Enhancing Active Learning of Anatomy and Physiology with the Use of I>clickers

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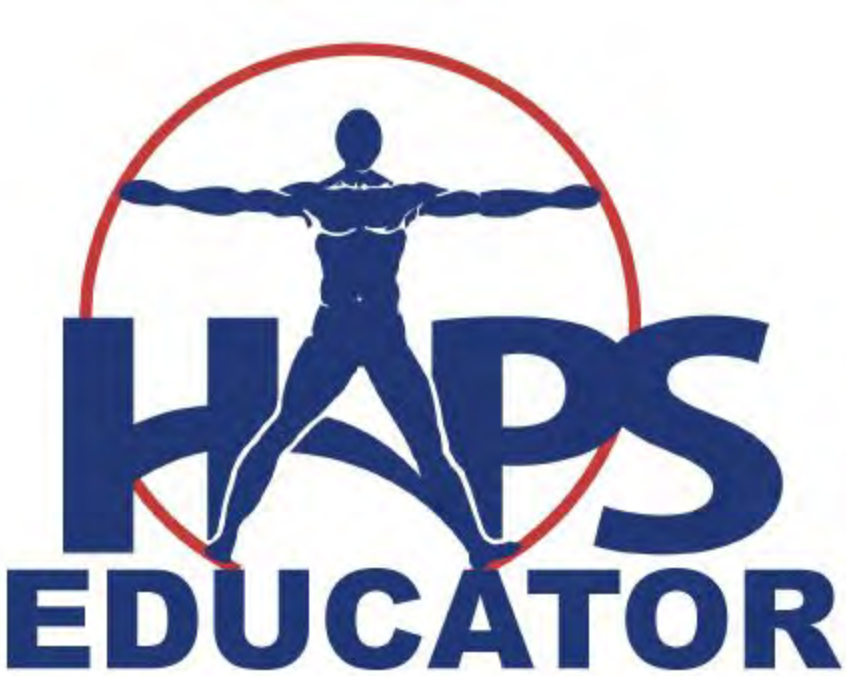

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Enhancing Active Learning of Anatomy and Physiology with the Use of I>clickers

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Abstract

One of the most challenging aspects of teaching anatomy and physiology is using teaching tools that enhance active learning and keep students actively engaged during the lecture courses. This study explored the use of a student response system that was easy to use, cost-efficient, and re-usable for multiple anatomy and physiology courses. More specifically, the impact of i>clickers on student performance in anatomy and physiology courses was investigated by comparing exam scores before and after the introduction of i>clickers. This study showed that the use of i>clickers during the lecture courses increased student engagement and improved the performance of students on the lecture exams covering the respiratory, digestive, urinary, reproductive, lymphatic, and immune systems. The overall performance of students in the anatomy and physiology lecture courses had also a tendency to increase. Furthermore, student feedback regarding i>clicker use was highly positive. http://doi.org/10.21692/haps.2022.002

Key words: anatomy and physiology, i>clickers, active learning, student performance, engagement

Introduction

Most educators acknowledge the value of active participation in the college classrooms; however, achieving success in eliciting it seems more difficult despite repeated efforts (Susak 2016; Weaver and Qi 2005). Students struggle with classroom participation due to factors that relate to their personal traits, the classroom size, logistics, seating arrangement, and the formal structure of the classroom environment (Susak 2016; Weaver and Qi 2005).

Similarly to what other educators experienced in other disciplines (Hyde and Ruth 2014; Karp and Yoels 1976; Susak 2016; Weaver and Qi 2005), we and others also noticed that most students remain passive members of the classroom environment during an anatomy and physiology lecture course (FitzPatrick et al. 2011; Geertsen 2015; Hoyt et al. 2010). The low classroom participation rate in our anatomy and physiology courses sparked my interest in implementing a student response system to increase active participation and enhance the learning experience of our students. There is strong evidence for the importance of active participation in class (Lyons 1989; Weaver and Qi 2005). Indeed, students were found to earn higher grades as their classroom participation increased (Handelsman et al. 2005; Rocca 2010). It was proposed that the more students participate, the more they know and comprehend, allowing them to engage in higher levels of thinking (Rocca 2010; Smith 1977).

Classroom participation increases with a student response system because students are able to answer questions anonymously. An interactive classroom response system allows an instructor to present a question to the class, allows students to enter their answers using the clickers, and instantly analyzes, summarizes and displays students' answers while protecting student anonymity (Beatty 2005; Dufresne et al. 1996). In addition, the immediate feedback provided by an interactive classroom response system technology, such as clickers, has been demonstrated to have a positive impact on student learning (National Research Council 2000; Yourstone et al. 2008). Clickers have been rated as effective learning tools by students enrolled in classes of a variety of levels and sizes (Addison et al. 2009; Caldwell 2007; FitzPatrick et al. 2011).

Mixed results were noticed on student performance in some health sciences courses, when an interactive student response system was used (Caldwell 2007; FitzPatrick et al. 2011). For example, the use of clickers in an exercise physiology course enhanced student performance, whereas in a human pathophysiology course the academic performance of students did not improve with the use of clickers. Furthermore, there is a limited number of studies and, hence, limited data regarding the impact of an interactive student response system on students' performance in anatomy and physiology courses. For example, one study showed that, in freshmen-level Anatomy and Physiology I and II courses, improvements in quiz performances were observed for some, but not all, lecture material during the clicker years (FitzPatrick et al. 2011). However, another study focused more on the perceptions of students when using a student response system during anatomy lectures, and less on students' outcomes (Geertsen 2015). The author noted that further investigation is needed to establish if a student response systems can enhance student performance in anatomy courses (Geertsen 2015).

The aims of this study were to: 1) increase classroom participation in anatomy and physiology courses by

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incorporating a clicker system that was reliable, easy to use, cost efficient, and reusable for multiple classes and across semesters, 2) further explore the effects of clicker use on student performance in two sophomore-level undergraduate biology courses (BSCI 21010 Anatomy and Physiology I and BSCI 21020 Anatomy and Physiology II), and, 3) examine student perceptions on clicker use. An important goal of our study was to test the hypothesis that students' performance in the anatomy and physiology courses would improve if the clickers (i>clickers) were used during the lectures. The impact of i>clicker use across semesters was evaluated using lecture exams scores and final lecture grades, comparing the years immediately before and after the introduction of the i>clickers. Student perceptions on i>clicker use were also assessed.

