Making Collaborative Learning Effective and Affordable

Requirements Specifications and Design Iterations

Brief Introduction about the project

Our project is to understand the collaborative learning methods that are being practiced currently in the smart classrooms and discussions and build a cost effective system that can be used with minimal resources. The goal of our project is to build a system that improves the quality and effectiveness of collaborative learning in smart classrooms or in group discussions and to bring them closer to as many people as possible by making it affordable.

Requirements Gathering

User Study 1

Purpose:

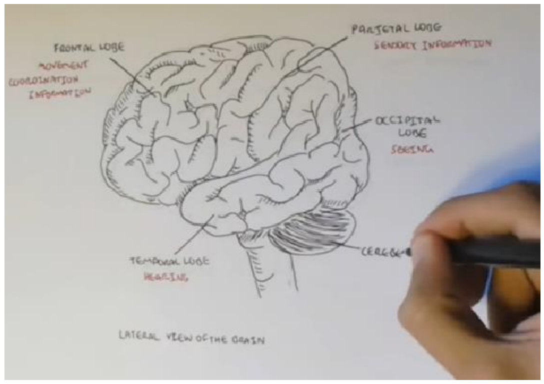
The purpose of this user study is to understand the memory retention and attention to detail of 3D visualizations when compared to it of 2D visualizations. Other general aspects and challenges in traditional classroom teaching methods were also monitored in the user study.

Description:

This user study is conducted to understand the memory retention of 3D visualizations when compared to it of 2D visualizations. The study is divided into 3 parts.

Part 1:

Two YouTube videos are shown to the participants. One video is about the anatomy of human's heart (https://www.youtube.com/watch?v=UMTDmP81mG4 (runtime: 2:40)) which resembles 3D visualization and other is about the anatomy of human's brain (https://www.youtube.com/watch?v=tRyp8EdRUiE (runtime: 5:10)) that resembles 2D visualization. The complexity level in terms of understanding is assumed to be the same for both videos.



Part 2:

A 4-minute quiz with 7 multiple choice questions each on anatomies of heart and brain was given. Two general questions (*"What kind of colors were used to describe the anatomy of heart?"* and *"What are the color of markers used to explain the anatomy of brain?"*) were asked to test the participants' attention to detail in the videos.

Part 3:

After the multiple-choice questions, an interview is conducted asking the participants about their experience on two videos and general questions related to the classroom lecture and discussion. The responses from the participants were audio recorded. The interview questions are as follows:

1. How do you the rate the video of heart in terms of understanding on scale of 1 – 5 (1 being the very tough to understand, 5 being very easy to understand)?
2. How do you the rate the video of brain in terms of understanding on scale of 1 – 5 (1 being the very tough to understand, 5 being very easy to understand)?
3. What do you think are the challenges in the conventional classroom lecture and discussion?
4. How would you clarify your doubts if something is not understood while lecture in the class or during the discussion with friends on any topic?
5. What technology if present would make understanding even better?
6. What are the most frustrating things in lecture in class or discussion with friends?

Instruments Used:

A quiz and structured personal interviews. The interviews were audio recorded on a mobile

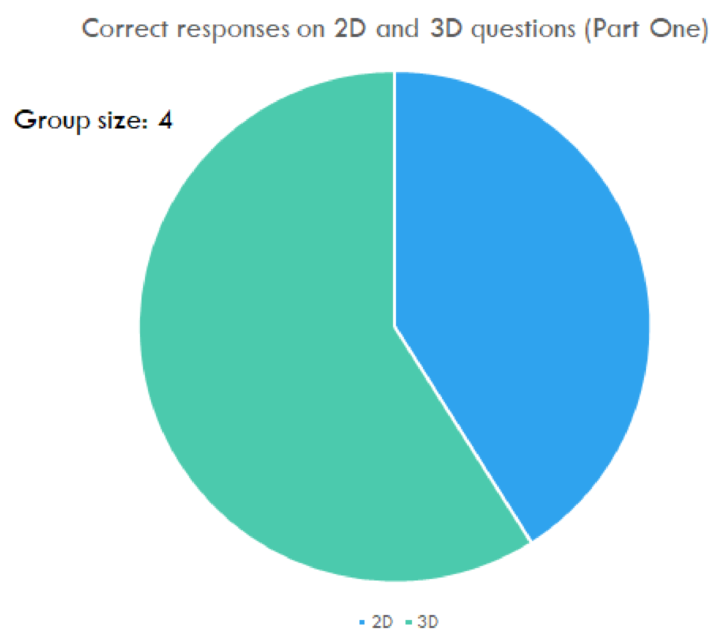
Group Size:

