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A Brilliantly Simple Classroom Response System

Nickie Nuñez, Nahiane Pipaón Fernández, Violeta Iosub, J. Scott McIndoe,* and Krista Kobylianskii*

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ABSTRACT: Laser pointers are an effective classroom response system in a chemistry context. Each student is given their own laser pointer to point, gesture, and participate in chemical simulations. Implementation is inexpensive and requires minimal instructor training or preparation but allows for a high degree of creativity. Students report high levels of adoption, engagement, and enjoyment.

KEYWORDS: *Classroom response system, Undergraduate lecture, Anonymous feedback, Laser pointers, Audience response system*

INTRODUCTION

Classroom response systems come in all shapes and sizes. Educators have employed endless creativity in coming up with ways to actively engage their students in learning during class. Tools such as clickers,[1,2] or the app-based versions thereof[3−9] have become very common in classrooms due to their efficacy in getting students to think and contribute.[10,11] Other approaches include hand raising, hand signals, or response cards with options like a/b/c/d or yes/no;[12−15] however, these lack the anonymity provided by the more technologically advanced classroom response systems.[16]

Here, we introduce a low-tech, simple, and anonymous method to get students engaged and participating in undergraduate chemistry lectures. Laser pointers are cheap and ubiquitous enough that they are sold for a few dollars each. In the lecture theater, they are the provenance of the instructor, but they do not need to be. Putting laser pointers in the hands of the students allows them to respond instantly and dynamically to a range of interactive questions. Furthermore, there is negligible added workload or training required of the instructor. We have tested this idea in the context of an undergraduate chemistry lecture, and the results have been sufficiently positive that we are keen to share the results more broadly. To our knowledge, laser pointers have been tested previously as an audience response system with moderate success in library information sessions[17] and a computer science class.[18,19] We propose that laser pointers provide an added benefit in the chemistry classroom, where laser dots can be used by students to not only answer standard multiple-choice questions but also to represent electrons, gas particles, and dynamic processes.

METHODOLOGY

Practical Considerations

Red laser pointers are commodity electronics and are sold in bulk in a variety of form factors. Keychain laser pointers, pens/LED lights/lasers, pet toys, and other combinations are common and inexpensive. We selected "mini red laser pointers" sold in a 6-pack from an inexpensive brand available on Amazon. Each laser pointer cost just over 2 USD at the time of purchase. These laser pointers worked well in both low light and direct sunlight. No other brand or model of laser pointers was tested; however, any similar low-powered (Class I) red laser is likely sufficient. A laser pointer with just a single button would be ideal to ensure that students do not accidentally trigger an LED light instead of a laser dot; however, this is not critical.

Class sizes ranging from 20−50 students are ideal for this approach. Smaller class sizes may still benefit; however, anonymity may be increasingly difficult to preserve. Larger classes make it difficult for students to identify their laser point and point it accurately. Laser dot overlap may also make it difficult for instructors to make sense of the feedback in larger classes.

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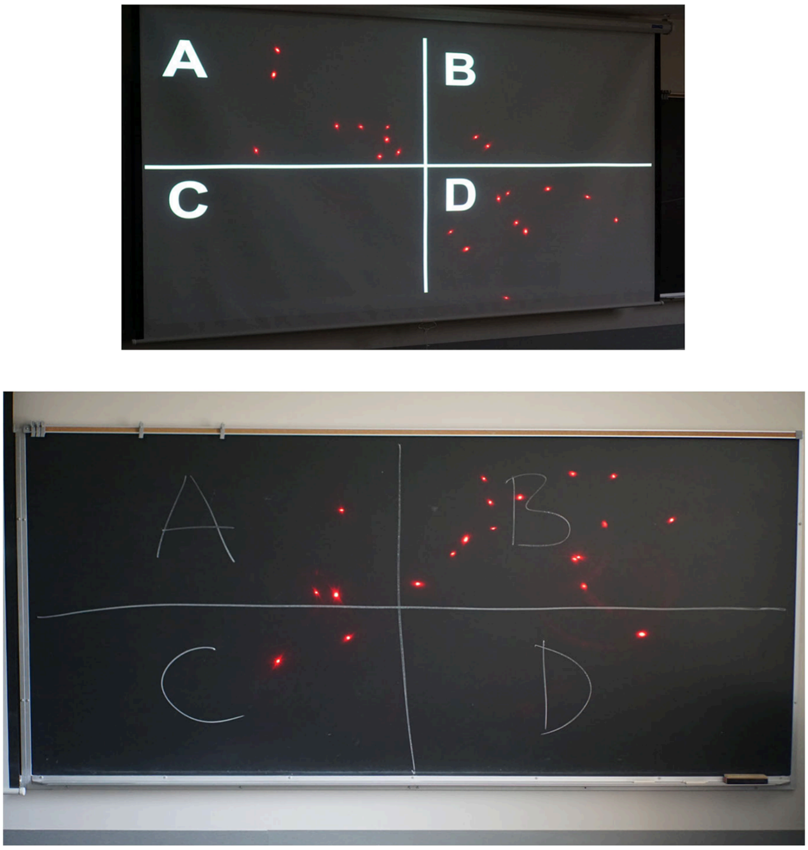

