



Capturing Technical Lectures on Lightboard

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J. Alex Birdwell, is a lecturing professor with the Mechanical Engineering department at Northwestern University. His research was conducted at the intersection of robotics and biomechanics, in the field of human-machine interactions, and explored novel ways to control robotic prosthetic hands. He is very passionate about student education and currently teaches five separate courses at the undergraduate level that include manufacturing, design, experimental methods, and thermodynamics. He greatly enjoys advising all levels of undergraduate and early graduate students. He is the producer for the Lightboard studio, and is currently exploring models for effective online and hybrid teaching models.

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Michael Peshkin, a Charles Deering McCormick Professor of Teaching Excellence awardee, has been at Northwestern University for 25 years. His research area is human robot interaction, particularly haptics, as well as investigation of bioinspired electrosense. He developed a very popular Electronics Design course for mechanical engineering students, which is a partially flipped course in the sense that in the classroom, and at home, the students build and debug circuits with the use of portable instrumentation. He developed the Lightboard in response to the needs of that class and his ongoing interest in methods for online teaching. In addition to his research and teaching interests, he has started four spinoff companies.

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Engineering lectures usually involve drawings and equations, drawn on chalkboards or whiteboards. In capturing lectures on video however, these traditional props become liabilities: the presenter must turn away from the audience to write or draw on the board, and the presenter's body often obscures the material.

We developed the Lightboard to create visually compelling videotaped lectures, to avoid the liabilities of chalkboards, and furthermore to be able to produce upload-ready video segments with no post-production.

The Lightboard is a glass board, carrying light internally from LED strips along its edges. A video camera captures the presenter and his/her writing by viewing through the glass. The result is vivid, luminous writing floating in front of the presenter, who can now face toward the camera while drawing and interacting with the material on the board (Figure 1). The video is mirror-imaged on the fly to correct left-right reversal.

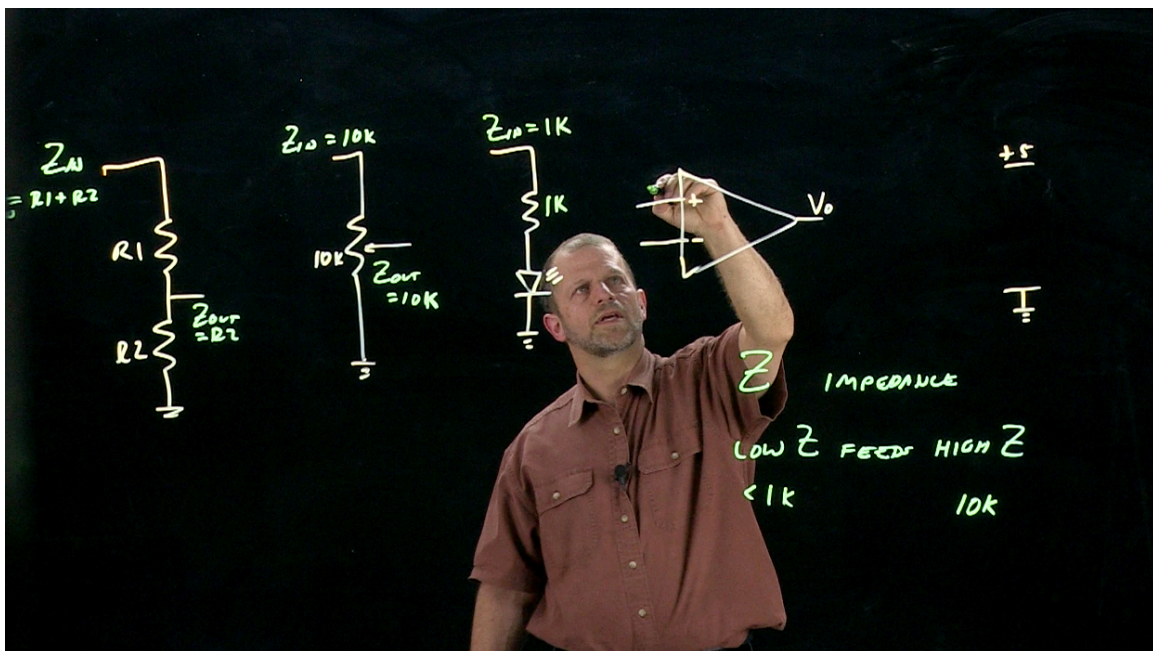


Figure 1. Presenter using the Lightboard, facing the audience while writing.

