

Supporting Information for
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*

Dept. of Chemistry and Chemical Biology, Cornell University, Ithaca NY 14853-1301, USA

A simple implementation of a light board projection system that has been used in a 500-person classroom at Cornell University is shown in Fig. S1. The light board was constructed primarily from T-slotted aluminum framing, a rapid prototyping material that can be cut to length with a bandsaw. This prototype was designed to allow the angle of the glass to be adjusted to the user's preference, which we have not found to be necessary to date. If this ability is not needed, a somewhat smaller implementation could be achieved by shortening the length of the vertical and side pieces, as described in Table S3.

The iPad sits on the same surface as the light board frame (*e.g.*, the podium) and is supported at the appropriate angle by an aluminum plate that is rigidly connected to the frame as shown in Fig. S2. The iPad is pressed against the aluminum plate by the binder clip. This design prevents the iPad from moving out of place when the frame is jostled (*e.g.*, while the board is being erased).

The light board works best when the instructor stands in front of a dark surface, such as an existing blackboard. If this is not feasible, a black cloth backdrop could be used. In contrast to studio-based light board implementations, we do not use supplementary lighting to illuminate the instructor. Although such lighting could easily be added to the light board frame, we have found ambient lighting in the classroom to be sufficient. Additional instructor lighting would reduce the contrast between the written text and the background image, which may be problematic when the instructor wears light-colored clothing.

Stray reflections from the glass are minimized in two ways. First, the linear polarizer in front of the tablet's camera suppresses reflection of the tablet's display. Second, the light board is best placed on a dark surface, such as the slate-topped podiums common in many chemistry lecture halls. Alternatively, black card stock could be placed on the bottom of the frame. A better solution to this issue may be the use of anti-reflective low-impurity glass, such as PPG Solarphire glass;¹ however, we have yet to try this option.

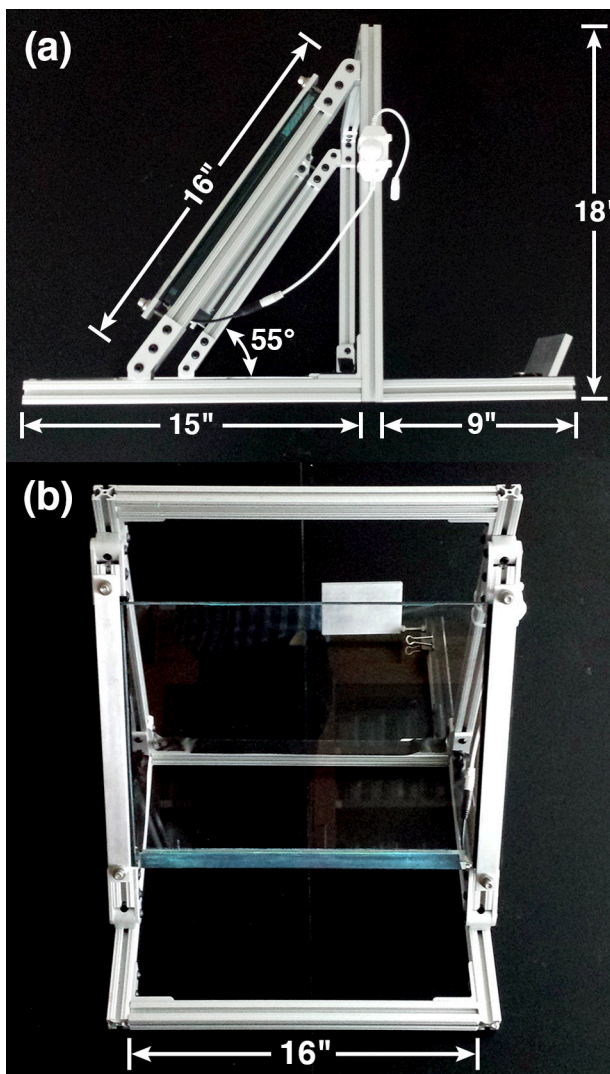


Fig. S1: (a) Side and (b) front views of the assembled light board.

The light board functions well with the Apple camera application; however, there is currently no way to suppress the display of the control button in the projected image. For this reason, we prefer the “Big Screen for Camera” iPad application.

