OPINION
The Benefits of a Real-Time Web-Based Response System for Enhancing Engaged Learning in Classrooms and Public Science Events

Mark A. Sarvary[1] **& Kathleen M. Gifford**[2]
[1]Investigative Biology Teaching Laboratories, Department of Neurobiology and Behavior, Cornell University, Ithaca, NY 14853; [2]Science Cabaret, Ithaca, NY 14850.

Large introduction to neuroscience classes and small science cafés have the same goal: bridging the gap between the presenter and the audience to convey the information while being engaging. Early classroom response systems became the cornerstone of flipped and engaged learning. These "clickers" helped turn lectures into dialogues, allowing the presenter to become a facilitator rather than a "sage on the stage." Rapid technological developments, especially the increase of computing power opened up new opportunities, moving these systems from a clicker device onto cellphones and laptops. This allowed students to use their own devices, and instructors to use new question types, such as clicking on a picture or ranking concepts. A variety of question types makes the learning environment more engaging, allows better examples for creative and critical thinking, and facilitates assessment. Online access makes these response systems scalable, bringing the strength of formative assessments and surveys to public science communication events, neuroscience journal clubs and distance learning. In addition to the new opportunities, online polling systems also create new challenges for the presenters. For example, allowing mobile devices in the classroom can be distracting. Here, a web-based, real-time response system called Poll Everywhere was compared to iClickers, highlighting the benefits and the pitfalls of both systems. In conclusion, the authors observe that the benefits of web-based response systems outweigh the challenges, and this form of digital pedagogy can help create a rich dialogue with the audience in large classrooms as well as in public science events.

Key words: audience engagement, science communication, science café, large classroom, formative assessment, engaged learning, public science events

Turning lectures into dialogues and engaging students in activities promotes deeper learning than lecturing to students who are just passive receivers of information (Bonwell and Eison, 1991; Mayer, 2001; Armbruster et al., 2009). While many instructors actively seek out these modern, more effective teaching methods (Tanner, 2013), it is challenging to implement them in large classrooms. Introductory courses often have several hundred students in a lecture hall. For example, the Introduction to Neuroscience course (http://www.nbb.cornell.edu/Courses) at Cornell University can house up to 420 students, while the Investigative Biology Laboratory course (http://investigativebiology.cornell.edu), an introductory course administered by the Department of Neurobiology and Behavior, has 432 students enrolled every semester.

In these learning environments technologies can help build a bridge between students and instructors. The cornerstone of engaged learning and flipped classrooms (Mazur, 2009) has been classroom response systems that allow the instructors to propose questions and hundreds of students to answer them simultaneously (Duncan, 2005; Bruff, 2009). These questions can be used to start a group discussion or the instructor can use the answers as formative assessment (Wees, 2012), providing immediate information about the students' understanding of the material. The most commonly used classroom response devices in the past decades were "clickers" that students needed to purchase and register. Instructors were able to poll the students and collect answers to multiple-choice questions using a receiver in the classroom (Duncan, 2005).

The rapid evolution of smart phones has expanded classroom engagement options. In 2015 up to 92% of students in the United States owned a smartphone, exceeding the ownership of laptops (Dahlstrom et al., 2015). The decreasing smartphone prices and increasing computing power opened up an opportunity for low-income students to have access to the internet in- and outside of the classroom (Anderson, 2015).

Simultaneously, classroom technologies have improved, including the increased strength of Wi-Fi signal in classrooms (Dahlstrom, 2015). It became inevitable to see in-lecture polling devices that need to be separately purchased being replaced by already owned cellphones, laptops and tablets, starting the Bring Your Own Device (BYOD) movement. Web-based polling began to be offered by a variety of companies, including Poll Everywhere, Top Hat, Reef Polling, Learning Catalytics, Web Clicker and others. As these response systems became phone accessible and web-based, they spread to seminar rooms, conferences, job interviews, and science cafés. They became fundamental methods for audience assessment and engagement.

We have used clickers in large introductory biology courses at Cornell University and at Ithaca College in Ithaca, NY. We switched to BYOD technology in 2012 and have been using it in large classrooms, seminars, and science cafés. Our personal experience, along with data collected in the classrooms, will be discussed, focusing on both the benefits and the pitfalls of switching from in house clickers to the BYOD form of digital, web based pedagogy.