The ability to produce a lecture segment in one take, essentially live, and without post-production, has proven to be a huge incentive to faculty. Graphics sources such as PowerPoint slides, close-up video of an experiment or demonstration, or content from a personal computer, can be merged in real-time with the Lightboard camera stream. This allows the presenter to interact with the material, and even to annotate it with markers on the glass board.

Faculty have used the Lightboard for recording lectures for flipped or hybrid classes, created lectures for distance learning courses and MOOCs, answered student questions with video responses, held live on-line review sessions, created engineering graphics tutorials, and recorded solutions for homework and example problems. Students have recorded final presentations for classes, design competition entries, and promotional videos for philanthropic and extra-curricular organizations.

Numerous other schools have constructed Lightboards from our plans and specifications, which we have offered as open-source hardware (<http://lightboard.info>). Neither we nor the other schools have yet completed assessments of effectiveness of Lightboard videos as a learning tool, as compared to other methods of video creation. At the present time, we and other early adopters of the Lightboard technology are developing pedagogic uses and best practices. Student response to Lightboard videos has been strongly positive, and indeed students have been using the Lightboard for their own creative endeavors as well.

This paper presents a brief overview of the technology and focuses on three application areas: online course content, student use, and live video conferencing.

The Lightboard Studio

The centerpiece of our Lightboard Studio is a chalkboard-sized sheet of 10mm thick Starphire architectural glass, supported by a metal frame (Figure 2A). Good video lighting for the instructor was arrayed around the glass. The instructor writes with fluorescent markers on the glass, and his or her writing glows brightly due to illumination carried inside the glass pane itself, from LED strips on the edges of the pane. The primary video camera was mounted perpendicular to the center of the Lightboard, about 20 feet away, viewing the presenter through the glass. The image was horizontally flipped using a mirror. A 50-inch LCD monitor was placed just below the camera, in direct view of the presenter, to display the live stream of the video content being recorded. This afforded the presenter the ability to compose the video content and view any merged video streams, such as graphics from a PowerPoint slide, in real-time. Figure 2B shows the layout of the studio.

Audio, from wireless microphones, and video streams are sent to a Blackmagic Design ATEM Television Studio Production Switcher, which handles up to six high-definition (HD) sources. Sources included the primary and secondary cameras and a computer, which was used to display PowerPoint slides and other graphics. Video is saved as MPEG-4 video at 1080i resolution and is immediately available to the presenter.

The entire Lightboard studio, equipment, use cases, and links to other documented Lightboards, are all described in detail at <http://lightboard.info>.

