Lightboard streaming technology for teaching and learning: Responding to student wellbeing and enhancing online learning

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Abstract

This chapter details the experience of a Senior Lecturer (SL) in Mechatronics leveraging lightboard technology, live streaming technologies and techniques commonly used by the gaming community, and educational technology pedagogies to create a custom-built advanced lightboard for engineering curriculum delivery. With a desire to attend to student wellbeing needs during the COVID-19 crisis, and responding to the mandate of emergency online teaching and learning (T&L), the SL adapted their teaching approaches to enable the delivery of curriculum with minimal disruption.

Supported by student feedback on the use of this technology for curriculum delivery, the chapter highlights the design, development, and successful implementation of the live streaming lightboard technology, while acknowledging areas for continued enhancement. The purpose is to share details about the development and setup as a contribution to the body of knowledge on innovative educational technologies, while demonstrating how attention to student needs and wellbeing can result in enhanced resources for T&L.

Keywords

lightboard
educational technology
live streaming
student wellbeing
teaching and learning
higher education
COVID-19

"After today, the University campuses will close to all students and staff, except those staff who provide essential services" (email communication, March 23, 2020). This was the message staff at a New Zealand (NZ) university received as the fifth week of a 12-week semester began. Resulting from a government-mandated national lockdown that was announced to commence within 48 hours, staff were advised to work from home, including no face-to-face teaching, effective immediately.

While many countries, sectors, and organizations were monitoring and responding to the accelerating COVID-19 crisis (Aristovnik, Keržič, Ravšelj, Tomaževič, & Umek, 2020), the rapid changes in NZ meant the reality of closing physical doors and moving all operations online was setting in – quickly. The swiftness of these changes in NZ is highlighted when considering the first case of COVID-19 reported in NZ was less than a month prior, and the introduction of a national Alert Level System[1] was announced only two days prior.

This chapter details the experience of a Senior Lecturer (SL) in Mechatronics leveraging gaming community live streaming technologies (e.g., Payne, Keith, Schuetzler, & Giboney, 2017; Pozo-Sánchez, López-Belmonte, Fuentes-Cabrera, & López-Núñez, 2021), educational technology pedagogies (e.g., Koehler, Mishra, Kereluik, Shin, & Graham, 2014; So & Kim, 2009), and a desire to attend to student wellbeing during a global crisis (e.g., Raaper & Brown, 2020) to create an advanced lightboard for engineering curriculum delivery. The chapter illustrates the design and and successful implementation, evidenced by student feedback. The intent is to share details about the development and setup as a contribution of an innovative approach to digital technologies for teaching and learning (T&L), while also addressing how attending to student needs and wellbeing can further enhance T&L resources. Furthermore, this is the first known work to report on students' preference between lightboard learning delivered in either a pre-recorded format, or through a live lecture.

The challenge: Emergency teaching and learning

Focused on continuity for student learning, this University's immediate response was one of emergency remote teaching (ERT) (Hodges, Moore, Lockee, Trust, & Bond, 2020) for emergency online learning (EOL) (Singh, Proches, Leask, & Blewett, C 2020) – rapidly shifting all content to fully online delivery. With a slightly extended mid-semester break, staff had four-weeks to adapt to a new reality – it was now obligatory for all course material, delivery, and assessment to be provided through a fully online mode.

This swift conversion to fully online T&L spaces was challenging for staff and students engaged in courses that had previously been taught with significant face-to-face, in-person components (Clune, 2020; Lederman, 2020; Pather et al., 2020). This new experience, where the whole T&L experience was required to be online, rather than supplementary online learning spaces or specifically designed online courses, presented challenges for staff and students (Cicha, Rizun, Rutecka, & Strzelecki, 2021). Staff who were responding to the ERT shift had originally designed their courses for campus-based delivery and engagement. Additionally, students adapting to EOL had enrolled with the expectation they would be

[1] https://covid19.govt.nz/alert-levels-and-updates/

studying in physical spaces alongside their peers, supported by the on-campus community of university staff and other students.

