

Let there be light!

Using a lightboard in an active learning environment during COVID-19*

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ABSTRACT

This study describes a small-scale lightboard pilot and build with accompanying at-home studio for an advanced undergraduate course in microeconomic theory taught at the University of Liverpool during the first term of the 2020–2021 academic year. This article will provide an overview of the lightboard literature in higher education, describe the author’s experience constructing and teaching with a lightboard and report results from a survey of students on how they perceived learning with a lightboard. We believe our study will be useful to educators looking to implement a flipped classroom environment while dealing with the stay-at-home requirements imposed by the COVID-19 pandemic.

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1 Introduction

In a flipped classroom environment, all material on key content is made available to students to read and/or watch at their own pace at home. Face-to-face time with lecturers is then reserved for learning consolidation and identifying and addressing specific difficulties through ‘active learning’ exercises such as problem solving and discussion.

Although the “at-home” learning experience in flipped classroom environments can be implemented using readings or audio podcasts, research suggests students are more likely to engage with and absorb the material when it is provided in video form. For example, Halyo and Le (2013) found that students prefer watching videos to reading about the same material in a textbook. Kao (2008) used video podcasts in an engineering classroom setting; a follow-up survey of students’ perceptions suggested that the vast majority found them helpful, especially because they allowed them to revisit the lectures when completing homework assignments. Other studies have reached similar conclusions (see *e.g.*, Beatty *et al.* 2019; Intani 2013).

Evidence also suggests that allowing students to view videos at home in their own time improved student learning. For example, in the study by Halyo and Le (2013), students were allocated into one of two types of classes: one in which they were asked to review a video during class and then engage in an active learning exercise and another where students reviewed the video at home before class. According to a perception survey, students would watch the video in more circumstances than would be possible from attending a classroom lecture. In a follow up study of the use of online video lectures in a more advanced course, Halyo and Le (2013) also found that students particularly liked how watching video lectures before class freed up class time for problem solving interactively with the instructor. Caviglia-Harris (2016) investigated how using videos in a flipped learning environment impacted students’ grades in an introductory microeconomics course. She found students in the flipped learning environment did significantly better on the final exam than students in an otherwise identical course that employed “traditional” lecture-based teaching methods.

Although evidence has consistently shown that pre-recorded lectures can be an effective means of enhancing the learning experience in a flipped classroom environment, it is also not the case that all videos are created equal. In a large scale study of video engagement, Guo *et al.* (2014) found that shorter videos, videos with talking heads and those that use Kahn-style tablet drawings are more engaging than providing voice-recordings over slides and even high quality pre-recorded classroom lectures.¹ (Similar results have been documented in subsequent studies (see *e.g.*, Beatty and Albert 2016).) Yu (2021) found that having the teacher present in a video significantly improved students’ academic achievement. Students reported especially liking how videos with the teacher’s face on-screen made the learning experience resemble a live classroom setting.

Using lightboards in pre-recorded lectures permits Kahn-style tablet drawings *and* enables students to view the lecturer’s head. Moreover, given writing space limitations on a lightboard—combined with the fact that it is more difficult to erase lightboards than it is to clear traditional whiteboards and chalkboards—it also encourages the content creator to cover a smaller amount of material and therefore create shorter videos.

So what *is* a lightboard? A lightboard is a sheet of glass illuminated by light that, when written on using florescent pens, makes writing glow (see the left-hand Figure 1). The lightboard allows the lecturer to combine a “chalk-and-talk” experience while simultaneously facing his audience. It is therefore thought to encourage more discussion and familiarity and make students more willing to participate in the learning experience, especially in a flipped classroom environment.

¹“Kahn-style tablet drawings” refer to the type of videos made popular by Sal Kahn of [KhanAcademy.org](https://www.khanacademy.org).

Given the lightboard is a relatively new technology, literature on its use and evaluation in flipped classroom environments is limited. Smith *et al.* (2017) assessed the impact of lightboard videos on students' perceptions of learning in a nutrition course. The qualitative feedback they analysed suggested that students found the lightboard videos more engaging and perceived having achieved a greater understanding of the material when they were used. Rogers and Botnaru (2019) intentionally interspersed lightboard videos with normal lectures in an undergraduate civil engineering course. They found students' performance on a weekly quiz was higher when they were exposed to lightboard videos as opposed to traditional face-to-face lectures. In an end-of-semester survey, students also reported finding the videos helpful for understanding and engaging with the material; lightboard videos were also associated with higher scores on overall student satisfaction. Other studies have found positive outcomes when students were asked to complete an assignment using the lightboard (Hite *et al.* 2017).

A number of case studies exist describing the use and implementation of lightboards in specific contexts. For example, Fung (2017) describes a small-scale pilot implementation of the lightboard in an introductory chemistry course taught at the National University of Singapore. Ye (2016) discusses its implementation in the context of Chinese language instruction and provides a particularly detailed overview of the set-up required and the advantages and disadvantages of the technology. McCorkle and Whitener (2020) present a detailed case study of small-scale lightboard pilot and full-scale lightboard build with accompanying studio used by a variety of faculties at a small, private liberal arts college in the U.S.