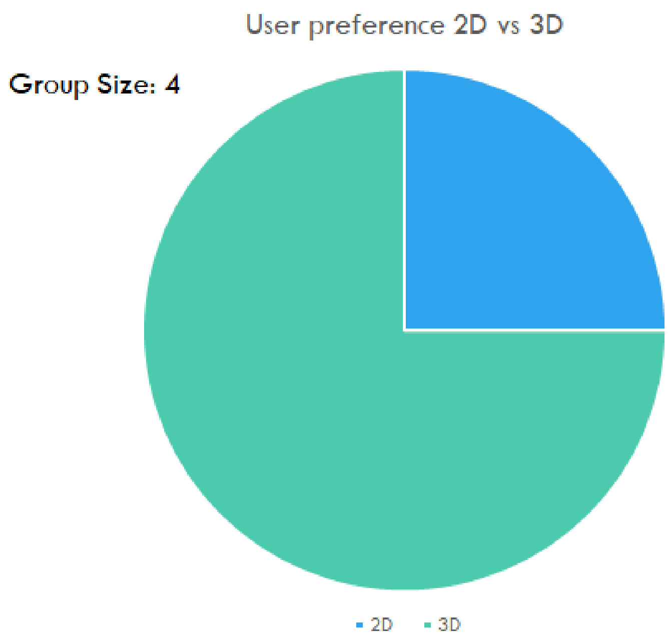
4 participants.

Observation:

1. All the 4 participants answered questions on the heart more easily than the questions on the brain.
2. When asked about the rating of both the videos in terms of understanding, Heart got more rating than the video of brain (3/4 – Heart, 1/4 – Same).
3. When the participants were asked about which video is better in terms of engaging and visualization, Heart was chosen by 3 participants and Brain was chosen by one participant.