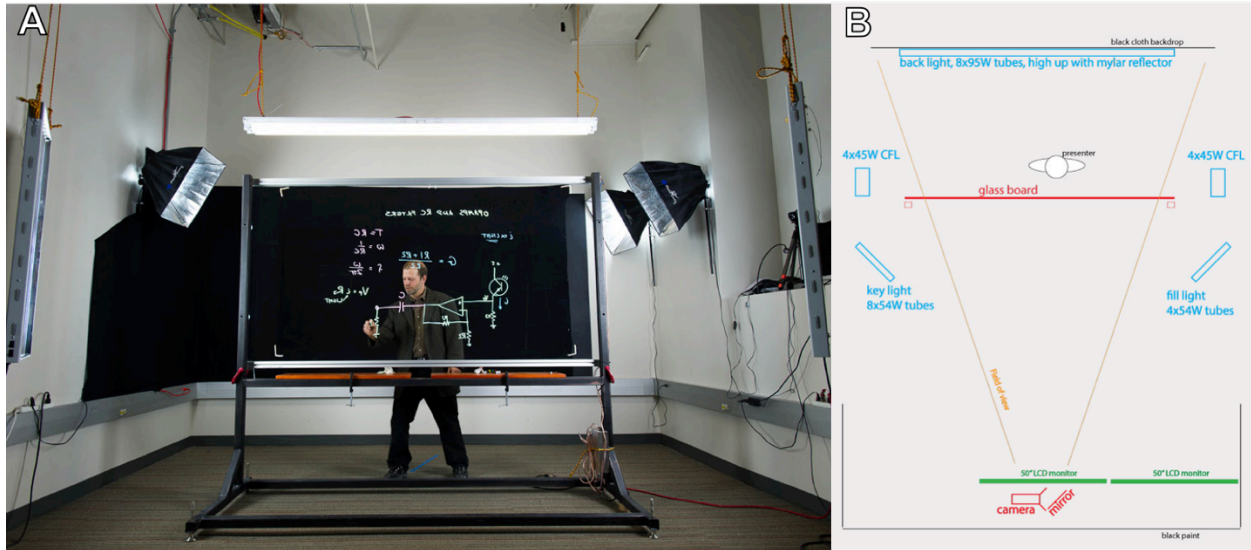


Figure 2. A) Lightboard studio centers around a glass board mounted on a rigid frame and lit internally. The presenter is illuminated by lights from the front (hanging on left and right), sides (wall mounted with black hoods), and from above. This picture was taken from the video camera's point of view. B) Schematic showing layout of studio.

Lightboard applications

The Lightboard studio has been available to faculty and students at Northwestern University for over a year. We have also have made it available to anyone wishing for a demo, often to gain information as they plan their own Lightboard studio. Many instructors have created Lightboard videos to flip their class, prepare material for a MOOC or online course, provide supplemental material to a traditional class, and increase student involvement.

We advise all our studio users to keep individual video segments short, typically five minutes or less. This imperative is reinforced by the need for a time-out to erase the board, which usually means the video segment is long enough.

We use video recording equipment designed for live television production, specifically the Blackmagic Design ATEM Television Studio hardware device. This allows us to record compressed video efficiently, and even to mix in other cameras or sources such as PowerPoint slides, on the fly. Immediately after a recording is made, it can be uploaded to cloud services such as YouTube or Vimeo, and students can watch it. The quickness of this production cycle, and that it can be done by an instructor without assistance, is in many cases a key to its usefulness.

Complementary Online Content, Flipped Classrooms, and MOOCs

The first use for many Lightboard instructors, and the one that requires the least amount of preparation, has been simply working out example or homework problem. This has been

well accepted by faculty as they already have example problems prepared, and students enjoy them because they may watch the problems repeatedly online with the ability to pause and rewind. Figure 3 shows an instructor working through a technical buckling problem with equations and diagrams. The instructor was able to interact with the material while facing the camera (audience) and writing on the board.