Not only did the ERT/EOL present a challenge for teaching new concepts, the SL also noticed the negative impact this swift change, amidst an uncertain external environment, had on students' wellbeing (Rapper & Brown, 2020). The course was not planned for fully online delivery; T&L activities relied heavily on live interaction between teaching staff and students. As originally designed, the SL supported students' learning of complex mathematics-based problems, diagrams, models, equations, and graphs across the curriculum through live interaction from a single campus or a specially designed video-linked teaching classroom. However, the SL needed to rapidly adopt available technologies to continue delivering the material without access to campus. Leveraging an understanding of educational technologies for student engagement and a recognition of ensuring appropriate pedagogical approaches for various learning environments, (Falloon, 2011; Garrison & Vaughan, 2008; Harris, Mishra, & Koehler, 2009), the SL pursued the development of an advanced educational technology – a lightboard for live streaming to enhance online learning.

The chapter continues by offering drivers for adoption of lightboard technologies and considerations as to why readily available tools for online delivery did not meet the needs of the students within this course. Following a consideration of the design of a lightboard for live streaming complex material, an overview of the advanced lightboard setup and use is provided. As Dhawan (2020) suggests "the challenge … is not only finding new technology and using it but also reimagining its education" (p. 9). It is in response to this challenge that this chapter contributes to the field of educational technologies. Combined with student feedback on the impact of the live streaming lightboard technology, the chapter demonstrates how the SL implemented gaming community streaming technologies and techniques for live overlay of information, images, and text to respond to the needs of students during a global crisis, and provides areas to continue enhancing T&L in a post-COVID world.

Background: The drivers and disruption

Before COVID-19 was a driver for change, this University had already highlighted strategic changes in terms of the future design of its academic offer, to ensure the physical infrastructure across its three campuses would be optimized and sustainable. For teaching staff, this signaled the consideration for the 'what' and 'where' courses would be taught and drew attention to the possibilities of increased online or blended delivery. Specifically, the SL in Mechatronics acknowledged this and began considering the delivery of high-quality online learning experiences for students in courses where curriculum had historically been delivered in a face-to-face physical classroom. He wanted to ensure any tools adopted to facilitate the creation and delivery of digital material would enhance the effectiveness of the T&L environments.

With options ranging from slide presentations with voice over, video screencasts, live classroom recordings shared with those not in attendance, studio recordings, desktop webcam recordings, or tablet-based freehand drawing videos (Guo, Kim, & Rubin, 2014), the SL considered several alternatives. Acknowledging appropriate pedagogical approaches for delivering the content (Rosenberg & Koehler, 2015), one reasonable option was a teaching style similar to that used by Khan Academy (Thompson, 2011). This would involve delivering content using an interactive pen display, such as a Wacom tablet, to explain concepts using handwritten equations or diagrams digitally. However, with the digital pen displayed across a black background and the teacher's voice overlaid, a notable 'missing' part of the T&L experience was that of a visible teacher (Kizilec, Papadopoulos, & Sritanyaratana, 2014; Bhat, Chinprutthiwong, & Perry, 2015).

To overcome this lack of face-to-face 'feel,' the SL explored the use of lightboard videos (Birdwell & Peshkin, 2015). Combining appropriate pedagogies, available educational technologies, and content knowledge (Koehler et al., 2014; Rosenberg & Koehler, 2015; So & Kim, 2009), he determined such a tool would be suitable for further investigation. With the importance of including a face-to-face 'feel' and the ability to describe complex concepts using images and handwritten annotations, the lightboard afforded students the visual of the teacher explaining concepts on a pane of glass, similar to writing on a whiteboard, but where the teacher appears behind the screen, facing the students.

Aligned with the University's intended strategic direction, and with a piqued interest in the idea of lightboard technology for teaching, including noticing that in some of the more advanced systems allow PowerPoint slides, code, and figures to be overlaid on the screen, the SL explored this concept further.

Lightboard technologies as a teaching tool

Lightboards have only recently been introduced as educational teaching tools (Birdwell & Peshkin, 2015), resulting in limited academic research supporting or negating their effectiveness in higher education. While some have studied the use of lightboard technology to enhance the T&L environment, and students have provided positive feedback for their use in both synchronous (Skibinski, DeBenedetti, Ortoll-Bloch, & Hines, 2015) and asynchronous (Rogers & Botnaru, 2019; Wendell, 2018) environments, there does not appear to exist statistically significant evidence of positive or negative impact on student academic performance (Rogers & Botnaru, 2019, Lubrick, Zhou, & Zhang, 2019).