Light board setup before the lecture is relatively rapid and takes no longer than the time previously allocated to washing the mechanized blackboard. The light board is lifted off a rolling cart and placed onto the podium. The power supply for the strip lighting is plugged in and turned on. The iPad is turned on, connected to AirPlay, and the camera application activated. Finally, the iPad is slipped into place. At the end of lecture, this process is reversed.

Table S1 shows the parts needed for this implementation and a cost estimate. A detailed parts list for the frame is given in Table S2, whereas Table S3 specifies the necessary lengths of aluminum framing material.

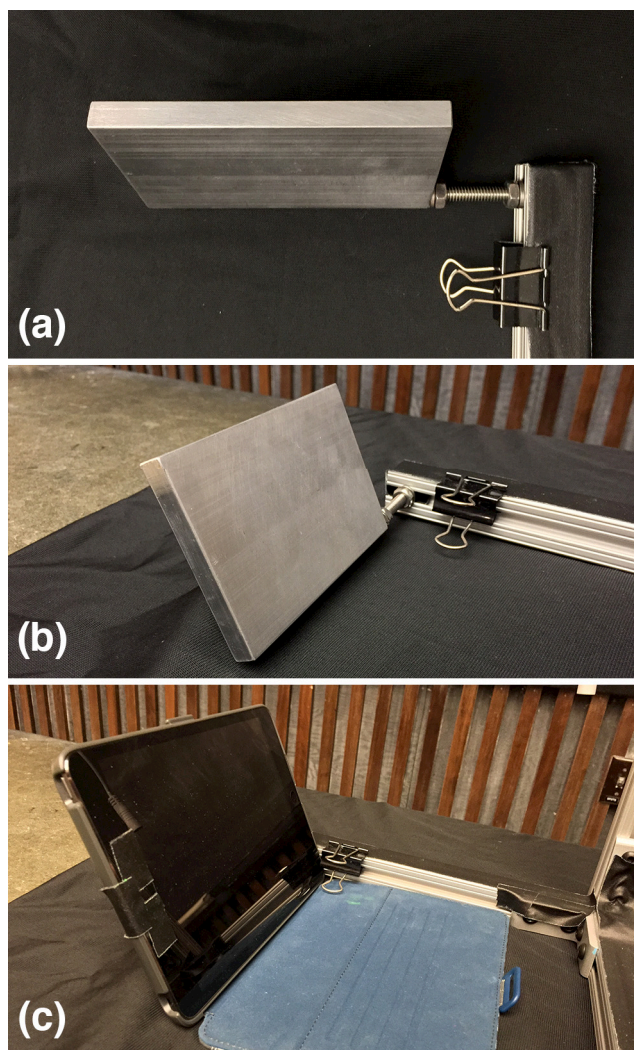


Fig. S2: (a) Top and (b, c) side views of the iPad mount. The hex nuts and lock washers on the threaded rod are used to hold the mount at the correct angle. When these are loosened slightly, the mount can be adjusted to the correct angle, then the nuts retightened. The binder clip holds the iPad in place. After use, the iPad slides out for safe keeping. The tape on the face of the iPad holds the linear polarizer over the front-facing camera.

Table S1: Parts list and estimated pricing (circa January 2015) for light board.

Item	Est. Price	Description/Part Number
iPad mini 2 (16 MB, wifi only)	\$279.00	Apple ME276LL/A
Apple TV	\$89.99	Apple MD199LL/A
Linear polarizer ^a	\$8.00	Polarizing Film, 4" x 4" (cut to size)
Liquid chalk markers ^b	\$17.99	Ala Board dry erase fine tip fluorescent chalk markers, 8-pack
Low-impurity glass, 18" × 12" × 3/8", all edges polished ^c (writing area: 15.75" × 11.25")	\$87.50	Starphire low-iron glass from GlassCages.com LLC
LED light strip ^d	\$20.95	HitLights PRO Cool White High Density LED Light Strip, 144 Lumens per foot
Dial Dimmer for LED strip lighting	\$6.25	HitLights LED Light Strip Dial Dimmer, 5 to 24V DC, 8A Max
Transformer for LED strip lighting	\$9.85	HitLights 24 Watt Power Supply, 110V AC to 12V DC, 2A
HDMI to VGA adapter ^e	\$35.99	Kanex ATVPRO Adapter for AirPlay, iPad and Apple TV Mirroring to VGA Projector
Black conformable (gaffer's) duct tape, 1" wide ^f	\$12.06	McMaster-Carr 7612A2
Big Screen for Camera (software)	\$0.99	Free or \$0.99 for ad removal; White Peak Software, Inc.
Frame	\$227.65	See Tables 2 and 3
Total	\$796.22	

^a Tape a 0.5" × 0.5" piece over the front-facing camera oriented to suppress back reflection of the polarized light from the tablet display as seen in Fig. S2(c).