MATERIALS AND METHODS

Students who enrolled in the Introductory Biology course at Cornell University in 2009-2010 and in the Fundamentals of Biology course at Ithaca College in 2011 purchased personal response devices called iClicker remotes (https://www.iclicker.com), designed to answer in-lecture multiple-choice questions. The student enrollment in the Introductory Biology and in the Fundamentals courses were ~500 students and ~200 students, respectively. The instructor used a computer-connected receiver, provided by the iClicker company. Setting up the receiver in the classroom was quick and simple. Students registered their own devices online, as every individual device had its own code. By registering, students authenticated their code to their names. The instructor received answers from the students, and downloaded these answers from the receiver. At the end of the semester the class roster and the registration list were synched with the answers, and students could receive credit for their answers. Only multiple-choice questions were asked, but the instructor could decide whether points were awarded for participation or for the correct answer. On their remotes, students were able to choose A, B, C, D or E as a correct answer, and see the summarized class response on the projected screen. Students could see whether their response was registered, but could not see their response histories.

Between 2012 and 2016, students used BYOD technology with the Poll Everywhere (https://www.pollevery where.com) web based interface in the Investigative Biology Laboratory course, with a 432-student enrollment. Students did not have to purchase a separate device, but they needed to bring a phone, a smartphone, a laptop or a tablet to answer questions. In addition to answering multiple-choice questions, instructors could ask open-ended questions and the answers could be listed as a text-wall, word cloud, cluster, or ticker. Students could rank answers, or the instructor could show an image, such as a picture of the brain, and students needed to click on the correct part of that picture to answer a question. In the Q&A the students could also submit questions and vote on each other's submissions. We created quizzes and surveys that included multiple questions, and students answered them on their own pace, in- or outside of the classroom. Example questions along with the detailed type descriptions can be found on the Poll Everywhere website (https://www.polleverywhere.com/how-it-works).

Questions were inserted into presentations and projected on a screen or shown in a web browser on the attendees' devices. The class had a unique URL where students entered their answers online. Students using texting received a phone number where they sent their answers as a text. Poll Everywhere has a user-friendly application that students can download from the app store and see the questions on their own devices, or even Tweet their answers during any live polling event. Students can instantly see whether they answered the questions correctly, and the answers remain in their response histories. Students must log in before every lecture to allow the instructor to connect their answers to their names.

Poll Everywhere was also tested in 2015 in informal science communication events held in cafés, bars, and restaurants, called science cafés. The overarching goal of Science Cabaret (http://www.ScienceCabaret.org), the monthly science café in Ithaca, NY, is to enhance the public's understanding of scientific discoveries and to increase science literacy in the community. This science café attracts a lay audience, and audience members can be assessed and surveyed through Poll Everywhere; it is free for up to 40 participants. Audience members can use their cellphones to text, or they can use the web browser or the app on the smartphones to answer the questions. Participants were able to answer questions without logging in, and therefore remained anonymous.

Both iClicker and Poll Everywhere questions require the presenter to set-up the questions prior to the presentation, decide how many times audience members can answer and whether they receive any credit for their answers.

Data about the devices used to answer poll questions was collected in Spring 2016 (n=323) in Investigative Biology at Cornell University. User data comparing texting answers vs. using web browsers was compared between Spring 2013 (n=323) and Spring 2016 (n=308) in Investigative Biology and in 2015 in Science Cabaret (n=52).

RESULTS

After over eight years of using iClicker and Poll Everywhere to engage audiences in classrooms and at a variety of science events, we evaluated and compared both systems. Their detailed comparison can be found in Table 1.

There was a decrease of Poll Everywhere answers being sent in a text (SMS) format from phones from Spring 2013 (26.9%) to Spring 2016 (5.8%). Simultaneously, the use of web-enabled devices in Investigative Biology increased from 73.3% (2013) to 94.2% (2016). The percentage of students using a variety of devices to answer Poll Everywhere questions in Spring 2016 is shown in Figure 1. As mentioned above, only 6% of the students texted their answers, and only 2% used a tablet. The majority of the students (51%) used a laptop, while 42% used a smartphone, with 31 of the 42 % preferring the Poll Everywhere application to an internet browser.

In Science Cabaret 69.3% of the audience members used their web-browsers, and 30.7% used texting to answer the questions. None of the audience members carried a laptop to the event, or downloaded the app onto their phones.

DISCUSSION

Classroom response systems such as iClickers have been fundamental tools to move large classroom pedagogy towards increased student engagement and flipped classroom format (Mayer, 2001; Duncan, 2005; Mazur, 2009). With the rapidly improving affordable technologies, instructors should reconsider whether purchasing a device used only for student engagement is advisable (Table 1).

While many instructors still ask students to put their phones and laptops away at the beginning of the class

Category	iClicker	Poll Everywhere
Device	Separate device necessary	Existing device
Question type	Multiple-choice	Multiple-choice, Open-ended, Q&A, Ranking, Clickable
Location	In-class	In-class, Distance learning, Homework
Response history	No instant feedback	Response history with correct answers visible online
Technology	Receiver is required	Strong Wi-Fi and/or phone service required
Cheating	One user with multiple devices	Answering in-class questions outside of classroom
Distraction	none	Social media and non-class related websites
Technical difficulties	Student did not register device	Student forgot to log in before answering questions
Price per student (in 2016)	~42 USD (purchased to own)	~14 USD (annual subscription fee)

Table 1. Comparison of iClickers and the Poll Everywhere web-based response system. IClickers were used in large classrooms in 2009-2011, while Poll Everywhere was used 2012-2016.