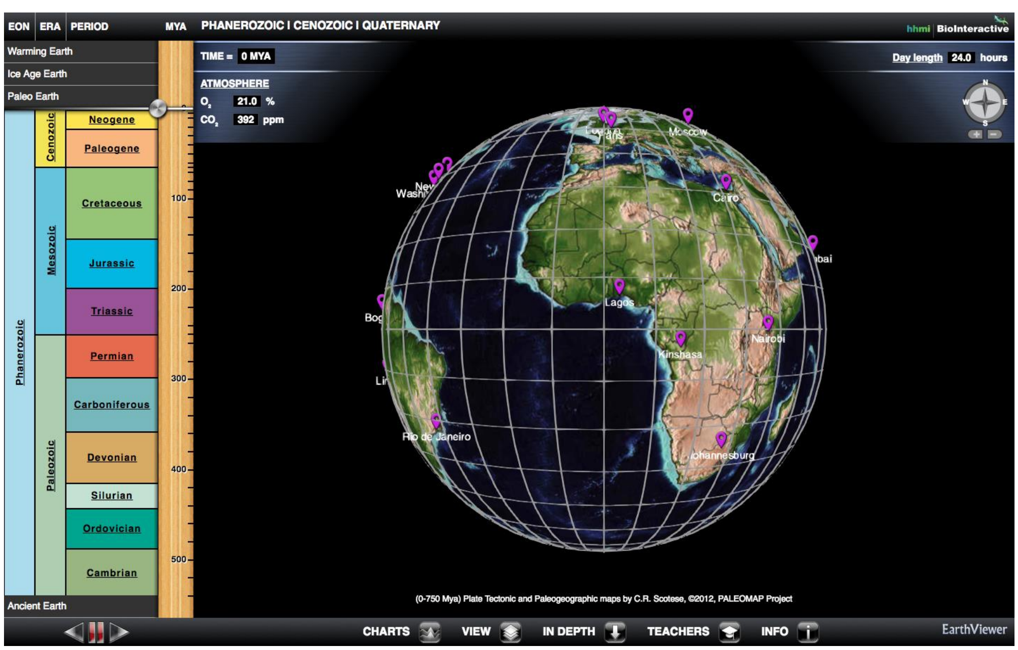
4. Even though 3D was never mentioned in the questions or in the interview, 3 out of 4 participants said that Heart is similar to a 3D visualization and it helped improve understanding than a 2D sketching of the brain did.
5. One participant mentioned that having 3D interactions while lecturing would make the conventional classrooms more engaging and less monotonic.
6. Two general questions such as *"What colors were used in the heart video?"* and *"How many kinds of markers/pens used in the Brain video?"* were asked. 3 out of 4 participants answered the Heart video question correctly whereas only 1 out of 4 participants answered the Brain Video correctly. This concludes that the participants' attention to detail in 3D visualization is better than in the 2D sketch.





User Study 2

This user study contained two tasks of the same format: for each task, the participants were given a visualization of the Earth in 3D then they were asked to solve a few questions together. What were displayed on the globe varied by task (NASA weather stations in task #1 and city markers in task #2). Each visualization came with a timeline which caused change in the displayed content when the users moved from one-time period to another.



The visualization used in task #2 of the study

Purpose

This study was conducted on the purpose of understanding:

- How people interact with 3D objects
    - How the provided interactions are used and how they are combined.
    - For which task (browse, search, analysis) each interaction is used.
- How group members communicate with each other.
- Are big screens (projection screen in this case) always preferable?
- Is there any difficulties of using a mouse to interact with 3D models?

Instruments:

Observation + *one-on-one interview*.

Group Size:

This study was done three times, each time on a pair of graduate students with different backgrounds (UIC/non-UIC, technology/business major). The sessions were video recorded.

The Applications

The visualization in task #1: http://thesis.allenkoren.com/

The visualization in task #2: http://media.hhmi.org/biointeractive/earthviewer_web/earthviewer.html

The visualizations provided basic interactions: rotating and zooming for the globe, dragging for the slider. The participants were asked to use a mouse to perform interactions. The laptop that the participants used was connected to a projector to give them more options.

Observations

- Although each of the three buttons (left, middle, right) on the mouse had its own rotating interaction, the participants only used the left button most of the time. It shows us that providing more interactions is not always a good choice. The interactions should not have similar functionalities.
- Ambiguous questions (*"What do you notice of the North pole in 230 million years ago?"*) tend to encourage the participants to talk to each other more than straightforward ones (*"How many cities are marked in the visualization?"*).
- Most of the time, the participants ignored the projection screen. The possible reasons are:
    - The group size (2) was too small so a 15" laptop screen was big enough for the users.
    - When interacting with the 3D object, the participants tried to bring the laptop closer to them. This is a disadvantage of the projection screen because it needs to stay at the same position most of the time.
- In task #1, since the timeline is dense with ticks, the participants had problem picking the exact position that they wanted to locate.

User Study 3

Purpose:

This user study was conducted in order to:

- Understand the difference in perception of objects' dimensions and structures using 2D images and pseudo-3D object models
- Note problems faced by group members in performing a common task in which each user has a distinct role in the task.