Figure 1. Captures of the screen (top) or board (bottom) during ABCD multiple-choice questions.

Safety

Low powered (Class I) red lasers only should be used. Students should be instructed to not point the laser at anyone, only at the board/screen.[20] Disclaimer: this approach should only be used for students with a reasonably high level of maturity, and we have only tested it in a university setting. The US FDA advises:

> *"Never aim or shine a laser pointer at anyone. 1. Don't buy laser pointers for your children. 2. Before purchasing a laser pointer, make sure it has the following information on the label (a) a statement that it complies with Chapter 21 CFR (the Code of Federal Regulations) (b) the manufacturer or distributor's name and the date of manufacture (c) a warning to avoid exposure to laser radiation (d) the class designation, ranging from Class I to IIIa. Class IIIb and IV products should be used only by individuals with proper training and in applications where there is a legitimate need for these high-powered products."*[21]

Basic Application

In its simplest iteration, an instructor can provide answer options for the class, e.g. A B C D, yes/no, and ask the class to indicate with the laser pointer what their answer is. Qualitatively, it is easy to judge what the class is thinking, and that is usually enough, i.e. "Most of you think the answer is C, quite a few like D. Let's dig into that". Figure 1 shows an example of what the screen or board looks like in different scenarios.

One difference between the laser pointers and clickers/apps is that students can see their classmates' responses, and drift happens as students change their minds after seeing the consensus. This phenomenon is manageable—if they drift to the right *or* wrong answer, it offers a powerful teaching moment to the instructor.

Chemistry-Based Applications

There are doubtless endless possibilities here and we anticipate educators being able to be very creative in this space. Some examples in the chemistry context include pointing at chemical structures, arrow pushing, modeling gas dynamics, and representing electrons (Figure 2).

Pointing. Ask the class to gesture at a figure, image, or structure, and ask the class a question, e.g., "Point at the ester functional group in this molecule." "Which one of these energy levels is the HOMO?" "Which element in the periodic table is the largest?" The question can be asked on the fly or preprepared: we found both to work well. This sort of question can be onerous to ask using a commercial classroom response system due to the chemistry-specific content, but using laser pointers makes it simple.

Arrow Pushing. Ask the students to start where the electrons are, then move in an arc to where they are going (i.e., trace the path of the arrow from tail to point). This exercise requires a large chemical structure to afford students enough spatial discrimination to trace an appropriate arc.

Modeling Gas Dynamics. Draw a closed vessel and ask the students to move their pointers as if they were an individual gas particle inside the vessel. Now ask them to imagine what would happen if the temperature was increased. Ask half the class to stop participating (e.g., "If your first name begins with the letters A-M, please switch off your pointers") to simulate a drop in pressure. This exercise is fun and highly engaging, as students are collaboratively building a simulation. Teaching moments arise from misunderstandings, e.g.,

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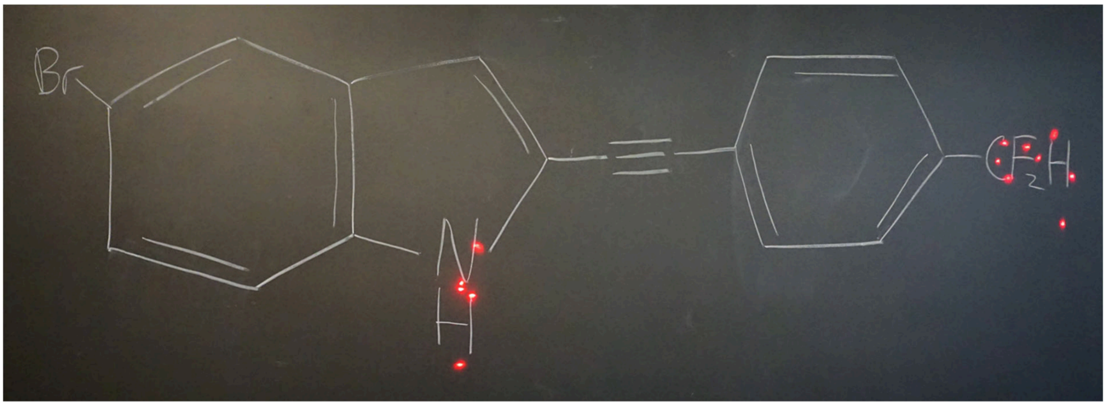