The purpose of this study is to build on this emerging literature describing student perceptions about and case study implementations of an "at-home" lightboard with accompanying recording studio for an advanced undergraduate economics course held between October 2020 and January 2021. It is believed that the results of this study will be particularly useful to educators looking to implement a flipped classroom environment while dealing with the stay-at-home requirements imposed by the COVID-19 pandemic.

The paper proceeds in the following order. Section 2 describes a small-scale lightboard (with accompanying at-home studio) pilot and build for a third-year undergraduate economics course taught at the University of Liverpool during the first term of the 2020–2021 academic year. Section 3 discusses the implementation of and results from a perception survey distributed to students at the end of the course. Section 4 concludes by identifying the advantages and disadvantages of incorporating the lightboard in a flipped classroom environment, particularly given stay-at-home requirements imposed by the COVID-19 pandemic. It also discusses several best practices the author identified while building and incorporating the lightboard into her flipped classroom learning environment.

2 Case study

Due to COVID-19, a significant portion of instruction in higher education has moved away from the traditional front-of-class lecture model to an active learning environment where instructors pre-record lectures and make other learning materials available in advance of a classroom experience that is instead devoted to engaging with students using active learning exercises. Many instructors are therefore required to invest a substantial amount of time into: (a) breaking their face-to-face lectures up into smaller units; (b) re-writing lecture notes so that content is clearer and better organised and students are able to easily understand and connect the videos, notes and required readings corresponding to them;² and (c) recording a large number of lectures.

In the following section, I describe a small-scale case study that will be particularly useful for contending with points (b) and (c). In the first half of the 2020–2021 academic year, I built and incorporated a light-

²This sort of tacit information is generally conveyed well in face-to-face settings such as at the beginning of a lecture. It is more difficult to communicate in online materials, given students may not watch and absorb them from start-to-finish.

board (along with an at-home recording studio) into my flipped learning environment for ECON342, an advanced undergraduate economics course I teach at the University of Liverpool. I found the lightboard enabled me to re-create my traditional “talk-and-chalk” lecture plan at home, and thus reduced the need to restructure and reorganise lecture materials to contend with the new active learning environment.³ I also found it to be an effective way to create a large number of pre-recorded instructional videos in a relatively short amount of time. I hope that by describing the results in a case study, my own experience can be useful for other instructors wanting to better engage their students while also dealing with the constraints imposed by the COVID-19 pandemic.

2.1 Context

ECON342 is an advanced undergraduate microeconomic theory course at the University of Liverpool. It is a required course in the Economics BSc and is usually taken during the first semester of the final year of students’ undergraduate studies.

ECON342 consists of three maths-intensive modules. In the first module, students are presented with two competing yet conceptually very similar methods of economic organisation: the so-called “jungle economy” and the more familiar “market economy”. The second module is devoted entirely to a fuller appreciation of market exchange. In the third and final module, the course investigates equilibrium with asymmetric information. Topics include adverse selection, moral hazard and an introduction to agency theory.

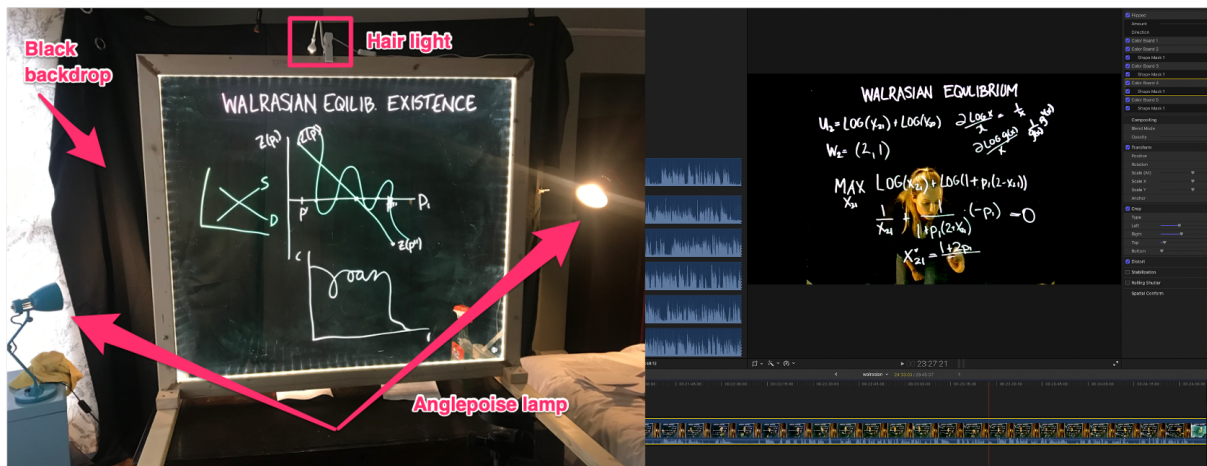
Instructor-facilitated problem solving performed during class is thought to be the most effective way to learn the material in maths-intensive economics courses. Unfortunately, it is performed at the expense of content coverage. Traditionally, ECON342 has put greater weight on the latter component relative to the former. Given the COVID-19 situation, however, the class was “flipped” in the first term of the 2020–21 academic year. In addition to enabling the course to meet stay-at-home requirements during the pandemic, “flipping” the classroom in this manner meant students could explore the lecture materials at their own pace, thus freeing up face-to-face seminar sessions to reinforce learning through guided problem-solving activities. The end result, it was hoped, would increase the amount of time students could devote to the more effective instructor-led problem-solving component of the course without forcing the instructor to sacrifice content coverage.

