Remote Education System

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Abstract. Lightboard needs a lot of expensive and professional equipment and big space for the setup that schools and companies don´t often possess. By taking a look at lightboard studio and using Axiomatic design method to build a single unit with all the necessary component are present to make it functional lightboard studio. The solution is a product that is called Lightboard Ready (LR) and is a unit that has a folding mechanism that gives lighting, mic, and camera fixed position and therefore gives an easy user experience. LR is successful in giving easy user experience, it takes only a few minutes to fold it together and move up to a wall so it won't be in the way when it is not in use. When in need the LR is only a handful of movements away.

1. Introduction

Teaching STEM field cores effectively need an engaging, personal teaching approach and a lot of feedback. Remote teaching lack every single one of those dimensions and student often struggle with STEM fields when it is taught remotely. Today have lightboard become popular because the teacher faces the camera and can give a lot of eye contact which gives engaging and personal feelings to the course.

> 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.[1]

The problem with lightboards is it needs a lot of expensive professional equipment (lights, cameras, and mic) and an expert to set them up and it needs a lot of space which is not what schools and companies possess often. By designing a unit that gives an easy user experience on a lightboard studio it could motivate schools and other companies to use this technology to produce high-quality education material.

1.1. Customer Needs

$\mathbf{CN}_0$: Need to set up lightboard studio easily.

$\mathbf{CN}_1$: Need to set up camera in correct place.

$\mathbf{CN}_2$: Need to set up lights in correct place.

$\mathbf{CN}_3$: Need to set up mic in correct place.

Figure 1: Design Decomposition flowchart

CN$_4$: Need to take little space when not in use.

CN$_5$: Need to transport the studio.

1.2. Functional Requirements

The product has to be able to show the material that is being taught to the students

FR$_0$: Fold lightboard studio.

FR$_1$: Guide the camera to its correct place.
Metric : Image fills the frame 80-99%.

FR$_2$: Guide the lights to its correct place.
Metric : Can see face expression.

FR$_3$ Guide the mic to its correct place.
Metric : Sound is 60-70 db[2].

FR$_4$: Fold together.
Metric : The width is less than 0.8 m.

FR$_5$ Move studio in one unit.
Metric : Can one person move it.

2. Background and Prior art

Today is STEM field remote education done on whiteboards, the problem with them is the teacher turns away from the student or camera when writing and gives a little eye contact. The writing isn't always clear and the teacher is often blocking what he's writing, which gives the class disengaging and impersonal feeling. Rocket book has a solution, it called rocket book beacons,

Figure 2: Rocketbook Beacons [3]

its a re-stickable, reusable Beacons convert writing surface into a smartboard by integrating with cloud services in the Rocketbook app. This product solves only one of the whiteboards problem and that is documenting what is written on the whiteboard, but it cost only $ 20 so its a cheap solution [3].

Revolution Lightboard is a company that makes lightboards and sells them as a studio kit. The problem with there product it's expensive ($ 15 000) and you need to have experience in setting up a studio[4].

When using a lightboard both the teacher's face and the writing are visible for the student so he gets more an engaging and personal feeling from watching tutorials created with lightboard than a whiteboard and Rocketbooks Beacons. Lightboard Ready has more depth in the recording because the position of the lights on the sides is further away from the glass. Because the camera is on a linkage system she is always in the correct length and height from the glass. It only takes 5 minutes to set up Lightboard Ready studio for people with no recording experience, where it takes a longer time when the camera and mic are not in a fixed location with a linkage system.

3. Design

Axiomatic design is implemented in our design, they are only rules (axiom) that needs to follow[5].

> Axiom 1, the independence axiom: Maintain the independence of the functional requirements
> Axiom 2, the information axiom: Minimize the information content of the design

We assume that there will be 230V mains where electric power is needed and users have a room where no sunlight is and the walls are dark (darkroom).

Figure 3: Studio Package from Revolution Lightboards [4]

3.1. Physical Solution

The Physical solution for the Functional requirement in chapter 1.2 are;

Phys. Scr. **0** : Lightboard with mechanical linkage system.

Phys. Scr. **1** : Linkage bar system for camera.
Metric : Length between camera and lightboard is $2m \pm 0.05m$ and height is $1.5m$.

Phys. Scr. **2** : Linkage bar system for lights.
Metric : Bar is 45° out from the lightboard.

Phys. Scr. **3** : Linkage bar system for mic.
Metric : Mic is pointing to the mouth of the teacher when he stands in the middle of lightboard.

Phys. Scr. **4** : Hinges on linkage system.
Metric : Hinges rotate min 135°.

Phys. Scr. **5** : Wheel under the frame.
Metric : Loading min 500 N per wheel and castor wheels.