Figure 2. Capture of the board during a pointing session (question asked: "Which hydrogen is most acidic?").

molecules orbiting rather than moving in straight lines, molecules moving outside of the flask, etc.

Representing Electrons. This idea arose spontaneously when a group of students decided to use their laser pointers to collaboratively draw the electrons around a bromide ion to generate a Lewis structure (Figure 3). This action was entirely unprompted and not on topic, but illustrates how the technology lends itself to creative applications.

Figure 3. Spontaneously collaborative construction of a Lewis structure.

Case Study

Laser pointers were incorporated as a classroom response tool in General Chemistry discussion sections in the Spring semester of 2024 at Rice University (Houston, USA). In total, four sections and 164 students (39−43 students per section) participated in the study.[22]

Over the course of the spring semester, laser pointers were used on four occasions: in the discussions on Gas Laws, Kinetics, Equilibrium, and Titrations. During these discussions, laser pointers were distributed to students at the start of class. During an initial 30 min lecture, students were periodically asked to respond to questions using the laser pointers. Questions included asking students to model the behavior of a gas particle, point to the correct spot on a titration curve or balanced chemical equation, or point to a simple yes/no or multiple-choice answer. Students spent the remainder of the discussion doing group work and laser pointers were not used during this time. Students returned the laser pointers at the end of class.

RESULTS AND DISCUSSION

Student Engagement

During the discussion on titrations, data were collected on how many students used the laser pointers. Students were asked five questions that involved pointing to various points on a titration curve. For example, "Where would you find the first equivalence point of phosphoric acid?" For each question, several pictures were captured showing the students' responses. The number of laser dots visible in each picture was counted. The picture that captured maximum participation on each question was used to calculate average participation over the five questions. The average participation was compared to the number of students who signed the attendance sheet at the start of class. This process was completed in each of the four discussion sections. An average of 68% participation was observed. We suspect that this value may under-represent actual participation for two reasons. 1) It was difficult to capture one image in which all students were participating in the same moment. Some students would indicate their answer with the laser pointer and then turn off their laser, while other students would take a longer time to decide on their answer before pointing at it. 2) Some stray laser points did not make it into the frame of the picture. A sample picture, the specific questions asked, and the full set of raw data are provided in the Supporting Information.

The effect of the laser pointer activities on learning outcomes was not directly measured but will be the focus of future work. Qualitatively, we observed that on days when laser pointers were brought to class, students were visibly excited to use them and interacted more frequently during the lecture segment of the class.

Student Feedback

We asked the students six questions: four assessing their classroom experience and two requesting feedback. 146 responses were collected, representing 89% of students enrolled in the class. A copy of the survey questions is provided in the Supporting Information. The results are summarized in Figure 4.

Student response was overwhelmingly positive. 75% of students self-reported always using the laser pointer to provide feedback when prompted. Another 21% reported usually using the laser pointer. This, again, may indicate a slight negative bias in our measured participation level of 68%. Students generally reported that it was enjoyable and easy to use the laser pointers