Underpinning the introduction of lightboards as teaching tools is a desire to help explain concepts that require hand-drawn examples and worked equations to students. When students are offered videos as a means of content delivery and can see an instructor engaging in dynamic drawing, it helps improve learning compared to having pre-written content appearing on the screen (Tufan, 2021). Further, when content videos include an instructor gesturing and pointing, students' learning outcomes have improved, as compared to just viewing a video of an individual talking (Pi, Zhang, Zhu, Xu, Yang, & Hu, 2017). Including lightboards as a means to deliver this type of content and in a way that supports student learning enables teachers to expose students to new, complex concepts in a variety of ways – not just within in-person, face-to-face classroom settings (Fung, 2017; Wendell, 2018).

Although the use of lightboards supports delivery of videos that create a live explanation, face-to-face 'feel', this technology has traditionally been used to deliver pre-recorded material, with the advantage of editing and post-processing of the video and audio. While some have investigated the use of lightboards for live streaming over YouTube-Live (Birdwell & Peskin, 2015), they observed approximately 45 seconds delay due to transcoding limitations and a further half second delay was added by the video capture device they used. This made it difficult to facilitate student questions during content delivery.

Despite the limited existing research into the learning effectiveness of lightboard systems, the SL felt that the lightboard teaching technique showed good promise for providing high quality digital teaching of mathematical and diagram rich content in a manner that would be engaging for students. With his desire to continue enhancing the T&L environment, and with potential changes to the T&L environment for his courses, the SL pursued options for integration of this technology for his curriculum.

An opportunity: Custom building a lightboard

Several commercial lightboard systems were found, which could be purchased from overseas, but the cost of these was out of budget – custom building a lightboard system was, therefore, the only option. The SL investigated the technical requirements of other lightboards, including the types of hardware others used and the possibility of free and open-source Open Broadcast Software (OBS) to enable the overlay of slides and images. However, early considerations did not include the necessity of live streaming or fully online delivery.

A global pandemic informing design

The urgency required for all teaching staff to move their courses online influenced the technical requirements of the lightboard system. Additionally, lessons learned from engagement with students in a new T&L environment continued to inform the design of the technology.

to the immediate ERT/EOL challenges and shifting his curriculum and T&L activities online, the SL used the live streaming and recording platform that was provided by the University for all teaching staff to continue delivering courses during the pandemic – Zoom. For course content that involved the need to display applications such as lecture slides, MatLab code and figures, and SolidWorks CAD diagrams, the ‘share screen’ function was often used. For material that required hand-drawn diagrams, equations, and annotation of documents, either a Wacom tablet or a touch screen laptop were used.

These teaching approaches afforded the SL to continue delivering material with minimal disruption, and many students found the changes beneficial as they were able to study from home and be more flexible in their study times. However, these rapid changes amidst a global crisis did not come without a cost. A significant number of students appeared to show signs of stress, increased rates of anxiety and depression, and a loss of engagement (Flack, Walker, Bickerstaff, Earle, & Margetts, 2020; Gasteiger et al., 2021). Educators also reported increased concern with student’s social isolation, student well-being, and the learning loss associated with COVID-19 (Flack et al, 2020).

Evidenced by staff and student feedback at this university, there remained several challenges or barriers to student engagement:

- Staff and students highlighted a reduction in the face-to-face 'feel' of online lectures
- Staff raised concerns about video and audio quality with ERT devices (e.g., laptops)
- Teaching staff expressed feelings of frustration not being able to teach in their practiced manner, such as in-person, face-to-face classroom settings
- Teaching staff were limited in their ability to gesture or point to objects on the slides. While interactive drawing tables were used, students suggested it was "less engaging [than seeing someone draw/write] as the writing appears to come out of nowhere"
- Students concerned about privacy issues chose not to engage using audio or video
- Students expressed hesitation about asking or responding to questions for fear of sounding "silly" on a recorded session that would remain available for the semester
- Students noted the lecturer was difficult to see when using a 'share screen' mode

Even though this might have been virtual contact only, the lack of ability to have this 'feel' of being face-to-face or two-way interaction seemed to amplify the elements of social isolation students were experiencing; the SL was concerned about the subsequent negative impact on student engagement and learning (Dhawan, 2020). To overcome these challenges relating to the isolation of students (Gillet-Swan, 2017; Raaper & Brown, 2020), the SL was interested in investigating the development of a live streaming lightboard system that would also abate privacy concerns. With the impetus for advancing an educational technology to help minimize social isolation felt by students engaging remotely, the SL helped shift the scope to a more advanced teaching tool. However, the requirements for live streaming differ from recorded video; one is not able to perform post-processing, and all audio and video processing and transitions must be done in real-time.

