JOURNAL OF CHEMICAL EDUCATION
Technology Report
pubs.acs.org/jchemeduc

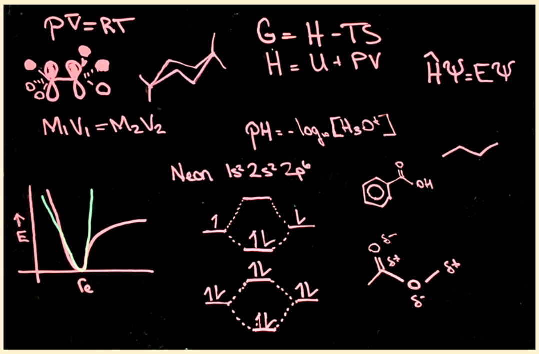
A Blackboard for the 21st Century: An Inexpensive Light Board Projection System for Classroom Use

Erik S. Skibinski, William J. I. DeBenedetti, Amnon G. Ortoll-Bloch, and Melissa A. Hines*

Department of Chemistry and Chemical Biology, Cornell University, Ithaca, New York 14853-1301, United States

Ⓢ *Supporting Information*

ABSTRACT: An inexpensive light board projection system that enables lecturers to face the classroom while lecturing is described. The lecturer's writing appears in high contrast in front of the lecturer; it is never blocked by the lecturer, even while writing. The projected image displays both the writing as well as the lecturer's gestures and facial expression. The size of the image can be tailored to the classroom, making the light board equally useful in small classrooms and large auditoriums. The lecture can be recorded for later playback.



KEYWORDS: *First-Year Undergraduate/General, Curriculum, Multimedia-Based Learning, Enrichment/Review Materials*

■ INTRODUCTION

Since their adaptation to the classroom in the 19th century, blackboards have become ubiquitous, primarily due to their low cost, simplicity, and extreme flexibility.[1] Nevertheless, blackboards suffer from a number of inherent disadvantages. When writing, the lecturer faces away from the classroom, and the lecturer's body often blocks students' view. The blackboard form factor is limited by human anatomy, making its use poorly suited to large auditoriums even when oversized chalk is used. The magnitude of this problem can be appreciated from Figure 1a, which shows the view from the back of a 500-person classroom. Additionally, technology for recording blackboard lectures, though existent, is unsatisfactory. Finally, chalk is messy and may induce asthma, dermatitis, and eczema in sensitive individuals.[2−4]

Although whiteboards and electronic whiteboards offer some advantages, they suffer from the same limitation: the lecturer faces away from the class, often obstructing student view.

Recently, light boards have been developed independently at Northwestern University[5] and San Diego State University[6] for studio-based lectures. In these, the blackboard is replaced by a panel of glass into which light is injected using LED strip lighting. When the glass is clean, this illumination has little effect, as the light is totally internally reflected. When fluorescent molecules are placed in the evanescent field by writing on the glass with a fluorescent marker, the molecules glow brightly, an effect commonly seen in fluorescent marker boards. Alternatively, liquid chalk markers scatter light, giving a similar effect. If the glass is clear, a viewer looking through the glass at the lecturer sees both the lecturer as well as crisp, high-resolution drawings. There is only one problem: the handwriting, viewed through the glass, is backward. To correct this, studio-based light board implementations videotape the reflection of the lecturer in a mirror or manipulate the image digitally.

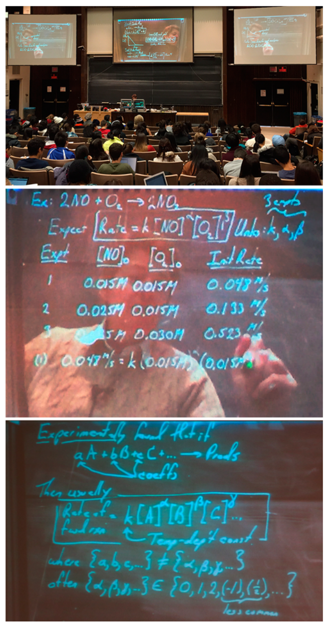


Figure 1. Light board in use. (a) View from the back of a 500-person auditorium. For scale, the lecturer is standing in front of a double-height mechanized blackboard. One light board projects on the center screen, while the other projects on the side screens. (b) The lecturer does not obscure the light board while writing. (c) Projected text.