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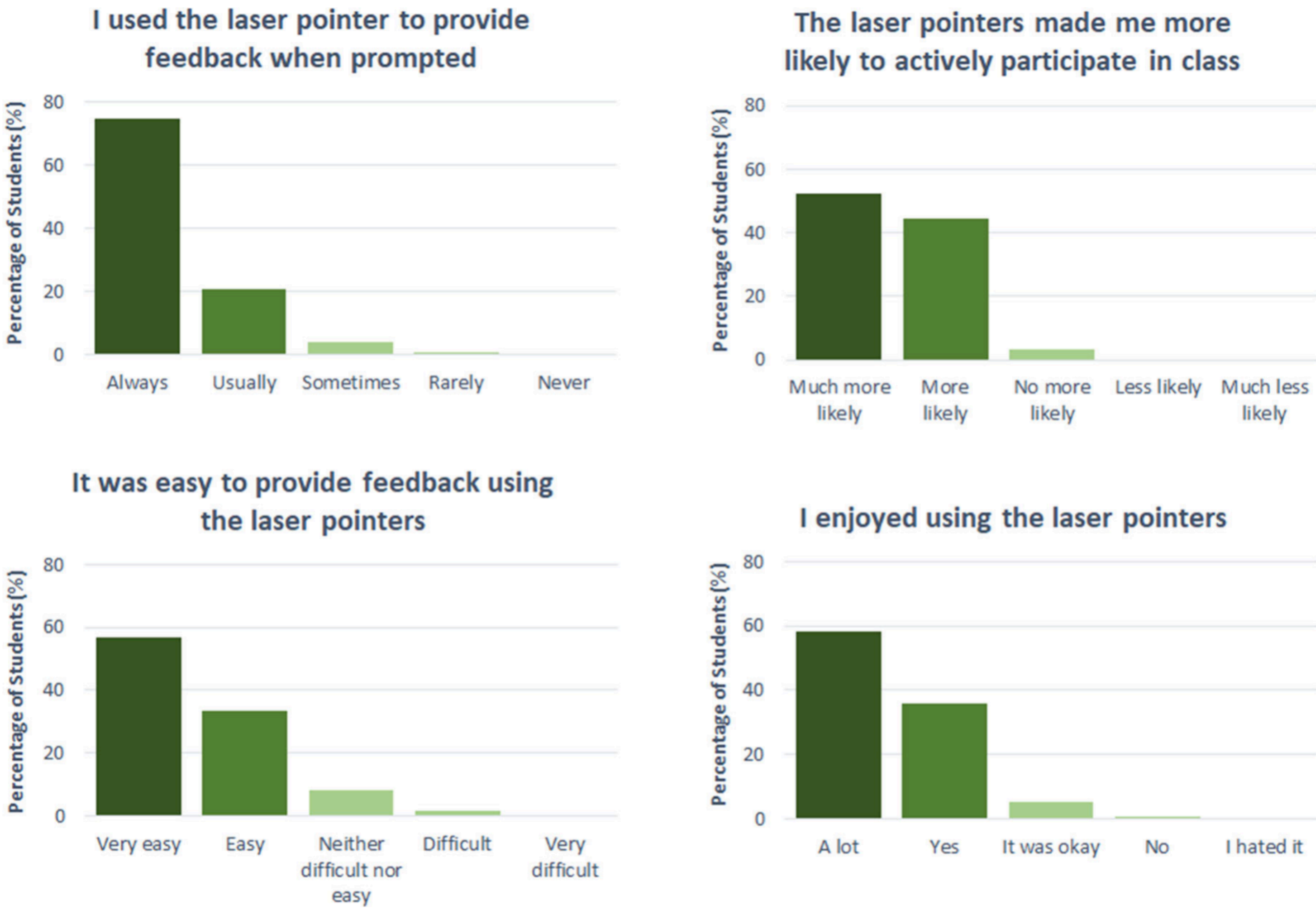

Figure 4. Survey responses to the four multiple-choice questions. 146 students were surveyed.

and that it made them more likely to actively participate in class.

The final two survey questions asked students about the strengths or advantages and weaknesses or disadvantages of using laser pointers as an audience response system. Many of the comments confirmed the well-known advantages of any anonymous classroom response system. Students appreciated the ability to remain anonymous while also seeing how the class as a whole was responding. Many reported less fear associated with participation. For example:

"I love the laser pointers! I feel like I hardly never participated last semester out of fear of being wrong but the anonymous system allows me to be confident enough to answer every time and be much more engaged."

"It was good to see what everyone was thinking and it made the class environment feel more open as it was ok to make mistakes since it was apparent that many people had the same presumptions."

"It allows everyone to answer a question rather than just a couple people raising their hands."

But there was also a heavy emphasis on how easy, fun, or engaging it was to use laser pointers. For example:

"It was cool."

"It was fun to point at the board."

"It was fun to press the buttons."

"It was really fun and interactive yet engaging in a way that kept us on focus."

"So much fun! I could also show my ideas without fear since it is anonymous. Since the whole class can participate, it was more interesting to see general thoughts."

Common reported disadvantages were difficulty in identifying which laser dot was yours, the potential for distraction, and the tendency for answers to drift toward conformity. For example:

"I think the only downside to the laser pointers is when you lose your laser. For example, when 30+ lasers are on the board you lose your own laser so you have to point to the ceiling and then take it down to your response. However, this is not really a bad thing because sometimes it can still be fun."

"I feel like sometimes it could be a bit of a distraction. It is very tempting to point the laser at random places during discussion."