An additional advantage of the flipped classroom environment is that it is thought to develop students’ critical thinking skills as economists—and therefore prepare future economists to be productive members of their future profession (Shulman 2005).⁴ This is a key objective of ECON342 as well as the University of Liverpool’s aim to enhance “research-connected teaching” as part of its Curriculum 2021 framework (University of Liverpool 2019).

When economists reason, they often do so by analogy in the form of economic models. Economic models are powerful tools from which to draw conclusions based on the similarities between the models and real life. But they are expected to apply *only* when differences between real life and the assumptions of the model do not matter to the conclusions that are drawn. This is a subtle and difficult concept to appreciate. In order to convey it, it requires: (i) a lot of introspective effort on the part of students to understand and learn the basic building blocks of specific models; (ii) plenty of opportunities to clarify those mechanics and discuss interpretations one-on-one with class instructors; and (iii) space to collaborate with others on problem-solving. It was hoped that a flipped classroom environment involving

³During class, I prove all theorems and work out most examples by hand. Evaluations over several years suggest students especially appreciate this particular aspect of my course.

⁴Shulman calls these discipline-specific teaching practices *signature pedagogies* and defines them as “the types of teaching that organise the fundamental ways in which future practitioners are educated for their new profession” (Shulman 2005, p. 52).



Note. Photo on the left depicts an at-home lightboard studio, including lightboard, black backdrop, anglepoise lamps on either side of the lightboard and a “hair light” attached to the top. Photo on the right is a screenshot of the author using Apple’s video editing software Final Cut Pro to make post-production video edits to a lightboard video.

Figure 1: An “at-home” lightboard studio and post-producing a video

lightboard videos would expand the scope to expose students to all three factors, and the first two, in particular.

2.2 Building the lightboard and constructing a recording studio

The cheapest lightboard that can be purchased “off-the-shelf” costs upwards of £1,000. I therefore decided to build my own. To assemble my lightboard, I followed closely instructions from Steve Griffiths: https://flippedlearning.org/how_to/how-to-make-a-lightboard-for-less-than-100. But the concept isn’t difficult: simply wrap LED lights around a large sheet of glass and then frame the edges in wood. (See the left-hand figure in Figure 1 for the final product.) Other designs that use plexiglass and wood clamps are even simpler to build. (See for example this video by Elisa Valkyria: <https://youtu.be/L1au1JxMSaA>.)

Filming lightboard videos additionally requires setting up a dark room in which to record the videos. The basic components of the recording studio are: (i) a black backdrop; (ii) two lamps that frame both sides of the lightboard and illuminate the “talent” (i.e., the instructor); (iii) a “hair light” clamped to the top of the lightboard that lights up the instructor’s face; (iv) a tripod; (v) a DSLR camera; (vi) a microphone; and (vii) Expo Neon Dry Erase Markers.

For the lighting elements, I used lamps I already owned in order to keep costs as low as possible. (All other materials were purchased on Amazon or Argos.) The hair light is a simple book light. The two lights flanking the lightboard are anglepoise lamps. Anglepoise lamps are adjustable and cover their bulbs with a solid, narrow cone that generates a focused beam of light. As a result, they are less likely to bleed light onto the black backdrop, meaning it shows up as black as possible in the videos.

In addition to lighting, the camera used to record the videos is also important. There will always be small scratches and smudges on the lightboard glass. Without proper camera settings, these imperfections will show up in the videos. Luckily, they are easy to remove: simply adjust the camera’s aperture setting above 5.0 and its shutter speed at around 500. Because both setting do not come standard on most smart phone cameras, you may need to invest in a basic DSLR or bridge camera. In my own case, I purchased the cheapest camera I could find with both settings—Kodak PixPro—and have been satisfied with its results.

The final component of the recording studio is a microphone. I purchased a very cheap lapel micro-

phone on Amazon. To record sound, I use the voice recorder that came pre-installed on my iPhone and then merge the recorded sound with the video post-production. Another option is to purchase a relatively inexpensive boom microphone and plug it directly into the audio jack on the recording camera. (Positioning the boom microphone may, however, require a second tripod.)

Filming during the day will require covering all exposed windows with black-out curtains and/or dark paper in order to limit outside light bleeding onto the black backdrop and highlighting scratches and smudges on the lightboard glass. Alternatively, simply film at night or early in the morning before the sun rises, as I did.⁵ By negating the need to cover up windows, filming while it's dark outside also makes your recording studio easier to take down and re-assemble, which may be especially useful if you lack a spare room that can be completely dedicated to filming lightboard videos.

2.3 Post-production

Post-producing lightboard videos is remarkably easy. The first decision involves software. I used the (free) 90-day trial version of Apple's Final Cut Pro and purchased the full version when the trial expired. The right-hand photo in Figure 1 displays a screenshot of me editing a lightboard video.⁶

The only post-production step that is actually necessary is to flip the video horizontally so that the instructor's handwriting doesn't appear backwards to the viewing audience. (And if you filmed your lightboard videos in a mirror, then no post-production is needed at all!) But although no more post-production video editing is technically required, several very simple edits can substantially improve the quality of your lightboard videos.