Rather than simply considering the use of lightboards for pre-recorded video lectures (Fung, 2017; Wendell, 2018) or to supplement synchronous taught content (Rogers & Botnaru, 2019), the SL focused on investigating how the gaming community set up their systems for live streaming over platforms, such as Twitch. The underpinning consideration for this was to ensure appropriate pedagogies employed for the content and context of the engineering courses (Koehler et al., 2014), and the SL recognized this community had been a leading influence in the development of high-quality live streaming.

The set-up: The finer details

The hardware setup used to create the lightboard system is shown in Figure 1. The lightboard consisted of 8 mm thick low iron glass of size 800 X 1000 mm, which was fixed inside a frame made of 40 mm aluminum extrusion. This glass is more transparent and does not have a greenish tint filtering effect that occurs with regular glass. Tests had been performed with standard glass and clear acrylic, but they were found to provide lower quality results.

A LED light strip was positioned inside the frame providing edge lighting of the glass. Fluorescent ExpoNeon marker pens, which glow when the glass is illuminated, were used for writing on the glass, and a black backdrop was positioned behind the lecturer to help make the writing stand out. The lightboard frame was placed on a table and the teacher was seated in front of it (Figure 2).

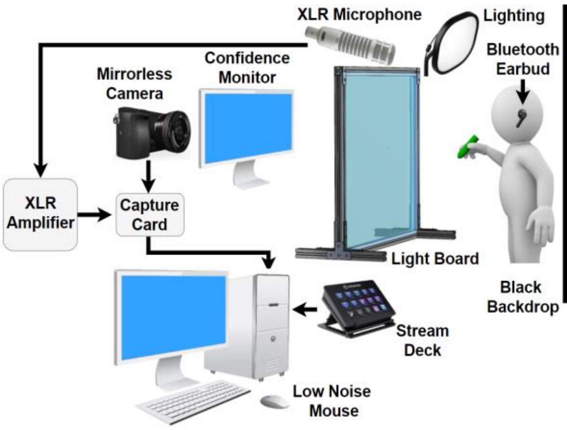

Figure 1: Block diagram lightboard setup *Figure 2: Caption: Lightboard in use*

The teacher was illuminated using LED lighting panels, which had a high Color Rendering Index (CRI) with soft edge lighting. The higher the CRI level the more accurately colors can be reproduced. The intensity and color temperature of the lighting was able to be controlled in software using WIFI control. This enabled each lecturer to automatically set up the lighting to best suit their skin tones. Although this is a nice feature, more standard lighting options that had manual adjustment could have been used.

A camera was positioned on the opposite side of the glass from the teacher and software used to flip the camera image so that the writing does not appear to be reversed. A mirrorless camera was used since it has better image quality and more control than a web camera. Because the camera was intended to be used for live streaming using a HDMI capture card, care was taken in selecting a camera that had features suitable for this application. Limited information was found relating to this from academic teaching related sources (clean HDMI output while maintaining auto focus, not powering off after a set time, and being able to power it off mains using a dummy battery). The HDMI capture card was able to operate at the desired 1080p resolution, had good color reproduction, and low latency. The computer used had a dedicated graphics card.

The camera images using default setting showed the background to be dark greyish color rather than dark black. Additionally, smudges on the glass from the markers were visible. To address this, the camera's white balance, aperture, and shutter time were adjusted to make the black background darker and reduce visibility of marker smudges. This was further enhanced using real-time video processing using a custom made Look Up Table to perform color correction and further make the background blacker.

A XLR microphone was used to provide high quality capture of the teacher’s voice. The models chosen were “legendary” microphones with a long history of use for radio and TV. These were directional and reduced picking up of background noise and reverberation effects. The signal was amplified using a XLR amplifier. This performed audio signal processing in real-time on hardware inside the amplifier, which reduced processing load from the computer. The audio processing performed was equalization (frequency domain filtering), compression (reducing the amplitude range between the loudest and quietest sounds), and sound gating (removing noise below a threshold). The parameters used were able to be controlled in software. The analogue output of the XLR audio amplifier was captured by the audio analogy input of the HDMI capture card. This was performed to ensure synchronization between the audio and video was achieved automatically. This audio system was found to be very effective at removing background noise such as people taking in the next room or air conditioning noise. This helped preserve the privacy of people near where the lecture was being recorded.