Description:

The study was operated in three parts on groups with two participants each. For the first part, each group was given four 2D images -- one image for each of the front and back sides and two images of the left side or a 4 sided building and were asked to perform a drawing task. For the second part, each group was shown a building in Google Street View and were asked to perform the same drawing task. The users were allowed to navigate in Google Maps around the building to complete the drawing task.

To perform the tasks, each group was given a laptop and stationery (pencils, color pencils, eraser, blank papers and pencil sharpeners). Each group member was assigned a dedicated role: one operated the laptop and the other was asked to draw. Then the participants were asked questions based on their experiences while performing task one and two.

The entire user study was video recorded for each group. Two study coordinators conducted the user study with each group: one explained the tasks and asked the interview questions, while one observed and noted the group members' significant issues when they were performing the tasks and their opinions. Once the user study was completed on each group, our team reviewed the video to find any observations which may have been missed.

Part 1:

The main purpose was to understand users' perception of dimensions and structure of a 3D object when only a few 2D images are shown. In part one, each group was given four 2D images: one image for each of the front, one of the back, and two images for the left side of a 4 sided building. The participants were asked to re-draw the front, back, and the left side of a building based on the three images. Then they were also asked to draw the right side and a top view of the same building based on the perceptions made from the four given images. Groups were asked to draw to a medium level of detail such that the structure of the building should be depicted. Groups were given ample time for drawing.