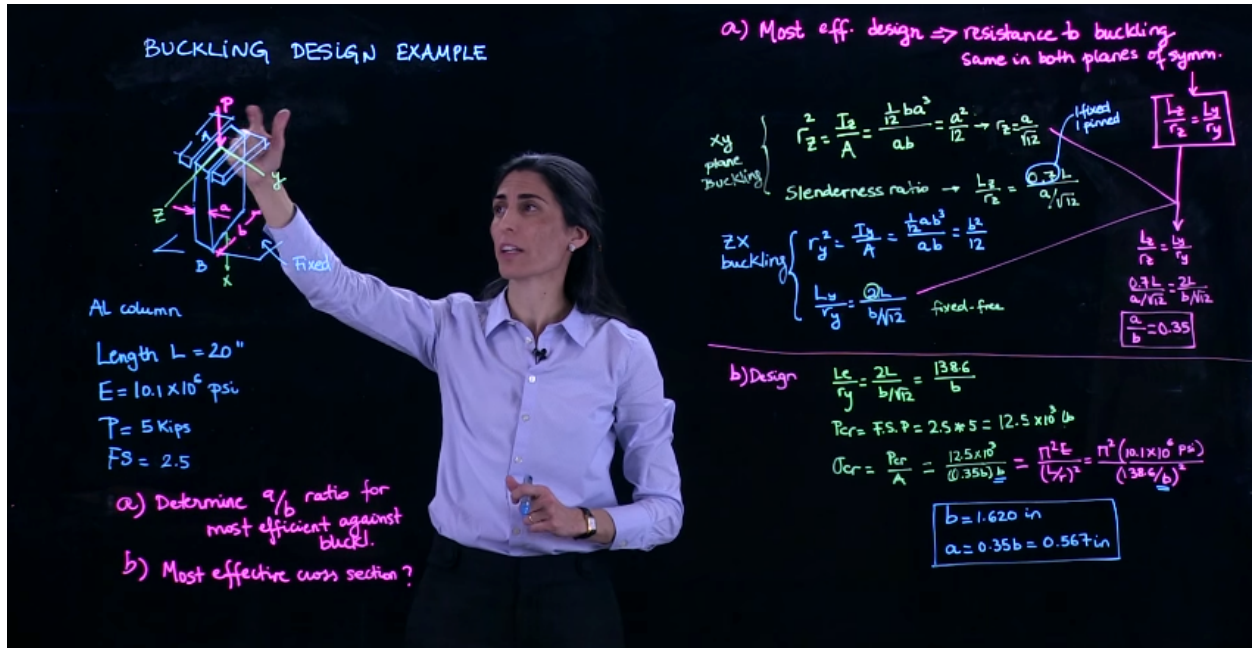


Figure 3. Instructor working through an example problem with diagrams.

The "worked example" videos complement a traditional learning environment. One advantage of the Lightboard studio is that faculty can immediately address a topic or student question by creating and uploading a video in a matter of minutes. A video of this nature can be created in response to student email requests, or to expand on a lecture topic for which there wasn't sufficient time in class.

Videos can also be recorded while preparing a course with the intent to complement the classroom content. At Northwestern University, all first-year engineering students take a project design course that covers engineering graphics, among other topics. A series of videos were developed to provide additional instruction and examples on how to construct these sketches. One video camera was mounted to view a table from above while one instructor sketched a model truck. Concurrently, a second instructor used the Lightboard to discuss any additional details during the demonstration. The two video sources were combined on the fly such that the instructor behind the Lightboard was inset with the graphics demonstration (Figure 4). Both instructors were recorded simultaneously in the same room, were able to see each other through the Lightboard, had a microphone, and provided commentary together throughout the video¹.

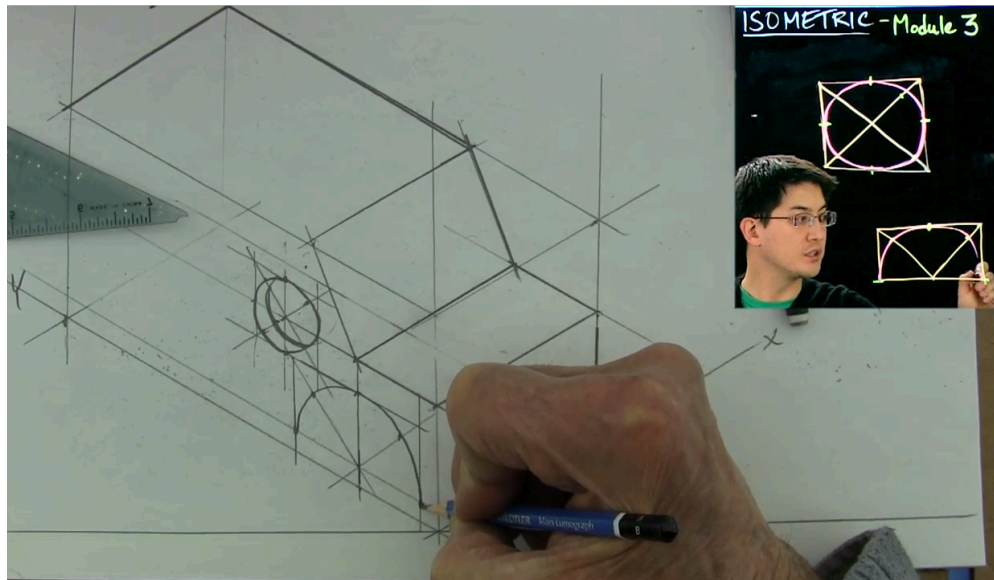


Figure 4. Two instructors merged live: engineering graphics plus Lightboard.

Two video sources can be merged in various screen layouts, and the video sources can be from cameras or computers. Figure 5 shows a screenshot of an instructor interacting with a graphic from a PowerPoint slideshow being displayed on his laptop. This instructor flipped his Stress Analysis course and recorded a series of videos using the Lightboard.