DOI: 10.1021/acs.jchemed.5b00155
J. Chem. Educ. XXXX, XXX, XXX−XXX

Although this technique can produce stunning videos, it is not well suited to the classroom. First, unless the light board is viewed in reflection (e.g., with the lecturer orthogonal to the class's viewing direction), the students see the lecturer writing in reverse. Second, a blackboard-size piece of glass is fragile, expensive, and very heavy. Moving the glass between lectures would be unwieldy and potentially hazardous. Finally, the studio-based light boards are expensive, with some costing[5] $10,000.

■ IMPLEMENTATION

We report a simple apparatus, optimized for the classroom, that can be realized with minimal wiring for about $800 in any projector- or TV-equipped classroom as shown in Figure 1 and described fully in the Supporting Information. The lecturer faces the class, writing with commercial markers on a small plate of low-impurity glass (e.g., 30 cm × 46 cm × 1 cm) supported at a comfortable angle (e.g, 35° from vertical). The lecturer's image is captured from the backside of the glass using a tablet computer, such as an Apple iPad. Because front-facing cameras on tablets are intended for videoconferencing, many automatically transpose the captured image in the horizontal plane. As a result, the image on the tablet shows the lecturer writing normally, not in reverse, even though the camera images the lecturer through the glass. This image is then streamed in real-time to a receiver (e.g, an Apple TV using AirPlay) or connected with a cable, and then displayed using a projector or television. Optionally, the lecture may be streamed for online learning[7,8] or recorded for problem-solving[9] or tutorial[10] videos.

During the presentation, the lecturer looks through the glass, monitoring the image in the tablet's display as illustrated by Figure 2. When the students view the projected image on a monitor or screen, they see the lecturer looking directly at the class and explaining to them.

This setup has many advantages. First and foremost, the lecturer's writing appears in high contrast in front of the lecturer; it is never blocked by the lecturer's body even during writing. The size of the image can be tailored to the classroom, making the light board equally useful in small classrooms and large auditoriums. Second and in contrast to overhead projectors and document cameras, the projected image displays both the writing as well as the lecturer's gestures and facial expression. This allows the lecturer to convey more information than sketches alone while also engaging students. Third, the lecturer writes at a comfortable angle and at a comfortable size while facing and interacting with the class. Fourth, the system is compact, inexpensive, and easily transportable. Because tablets were designed for informal videoconferencing, they function well under low-light conditions, and supplemental lighting is typically not needed. Fifth, the use of wireless streaming between the tablet and the receiver enables a very simple installation. Only a single cable is needed to power the LEDs, and the tablet runs off battery power. Finally, video recording is built in to most tablets. Optionally, a switch between the receiver and the projector enables the lecturer to rapidly toggle between the light board and presentation software (e.g., PowerPoint). Although techniques to overlay and annotate graphics,[5,6] such as videos or PowerPoint slides, on light boards have been developed, these add significant complexity, and other technologies, such as digital styluses, may be more appropriate.

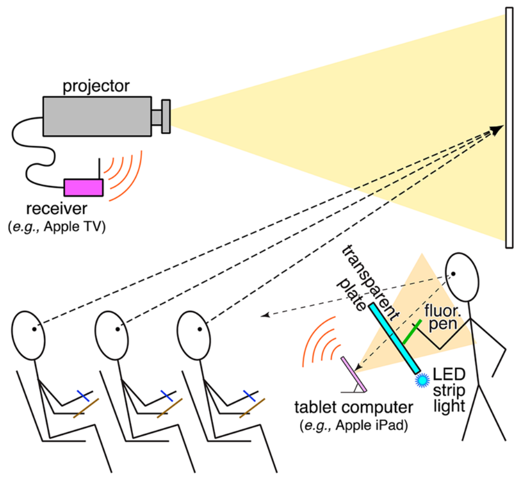


Figure 2. Schematic of light board system. The lecturer writes on the glass with a marker while monitoring the image in the tablet. The tablet simultaneously captures an image of the writing and the lecturer (orange field of view), then transmits the image to a projector. The students, who watch the projected image, perceive the lecturer to be looking at them.

In this implementation, the tablet serves four separate functions: video camera, video recorder, video monitor, and video transmitter. Most of the simplicity and cost savings of this system are due to this multiplicity of purpose. In our experience, an hour-long lecture depletes the battery of an iPad mini by 15%, enabling multiple lectures between charges.