Figure 4: The schematic of Lightboard Ready

The Design Decomposition flowchart is shown in figure 1. This system is decoupled (path-dependent) because FR_1, FR_2 and FR_3 need to have two physical solutions to fulfill the functional requirement. In other words, how camera, light, and mic are guided to its place depends on the hinges. A decoupled design is worse than an uncoupled but still allows the exact adjustment of the functional requirements.[6].

Phys. Scr. **1** Is implemented with a linkage system from the lightboard. Two hinges make it foldable. When folded it is in the correct height and length from the lightboard. The length was estimated after a trip to a lightboard studio setup with StudyHax.

Phys. Scr. **2** The same linkage system design is used for the three lights. Hinges are used for the foldability of the arms and give the desired angle of the lights. The length is 700 mm that gives the lights the proper distance from the lightboard after measuring the distance in StudyHax studio.

Phys. Scr. **3** The linkage system that is used for the light above the teacher is used here. Because of the x-profile, it is possible to put a holder on the side of the linkage system that holds the mic in place. The holder can be placed in different angles in the right direction.

Phys. Scr. **4** Next to the lightboard for the lights will be a hinge (see B in figure 14) that can move the linkage system in desired angle. For the camera will be two hinges to fold the camera stand.

Phys. Scr. **5** Under the frame is 4 castor wheels with the brake as is shown in C in figure 14. They will be fixed with bolts and nuts to the frame.

Modular Dependency Diagram or System Diagram can be seen in figure 12

Figure 13 shows our first idea of the concept. It shows a sketch of a linkage system connected to a lightboard. There are lights on the sides and lights above the teacher. Also is a v-shaped linkage system for the camera. Figure B1 and B2 shows a physical model of the idea but there we have added hinges on the linkage system for the light so the system would take less space in

Figure 5: Sketches of different concepts

storage. The beta prototype is shown in figure 15 and shows the lightboard built with x-profiles and the linkage system for the lights and mic has hinges for foldability. The linkage system for the camera has been simplified and this structure makes the feet on the lightboard more robust. There is a latent need with this design, that is it's possible to move the camera stand closer to the writing surface if needed. There are hinges on the camera linkage that goes away from the lightboard so it has foldability, and also a beam with rubber dampers on the camera stand that makes the camera stand stable. Under the frame are castor wheels with brakes for mobility.

The final prototype can be seen in figure 15.

4. Results and Discussion

The arm nr. 1, 3, and 4 shown in figure 15 need to be tested according to physical solutions, in chapter 6.1 is stated that the arm nr 3 need too let the camera be 2 meters away from writing surface and arm 4 makes the camera be 1.5 m from the ground, this need to be tested to see if the position of the camera is correct. Arm nr. 1 in figure 15 need to be tested according to PS 2 too see if the lights are in correct place and fulfill its functional requirement. The arms are made in ... by Hannes and are attach to the lightboard frame that we have access to from StudyHax. Test video will be made with smart phone to see if the position is correct and meanwhile the light are tested with on of us to see if the lights are in correct place.

This idea is going to be tested with building the frame for the camera stand and mount it to a lightboard that we have access to. For the lights, we will make an adjustable arm to hold them in the correct position and also mount them on the lightboard. In figure B1 is a physical model that shows the layout of the lightboard with lights and camera stand ready for use. In figure B2 is it folded together for transport or storage.

The plan for the test is to have a dark room that we can put up our equipment for recording a short video that shows how this idea works. The video is going to show both what is seen in

Figure 6: Sketches of different concepts

videos made with this and also the layout of our equipment.

5. Product Architecture

The product line is two, Medium (2m width) and Large (3m width). Both of them have a 16:9 ratio so the camera and video will cover the whole glass without it need to stretch or crop the recordings. One possible assignment of elements to chunks is shown in figure 12. The importance of industrial design in the development of the Lightboard Ready are shown in table 1

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Figure 7: Lightboard ready folded with detail view of the hinge and caster that is used

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Figure 8: Physical model

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Figure 9: Physical model, folded together

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Figure 10: Rocketbook Beacons [3]

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6.3. Design for Manufacturing

The market in Iceland is schools at all levels.There are 237 schools in Iceland[7]. So we estimate that every third school will buy and then the market for Lightboard Ready is 80 units.

We are buying everything in correct lengths and drilled so there is no labor cost in table 3 except for the packaging. These prices are found on 80/20.net and then the transport cost is estimated from that all 80 units are imported in one container. The reason that USD is used is that the ISK is always changing and on the BOM list is everything imported except for the glass.

Lightboard Ready is going to be sold dissembled in flat boxes and the buyer assemble it themself and this will thereby making it cheaper. This design uses only two angles in cutting, 90 and 45 degrees. All combinations on the x-profile fit together so it is possible to use standard connections that are cheaper. It also makes this design for the frame more robust.