Methods

The i>clicker Student Response System

After researching the market for a student response system that would fulfill all our needs, I came across the i>clicker system (https://www.i>clicker.com/) and with the gracious help of the Kent State University Teaching Council, I was able to buy the i>clicker Student Response System to use in my anatomy and physiology courses. This was a one-time purchase and included the instructor kit (presenter kit) with the receiver base and an instructor remote, and a set of 28 student remotes (i>clickers). The software was available to download for free from the i>clicker website, did not require prior installation, was reliable, and most importantly, this i>clicker system was able to be used in multiple anatomy and physiology courses during a semester or during multiple semesters, and there were no fees associated with in-class registration for multiple classes.

The student remotes (i>clickers) were kept in the classroom, in groups of four in a basket, with one basket per table, because each laboratory table could seat a maximum number of 4 students. The student remotes were numbered on the back using permanent marker so that, in addition to the identification number, each i>clicker had a unique number on the back to help with its identification by the students. At the beginning of each semester, students in each anatomy and physiology class chose an i>clicker from the basket and they were then registered, so that each i>clicker was linked with a student name from the roster. A great advantage of using the i>clicker system was to be able to register the student i>clickers in-class for free, for all classes.

Prior to the first lecture course meeting, I integrated my rosters manually by copying and pasting my students' names in the roster blank document provided by the i>clicker software. When the Roll Call Registration was run in-class, the names of the students appeared on the screen; each name was associated with a two-character code, which my students were able to enter into their i>clickers, to complete the in-class registration of their i>clickers for our course. At the end of the anatomy and physiology course, students would leave their i>clickers in the baskets on the tables.

Study Design

This study included students that were enrolled in two sophomore-level undergraduate anatomy and physiology courses at Kent State University, Geauga campus: BSCI 21010 Anatomy and Physiology I and BSCI 21020 Anatomy and Physiology II. These courses were worth 4 credit hours each, and they were part of the Kent Core Basic Sciences, consisting of combined lecture and laboratory courses. The data for the i>clicker semesters (Spring 2017, Fall 2017, Spring 2018) and for the semesters immediately prior to the i>clicker use (Spring 2016 and Fall 2016) were collected, analyzed, and compared. Importantly, within a given course across time, the instructor as well as the lecture content coverage and quiz /exam format and coverage were all the same. The lecture sections of these courses used i>clickers and all courses had associated laboratory sections which did not use i>clickers. This study was approved by the Institutional Review Board of Kent State University, protocol # 17-030, and informed consent was obtained from all participants.

The weekly 100-minute lecture course was interactive and included open- and closed-ended questions posed by the professor, videos or animations demonstrating a specific topic covered in the lecture, and other active learning activities such as completing Venn diagrams. Toward the end of the lectures, five i>clicker questions were posed that pertained to the lecture material that had been discussed that day and they included multiple choice questions or/and true/false questions (Figure 1). Students were given time (30 seconds) to consider the options (during this time there was peer-peer interaction among the 2-4 students at each table) and then their responses were gathered by the i>clicker system. A histogram showing the response distribution was displayed on the screen together with the correct answer. Discussions followed (student-student interactions between students located at other tables) concerning the rationales for choosing a particular answer and immediate feedback was provided by the professor (direct interactions between the professor and students).

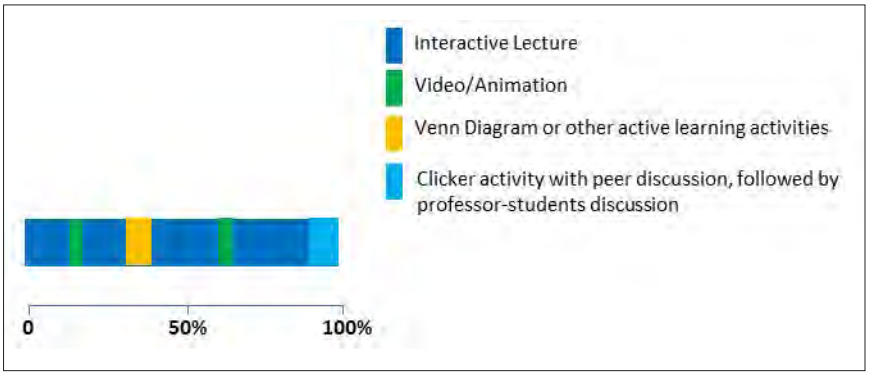

Figure 1. *The teaching strategy.*

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The effect of i>clickers on student performance was assessed by comparing exam scores (Bunce et al. 2006; Crossgrove and Curran 2008; FitzPatrick et al. 2011). To complete the lecture portion of the A&P I course, students needed to take four A&P I exams. The topics covered by each of these exams included, as follows: A&P I Lecture Exam 1 covered the general overview of the human organism, anatomical terms, homeostasis, cell biology, tissue, and the integumentary system, A&P I lecture exam 2 covered the skeletal and muscular systems, A&P I lecture exam 3 targeted the functional organization of the nervous tissue, spinal cord, and spinal nerves, and the fourth and final lecture exam tested knowledge of the anatomy and physiology of the brain, cranial nerves, integration of nervous system functions, and the autonomic nervous system.

Similarly to the A&P I lecture courses, the students were evaluated for the retention of the lecture course material in the A&P II lecture courses with the help of four exams, as follows: A&P II Lecture Exam 1 covered the cardiovascular system, including the blood, heart, and blood vessels, A&P II Lecture Exam 2 covered the respiratory and digestive systems, lymphatic system and immunity, A&P II Lecture Exam 3 covered the urinary and reproductive systems, and A&P II Final Lecture Exam tested knowledge of the functional organization of the endocrine system and the endocrine glands.

Student Survey

Student perceptions on the degree to which i>clicker use in the anatomy and physiology lecture courses improved their learning was investigated by asking students to complete anonymous surveys at the end of the lecture course. This survey was a modified Student Assessment of Their Learning Gains survey (http://www.salgsite.org/; FitzPatrick et al. 2011) and consisted of 10 questions (Table 1). The scale used to score the answers was: 1 = strongly disagree, 2 = disagree, 3 = unsure, 4 = agree, and 5 = strongly agree.