"Sometimes people would bunch up to one answer, so I felt inclined to respond with the answer my classmates think it is vs. what I think the answer it is."

Laser pointers were not mentioned in our standard end-of-semester survey, but students were asked for any additional comments about the TA, instructor, or the discussion in general. Unprompted, 5 students left positive comments about the laser pointers. For example:

"I liked using the laser pointers in discussion! They kept me more engaged with the material."

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J. Chem. Educ. 2024, 101, 4005−4010

Comparison to Other Classroom Response Systems

The use of laser pointers as a classroom response system has a combination of advantages that make it uniquely appealing in a chemistry lecture setting (Table 1). Like simple hand-raising or response cards, lasers are inexpensive and simple to use. But, like Clickers or classroom response apps, they allow for anonymity: a feature highly valued by many students we surveyed. While classroom response apps can be highly effective and anonymous they can also lead to distractions. Students, once they take their phone out to respond to a class question, may decide to check their social apps. Technological difficulties can also lead to disruptions and dead time during class which may cause students to lose focus.[23] The use of laser pointers eliminates these issues while maintaining anonymity.

Table 1. Summary of the Advantages and Disadvantages of Using Laser Pointers Compared to Other Classroom Response Systems

Advantages	Disadvantages
No phone or laptop required	Not linkable to student IDs
Fewer technological issues	Sometimes difficult for students to identify their dot
Inexpensive	Lasers do not work on LCD displays
Anonymous	Potential for mischief
Fun!	
No in-class "dead" time	
Little to no prep time	

For teaching chemistry specifically, lasers allow greater creativity on the part of the instructor. There are many opportunities during lectures to model the behavior of particles or electrons, or point to specific chemical sites or species. Commercial classroom response systems struggle to accommodate these types of activities,[4] while the use of laser pointers makes them trivial. In addition, laser pointers allow for more flexibility in real time. Impromptu questions can be easily posed to probe student understanding by simply directing students to point to various images or spots in the classroom. The result is a more conversational feel to the lecture. While it is possible to generate questions on the fly with some app-based classroom response systems, we find this often leads to a disruption in classroom discussion as the instructor shifts their focus from the classroom to the app.

The most noted disadvantage in our case study was the difficulty that students reported in tracking their own laser dot. This issue can be mitigated by using a large response area that allows for ample spatial discrimination. Students may also be directed to first point to the ceiling to find their dot before pointing to an answer. The potential for mischief or distraction was also mentioned by students, although in practice, and with appropriate priming on the responsible use of lasers, we did not observe this to be an issue. The vast majority of students involved in the case study were first-year university students. The potential for mischief or distraction may be significantly higher for applications involving high school or middle school students. Finally, if attendance or participation tracking is required, laser pointers will not suffice.

We observed a strong tendency for responses to drift toward consensus. Several students cited this as a disadvantage in the survey; however, we believe it to be a useful teaching tool. The drift happens in real time and is obvious to everyone in the class. The instructor can see the initial and the revised responses. First, this allows for a more nuanced analysis of how well the class understands the material and how confident they are in their responses. Second, the instructor can revisit the initial distribution of responses to clarify possible misunderstandings.

CONCLUSIONS

As advancements in technology continue to offer novel and exciting possibilities in the classroom, it is easy to assume that new technology is inherently better. However, in teaching, simple is often best. Laser pointers offer a classroom response tool that is inexpensive, anonymous, easy to apply, amenable to chemistry-specific content and that students praise as "fun and interactive!" From an instructor's perspective, we find this approach effective and refreshingly simple.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.4c00771.

Measure of student engagement; student feedback (PDF; DOCX)

AUTHOR INFORMATION

Corresponding Authors

J. Scott McIndoe − *University of Victoria, Victoria, British Columbia V8P 5C2, Canada;* orcid.org/0000-0001-7073-5246; Email: mcindoe@uvic.ca

Krista Kobylianskii − *Rice University, Houston, Texas 77005, United States;* orcid.org/0000-0002-5585-6952; Email: kristakobyl@rice.edu

Authors

Nickie Nuñez − *Rice University, Houston, Texas 77005, United States*

Nahiane Pipaón Fernández − *University of Victoria, Victoria, British Columbia V8P 5C2, Canada*

Violeta Iosub − *University of Victoria, Victoria, British Columbia V8P 5C2, Canada*

Complete contact information is available at: https://pubs.acs.org/10.1021/acs.jchemed.4c00771

Notes

The authors declare no competing financial interest.

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