- **Merge sound and video.** Any separately recorded sound files will need to be merged with the video file. Assuming the video file has also captured sound, then this can be easily achieved using, *e.g.*, Final Cut Pro's "Synchronize clips" functionality, which automatically analyses and syncs audio and video clips that were all recorded during the same take.
- **Apply a sound compressor.** Most video editing software has a function that emulates the sound and response of a professional-level analogue compressor—*e.g.*, the "the compressor effect" in Final Cut Pro. Applying custom or preset settings (for example, the "Vocal Compressor 01" in Final Cut Pro) will greatly enhance your audio by reducing background noise, increasing the volume of your voice and bringing it into focus.
- **Adjust the exposure.** By adjusting exposure, one can almost (or even completely) eliminate larger scratches and smudges on the glass and reduce glare from too much background light. I suggest first adjusting the overall exposure to eliminate minor imperfections and then using shape masks to target any remaining scratches and smudges that are still noticeable in the videos.
- **Add an intro.** Adding an introduction with music and graphics is very easy to do with most video editing software—indeed, software like Adobe Premier Pro and Final Cut Pro come with a large number of introduction template generators pre-installed. Combine these with short, fun music clips to create an attractive introduction to your videos that will impress your students!
- **"Fast-forward" slow parts.** If you have to wipe the board, write out a long equation or draw a particularly detailed diagram while in the middle of filming, I suggest speeding that portion of the video up to 8x or 20x speed in post-production. Students appreciate not having to wait in

⁵I filmed most of my lightboard videos between October and December in Liverpool, where the sun rises around 08:00 and sets as early as 16:00. Instructors filming during the summer or in locations closer to the equator may find this suggestion impractical.

⁶The software details described in this article are specific to Final Cut Pro, but similar video editing capabilities are available in Camtasia Studio and Adobe Premiere Pro.

Table 1: No. and length of videos per module

Module	Lightboard videos	Other videos	Average length	Total length
The jungle vs. the market	10	0	14:51	02:28:35
An exchange economy	18	1	17:24	05:13:17
Asymmetric information	13	5	19:21	05:48:21
Total	41	6	17:37	13:30:13

real time for these tasks to be finished and I’ve found speeding them up is both less jarring and actually requires less video editing effort than cutting them out of the video entirely.

- **Reduce the file size.** Final Cut Pro produces gigantic video files. Reduce them to manageable sizes using freely available software such as the open source video transcoder HandBrake (<https://handbrake.fr>).

2.4 Final results and costs

In total, I made 47 videos for ECON342, almost 90 percent of which used the lightboard. Average video length was 17 minutes 37 seconds; total video time was 13 hours 30 minutes and 13 seconds. A sample lecture is available on Youtube: <https://youtu.be/JFXhyRIJw24>. To view all of the videos, please self-enrol in ECON342 using the following web address: <https://liverpool.instructure.com/enroll/WY6A8Y>.

Table 1 breaks down the number of videos created per module. A total of ten videos—all of which were filmed using the lightboard—were recorded for the first module, “The jungle vs. the market”. On average, videos were about 15 minutes long; total video length was around 2.5 hours. The second module (“An exchange economy”) contained 19 videos, all but one of which was made with a lightboard. Average video length was about 17 minutes; total video time was a little over 5 hours. The final module (“Asymmetric information”) consisted of 13 lightboard videos and five videos that were recorded without using the lightboard. Average video length and total video time were both slightly longer than the other two modules (19 minutes 21 seconds and 5 hours 48 minutes and 21 seconds, respectively).

Table 2 breaks down the total monetary costs I incurred when building my lightboard and constructing the accompanying recording studio. The total costs I incurred constructing the lightboard amounted to £253.54. This included 10mm safety glass (1m × 1.2m) which I used as the glass board,⁷ the timber that frames the board’s edges, the LED lights as well as metal shelving brackets that are attached to the base to support the board. Because I did not already own a router saw, I purchased the cheapest one available, which cost £50. Additional miscellaneous items included wood glue and filler, sandpaper and screws, washers, *etc.* The cumulative cost of these items was about £20. EXPO Neon Dry Erase Markers are best for writing on the lightboard; they cost an additional £14.07.

Building the recording studio was slightly less expensive than constructing the lightboard. The black backdrop cost £20.99 on Amazon, but I had to additionally purchase an adjustable background stand to position it on, which cost an extra £42.99. The cost of purchasing both the backdrop and stand was therefore £63.98. As I did not already own a DSLR camera, I purchased the cheapest one could find that allowed adjusting the aperture and shutter speed. It cost £133.94 at Argos. The two remaining recording-studio costs were the cost of the tripod that held the camera in place while filming and a very inexpensive lapel microphone. Both items were purchased on Amazon for £19.48 and £10.99,

⁷As I discuss in Section 4, however, use plexiglass instead of actual glass. It is both substantially cheaper—a similarly sized sheet of plexiglass costs no more than £50—and much lighter and easier to work with.