Data Analysis

Question difficulty was calculated by dividing the number of students answering that question correctly by the total number of respondents (Osterlind 1998; Tarrant & Ware 2010). A question difficulty factor of less than 0.4 reflected a difficult question, between 0.4 and 0.8 reflected a question of moderate difficulty, between 0.8 and 0.9 reflected an easy question and between 0.9 and 1.0 identified a very easy question (Osterlind 1998; Roschelle et al. 2004). The clicker question difficulty factors were calculated for all i>clicker questions that were used in both A&P I (45 questions) and A&P II (50 questions).

All statistical analyses were performed with the GraphPad Prism, *GraphPad 9.0 Software*, La Jolla, CA, using unpaired t-tests. Data represent the means ± SEM. In addition, data from 88 anonymous student surveys were collected at the end of the i>clicker semesters. The average score and the distribution of responses for each survey question, as well as all responses to the narrative question, were collected and analyzed. All narrative comments were read and rated as positive or negative, counted, and reported as percentages out of the total number of comments.

Student Survey
1. Participation with clickers increased my feeling of belonging in this course.
2. I enjoyed the opportunity to answer a question anonymously.
3. Participation with clickers improved my understanding of the subject content.
4. Participation with clickers increased my interaction with other students.
5. I enjoyed participation with clickers.
6. I would recommend using clickers again in this course.
7. Was the number of questions asked in each session optimal?
8. Participation with clickers improved my grade in the course.
9. What would be an optimal number of questions that you would prefer to be asked during each session?
10. Please write any comments or suggestions.

Table 1. *Student survey.*

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Results

Use of i>clickers in A&P I Lecture Courses

To complete the lecture portion of our A&P I course, students wrote four A&P I lecture exams. Although there was a tendency to perform a little better on most A&P I lecture exams, when the average class scores during the i>clicker semesters were compared to the ones when no i>clickers were used the difference in student performance was not statistically significant (Figures 2B, 2C, and 2D). This trend was noticed for Exam 2 (average class score 83.5 for i>clickers *versus* 79.5 for no i>clickers), Exam 3 (83.7 for i>clickers *versus* 82.2 for no i>clickers), and the Final Exam (82.3 for i>clickers versus 78.1 for no i>clickers).

Use of i>clickers in A&P II Lecture Courses

Interestingly, the use of i>clickers during the lecture courses of A&P II classes improved the performance of students on A&P II Lecture Exams 2 and 3 (Figures 3B and 3C). The average class score for Exam 2 was 84.6 when the i>clickers were used versus 76.9, when the i>clickers were not used ($p = 0.017$, Figure 3B). Regarding Exam 3, the average class score was 88.4 when the i>clickers were used compared to 82.5, when no i>clickers were used ($p = 0.0382$, Figure 3C). The use of i>clickers did not enhance the performance of students on Exam 1 (Figure 3A). Despite the trend toward increased student performance on the Final Exam when i>clickers were used (the average class score was 112.9), there was no statistically significant difference when compared to the students who did not use i>clickers (the average class score was 108.6, Figure 3D).

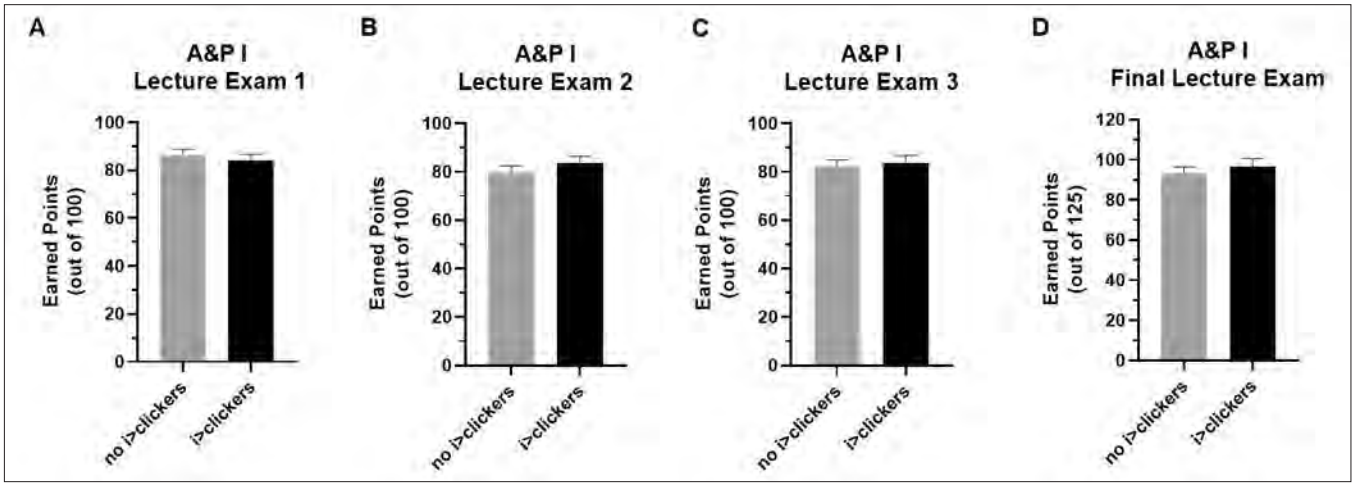

Figure 2. *Average scores earned by students on the Anatomy and Physiology I (A&P I) lecture exams (n = 33-34 for no i>clickers and n = 31-33 for i>clickers). Mean + SEM.*