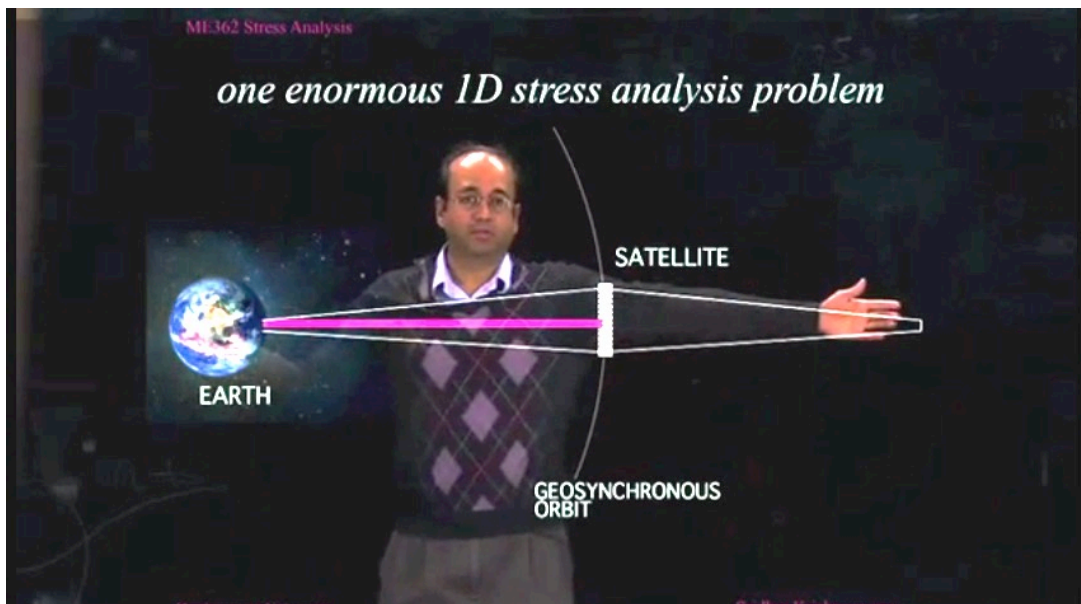


Figure 5. Instructor interacting with graphic, for a flipped classroom lecture.

The Lightboard is a new presentation format, and we try to dissuade instructors from simply replicating a classroom lecture in front of the camera. Instead, the content needs to be broken down into multiple segments, each being less than 10 minutes, and the instructor should consider utilizing the ability to combine written text and multi-media simultaneously. Videos created using the Lightboard can also be used for courses that are

offered online, such as distance learning offerings and massive open online courses (MOOCs), for professional programs, and for remotely attending conferences (Figure 6).