Table 2: The cost of making lightboard videos

Item	Cost (£)
Lightboard	
10mm safety glass	118.00
Timber	10.96
LED lights	27.00
Metal shelving brackets	13.00
Miscellaneous items	20.00
Router saw	50.00
EXPO Neon Dry Erase Markers	14.07
<i>Sub-total</i>	<i>253.03</i>
Recording studio	
Black backdrop + stand	63.98
Tripod	19.48
Lapel microphone	10.99
Kodak PixPro camera*	133.94
<i>Sub-total</i>	<i>228.39</i>
Post-production	
Apple Final Cut Pro*	299.99
<i>Sub-total</i>	<i>299.99</i>
Total	781.41

* Denotes an optional item or an item which can be replaced by a similar item that is free.

respectively. In total, it cost me £228.39 to construct my recording studio. If you already own a DSLR camera—or decide to film simply with a smart phone camera—your costs may be substantially lower.

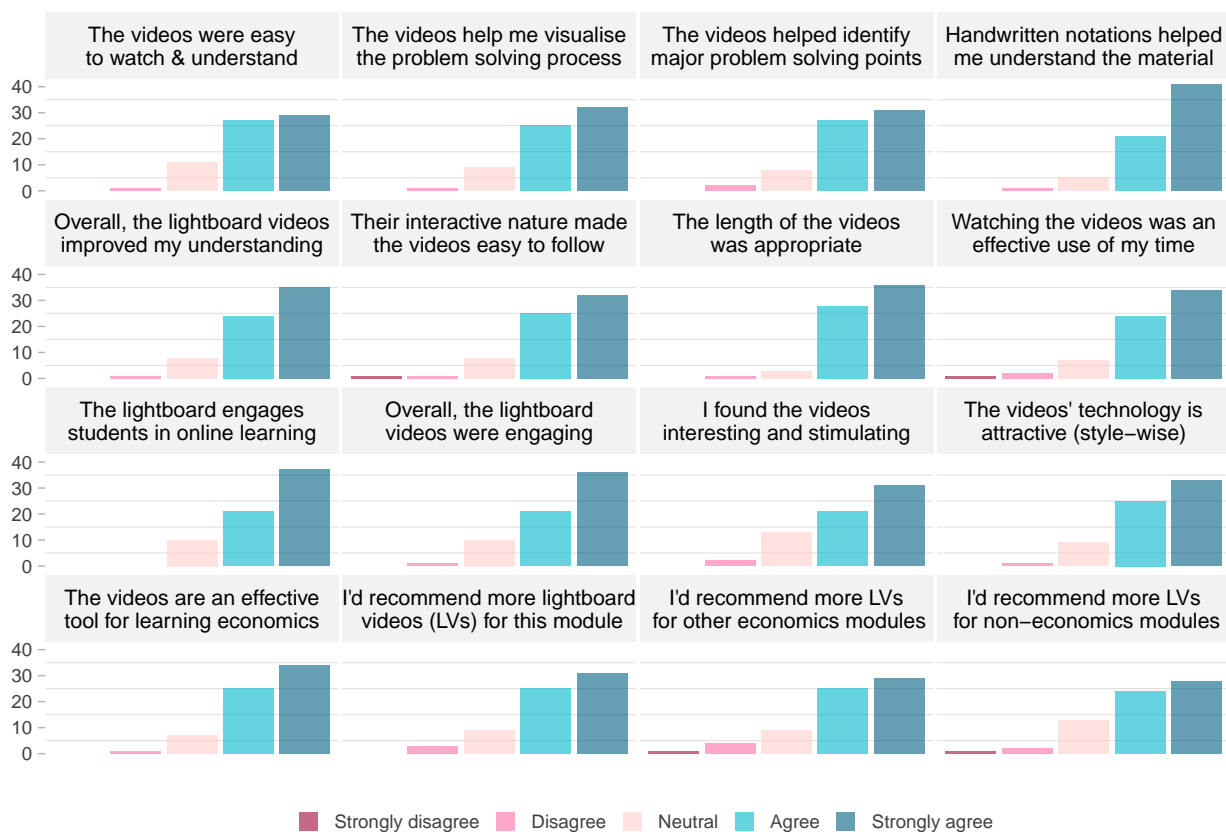
The final cost involved in making lightboard videos is the price of the video editing software used in post-production. As already mentioned in Section 2.3, I used the (free) 90-day trial version of Apple’s Final Cut Pro and purchased the full version when the trial expired. It cost £299.99. Camtasia Studio and Adobe Premiere Pro are similarly priced, although the latter can be purchased as a monthly subscription for a substantially lower price. Check with your institution to see whether they have already purchased a site license for video editing software or if you benefit from an educational discount. Many people will also find that the functionality provided by free video editing software is more than sufficient.

3 Feedback

3.1 Methodology

After completing their final exam, all 350 ECON342 students at the University of Liverpool were invited to participate in the anonymous, voluntary, online survey available at: <https://liverpool.onlinesurveys.ac.uk/lightboard-survey>. No incentives were offered for completing it. As of 14 May 2021, students have been sent two follow-up emails reminding them of the survey.

After reading a participant information sheet and completing a consent form, students are presented with 26 questions. The first 16 questions are Likert-scale questions on their perceptions about the lightboard videos. Each set of questions is separated into three broad categories—understanding, engagement and satisfaction—and are adapted from Sturges *et al.* (2009) and Rogers and Botnaru (2019). Following these quantitative questions, students are also asked five open-ended short-answer questions on their experience learning from a lightboard in a flipped classroom setting. All five questions are adapted from Rogers and Botnaru (2019). The survey concludes by asking students to answer five questions about



Note. Figure displays histograms of responses to each of the 16 Likert-scale questions on students' perceptions about the use of lightboard videos in ECON342.