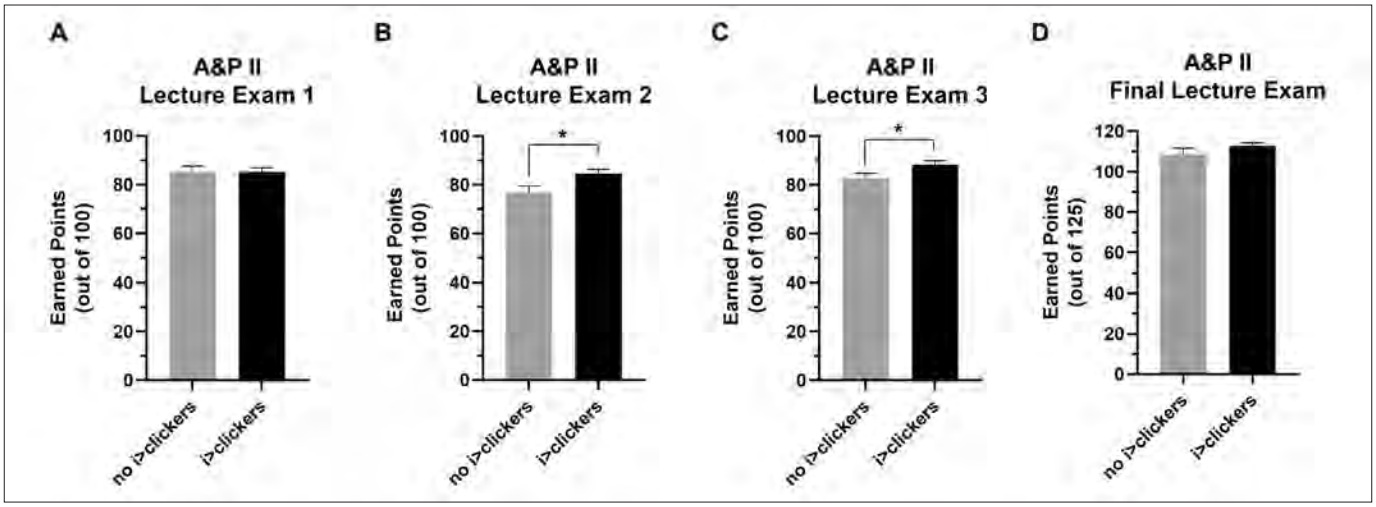

Figure 3. *Average scores earned by students on the Anatomy and Physiology II (A&P II) lecture exams (n = 30-31 for no i>clickers and n = 65-68 for i>clickers). Mean + SEM (*p = 0.017 and 0.0382, respectively).*

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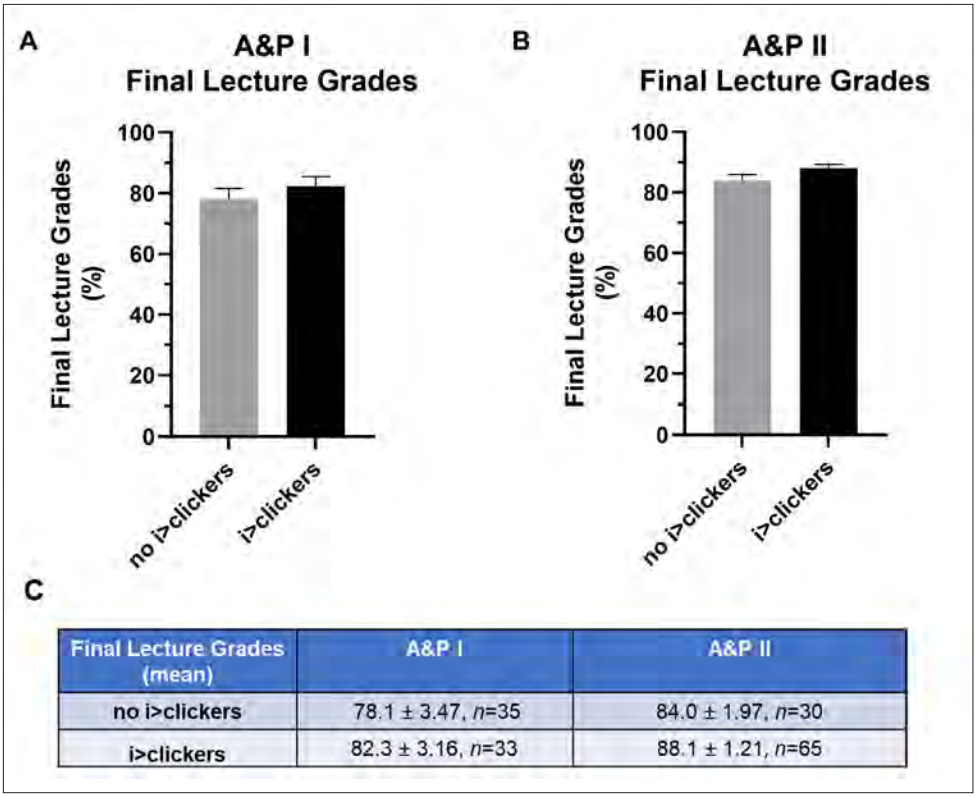
Overall student outcomes both A&P I and A&P II lecture courses

To evaluate whether the use of i>clickers had a positive impact on the overall performance of students in the anatomy and physiology courses, the final lecture grades earned by students in A&P I and A&P II during the i>clickers semesters were compared to those earned during the no i>clickers semesters. The performance of students in A&P I when i>clickers were used had a tendency to increase when compared to that of students in the A&P I courses when no i>clickers were used (Figures 4A and 4C). The average final lecture grade was 82.3% (with i>clickers) compared to 78.1% (no i>clickers), but this was not a statistically significant difference. Similarly, the performance of students in A&P II courses tended to be enhanced when i>clickers were used (88.1%), when compared to no i>clickers (84.0%; Figures 4B and 4C). Although these differences were not statistically significant, the results showed trends that were encouraging.

Difficulty of i>clicker questions

When we analyzed the difficulty of all i>clicker questions that were used during the A&P I and A&P II lecture courses, we noticed that most of the i>clicker questions in both A&P courses scored in the easy and very easy categories (difficulty factor >0.80) and less than 25% of the i>clicker questions were questions of moderate difficulty (Figure 5). The ability of most students in both A&P I and A&P II to answer the i>clicker questions correctly demonstrated the student gains and the importance of the i>clicker sessions coupled with peer discussions on student performance. These data were in accordance with the increased performance observed on some of the exams.



