) 'Designing effective questions for classroom response system teaching', American journal of physics, 74(1), 31-39.

Buyukkurt, M. D., Li, Y., & Cassidy, R. (2012). Using a classroom response system in an introductory business statistics course: Reflections and lessons learned. In Proceedings of Informing Science & IT Education Conference (pp. 379-388).

Caldwell, J. E. (2007) 'Clickers in the large classroom: Current research and best-practice tips', CBE—Life Sciences Education, 6(1), 9-20.

Chambers, E. L. (2020) 'Clicking for the Success of All Students: A Literature Review and Classroom Study Investigating the Possible Differential Impact of Clickers', (Doctoral dissertation, Arizona State University).

Chen, L., Chen, T. L., and Liu, H. K. (2020) 'Identifying Students Perception of Clickers via Bring Your Own Device (BYOD) in Flipped Classrooms', International Journal of Organizational Innovation (Online), 13(1), 105-117.

Chen, X., & Carroll, C. D. (2005). First-Generation Students in Postsecondary Education: A Look at Their College Transcripts. Postsecondary Education Descriptive Analysis Report. NCES 2005-171. National Center for Education Statistics.

Choy, S. P. (2001). Students whose parents did not go to college: Postsecondary access, persistence, and attainment.

Chung, G. K., Shel, T., & Kaiser, W. J. (2006). An exploratory study of a novel online formative assessment and instructional tool to promote students' circuit problem solving. The Journal of Technology, Learning and Assessment, 5(6).

Creswell, J. W. (2014) 'A concise introduction to mixed methods research'. SAGE publications.

Crouch, C. H., & Mazur, E. (2001). Peer instruction: Ten years of experience and results. American journal of physics, 69(9), 970-977.

Deslauriers, L., Schelew, E., and Wieman, C. (2011) 'Improved learning in a large-enrolment physics class', Science, 332(6031), 862-864.

Draper, S. W., Cargill, J., and Cutts, Q. (2002) 'Electronically enhanced classroom interaction', Australasian Journal of Educational Technology, 18(1)

Duncan, D. (2006). Clickers: A new teaching aid with exceptional promise. Astronomy Education Review, 5(1), 70-88.

Durbin, S. M., and Durbin, K. A. (2006). Anonymous polling in an engineering tutorial environment: A case study. In Audience response systems in higher education: Applications and cases (pp. 116-126). IGI Global.

Eastman, J. K. (2007) 'Enhancing classroom communication with interactive technology: How faculty can get started', College Teaching Methods and Styles Journal (CTMS), 3(1), 31-38.

Eastman, J. K., Iyer, R., and Eastman, K. L. (2009) 'Interactive technology in the classroom: An exploratory look at its use and effectiveness', Contemporary Issues in Education Research (CIER), 2(3), 31-38.

Eastman, J. K., Iyer, R., and Eastman, K. L. (2011) 'Business students' perceptions, attitudes, and satisfaction with interactive technology: An exploratory study', Journal of Education for Business, 86(1), 36-43.

El-Rady, J. (2006) 'To click or not to click: That's the question', Innovate: Journal of online education, 2(4).

Emenike, M. E., & Holme, T. A. (2012). Classroom response systems have not "crossed the chasm": Estimating numbers of chemistry faculty who use clickers. Journal of Chemical Education, 89(4), 465-469.

English, M. C., & Kitsantas, A. (2013). Supporting student self-regulated learning in problem- and project-based learning. Interdisciplinary journal of problem-based learning, 7(2), 6.

Fies, C., and Marshall, J. (2006) 'Classroom response systems: A review of the literature', Journal of Science Education and Technology, 15(1), 101-109.

Fitch, J. L. (2004) 'Student feedback in the college classroom: A technology solution', Educational Technology, Research and Development, 52, 71–81.

Fitzpatrick, K. A., Finn, K. E., and Campisi, J. (2011) 'Effect of personal response systems on student perception and academic performance in courses in a health sciences curriculum', Advances in Physiology Education, 35(3), 280-289.

Freeman, M., Blayney, P., and Ginns, P. (2006) 'Anonymity and in class learning: The case for electronic response systems', Australasian Journal of Educational Technology, 22(4).

Gachago, D., Morris, A., & Simon, E. (2011). Engagement levels in a graphic design clicker class: Students' perceptions around attention, participation and peer learning. Journal of Information Technology Education: Research, 10(1), 253-269.

Gauci, S. A., Dantas, A. M., Williams, D. A., & Kemm, R. E. (2009). Promoting student-centered active learning in lectures with a personal response system. Advances in physiology education, 33(1), 60-71.