Figure 2: Histograms of students' responses about the use of lightboard videos in ECON342

themselves: their degree programme, year of study, gender, nationality and age.

3.2 Results

As of 14 May 2021, 68 students have responded, representing a 19.4 percent response rate. The response rate is reasonable, but may have been depressed by two factors: (i) the survey was initially distributed in the middle of exam week; (ii) reminders sent after that may have been ignored given ECON342 had ended.

The majority of respondents (90 percent) are BSc Economics students; four are completing an honours degree that combines economics and another subject (*e.g.*, politics or philosophy). All responding students are in their final year of study.

As for demographics, 66 percent of responding students are female and all are between 17–25 years of age. Nationality-wise, most are from China (76 percent); 19 percent are from the UK; the remaining four percent are from other European countries. Respondents' gender, age and nationality distributions are roughly equivalent to corresponding distributions across the entire population of ECON342 students.

3.2.1 Quantitative analysis

Figure 2 displays histograms of responses to each of the 16 Likert-scale questions on students' perceptions about the use of lightboard videos in ECON342. All data analysis was conducted in R.

The first five questions relate to understanding—*i.e.*, they sought information on how and whether students perceived that the lightboard contributed to their understanding of the underlying material.

Across all five questions, the most popular answer was “strongly agree”, indicating that students consider that the lightboard videos improved their understanding. Students saw the ability to see the instructor’s handwritten notations to be particularly helpful for their overall understanding.

The following five questions focused on engagement—and specifically whether students thought that lightboard videos helped them engage with the lecturer and the material. Again, the majority of students “strongly agreed” with each question. Of particular interest, over 84 percent of respondents “strongly agreed” or “agreed” that the interactive nature of the lightboard videos made them easy to follow; 85 percent agreed or strongly agreed that the videos engaged them in online learning.

The remaining six questions probed how satisfied students were with the lightboard videos. Results in this section were slightly more variable—the average standard deviation of responses to the first ten questions was 0.77 but it was 0.85 for the six satisfaction questions.⁸ In general, students found the videos interesting/stimulating, attractive and effective for learning economics. They are slightly more likely to recommend additional lightboard videos for ECON342 (mean 4.24; standard deviation 0.85) than they are to recommend lightboard videos for other economics modules (mean 4.13; standard deviation 0.96) and non-economics modules (mean 4.12; standard deviation 0.92).

3.2.2 Qualitative analysis

The second part of the perception survey includes five open-ended questions that investigate students’ perceptions of the flipped classroom. Table 3 provides a representative sample of the responses students gave. (Note that some responses may have been combined with similar responses, paraphrased and/or edited for typos, grammatical mistakes and identifying information.)

Table 3: Qualitative data

Question	Response
What did you like most about the ‘flipped classroom’ (FC) approach used for ECON342?	The lightboard made it easier to understand the working out process. I could follow step-by-step as the instructor worked out examples, derivations and proofs.
	I loved the online lectures and how they were recorded using a board. They were so helpful!
	The lightboard is very flexible.
	I can clearly see the procedure and contents on the lightboard, which I am not always able to do in a face-to-face classroom setting, especially when I sit far from the board.
	Short 10–30-minute videos with the glass board displays are more engaging than long 1–2 hour slideshows with voice-over recordings. Accompanying notes with videos are helpful for clarification.
	The videos were so helpful and easy to understand. It felt like a real lecture and was very engaging.
	I found this new approach to learning really interesting and fun. It’s more efficient than the normal way of online teaching. I can understand the diagrams and theories more directly and quickly.
	I like how the videos can be watched again and again.
	I found I learned more effectively and logically.
	I liked how I could see the lecturer’s face.
	I thought the videos were interesting and intuitive and easy to understand.
	The flipped classroom environment is efficient. I think it is easier to follow than a presentation format and more engaging.
	I thought this class was the closest we got to an actual classroom learning environment and I like that. It’s better than PowerPoint presentations because the instructor was able to point and highlight specific things on the lightboard and the viewers are able to see the problem progress as she drew it out in front of us.
	This was without a doubt the best module and the best taught module in my 3 years at university.

⁸To calculate standard deviations and means, I assigned 1 to “strongly disagree” responses, 2 to “disagree” response, etc.

I liked how I was able to see the problem solving process in action rather than as steps on a paper.
 I thought the lightboard made teaching more vivid.
 I found the videos simple and easy to follow. The solutions to problems are very clear and easier to understand in the flipped classroom environment.
 The lightboard allowed us to visualise the problem in a more elegant manner than most economics modules.