Final Lecture Grades (mean)	A&P I	A&P II
no i>clickers	78.1 ± 3.47, *n*=35	84.0 ± 1.97, *n*=30
i>clickers	82.3 ± 3.16, *n*=33	88.1 ± 1.21, *n*=65

Figure 4. *A) Average final lecture grades of students enrolled in the A&P I when no i>clickers were used (n = 35) compared to when i>clickers were used (n = 33)***.** *B) Average final lecture grades of students enrolled in two A&P II when no i>clickers were used (n = 31) compared to when i>clickers were (n=65). C) Actual average final lecture grades earned by students in A&P I and A&P II courses when no i>clickers were used, compared to when i>clickers were used (mean ± SEM).*

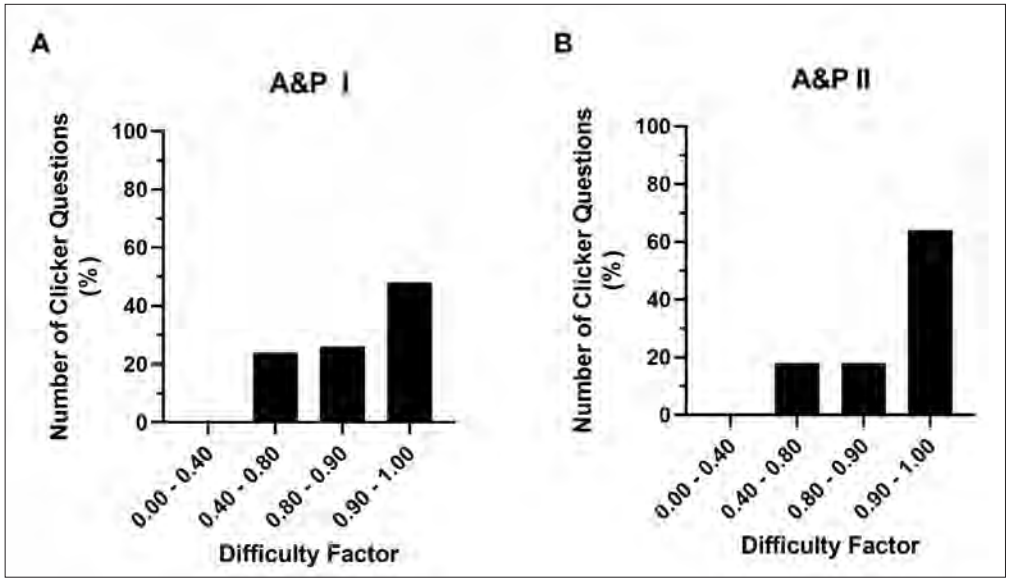


Figure 5. *Difficulty of i>clicker questions used in A&P 1 (A; 45 questions) and A&P II (B; 50 questions). A difficulty factor of less than 0.4 reflects a difficult question, between 0.4 and 0.8 reflects a question of moderate difficulty, between 0.8 and 0.9 reflects an easy question and between 0.9 and 1.0 reflects a very easy question.*

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Students' perception of i>clicker use

Of the 98 students completing the A&P I and II courses when the i>clickers were used, 82 students completed the survey, for an overall response rate of 83.7%. A&P I and A&P II courses did not differ greatly in the student responses. The mean ratings ranged from 3.8 to 4.4 for the A&P I course (Figure 6A and Table 2) and between 3.7 and 4.6 for the A&P II courses (Figure 6B and Table 3). It was also exciting to notice that all questions that reported one mode were scored as 4 or 5 (Tables 2 and 3). In conclusion, student's perception on the i>clicker use in the anatomy and physiology courses was highly positive, showing that the students enjoyed the use of i>clickers in our anatomy and physiology courses and they felt that the i>clicker system enhanced their active learning, participation, and sense of belonging in the class.

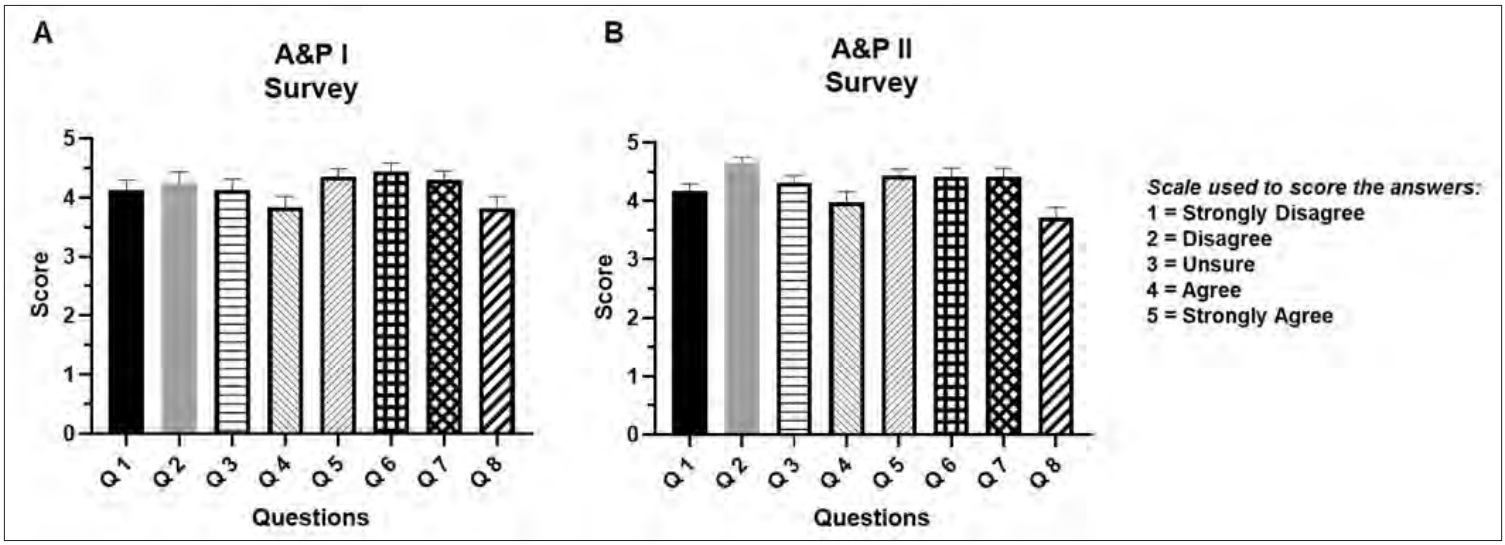

Figure 6. *Perception of A&P I (A) and A&P II (B) students regarding the use of i>clickers in response to the first 8 questions of the survey (Table 1).*