OBS was the main software used with the lightboard system. Lecture slides, computer coding (MatLab scripts and figures), CAD (SolidWorks), and printed circuit board design (Altium Designer) images could be overlayed over the camera image as transparencies. This allowed the teacher to point and annotate content in an augmented reality manner. Figure 3 provides an example where the background color of a MatLab figure was set to be transparent in OBS.

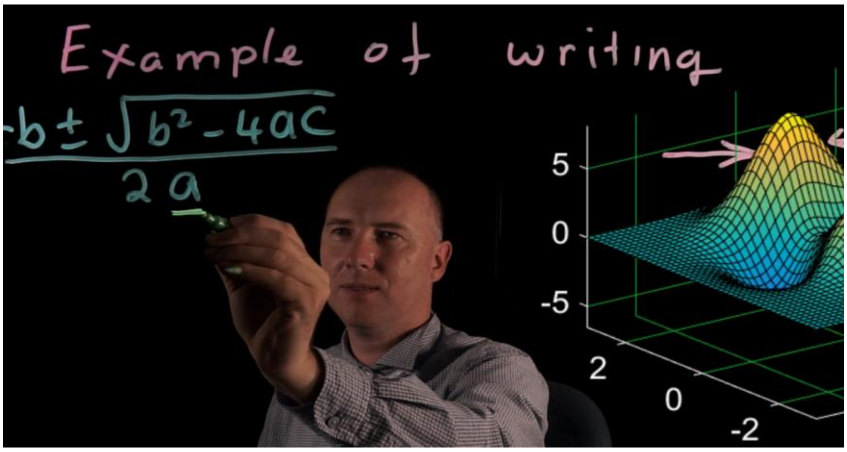

Figure 3: Lightboard in use with writing and a MatLab figure overlaid over the camera image

An Elgato Stream Deck was used to automate the operation of the lightboard system and make it easier for staff to use the system during live streaming of lectures. This device has customizable LCD displays on each key (Figure 4). Each key can be programmed to perform multiple actions when pressed. This device is commonly used by streamers in the gaming community to move seamlessly between displays. However, evidence is lacking for this enhancing academic teaching. Buttons were configured to set up the lightboard system (e.g., starting software, wirelessly configuring the lights) and switch seamlessly between different OBS scenes. For example, the top left button was used to provide a full screen camera image of the lightboard. The button next to this would add PowerPoint slides as an overlay over the camera image. It would also bring the PowerPoint application window to the front (top-most window).

Figure 4: Stream Deck custom configured to automate operation of lightboard system

Streaming directly from OBS to a gaming platform such as Twitch or YouTube-Live would have been easier; however, there were concerns about privacy of students and in-chat spam by bots (Payne et al., 2017). Lectures were, therefore, streamed over Zoom using the output of OBS as virtual camera source and microphone sources. Recordings were made using OBS so that one could record only the lightboard video and the teacher’s voice. This maintained students' privacy by not recording their voices, images, and names to encourage increased active student participation students in synchronous sessions.

The outcome: A live streaming lightboard system in use

The lightboard system described has been used by the SL as well as another Lecturer for live streaming of content across three engineering courses. Two of these courses were delivered with online components to cohorts of students studying at two of the University’s different campus locations (different cities). The result, as highlighted by staff and students, was a more natural feeling during lectures than using an electronic writing tablet. The functionality of the lightboard also meant that lecturers were able to incorporate more worked examples in their teaching activities. The Stream Deck was found to make the setup and changing of OBS scenes much easier during live lectures, compared to alternating between ‘share screen’ options in synchronous sessions.

In addition to unsolicited positive comments from students, who articulated the use of live lightboard T&L activities was the closest ‘feel’ to a face-to-face lecture that they experienced for online lectures, feedback has been garnered from a voluntary, anonymous survey of students who engaged in courses using this technology. Using a 5-point Likert scale (where any mean result above 3.0 represents a positive response), responses from 28 students indicated positive responses (agree or strongly agree) when asked about the influence of the lightboard technologies in their course. This is evidenced in the summarized feedback in Table 1 across four broad topics.