6.4. Design for Environment

Lightboard Ready is made mostly out of Aluminium, galvanic steel and glass wish can be recycled constantly without loss of performance and thereby create new industrial material. The only natural material in Lightboard ready is the packaging, wish is a cardboard that fully recycles or can fully return to earth natural cycles, and thereby create new natural material.

Ergonomics	Level of importance	Explanation
Ease of use		So people with little light and camera settings experience can use lightbord.
Ease of maintenance		The system is robust with little mobility
Quantity of interaction		There are only two function on the product, assemble and disassemble .
Novelty of user interaction		The product is known, but not with this installation.
Safety		There are safety issues because it is possible to get stuck between two rods.
Aesthetics		
Product differential		This is a new method
Pride of ownership		It is a matter of comfort.
Team motivation		It is a new concept

Table 1: Assessing the importance of industrial design for Lightboard Ready

Part nr.	Component	Material	Number of parts
1	4040-Lite-Black 700mm	Aluminium	4
2	4040-Lite-Black 1000mm	Aluminium	2
3	4040-Lite-Black 1400mm	Aluminium	1
4	4040-Lite-Black 1900mm	Aluminium	3
5	4040-Lite-Black 2000mm	Aluminium	3
6	Standard Anchor Fastener	Galvanic steel	4
7	Double Anchor Fastener	Galvanic steel	4
8	Caster with brake	Galvanic steel and rubber	4
9	Floor Nylon-Glide	Nylon	2
10	2 Hole-Pivot Joint	Galvanic steel	5
11	Self-Aligning T-Nut	Galvanic steel	4
12	45 Degree Support 640mm	Aluminium	6
13	45 Degree Support 160mm	Aluminium	2
14	Starphire Glass	Glass	1
15	LED Strip		1
16	Power Supply		1
17	Black Glass Gasket	Thermoplastic Elastomer	1
18	Packaging	Cardboard	1

Table 2: Bill of material

Component	Purchased Materials	Assembly (Labor)	Total Unit Variable Cost
4040-Lite-Black 700mm	53.79		53.79
4040-Lite-Black 1000mm	49.56		49.56
4040-Lite-Black 1400mm	33.92		33.92
4040-Lite-Black 1900mm	143.82		143.82
4040-Lite-Black 2000mm	158.46		158.46
Standard Anchor Fastener	14.80		14.80
Double Anchor Fastener	23.20		23.20
Caster with brake	41.20		41.20
Floor Nylon-Glide	4.80		4.80
2 Hole-Pivot Joint	94.50		94.50
Self-Aligning T-Nut	7.20		7.20
45 Degree Support 640mm	198.90		198.90
45 Degree Support 160mm	35.80		35.80
Black Glass Gasket	12.25		12.25
Starphire Glass	264.00		264.00
LED Strip	29.99		29.99
Power Supply	26.50		26.50
Packaging	5.00	20.00	25.00
Total Direct Costs	1197.69.89	20.00	1217.69
Overhead Charges	119.8	5	125.58
Transport from Supplier			97.66
Total Cost			**1440.93**

Table 3: Cost estimate in USD [8] [9]

Figure 11: Studio Package from Revolution Lightboards [4]

No toxin material cannot be safely processed by either natural or industrial cycles.

The product is assembled in Iceland that has renewable and clean energy. The glass is made in Iceland with renewable energy. The x-profiles are coming from a supplier that uses aluminum produced in Iceland in their product.

7. Results and Discussion

7.1. Physical Test

The arm nr. 1, 3, and 4 shown in figure 15 need to be tested according to physical solutions. In the chapter, 6.1 is stated that the arm nr 3 need too let the camera be 2 meters away from writing surface and arm 4 makes the camera be 1.5 m from the ground, this need to be tested to see if the position of the camera is correct according to FR_1 in chapter 1.2.

Arm nr. 1 in figure 15 needs to be tested according to *Phys. Scr.* 2 to see if the lights are in the correct place and fulfill its functional requirement.

The folding mechanism with *Phys. Scr.* 4 are tested to see if it will full fill FR_4

The Caster nr. 8 in figure 15 is added to the lightboard and it is moved around by one person if so the design will full fill FR_5 in chapter 1.2

The arms and hinges are made by Hannes (see figure 17) at his workshop and are attached

Figure 12: The schematic of Lightboard Ready

to the lightboard frame that we have access to from StudyHax[1], figure A2. Test video will be made with a smartphone to see if the position is correct and meanwhile the light is tested with one of us to see if the lights are in the correct place, see figure 16.

7.2. Power consumption and mass of system

The LED lights that lights up the glass use 24 Volt and 1.8 ampler, with the Power law (equation 1)

$$P = V \times I \tag{1}$$

It is determent the LED consume 43 Watts. This is measured with the DC power supply from UNIROI shown in figure 18

The mass of the system is 79 kg as is shown in table 4, note this is the beta prototype shown in figure 15.