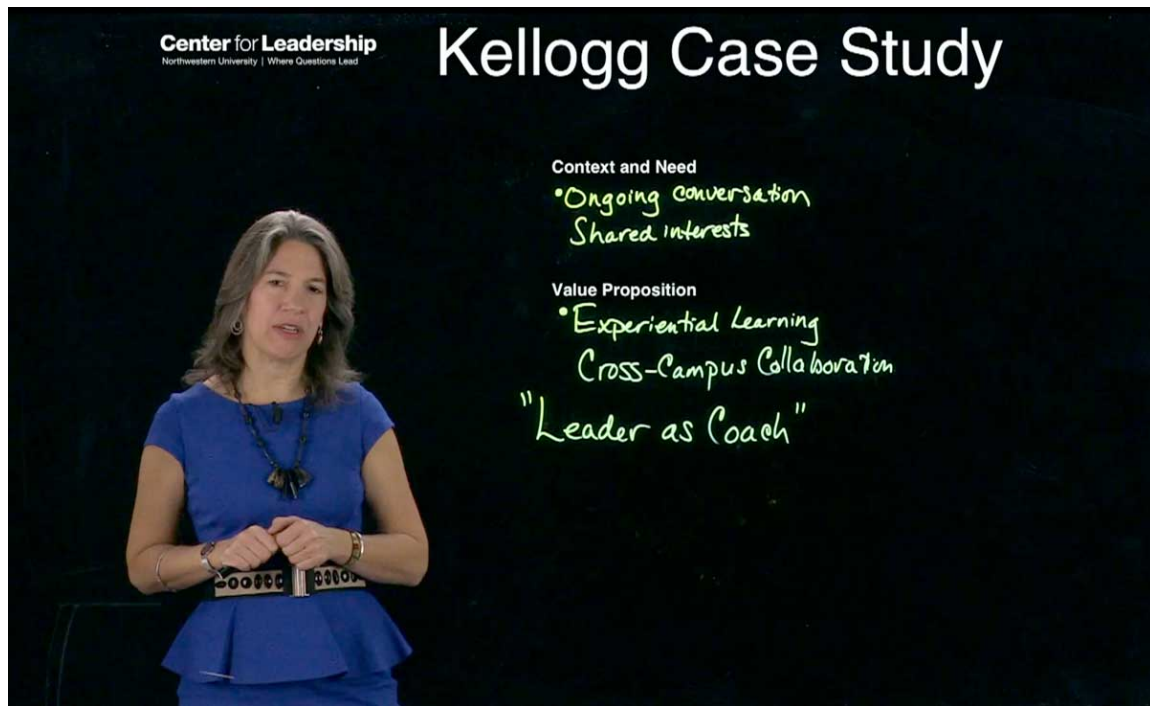


Figure 6. Lightboard video recorded for a conference presentation when attendee was unable to attend in person.

Student Involvement

The Lightboard was initially developed to serve as a tool for instructors, but is now also used by students. Both undergraduate and graduate students have used the Lightboard to create videos for class presentations and student organizations. Graduate teaching assistants (TAs) have recorded demonstrations for their classes. Figure 6A shows a large apparatus brought in to demonstrate pendulum motion. The TA annotated on the Lightboard the variables and system equations that pertained to the demonstration. Figure 6B shows another TA demonstration using an oscillator, and the student derived the system equation on the board before annotating a graph of the resultant motion. Undergraduates have also used the Lightboard to record final project presentations for classes, which were then uploaded for instructor and peer grading.

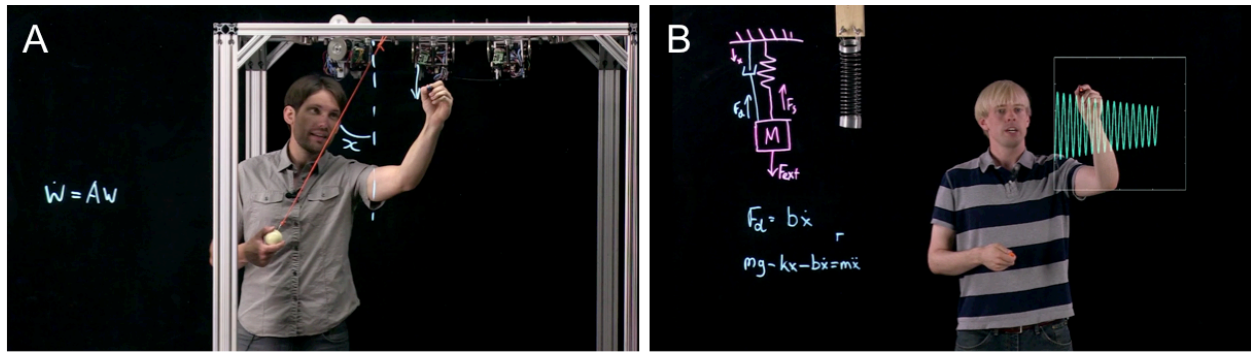


Figure 6. A) Graduate TA annotating a live demo on the Lightboard. B) Graduate student demonstrating a oscillating system, deriving the system equations by hand, and annotating a plot of the resultant motion.

The Lightboard has also been getting use by students for non-class related videos. These have included promotional and recruitment videos for student organizations and activities, entries for student competitions, and presentations for professional meetings.

Academic Advising, Review Sessions, Online Courses

Our engineering school recently overhauled its first-year advising system, and part of that process involved developing methods to contact students before they arrived at campus and providing them with resources to help them prepare for their courses. The team of freshman advisers used the Lightboard to create a series of videos to cover commonly asked questions, such as how to choose your first classes (Figure 7) and what each major entailed. These were then posted on the school’s website and social media pages. These advisers have held question-and-answer sessions using Google Hangouts, from their individual offices, which were webcast live to the incoming freshman class.