A&P I	Q 1	Q 2	Q 3	Q 4	Q 5	Q 6	Q 7	Q 8
Mean	4.13	4.26	4.13	3.84	4.35	4.45	4.31	3.82
SEM	0.17	0.18	0.18	0.18	0.13	0.14	0.14	0.19
n	31	31	31	31	31	29	29	28
Mode	4	5	4 and 5	4	5	5	4 and 5	4

Table 2. *Mean and mode scores of the first 8 questions of the survey from the A&P I students.*

A&P II	Q 1	Q 2	Q 3	Q 4	Q 5	Q 6	Q 7	Q 8
Mean	4.17	4.65	4.31	3.98	4.43	4.42	4.42	3.72
SEM	0.12	0.10	0.12	0.18	0.12	0.15	0.14	0.17
n	51	51	51	51	51	43	43	43
Mode	4	5	5	5	5	5	5	3 and 5

Table 3. *Mean and mode scores of the first 8 questions of the survey from the A&P II students.*

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When students were asked for their input regarding the optimal number of questions that they would prefer to be asked during a lecture session (question 9 of the survey), 71.4% of students answered that 5 questions would be optimal, 27.1% mentioned that they would prefer more than 5 questions per session, and only 1.4% suggested less than 5 questions (Figure 7A). For the narrative question (question 10 of the survey), 80.8% (*n*=21) of students responded to this question with a positive comment, whereas only 19.2% (*n*=5) had a negative comment (Figure 7B). Samples of the positive and negative comments are shown in Figure 8. The negative comments were referring mainly to not having enough questions or needing more time to complete or discuss the i>clicker questions.

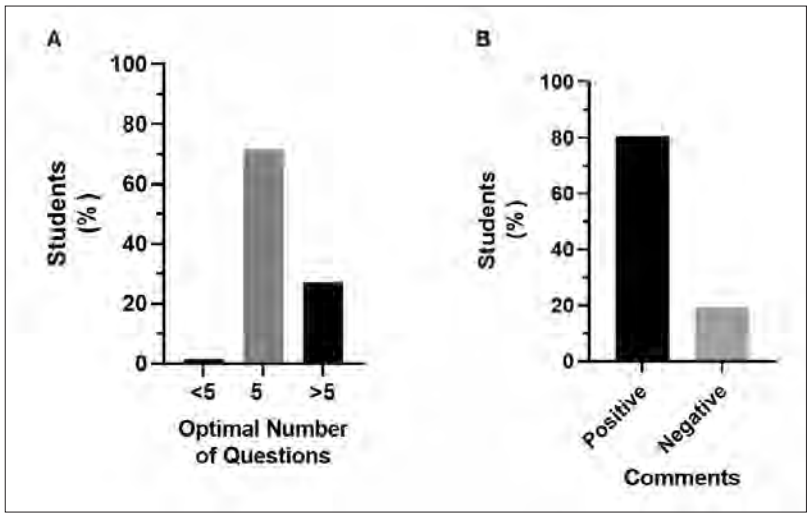

Figure 7. *Student responses to the last two questions of the survey (Table 1).*

Samples of Positive Comments
I liked how the clicker questions gave us a little insight as to what the main ideas of the chapter were.
Loved the clickers! Helped improve my knowledge.
Loved the clickers! So much fun and interactive.
Thank you for a great year!
This learning tool could be used in other courses as well.
It helped me in applying what I learned.
Overall a great learning environment!
I feel that when I got an answer wrong, I remembered the correct answer better when we took the quiz [test].
Improved my grade.
Continue clickers.
I thought it was very helpful
I enjoyed the use of the clickers. It was almost equivalent to a mini-review session when we used them. This helps to "cement" the concepts into your brain.

Samples of Negative Comments
Having to answer 5 questions correctly for 1 point really is not worth it.
I wished there were more questions to show understanding of full material and more time to complete the quiz and understanding "why" to learn the correct answers and reasoning.
Just wished we had more time to really take in the clickers. I know I couldn't stay some of the time because I had to get to work.

Figure 8. *Samples of positive and negative comments received from students in response to the narrative question of the survey.*

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Discussion

Although there is a general consensus regarding the benefits of using a student response system in the classroom and these benefits have been discussed widely in the literature (Beatty 2005; Caldwell 2007; National Research Council 2000; Poulis et al. 1998; Roschelle et al. 2004; Solomon et al. 2018), there is still limited data regarding the use of clickers in undergraduate anatomy and physiology courses. In this study we focused on incorporating the i>clicker system into two sophomore-level anatomy and physiology courses to increase active participation of our students during the lectures; we also explored the effects of clickers on student achievement and examined the student perception on the i>clicker use.

The students who usually register for the A&P I and II courses at the Kent State University, Geauga campus, are very diverse: some students are traditional students, and some are non-traditional students. Some are first-generation students, and some are not first-generation students. Taking into account the diverse backgrounds of our students, as well as the challenges of an anatomy and physiology course (an intense course that requires a lot of memorization), it was important to find an approach to increase classroom participation because students who actively participate in the learning process have been shown to learn more than those who do not (Tinto 1997; Weaver & Qi 2005).

As Dunham (2011) noted, due to the variety of students in a class, it is often very difficult for a professor to incorporate teaching strategies that would make every student an active participant. Notably, a student response system provides all students in a class with the opportunity to actively participate in the learning process, which has been shown to increase student performance (Poulis et al. 1998). The no cost, web-based tools that were available online and could have been used in a classroom relied on the use of smart cell phones, tablets, or laptops. Due to the diverse socioeconomic status of our students, those tools were not incorporated in our anatomy and physiology courses because not all our students have access to an internet-connecting device or a smart phone.

The i>clicker system that was incorporated in our anatomy and physiology courses as a student response system was a one-time purchase and we were able to use it with multiple classes. With most student response systems, students need to buy their own clicker, however, with the i>clicker system we were able to keep the educational costs of our students low by keeping a set of i>clickers in the classroom. Moreover, this approach also eliminated the possibility of students forgetting to bring their own clicker to each lecture since the i>clickers were provided to them. In addition to its re-usability and ability to register each student i>clicker in-class for free for multiple classes each semester and across years, the i>clicker system also presented the ability to be used for testing and to view the results of the i>clicker sessions in an anonymous way, increasing student participation and engagement, and extending the opportunity to provide immediate bidirectional student-professor feedback. According to Roschelle and colleagues (2004), a student response system has the ability to facilitate a classroom network or a community-centered environment because it "connects the learning of each student with the learning of the group and provides helpful feedback to each student, while giving the teacher a rapid insight into the current level of understanding in the classroom."