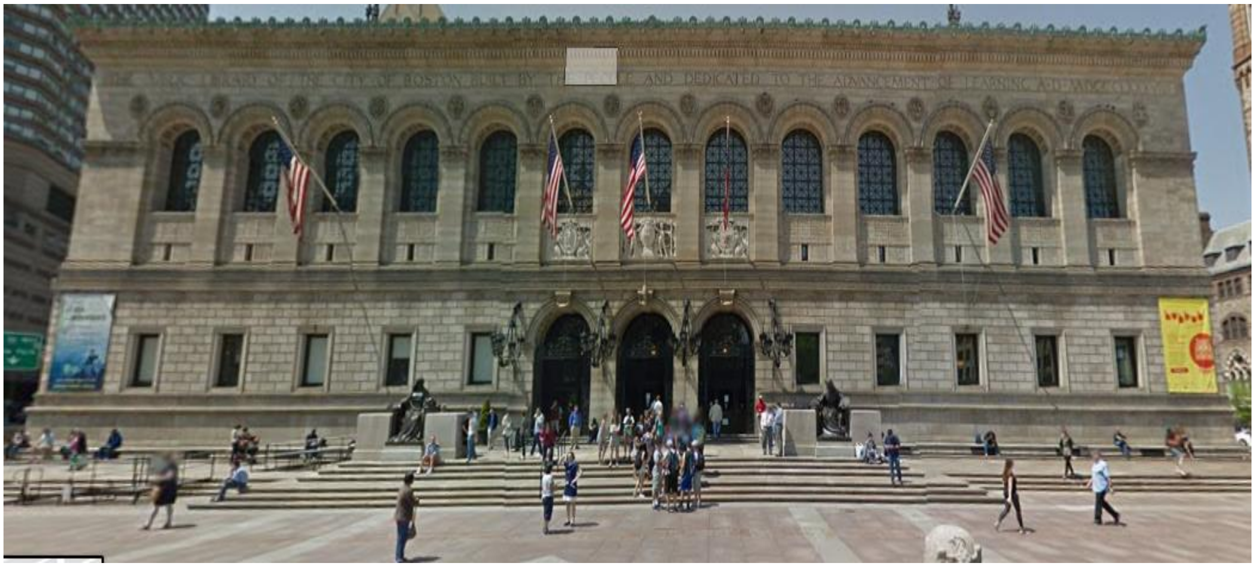


Fig 1: Building's Front Image

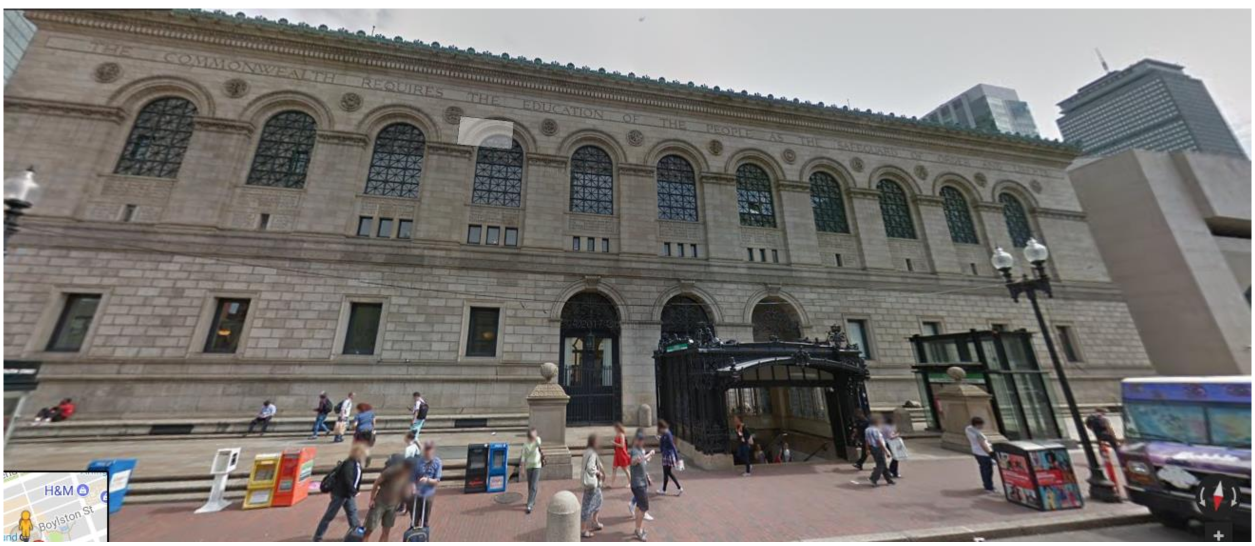


Fig 2: Building's Left Side (Image 1)

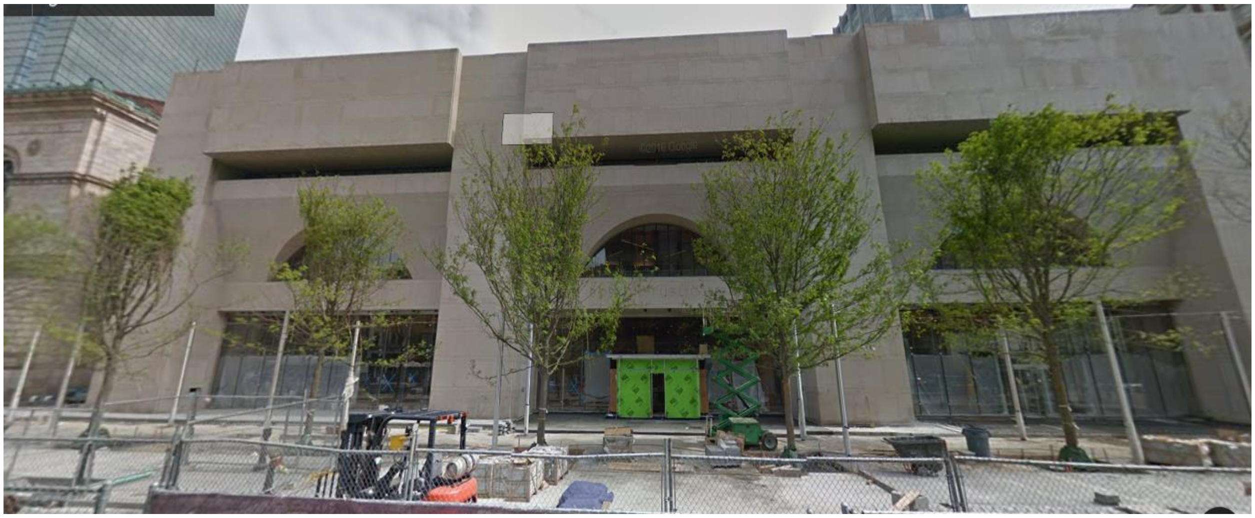


Fig 3: Building's Left Side (Image 2)