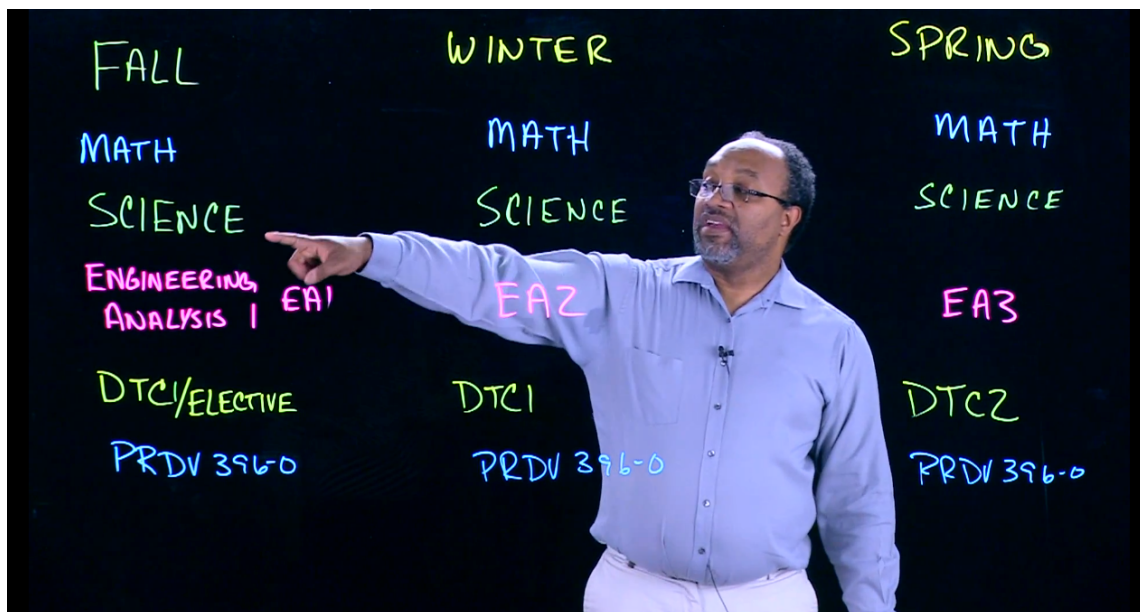


Figure 7. A first-year advisor explaining a typical course-load during the freshman year.

Live sessions and studio sessions

Latency (communication lag) determines what is practical for live sessions. We have experimented with different formats for different latencies. In one situation, we used YouTube-live, which provides a high quality video stream that can be accessed at any desired resolution by any number of viewers, optimized for the bandwidth that each viewer has available. We used YouTube-live for an evening review session, in which 70 students participated from home. The transcoding (handled by Google) takes time, so that viewers are actually seeing a stream that is delayed by 45 seconds. This latency precluded live audio communication between the instructor at the Lightboard and students watching at home. The students asked questions by typing into a shared Google spreadsheet that was monitored by a TA in the Lightboard studio. The TA relayed questions to the instructor at the Lightboard. In this situation the 45-second delay was transparent to the students.

Teleconferencing services such as Adobe Connect, GoToMeeting, Google Hangouts, and Zoom have latencies of only a fraction of a second and some can support high-resolution video appropriate for the Lightboard. However, the Blackmagic Design ATEM switcher that we use for combining the Lightboard camera with other video sources introduces its own delay of about half a second. This is marginally tolerable for spoken communication, but the echo cancellation software built into the teleconferencing services may not be able to handle it. For true teleconference use of the Lightboard, we remove the video switcher, and feed video from the Lightboard camera directly to the teleconferencing computer, via a Blackmagic Design Ultrastudio Mini-Recorder.

It would seem unlikely to invite students to come to the studio, because the students' view from the "wrong" side of the Lightboard is mirror-reversed. However student participation, live and in-person can be beneficial both to the participants and to viewers. Matt Anderson has experimented with studio audiences in his "Learning Glass" studio at San Diego State University ². He provides a live un-mirrored image on a projection screen for studio participants to view.

Bibliography

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- [2] Jacobs, H., "Illumination in Education", SDSU NewsCenter, 2014.