Table 1. Student perceptions of lightboard technology in T&L activities

Topic	**Influence of lightboard technology**	**Mean Score**
Understanding	lectures are easy to attend; content is easy to understand	4.15
Engagement	interactive and easy to follow; effective use of my time; appropriate technology for online learning; engaging	4.08
Satisfaction	interesting and stimulating; stylistically attractive; effective for learning engineering concepts; appropriate for delivering online content; would like to see them more frequently used	4.28
Student Wellbeing	helped me feel more connected to students/staff compared to traditional offerings; helped me feel safe; helped me feel less anxious by giving me an option to attend remotely; made me feel more emotionally engaged; allowed me to participate in an online session without my voice being recorded	4.07

When considering their experiences in terms of engagement (ability to follow content and maintain attention) and visual impact (visually appealing and interesting to attend/watch), students showed a strong preference for lightboard lectures as shown in Table 2.

Table 2. Student preferences in content delivery mode

Lecture delivery mode	**Mean score - Engagement**	**Mean score - Visual impact**
Pre-recorded using PPT slides	2.75	2.43
Live streaming using PPT slides or shared screen	3.32	3.43
Live streaming using whiteboard	3.64	3.43
Pre-recorded using lightboard technology	3.75	3.64
Live streaming using lightboard technology	4.21	4.32

Feedback and improvements

Reflecting on the design, development, and implementation of this lightboard system, there remain areas for continuous improvement and to explore lower-cost alternatives, such as using a webcam to record voice and video. Good results with lower quality were obtained, see Fig. 6. Using the webcam reduces cost by illuminating most of the more expensive items (XLR microphone and preamp, mirrorless camera, and HDMI capture card), and audio signal processing can be performed in OBS. Lower cost lighting options can also be used, and low iron glass could be replaced with clear acrylic (though this is more susceptible to scratching).

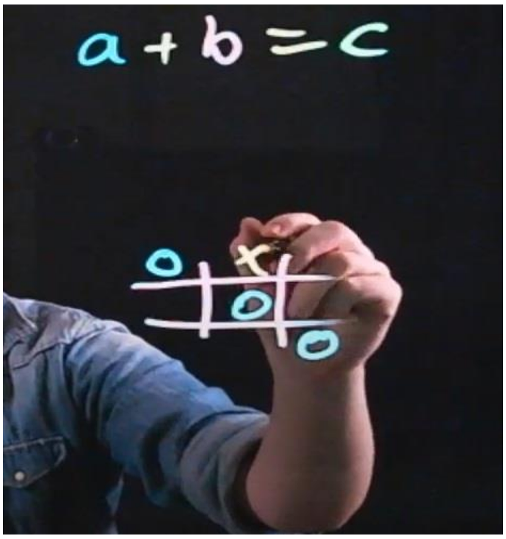

Figure 5: Lightboard video captured using a web camera after real-time video processing color correction had been performed

Final thoughts: Continuing to enhance T&L

The COVID-19 pandemic has resulted in a broad range of responses from higher education providers globally, ranging from no response, to full social isolation strategies and rapid curriculum development for online-only teaching modes (Crawford et al., 2020). It is likely that students' study modes, and therefore academics' teaching modes, will continue to be influenced for some time. However, as education institutions respond to these changes and implement new practices, it is prudent to ensure new T&L environments acknowledge and respond to the needs of students. While staff are encouraged to try new practices and embrace opportunities (Raaper & Brown, 2020), the lack of direct academic and wellbeing support for students must be at the forefront of decisions made, including ensuring relevant pedagogies underpin the T&L environments (Gillet-Swan, 2017).

The purpose of this chapter was to share the experience of a SL who leveraged lightboard and gaming community live streaming technologies, combined with their understanding of educational technologies and HE pedagogies to meet the needs of students during the COVID-19 global pandemic. The SL's concern for meeting the academic needs and wellbeing of students influenced the development of a new lightboard technology and provided initial positive outcomes. The intent was to help advance the discourse on educational technologies, and the feedback to date has been positive. To continue extending this knowledge base, in line with Lubrick et al.'s (2019) suggestion, it is recognized that there is a need for more experimental studies on classes using a lightboard compared to a traditional approach, with both student results, and focus group survey responses made available. This would allow fair assessment of learning outcomes, cognitive load and engagement or attention data from contrasting teaching approaches.

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