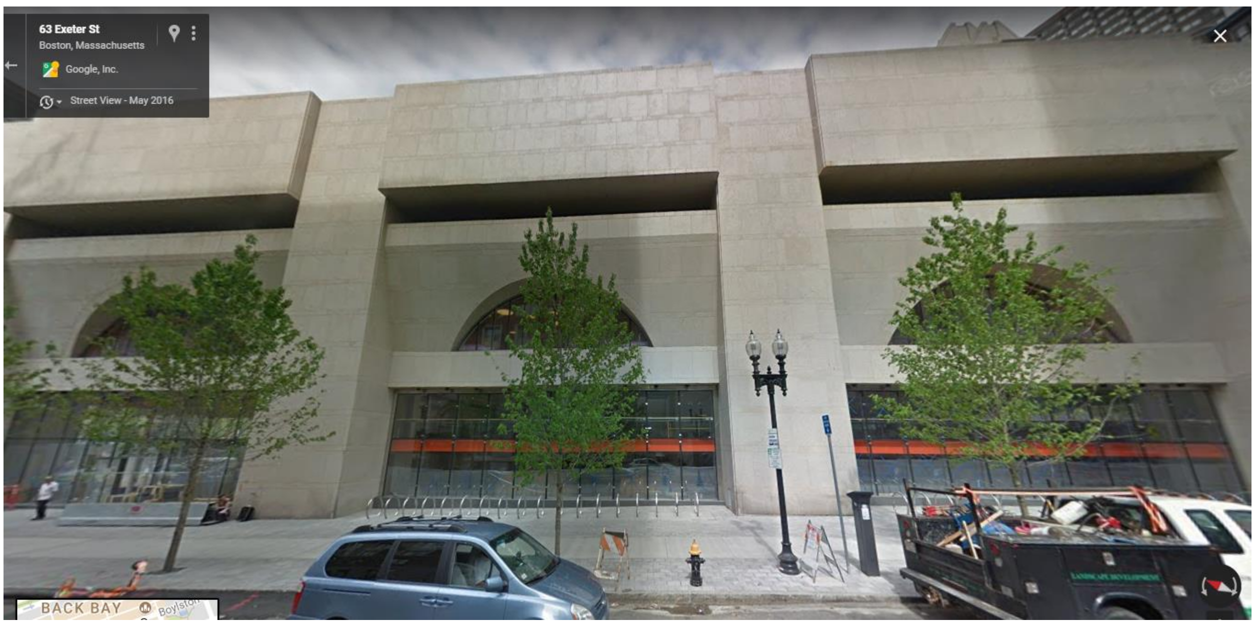


Fig 4: Building's Back Side

Part 2:

The main purpose was to understand human's perception of dimensions and structure of a 3D object when interact with pseudo 3D objects. Groups were shown a building in Google Street View on a laptop and were asked to draw a top-down view and a view of all sides of the building. This selected building was the Westin Hotel in Boston which had more than four sides. The groups were allowed to maneuver in Google Street View using a keyboard and a mouse. Groups were asked to draw to a medium level of detail such that the structure of the building should be depicted. Groups were given ample time for drawing.

The building which the users were shown is the '**The Westin Copley Place, Boston**'

Part 3:

Users were interviewed about their experience when performing the task in part one and part two. Following are some of the questions asked by the coordinator to the groups.