The i>clicker sessions kept the students motivated, focused, and engaged with the lecture material. Each i>clicker session had the format of a short quiz during which students were able to collaborate in small groups of two to four students. Four has been suggested to be the largest number of students that can interact comfortably (Felder & Brent 2009). Active learning occurred during these i>clicker sessions via both peer-to-peer and professor-student interactions. Felder and Brent (2009) defined active learning as "anything course-related that all students in a class session are called upon to do other than simply watching, listening, and taking notes". The i>clicker sessions actively engaged the learners by shifting the focus of teaching away from knowledge transmission to knowledge construction (Singh et al. 2019).

The majority of the i>clicker questions tested student knowledge and comprehension of the lecture material. While these are basic levels of Bloom's taxonomy (knowledge and comprehension), they are an essential part of learning anatomy and physiology and necessary prerequisites for moving forward with questions that help evaluate deeper understanding, such as application of knowledge and analysis (Crowe et al. 2008). When we examined the difficulty of all i>clicker questions (Osterlind, 1998), we found that most of them in both A&P I and A&P II courses were answered well (difficulty factor >0.80) and less than 25% of the i>clicker questions were moderate questions (difficulty factor 0.4-0.8). These results are in accord with the positive impact on student achievement we observed during the i>clicker semesters.

In this study we showed that the use of i>clickers during the anatomy and physiology lecture courses improved the performance of students on some lecture exams and showed a trend toward improvement for others. Together these data indicate that incorporating the i>clicker system into the anatomy and physiology courses enhanced the active learning of anatomy and physiology by engaging students in the learning process, increasing participation, focus, and motivation.

In addition, the use of the i>clicker system during the lecture courses tended to improve overall student performance in the lecture portions of both A&P I and A&P

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II courses. We were able to compare the results of the no i>clicker semesters with the i>clicker semesters because all anatomy and physiology courses were taught by the same professor, using the same lecture material, and the same format of the course. Even though the overall increase in student achievement was not statistically significant, the trends showing higher average final lecture grades when i>clickers were used were encouraging. Other studies have also shown some variability in terms of student performance between various portions of a course or between various courses (Caldwell 2007; Crossgrove & Curran 2008; FitzPatrick et al. 2011).

It is hard to isolate a single intervention when evaluating student outcomes. For example, the fact that we did not observe a higher performance on the A&P I lecture exams when i>clickers were used could be explained by the fact that the professor teaching these courses already had incorporated other active learning tools, such as the use of Venn diagrams, before beginning the use of i>clickers. It is also possible that more time dedicated to the i>clicker sessions and peer instruction (Crouch & Mazur 2001) could have had a greater impact on overall student performance. This approach could be considered in the future. However, we need to keep in mind that the anatomy and physiology lecture courses are intense courses during which a professor needs to cover a lot of lecture material. Therefore, finding the time to increase the duration of the i>clicker sessions could be challenging.

As Poulis and colleagues (1998) observed in physics classes, increased active participation of students during a lecture course is one of the factors that could explain the positive effects of clickers on student performance. Other factors may also be important for facilitating learning such as an increased course structure in the form of weekly short quizzes. Quizzing not only serves as an evaluation tool; formative assessments have been shown to promote effective learning via the "testing effect" (Freeman et al. 2011; Orr & Foster 2013; Walck-Shannon et al. 2019). Therefore, in addition to making each student an active participant in the learning process, it is also possible that our i>clicker sessions may have supported learning through the testing effect. It would be interesting in the future to evaluate the effect of increasing the number of i>clicker sessions during a lecture course and also evaluate if re-quizzing has an impact on student performance and knowledge retention in our A&P courses (Walck-Shannon et al. 2019).

Similarly to what others have found regarding student feedback on the use of a student response system (Addison et al. 2009; Caldwell 2007; Draper 2002; FitzPatrick et al. 2011; Geertsen 2015; Kay & Knaack 2009), the perception of students enrolled in the A&P I and II courses on the i>clicker use was highly positive and consistent across semesters and courses. The overall response rate of student completing the survey was very good. Students agreed that using the i>clickers during the lecture course increased their sense of belonging in the course. Students also agreed that i>clicker use increased their participation, allowed them to answer questions in an anonymous fashion, improved their understanding of the lecture material, promoted interactions with other students, and they both enjoyed and recommended continued i>clicker use. The majority of students responded to the narrative question (question 10 of the survey) with a positive comment and agreed that having five i>clicker questions was the optimum number to use per lecture. Interestingly, the fact that almost 30% of the students wished that there were more than 5 i>clicker questions per lecture demonstrated that students greatly appreciated the use of i>clickers as part of their learning journey, and that we may need to find ways to allocate more time to the i>clicker sessions in the future.

Conclusions

The results of this study demonstrated that the use of clickers during lecture courses had a positive impact on active learning, student engagement, participation, and academic performance. These data, together with the highly positive student feedback and the advantages of the i>clicker system, including its cost-efficiency, reliability, versatility, and reusability for multiple classes during a semester, or during multiple semesters, motivate us to continue using this student response system in our anatomy and physiology courses. These results also give us hope that we could also increase student performance, in general, by incorporating the i>clicker system in other courses, especially during the post pandemic times when more and more courses will return to their traditional face-to face teaching format.