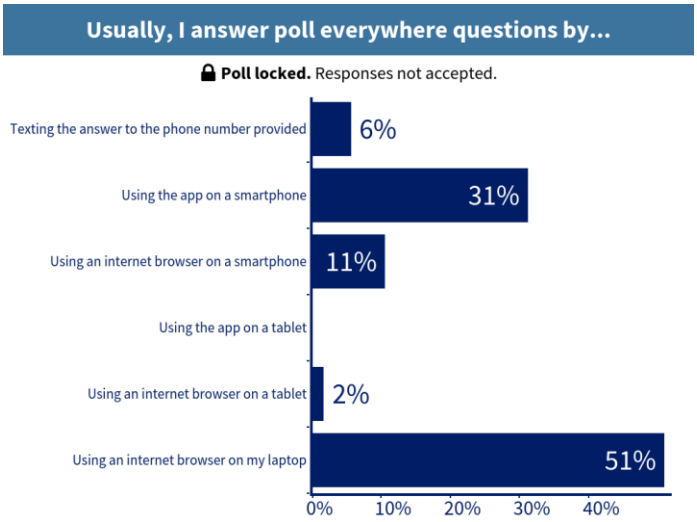

Figure 1. A Poll Everywhere question answered by 323 students using the Poll Everywhere software in the Investigative Biology Laboratory course at Cornell University in Spring 2016. The percentage of students choosing each answer is listed on the x-axis.

(Shirky, 2014; Henderta, 2016), web-based, digital pedagogy has started to become an important part of engaged learning (Johnson et al., 2015; Sarvary, 2016; Sarvary and Gifford, 2016; Valentine and Kurczek, 2016).

Data collected in Investigative Biology lectures showed that the number of web-enabled devices used by students increased in the classroom in the past three years. This may be due to the fact that smartphones became more affordable, and they are becoming an increasingly popular device to access the internet (Anderson, 2015). Texting answers has decreased over the past three years in Investigative Biology, while the use of smartphones is almost at the level of using laptops. The Poll Everywhere application developed for smartphones has increased the convenience of using this BYOD technology, and further increase of smartphone use in education is expected (Katz, 2005; Campbell, 2006, Johnson et al., 2015).

One of the greatest benefits of BYOD technology is how it scales to the location and the size of the audience. For example, the authors have been using Poll Everywhere in public science events, such as a monthly science café series held in a local bar in Ithaca, NY. Audience members are asked to form their opinions before and after a presentation, comment on the live event, or provide feedback (Sarvary and Gifford, 2016). Since science café attendees were not told in advance that they would be using this polling software, they did not bring a laptop or tablet to the event. However, this did not prevent the science café attendees from using Poll Everywhere on their own cellphones or smartphones to communicate with the presenters during the events. BYOD devices can also be used in Massive Open Online Courses (MOOCs) and other forms of distance learning (Lee, 2012). Students do not need to be in the same room with the instructor, and can answer questions as long as they have internet or phone access (Table 1).

The greater variety of questions in BYOD applications opens up opportunities for new ways to engage audiences. Using the open-ended questions, ranking, and picture click format, Investigative Biology instructors wrote new case studies for the lectures, had the students approach problems in a unique way, and thus encouraged creative and critical thinking by going beyond multiple-choice questions. The survey function in Poll Everywhere was actively used for data collection, getting feedback from the students and creating take-home quizzes. BYOD technologies increased the use of peer-instruction by asking students to explain a biological phenomenon to their neighbor (Mazur, 1997), reflect on what they learned, and identify the most complicated, muddiest point in the lecture.

Despite the described benefits of BYOD technologies, only 26% of instructors allowed mobile devices in classrooms in 2013 in the United States, and it just slightly increased to 31% by 2015 (Dahlstrom et al., 2015). The main reason why BYODs have not replaced traditional clickers in the classrooms yet is the perceived distraction caused by these electronic devices (McCoy, 2013). Using self-reported student responses, Fried (2008) found laptops and Campbell (2006) found mobile phones somewhat distracting when used in classrooms. Even at Cornell University there are instructors who still ban these devices from their lectures (Hendarta, 2016).