If you could offer one suggestion to improve the FC learning experience, what would it be?	<p>Make sure all information written on the lightboard is visible to the camera. The lecturer spoke quickly and it is difficult for non-native speakers to follow. It would be easier for the students to find the content they want to review if there are text nodes on the video progress bar indicating the content of the next section of the video. Watching the lecturer wipe the board is tedious. When we move back to face-to-face teaching, continue using the lightboard for problem sets and worked examples (but have live lectures). Please make a word or PDF version of the notes available so that I can print them and take notes on them. There were a few audio errors and the different coloured pens were not always distinguishable.</p>
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In what ways has the FC helped you learn this semester?	<p>The lightboard made it easier to go through calculations. I also actually got to see the lecturer so it was similar to a real lecture setting. The pre-recorded lectures are fantastic. The lightboard makes the difficult content digestible. This module was more engaging than other modules. I found I paid more attention compared to other instructors who just talked over their slides. I liked how I can interact with the lecturer's facial expressions and body language, which helped me concentrate more. I appreciated how I could repeat parts of lectures. I feel I understood the content better because it was presented in a much clearer, helpful way. This is an alternative to having classes face-to-face. I thought it was really interesting and efficient. I feel I understood the content of the module more deeply. I think both the accompanying articles and videos improved how efficiently I was able to learn the material. The lightboard videos made it easier to follow the tutor's logic step-by-step. The detailed explanations of the lecture content and seminar questions really helped me. The videos were detailed and well-explained, and the ability to rewind a section is very nice as it allows me to repeat a section in order to better understand it. I think the lightboard videos made it easier for me to pick up the intuition behind the process. The video is vivid and therefore more engaging because I can see the instructor teaching on-screen. I think the lightboard videos helped me focus more when I study. The lightboard videos have helped me understand some tricky problems that the textbooks were not fully clear on.</p>
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In what ways did the FC not help you learn this semester?	<p>Sometimes the videos were hard to follow because the instructor's handwriting would go off camera. The module is very difficult so it would also have been good to have some on-campus face-to-face content. I struggled to follow the content besides the specific examples the lecturer worked through. This made the exam extremely difficult for me compared to all other modules I've done at university. It's hard to interact with other students. I thought the class focussed too much on problem solving without giving anecdotal evidence as to how the problem related to the field of economics both theoretically and in real world settings. The surface area of the lightboard is too small.</p>
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Note. Table contains responses to the five open-ended questions in the survey. Note that some responses may have been combined with similar responses, paraphrased and/or edited for typos, grammatical mistakes and identifying information.

4 Discussion

4.1 Advantages and disadvantages of the lightboard

The lightboard has several advantages to recommend it to instructors looking to re-create their lectures in the face of COVID-19-related lockdown rules. The primary advantage is that, beyond the cost of designing the lecture, creating lightboard videos requires very little technical expertise and labour—and almost none if you video-record lectures through a mirror. This means that the marginal cost of creating additional videos is very low, and therefore makes it an ideal solution for lecturers who have to create many videos in a short amount of time.

One of the big (personal) drawbacks I have found in having to pre-record lectures is that it is more difficult to sound enthusiastic without the presence of a live student audience. This is an important factor given studies show lecturer enthusiasm correlates positively with student evaluations (see *e.g.*, Lindsay *et al.* 2002; Murray 1983). Nevertheless, I found the novelty of creating videos with a lightboard made me more enthusiastic during recording sessions and that enthusiasm partially or even wholly compensated for what I must have lost from no longer having a live audience to react to.

There are several other benefits to the lightboard technology that recommend it for more general adoption even after the COVID-19-related stay-at-home orders are relaxed. First, the lightboard allows the lecturer to face the audience. This is thought to foster a more engaging and interactive experience with students (see *e.g.*, Guo *et al.* 2014). As discussed in Ye (2016), the lightboard requires that student engage their auditory and visual working memory simultaneously, which may increase working memory capacity more than using each in isolation (Mayer and Moreno 1998) and the combination of audio and hand gestures may be especially effective (Kelly *et al.* 2008). A recent study by Yu (2021) also found that being able to see the teacher in a video improved students' academic achievement.

Nevertheless, the lightboard is not appropriate in all circumstances. First and foremost, the lightboard is obviously not very relevant for courses that wouldn't use the whiteboard or chalkboard anyway—*e.g.*, courses which use very little maths or few diagrams. In this instance, the cost of building the lightboard and accompanying studio is unlikely to be justified by the benefits.

A second, related disadvantage is that lightboards are not trivial—or necessarily inexpensive—to build. In my own case, I had to purchase a router; I already owned a table saw, but if you do not, you may have to buy that as well. Indeed, as illustrated in Table 2 the total cost of simply building a lightboard came to £253.03; after adding in the cost of setting up the recording studio and buying video editing software, I have spent almost £800 on the entire project. Moreover, building a lightboard requires, at a minimum, a basic familiarity with carpentry (*e.g.*, knowing how to use a router to recess a channel in the wooden frame to hold the glass). Depending on the thickness of the glass used, one may also need more than one person to help construct the lightboard and, in particular, position the glass properly into the wooden frame.⁹

The third and fourth drawbacks of the lightboard are that it: (i) requires the instructor to carefully plan the lecture in advance; and (ii) is not practical for long videos. The fundamental issue behind both drawbacks is that there is only so much “real estate” on a lightboard available for writing. So if the video lasts longer than 5–10 minutes, then the instructor will likely have to clean the board while he is in the middle of filming—and cleaning a lightboard is a much more time consuming task than erasing a whiteboard or chalkboard. Although a small amount of post-production editing—*e.g.*, cutting out the period when the instructor is cleaning the board or simply speeding it up—can eliminate this

⁹Having said this, there are several much easier and less expensive methods of building a lightboard that work almost as well—and result in videos that look just as professional—as the lightboard I built. For example, instead of using glass and building a wooden frame, one can simply attach LED lights around the perimeter of plexiglass using clamps (see, for example, [Elisa Valkyria's](#) tutorial).

inconvenience for students, doing so may require more video editing skill than some users are willing to spend the time to obtain.