In contrast to blackboards and studio-based light boards, the writing surface is not vertical; it is angled away from the lecturer for two reasons. First, the angle makes writing more natural and comfortable. The lecturer can rest his wrist against the writing surface, enabling finer control of the marker and better handwriting. Second, the angle reduces students' view of the back of the glass, avoiding the cognitive dissonance engendered by backward writing.

Student response to the light board has been very positive. In comparison to a standard double height mechanized chalk-board, the large size of the light board's projected image makes the lecturer's writing easier to see from the back of the classroom and from the balcony. To approximate the screen space available on a double blackboard, two light boards are placed side by side, with one projecting to a center screen and the second to two side screens as seen in Figure 1a. The lecturer can alternate between the boards, which allows ample time for student note-taking between erasures.

■ CONCLUSION

In the future, the light board might be superseded by a large-screen tablet equipped with a stylus and front-facing camera; however, there are currently technical limitations to this approach. Though some artists have produced images with exquisite detail on a tablet, many people have found that current technology leads to unacceptable handwriting degradation, although some report success with simple annotations.[11,12] In addition, many find that the screens on tablets are too small to effectively replace a blackboard.

DOI: 10.1021/acs.jchemed.5b00155
J. Chem. Educ. XXXX, XXX, XXX−XXX

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.5b00155..

A description of the apparatus, implementation notes, and a cost estimate (PDF)

AUTHOR INFORMATION

Corresponding Author

*E-mail: melissa.hines@cornell.edu Phone: +1-607-255-3040.

Notes

The authors declare no competing financial interest.

ACKNOWLEDGMENTS

This work was supported by the National Science Foundation (NSF) under CHE-1303998 and DMR-1120296. E.S.S. was supported by DGE-0903653.

REFERENCES

(1) Snell, F. D.; Fox, B. S. Glass Versus Slate Blackboards. *J. Chem. Educ.* **1931**, *8*, 320−327.

(2) Moreau, L.; Alomer, G.; Dubé, N.; Sasseville, D. Contact Urticaria From Carboxymethylcellulose in White Chalk. *Dermatitis* **2006**, *17*, 29−31.

(3) Corazza, M.; Zauli, S.; Pagnoni, A.; Virgili, A. Allergic Contact Dermatitis Caused By Metals in Blackboand Chalk: A Case Report. *Acta Derm Venereol* **2012**, *92*, 436−437.

(4) Larramendi, C. H.; Marco, F. M.; Llombart, M.; de la Vega, A.; Chiner, E.; García-Abujeta, J. L.; Sempere, J. M. Allergenicity of Casein Containing Chalk in Milk Allergic Schoolchildren. *Ann. Allergy, Asthma, Immunol.* **2013**, *110*, 335−339.

(5) Peshkin, M. Lightboard. http://lightboard.info/ (accessed May 2015).

(6) Anderson, M. Learning Glass http://its.sdsu.edu/docs/Learning_Glass_Specifications.pdf (accessed May 2015).

(7) Leontyev, A.; Baranov, D. Massive Open Online Courses in Chemistry: A Comparative Overview of Platforms and Features. *J. Chem. Educ.* **2013**, *90*, 1533−1539.

(8) Phipps, L. R. Creating and Teaching a Web-Based, University-Level Introductory Chemistry Course That Incorporates Laboratory Exercises and Active Learning Pedagogies. *J. Chem. Educ.* **2013**, *90*, 568−573.

(9) Richards-Babb, M.; Curtis, R.; Smith, V.; Xu, M.; Wang, Z.; Tan, S.; Wang, B.; Yang, J.; Hou, J. G. Problem Solving Videos for General Chemistry Review: Students' Perceptions and Use Patterns. *J. Chem. Educ.* **2014**, *91*, 1796−1803.

(10) He, Y.; Swenson, S.; Lents, N. Online Video Tutorials Increase Learning of Difficult Concepts in an Undergraduate Analytical Chemistry Course. *J. Chem. Educ.* **2012**, *89*, 1128−1132.

(11) Johnson, A. E. Digital Ink: In-Class Annotation of PowerPoint Lectures. *J. Chem. Educ.* **2008**, *85*, 655−657.

(12) Tofan, D. C. Using a Tablet PC and OneNote 2007 to Teach Chemistry. *J. Chem. Educ.* **2010**, *87*, 47−48.

DOI: 10.1021/acs.jchemed.5b00155
J. Chem. Educ. XXXX, XXX, XXX−XXX