[1] There website is `https://www.studyhax.is`

figure 40-1 Caption: Idea for frame

Figure 14: Lightboard ready folded with detail view of the hinge and caster that is used

X-profile [8]	39 kg
Glass [9]	37 kg
LED and transformer	1 kg
Fasteners, hinges and wheels	2 kg
Total	79 kg

Table 4: Weight of Lightboard Ready

7.3. Result from physical test

With our alpha prototype, we measured the metrics that were set in chapter 6.1. The camera is 1,5 m high and 2 m away from the glass. The linkage system for the lights can be 45° from the lightboard and the hinges can rotate 180° where the metric says that it should rotate min 135°, see figure A3 and A4. Also, it is possible to change the height of the light.

In the garage, the light was tested but it was too bright inside and therefore we could not determent for sure if the position of the light was correct. see figure 16, The folding mechanism was successful, the width of the lightboard was within 0.8 meters, see the test in chapter Appendix A.

After we added caster wheels under the lightboard the frame is easily moved by a single

Figure 15: Lightboard ready

	Functional Requirements	Metric	Result
FR1	Guide the camera to its correct place.	Image fills the frame 80-99%	Unknown
FR2	Guide the lights to its correct place.	Can see face expression	Unknown
FR4	Fold together	The width is less than 0.8 m	Success
FR5	Move studio in one unit	Can one person move it	Success

Table 5: Result from Physical test

person.

See table 5 for the summary of the physical test.

7.4. Survey

A survey was done remotely in Google Forms to see the reaction from people what they think about the product, the following question was asked after we showed them a couple of pictures of us folding the lightboard. The survey was sent to 30 people.

(i) Do you think it would be easy to fold the lightboard like in figure 3 and 4?

Figure 16: Lightboard and light in illuminated room

(ii) Notice in figure 4 there is a wheel under the lightboard, do you think it would be easy to move it around?

(iii) Do you think the Lightboard is pretty?

The survey can be viewed in the following link :
`https://forms.gle/c1GtxNujG47PhEmR7`

7.5. Result from survey

On Sunday 2020-03-22, 17 people have responded to the survey, and the result is 75% do think it would be easy to fold the lightboard. 94.1 % think it would be easy to move the lightboard around and 47.1 % think it looks very pretty. The result is shown in figure 19.

7.6. Discussion

The system performance meets expectations in many ways. The folding mechanism was successful, the width of the lightboard was within 0.8 meters, see the test in chapter Appendix A. After we added a caster wheel under the lightboard the frame was easily moved by a single person. It gives the camera the correct position for height. Because of COVID-19, we could not provide the right camera and lens (25 mm) to test if 2 m is the correct length but in figure A5 is a photo taken from the camera stand with Samsung Galaxy S7 phone.

The light was tested in too much light and therefore we could not determent for sure if it's good or not.

Figure 17: Hinges made by Hannes at his workshop for alpha prototype

The survey tells that people think that it is easy to fold and with wheels that it is easy to transport it. Most people like the look of the Lightboard Ready.

Due to the COVID-19 Pandemic, we had limited material and option to test our product, we wanted to make a better survey by letting people try the Lightboard Ready and get better and more reliable data and feedback.

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[2] 2003-2004 Application of axiomatic design accessed on given date 2020-03-15 URL `http://sysdesign.org/msdd/axiomaticdesign.htm`

[3] Rocketbook™ 2020 Rocketbook beacons URL `https://getrocketbook.co.uk/collections/all-products/products/rocketbook-beacons?variant=30324556333128`

[4] Lightboards™ R 2020 Height adjustable studio package, extra large (95") URL `https://revolutionlightboards.com/collections/studio-packages/products/height-adjustable-studio-package-extra-large-95`

[5] Suh N P 2001 *Axiomatic design: advances and applications* (Oxford University Press, USA)

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[8] 80/20inc T-slotted profiles accessed on given date 2020-02-22 URL `https://8020.net/framing-options/t-slotted-profiles.html`

[9] Einfalt gler accessed on given date 2020-02-22 URL `https://ispan.is/form/pontun`

Figure 18: Power consumption for LED strip

Do you think it would be easy to fold the lightboard like in figure 3 and 4?

16 responses

Notice in figure 4 there is a wheels under the lightboard, do you think it would be easy to move it around?

17 responses

Do you think the Lightboard is pretty?

17 responses

Figure 19: Result from survey on google forms

Appendix A. Graphics from physical test

Figure A1: Camera stand folded

Figure A2: Light folded to glass and camera stand mounted

Figure A3: Sidebar for light

Figure A4: Sidebar for light folded

Figure A5: Photo taken from camera stand with Samsung Galaxy S7

Appendix B. Graphics from physical model

Figure B1: Physical model

Figure B2: Physical model, folded together