Finally, lightboards are impractical for most live classroom settings and even synchronous online events. The difficulty comes from having to flip the instructor’s handwriting in real time. Although some professional lightboard setups exist that will do this—thus allowing a live audience to experience the presenter’s writing in reverse—they are not cheap. Figures in Ye (2016) suggest they cost upwards of \$10,000.

4.2 Best practice

Due to COVID-19, a significant portion of instruction in higher education has moved away from the traditional front-of-class lecture model to an active learning environment. In this paper, I have described how and why I adopted a lightboard to facilitate this. Based on my experience implementing the case study and the results of the student perception survey, I have identified the following best practices in integrating the lightboard into an “at home” flipped learning environment.

1. **Use plexiglass.** Having used 10mm safety glass myself, I can confidently say that if I were rebuilding my lightboard, I would simply use plexiglass. Although glass is clearer than plexiglass, it comes with several disadvantages. First, 3mm picture glass is cheap and can be easily purchased from a picture framer but easily breaks. Thicker toughened glass is the safer option, but it is also substantially more expensive, extremely heavy and must be sourced from a speciality retailer. Plexiglass, on the other hand, is lightweight, cheap and can be easily purchased from your local hardware store. While plexiglass does scratch more easily than glass, they can be easily removed by adjusting the exposure post-production.
2. **Film at night.** Lightboard videos look best if they are filmed against a black backdrop and the only light in the room is from the lightboard and optionally lights specially set up to illuminate the person speaking. Unfortunately, my own home has lots of windows. Instead of blacking out all of the windows in the room where I recorded the videos, I chose to film most videos at night. Early birds and night owls—or those (like me) who live closer to a pole and are filming in winter—may find this option similarly appealing. It also has the added benefit of making the recording studio much easier to quickly take-down and re-assemble, which will be attractive to those who film their videos in rooms that also serve other purposes (*e.g.*, a bedroom).
3. **Invest in professional lighting.** Basic lighting using anglepoise lamps work fine, especially when combined with a small investment in the post-production effort required to remove shadows, glare and scratches. The best setups, however, use professional lighting including LED studio lights—with barn doors to make the backdrop completely black—on each side of the lightboard, and a “hair light” to the top of the lightboard to illuminate the speaker’s face.
4. **Buy a DSLR camera.** Although you don’t need a DSLR camera, careful selection of the shutter speed and aperture will reduce smudges and, especially, increase the contrast with the colour. (And keep in mind that without these controls, viewers will have a hard time distinguishing between colours.)
5. **Employ basic video editing.** Invest a small amount of time in learning how to do a limited number of video editing tasks—*e.g.*, “fast-forwarding” wiping the board, add an intro and apply a sound compressor. Each activity requires very little skill and only a minimal amount of time investment post-production to implement. But they will take your lightboard videos from zero to hero—a little bit of polish goes a long way. I got more emails from students complementing me on the intros I made for each video than I did on the content than was in them!

6. **Structure content into week-by-week chunks.** I initially decided to distribute the course content on a module-by-module basis (*i.e.*, all material on module 1 was released at the same time; then all material on module 2, *etc.*). The idea was that students could then decide when and how to watch, read and complete the content in each module; the only guidance I gave was the date all of the work for a particular module should be completed. While some students adapted well to this approach, others struggled. I therefore eventually created a more detailed (and optional) syllabus that identified exactly which videos, texts and problems students should complete each week. I found this small addition to my course helped several students who had difficulty organising their time without more detailed guidance from me.
7. **Paint the lightboard frame black.** I did not paint the frame around my lightboard, so to make the entire background of the video black, I cropped the videos just at the point where the frame met the glass. Unfortunately, in a small number of instances I accidentally cropped out too much—and consequently deleted a small portion of something I had written on the board. To avoid this in the future while maintaining a perfectly black background, I have since painted the frame around my lightboard black. As long as a video is only cropped at a point outside of the inner edge of the frame, I won't accidentally delete anything I've written on the board; meanwhile, the uncropped black frame is indistinguishable from the black background after adjusting the video's exposure post-production.

5 Conclusions

This study has described a small-scale lightboard pilot and build with accompanying at-home studio for an advanced undergraduate economic theory course taught at the University of Liverpool during the first term of the 2020–21 academic year. My experience with the lightboard over the past year has been very positive. I find the technology relatively easy to create and exceedingly easy to use once the lightboard is built and studio is set up—indeed, I have found that it drastically facilitated creating a large number of videos in a relatively short amount of time. Importantly, it has also allowed me recreate my “chalk-and-talk” lectures while having to teach remotely during the COVID-19 pandemic. Both factors have made the process of adapting to the constraints imposed by the virus more efficient and less time consuming. Students have found the videos engaging and useful for understanding, especially as they allow me to face the audience as I write out derivations and work through examples. I plan to continue incorporating the lightboard into my teaching for at least as long as COVID-19 restrictions remain in place—and likely beyond!

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