Gibbons, M. M., Rhinehart, A., & Hardin, E. (2019). How first-generation college students adjust to college. Journal of College Student Retention: Research, Theory & Practice, 20(4), 488-510.

Gibbons, R. E., Laga, E. E., Leon, J., Villafañe, S. M., Stains, M., Murphy, K., & Raker, J. R. (2017). Chasm crossed? Clicker use in postsecondary chemistry education. Journal of Chemical Education, 94(5), 549-557.

Greer, L., & Heaney, P. J. (2004). Real-time analysis of student comprehension: An assessment of electronic student response technology in an introductory earth science course. Journal of Geoscience Education, 52(4), 345-351.

Guerrero, M., & Rod, A. B. (2013). Engaging in office hours: A study of student-faculty interaction and academic performance. Journal of Political Science Education, 9(4), 403-416.

Guthrie, R., & Carlin, A. (2004). Waking the dead: Using interactive technology to engage passive listeners in the classroom. AMCIS 2004 Proceedings, 358.

Hake, R. R. (1998) 'Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses', American journal of Physics, 66(1), 64-74.

Han, J. H., and Finkelstein, A. (2013) 'Understanding the effects of professors' pedagogical development with Clicker Assessment and Feedback technologies and the impact on students' engagement and learning in higher education', Computers and Education, 65, 64-76.

Hatch, J., Jensen, M., and Moore, R. (2005) 'Manna from heaven or" clickers" from hell', Journal of College Science Teaching, 34(7), 36.

Herreid, C. F. (2010). The scientific method ain't what it used to be. Journal of College Science Teaching, 39(6), 68.

Hoekstra, A. (2008). Vibrant student voices: Exploring effects of the use of clickers in large college courses. Learning, Media and Technology, 33(4), 329-341.

Holden, C. L., Wright, L. E., Herring, A. M., & Sims, P. L. (2021). Imposter syndrome among first-and continuing-generation college students: The roles of perfectionism and stress. Journal of College Student Retention: Research, Theory & Practice, 15210251211019379.

Hu, J., Bertok, P., Hamilton, M., White, G., Duff, A., and Cutts, Q. (2006) 'Wireless interactive teaching by using keypad-based ARS', In Audience response systems in higher education: Applications and Cases, (pp. 209-221). IGI Global.

Johnson, J. T. (2005) 'Creating learner-centered classrooms: use of an audience response system in pediatric dentistry education', Journal of Dental Education, 69(3), 378-381.

Johnson, K., and Lillis, C. (2010) 'Clickers in the laboratory: Student thoughts and views', Interdisciplinary Journal of Information, Knowledge, and Management, 5, 139.

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.

Judson, E., and Sawada, D. (2006) 'Audience response systems: insipid contrivances or inspiring tools?', In Audience response systems in higher education: Applications and cases (pp. 26-39). IGI Global.

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

Keough, S. M. (2012) 'Clickers in the Classroom: A Review and a Replication', Journal of Management Education, 36(6), 822-847.

King, D. B., and Joshi, S. (2008) 'Gender differences in the use and effectiveness of personal response devices', Journal of Science Education and Technology, 17(6), 544-552.

Klein, K. (2009). Promoting collaborative social learning communities with student response systems. Journal of Online Learning and Teaching, 5(4).

Latessa, R., and Mouw, D. (2005) 'Use of an audience response system to augment interactive learning', Family Medicine, 37, 12–14.

Ma, S., Steger, D. G., Doolittle, P. E., and Stewart, A. C. (2018) 'Improved academic performance and student perceptions of learning through use of a cell phone-based personal response system', Journal of Food Science Education, 17(1), 27-32.

MacGeorge, E. L., Homan, S. R., Dunning, J. B., Elmore, D., Bodie, G. D., Evans, E., Khichadia, S.; Lichti, S. M.; Feng, B.; and Geddes, B. (2008) 'Student evaluation of audience response technology in large lecture classes', Educational Technology Research and Development, 56(2), 125-145.

Maguire, P., & Maguire, R. (2012). An Investigation into the Use of Clickers in Groups for Teaching Data Structures and Algorithms.

Marshall, C., and Rossman, G. B. (2014) 'Designing qualitative research', Sage publications.

Mollborn, S., & Hoekstra, A. (2010). "A meeting of minds" using clickers for critical thinking and discussion in large sociology classes. Teaching sociology, 38(1), 18-27.

Morales, L. (2011). Can the use of clickers or continuous assessment motivate critical thinking? A case study based on corporate finance students. Higher Learning Research Communications, 1(1), 33-42.