^b These markers have a relatively fine point and can be easily erased with a dry paper towel. Others prefer Expo Brightsticks fluorescent markers, which are more colorful but also more difficult to erase.

^c Standard soda lime glass absorbs strongly in the green due to a high concentration of iron, leading to an intense green hue when viewed from the edge. To prevent unwanted absorption of the injected light, low-impurity architectural glass, such as Starphire low-iron glass, must be used. Plexiglas and other transparent polymers are prone to scratching and should be avoided.

^d Less intense lights could be used, as we typically operate the lights near the lowest dimmer setting. Blackboard-sized light boards typically use 2 light strips (top and bottom); however, we found this unnecessary. One roll of LED strip lights is sufficient for 10 light boards.

^e (if necessary) Provides HDMI to VGA conversion if required by the projector.

^f A strip of duct tape over the exposed edge of the glass panel (top or bottom) reduces stray light. The tape is also useful for suppressing unwanted reflections from the aluminum frame.

Table S2: Parts list and estimated pricing (circa January 2015) for frame.

Quantity	Item	Est. Price	Part Number
3	Aluminum T-slotted framing extrusion, single profile, 1" size, solid, 4' long, cut to size ^a	42.60	McMaster-Carr 47065T101
4	180° inline pivot, 3" long for 1" high single profile aluminum T-slotted framing extrusion	65.32	McMaster-Carr 47065T191
9	Extended 90° 4-hole bracket for 1" aluminum T-slotted framing extrusion	41.04	McMaster-Carr 47065T175
13	Compact end-feed fastener, 1/4"-20 thread for aluminum T-slotted framing extrusion (4-pack)	24.05	McMaster-Carr 47065T139
4	Neoprene sheet, 12" × 1" × 1/4" ^b	10.00	Purchased in house
1	Sheet metal bracket for LED strip ^c	2.00	Machined in house
2	Aluminum retaining bar for glass, 14" × 1" × 1/4" with 2 holes ^d	2.63	Machined in house
4	1/4"-20 × 1.5" stainless steel screw ^d	2.00	Purchased in house
15	Steel end-feed fasteners for 1" single aluminum T-slotted framing extrusion (4-pack) ^d	34.50	McMaster-Carr 47065T142
1	Aluminum block to support iPad mini, 4.625" × 3" × 3/8" tapped 1/4"-20, 0.5" deep in one corner (3/16" from each edge)	2.00	Machined in house
1	1/4"-20 × 1.5" stainless steel threaded rod	0.91	Purchased in house
2	Steel hex nut, 1/4"-20	0.13	McMaster-Carr 93827A211
6	1/4" stainless steel split lock washer	0.15	McMaster-Carr 92147A029
1	Binder clip, steel wire, 5/8" cap, 1-1/4" wide	0.32	Amazon UTD-UNV10210VP
	Total	227.65	

^a T-slotted aluminum framing material is ideal for rapid prototyping and yields an exceptionally stiff frame; however, it is arguably overkill for this purpose. Other easily machinable materials, such as wood, would also be suitable.

^b Out of an abundance of caution, we sandwiched the glass panel between sheets of neoprene. This may not be necessary.

^c In retrospect, black duct tape alone would probably be sufficient. The prototype board uses LED lighting along the bottom edge. Installation along the top edge would prevent cleaning solution from dripping on the lights and may be preferable.

^d Used to fasten glass retaining bracket to frame.

Table S3: Quantities and lengths of the T-slotted framing material. The lengths in parenthesis would result in a somewhat smaller, fixed angle light board.

Piece Length	Quantity
9"	1
15" (or 11.5")	2
16"	5
18" (or 16")	2

¹ www.ppg.com/en/solutionbyindustry/energy/solar/Documents/FinalSolarphirePVproductdatasheet.pdf (Accessed Mar 2015)