Instructors should have an audience-centered approach, where they focus on how the learner can be aided by the technology rather than a technology-based approach, where instructors apply new technologies, just because those technologies are available (Mayer, 2001). The instructional medium is the technology (phone, laptop) the instructor uses to engage the audience, while the instructional method is the application of these

technologies in our pedagogy (asking students to summarize a concept, express their opinion or critically evaluate answers). If instructional methods drive the use of the instructional media (Clark, 2001; Mayer, 2001), distractions or misuse of these devices will decrease. We are on the forefront of digital pedagogy (Brooks, 2015; Johnson et al., 2015), and it is inevitable that digital devices will be more and more embraced to aid active learning activities.

In summary, the authors' opinion is that the benefits of BYOD outweigh the negative effects of allowing these devices to aid education and science communication. Polling software, such as Poll Everywhere, open up opportunities to start a dialogue with audiences from small science cafés to large lectures without the need of any additional device but the phones in our pockets. The broad variety of questions, assessment and surveys methods available let adventurous presenters engage audiences at a completely new level. Digital devices are part of our everyday life, and we must harness their benefits in education and science communication.

REFERENCES

Anderson M (2015) 6 Facts about Americans and their Smartphones, Pew Research Center FactTank, April 1, 2015.

Armbruster P, Patel M, Johnson E, Weiss M (2009) Active learning and student-center pedagogy improve student attitudes and performance in introductory biology. CBE-Life Sci Educ 8:203-213.

Bonwell CC, Eison JA (1991) Active learning: creating excitement in the classroom. ASHE-ERIC Higher Education Report No. 1. Washington, D.C.: The George Washington University, School of Education and Human Development.

Brooks CD (2015) ECAR Study of Faculty and Information Technology, 2015, research report. Louisville, CO.

Bruff D (2009) Teaching with classroom response systems – Creating active learning environments. San Fransisco, CA: Jossey-Bass.

Campbell S (2006) Perceptions of mobile phone in college classrooms: Ringing, cheating, and classroom policies. Comm Educ 55:280-294.

Clark RE (2001) Learning from media: arguments, analysis, and evidence. Greenwich, CT: Information Age Publishers.

Dahlstrom E, Brooks CD, Susan G, Reeves J (2015) ECAR study of students and information technology, research report. Louisville, CO.

Duncan D (2005) Clickers in the classroom: how to enhance science teaching using classroom response systems. San Francisco, CA: Pearson/Addison-Wesley.

Fried CB (2008) In-class laptop use and its effects on student learning. Comput Educ 50:906-914.

Hendarta S. (2016) Cornell faculty explain changes to in-class laptop policy. Cornell Daily Sun. February 25, 2016.

Johnson L, Adams BS, Estrada V, Freeman A (2015) NMC Horizon Report: 2015 Higher Education Edition. Austin, Texas: The New Media Consortium.

Lee JH (2012) Real-Time mobile distance learning system for Smartphone. In: Cooperative Design, Visualization, and Engineering; 9th International Conference, CDVE 2012, Osaka, Japan, September 2-5, 2012. Proceedings (Lou, eds.)

Katz JE (2005) Mobile phones in educational settings. In: A sense of place: the global and the local in mobile communication (Nyiri K, ed) pp 305-317. Vienna: Passagen Verlag.

Mayer RE (2001) Multimedia learning. New York: Cambridge University Press.

Mazur E (1997) Peer instruction: a user's manual. Prentice Hall, N.J.

Mazur, E (2009) Education. Farewell, lecture? Science 323:50-51.

McCoy B (2013) Digital distractions in the classroom: student classroom use of digital devices for non-class related purposes. Faculty Publications, College of Journalism & Mass Communications. Paper 71.

Sarvary MA (2016) Cornell time machine? Retrieved from http://investigativebiology.cornell.edu/2016/03/06/cornell-time-machine/.

Sarvary MA, Gifford KM (2016) Engaging students in large classrooms: turning classical lectures into dialogues using digital pedagogy. Examples, Benefits and Pitfalls. Proceedings of the 8th annual International Conference on Education and New Learning Technologies (EduLearn16), pp 7089-7097

Shirky C (2014) Why I just asked my students to put their laptops away. Retrieved from http://pscourses.ucsd.edu/ps100da/.

Tanner KD (2013) Structure matters: twenty-one teaching strategies to promote student engagement and cultivate classroom equity. CBE Life Sci Educ 12:322-331.

Valentine A, Kurczek J (2016) "Social" neuroscience: leveraging social media to increase student engagement and public understanding of neuroscience. J Undergrad Neurosci Educ 15:A94-A103.

Wees D (2012) 56 examples of formative assessment. Retrieved from: http://www.edutopia.org/groups/assessment/250941.

Received February 16, 2017; revised March 14, 2017; accepted March 14, 2017.

Address correspondence to: Mark A. Sarvary, Ph.D., Investigative Biology Teaching Laboratories, Department of Neurobiology and Behavior, 1140 Comstock Hall, Cornell University, Ithaca, NY 14853. Email: mas245@cornell.edu