Naibert, N., Vaughan, E. B., Brevick, K., and Barbera, J. (2022) 'Exploring Student Perceptions of Behavioral, Cognitive, and Emotional Engagement at the Activity Level in General Chemistry', Journal of Chemical Education, 99(3), 1358-1367.

Niemeyer, E. D., and Zewail-Foote, M. (2018) 'Investigating the influence of gender on student perceptions of the clicker in a small undergraduate general chemistry course', Journal of Chemical Education, 95(2), 218-223.

Nikou, S. A., and Economides, A. A. (2018) 'Mobile-Based micro-Learning and Assessment: Impact on learning performance and motivation of high school students', Journal of Computer Assisted Learning, 34(3), 269-278.

Oigara, J., and Keengwe, J. (2013) 'Students' perceptions of clickers as an instructional tool to promote active learning', Education and Information Technologies, 18(1), 15-28.

Parkman, A. (2016). The imposter phenomenon in higher education: Incidence and impact. Journal of Higher Education Theory & Practice, 16(1).

Patry, M. (2009). Clickers in large classes: From student perceptions towards an understanding of best practices. International Journal for the Scholarship of Teaching and Learning, 3(2), n2.

Peftitsis, D., and Mavroudi, A. (2022) 'Students Perceptions on Teaching Design of Power Electronics Using Student-Response Systems: Thematic Content Analysis of Interviews', IEEE Access, 10, 64059-64071.

Porter, A. G., and Tousman, S. (2010) 'Evaluating the effect of interactive audience response systems on the perceived learning experience of nursing students', Journal of Nursing Education, 49(9), 523-527.

Prensky, M. (2001). The games generations: How learners have changed. Digital game-based learning, 1(1), 1-26.

Preszler, R. W., Dawe, A., Shuster, C. B., and Shuster, M. (2007) 'Assessment of the effects of student response systems on student learning and attitudes over a broad range of biology courses', CBE—Life Sciences Education, 6(1), 29-41.

Ramsey, K., & Peale, C. (2010). First-generation college students stay the course. USA Today, 29.

Richardson, A. M., Dunn, P. K., McDonald, C., and Oprescu, F. (2015) 'CRiSP: An instrument for assessing student perceptions of classroom response systems', Journal of Science Education and Technology, 24(4), 432-447.

Schwartz, S. E., Kanchewa, S. S., Rhodes, J. E., Gowdy, G., Stark, A. M., Horn, J. P., McKenna, P., & Spencer, R. (2018). "I'm having a little struggle with this, can you help me out?": Examining impacts and processes of a social capital intervention for first-generation college students. American Journal of Community Psychology, 61(1-2), 166-178.

Sharma, M. D., Khachan, J., Chan, B., and O'Byrne, J. (2005) 'An investigation of the effectiveness of electronic classroom communication systems in large lecture classes', Australasian Journal of Educational Technology, 21(2).

Siau, K., Sheng, H., and Nah, F. H. (2006) 'Use of a classroom response system to enhance classroom interactivity', IEEE Transactions on Education, 49(3), 398-403.

Simpson, V., and Oliver, M. (2007) 'Electronic voting systems for lectures then and now: A comparison of research and practice', Australasian Journal of Educational Technology, 23(2).

Smith, M. K., Trujillo, C., and Su, T. T. (2011) 'The benefits of using clickers in small-enrolment seminar-style biology courses', CBE—Life Sciences Education, 10(1), 14-17.

Stowell, J. R. (2015) 'Use of clickers vs. mobile devices for classroom polling', Computers and Education, 82, 329-334.

Stowell, J. R., & Nelson, J. M. (2007). Benefits of electronic audience response systems on student participation, learning, and emotion. Teaching of psychology, 34(4), 253-258.

Terrion, J. L., and Aceti, V. (2012). Perceptions of the effects of clicker technology on student learning and engagement: a study of freshmen Chemistry students. Research in Learning Technology, 20.

Tomkin, J. H., Beilstein, S. O., Morphew, J. W., & Herman, G. L. (2019). Evidence that communities of practice are associated with active learning in large STEM lectures. International Journal of STEM Education, 6(1), 1-15.

Tophatmonocle Corporation. 2017 'Homepage. Available from: https:// tophat.com/',

Vega, V. (2013). Technology integration research review: Additional tools and programs. George Lucas Educational Foundation.

Walklet, E., Davis, S., Farrelly, D., and Muse, K. (2016) 'The impact of Student Response Systems on the learning experience of undergraduate psychology students', Psychology Teaching Review, 22(1), 35-48.

Woelk, K. (2008) 'Optimizing the use of personal response devices (clickers) in large-enrolment introductory courses', Journal of Chemical Education, 85(10), 1400.