About the Author

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Literature Cited

Addison S, Wright A, Milner R. 2009. Using clickers to improve student engagement and performance in an introductory biochemistry class. *Biochem Molec Biol Educ* 37(2):84–91. https://doi.org/10.1002/bmb.20264

Beatty ID. 2005. Transforming student learning with classroom communication systems. ArXiv:Physics/0508129. http://arxiv.org/abs/physics/0508129

Bunce DM, VandenPlas JR, Havanki KL. 2006. Comparing the effectiveness on student achievement of a student response system versus online WebCT quizzes. *J Chem Educ* 83(3):488. https://doi.org/10.1021/ed083p488

Caldwell JE. 2007. Clickers in the large classroom: Current research and best-practice tips. *CBE—Life Sci Educ* 6(1):9–20. https://doi.org/10.1187/cbe.06-12-0205

Crossgrove K, Curran KL. 2008. Using clickers in nonmajors- and majors-level biology courses: Student opinion, learning, and long-term retention of course material. *CBE—Life Sci Educ* 7(1):146–154. https://doi.org/10.1187/cbe.07-08-0060

Crouch CH, Mazur,E. 2001. Peer instruction: Ten years of experience and results. *Am J Physics* 69(9):970. https://doi.org/10.1119/1.1374249

Crowe A, Dirks C, Wenderoth MP. 2008. Biology in bloom: Implementing Bloom's taxonomy to enhance student learning in biology. *CBE—Life Sci Educ* 7(4):368–381. https://doi.org/10.1187/cbe.08-05-0024

Draper SW. 2002. Ensuring effective use of PRS: results of the evaluation of the use of PRS in Glasgow University, October 2001-June 2002. https://www.psy.gla.ac.uk/~steve/evs/papers/eval.pdf

Dufresne RJ, Gerace, WJ, Leonard WJ, Mestre JP, Wenk L. 1996. *Classtalk*: A classroom communication system for active learning. *J Comput High Educ* 7(2), 3–47. https://doi.org/10.1007/BF02948592

Dunham, VK. 2011. *The impact of a student response system on academic performance*. [Doctoral dissertation, South Carolina State University]. ProQuest LLC. https://www.proquest.com/docview/912168999

Felder R, Brent R. 2009. Active Learning: An Introduction. *ASQ High Educ Brief* 2:4-9.

FitzPatrick KA, Finn KE, Campisi J. 2011. Effect of personal response systems on student perception and academic performance in courses in a health sciences curriculum. *Adv Physiol Educ* 35(3):280–289. https://doi.org/10.1152/advan.00036.2011

Freeman S, Haak, D, Wenderoth MP. 2011. Increased course structure improves performance in introductory biology. *CBE—Life Sci Educ* 10(2):175–186. https://doi.org/10.1187/cbe.10-08-0105

Geertsen SS. 2015. Evaluating the use of a student response system in high enrollment anatomy lectures. *Improv Univ Sci Teach Learn* 7(1-2):99-112.

Handelsman MM, Briggs WL, Sullivan N, Towler A. 2005. A measure of college student course engagement. *J Educ Res* 98(3):184-192. https://doi.org/10.3200/JOER.98.3.184-192

Hoyt A, McNulty JA, Gruener G, Chandrasekhar A, Espiritu B, Ensminger D et al. 2010. An audience response system may influence student performance on anatomy examination questions. *Anat Sci Educ* 3(6):295–299. https://doi.org/10.1002/ase.184

Hyde C, Ruth B. 2014. Multicultural content and class participation. *J Social Work Educ* 38:241–256. https://doi.org/10.1080/10437797.2002.10779095

Karp DA, Yoels WC. 1976. The college classroom: Some observations on the meanings of student participation. *Soc & Soc Res* 60(4) 421–439.

Kay R, Knaack L. 2009. Exploring the use of audience response systems in secondary school science classrooms. *J Sci Educ Tech* 18:382–392. https://doi.org/10.1007/s10956-009-9153-7

Lyons PR. 1989. Assessing Classroom Participation. *College Teach* 37(1):36–38. https://doi.org/10.1080/87567555.1989.10532154

National Research Council. 2000. How People Learn: Brain, Mind, Experience, and School: Expanded Edition. Washington (DC): The National Academies Press. https://doi.org/10.17226/9853

Orr R, Foster S. 2013. Increasing student success using online quizzing in introductory (majors) biology. *CBE—Life Sci Educ* 12(3):509–514. https://doi.org/10.1187/cbe.12-10-0183

Osterlind SJ. 1998. Constructing test items: Multiple-choice, constructed-response, performance and other formats, 2nd ed. Dordrecht (Netherlands): Kluwer Academic Publishers.

Poulis J, Massen C, Robens E, Gilbert M. 1998. Physics lecturing with audience paced feedback. *Am J Physics* 66(5):439–441. https://doi.org/10.1119/1.18883

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Rocca KA. 2010. Student participation in the college classroom: An extended multidisciplinary literature review. *Communica Educ* 59(2) :185–213. https://doi.org/10.1080/03634520903505936

Roschelle J, Penuel WR, Abrahamso, L. 2004. The networked classroom. *Educ Lead* 61(5):50.

Singh K, Bharatha A, Sa B, Adams OP, Majumder MdAA. 2019. Teaching anatomy using an active and engaging learning strategy. *BMC Med Educ* 19:149. https://doi.org/10.1186/s12909-019-1590-2

Smith DG. 1977. College classroom interactions and critical thinking. *J Educ Psychol* 69(2):180-190. https://psycnet.apa.org/doi/10.1037/0022-0663.69.2.180

Solomon ED., Repice MD, Mutambuki JM, Leonard DA, Cohen CA, Luo J, Frey RF. 2018. A mixed-methods investigation of clicker implementation styles in STEM. *CBE—Life Sci Educ* 17(2):ar30. https://doi.org/10.1187/cbe.17-08-0180

Susak M. 2016. *Factors that affect classroom participation*. [Thesis, Rochester Institute of Technology]. https://scholarworks.rit.edu/theses/9370

Tarrant M, Ware J. 2010. A comparison of the psychometric properties of three- and four-option multiple-choice questions in nursing assessments. *Nurse Educ Today* 30(6):539–543. https://doi.org/10.1016/j.nedt.2009.11.002

Tinto V. 1997. Classrooms as communities. *J High Educ* 68(6):599–623. https://doi.org/10.1080/00221546.1997.11779003 v

Walck-Shannon EM, Cahill MJ, McDaniel MA, Frey RF. 2019. Participation in oluntary re-quizzing Is predictive of increased performance on cumulative assessments in introductory biology. *CBE—Life Sci Educ* 18(2), ar15. https://doi.org/10.1187/cbe.18-08-0163

Weaver RR, Qi J. 2005. Classroom organization and participation: College students' perceptions. *J High Educ* 76(5):570-601. https://doi.org/10.1353/jhe.2005.0038

Yourstone SA, Kraye HS, Albaum G. 2008. Classroom questioning with immediate electronic response: Do clickers improve learning? *Decision Sci J Innovative Educ* 6(1):75–88. https://doi.org/10.1111/j.1540-4609.2007.00166.x

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