1. What difficulties did you face while performing the two tasks in a group?
2. According to you what were the challenges you faced when working with 2D images?
3. What were the challenges you faced when working with pseudo 3D model (Google Street View)?
4. What improvements do you want to make while interacting with pseudo 3D models?
5. Follow up question: Why would you not want to use a device like hololens for interacting with 3D objects?
6. Would you find it easier to perform this task on your own? If so, what improvements can you make so that this task can be performed in a collaborative environment?

Instruments Used:

Observations and *unstructured interview*. Scenes of the experiments were all recorded using video camera.

Group Size:

The user study was performed on two groups of size 2.

Observations:

Based on the participants' answers in interviews, drawings made by them, and our observations made when they were performing tasks in part 1 and part 2, following major problems were noted in collaborative learning:

1. Users found issues in interacting with 3D objects in Google Street View using a mouse and a keyboard.
2. In Google Street View, the participants were frustrated because the visualization suddenly jumped from one point to another in interactions instead of moving smoothly.
3. Based on the images drawn and interview questions, the users found difficulties in understanding dimensions and shape of an object using 2D images.
4. When interacting with 3D models, the user's prefered to stay in their seat while interacting with the 3D model instead of physically moving around it.
5. Many users stated that it would be easier to perform this activity individually and to improve collaboration suggestions were made that each user should have access to the content for observing individually.

The user study was performed on two groups.

User Study 4

We observed two lab sections of CS 151 on how students collaborate for problem solving. Each class of 30 students were divided into groups of 4. The students were allowed to work in group and open any material to solve their weekly lab assignment. The answers were written individually.

Purpose

The main purpose of this observation is to understand the nature of collaboration in problem solving. Beside observing the groups, we also handed out a quick survey (1 minute long) at the end of each section to ask the students:

- What encourages them to collaborate with their peers. Five options were given: (1) Dividing the work, (2) Reviewing materials, (3) Discussing solution, (4) Cross-checking answers, and (5) Offering help to peers. The students were asked to rank each option from 1 (absolutely not motivated) to 5 (highly motivated).
- Whether they prefer digital or physical materials.

Instruments:

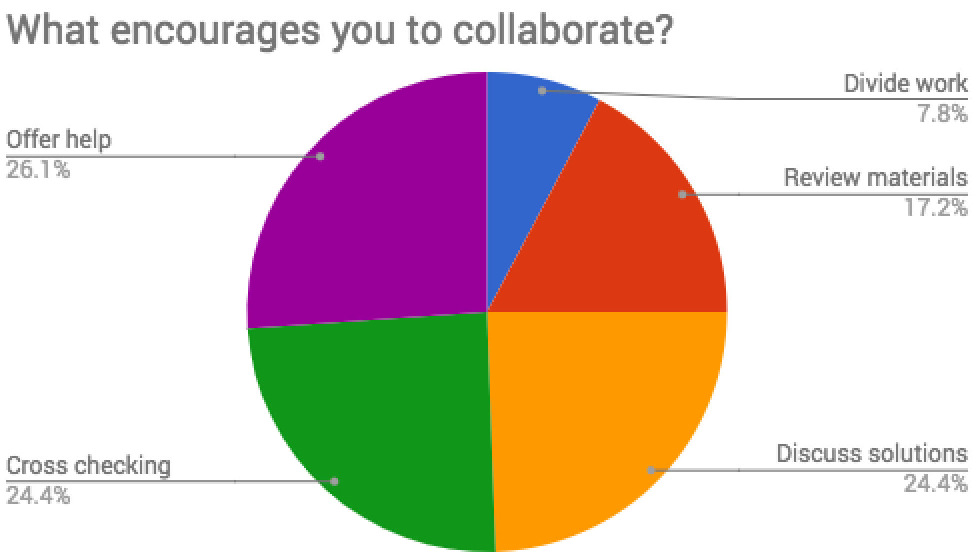
O*bservation* + *survey.*

Group Size:

30 participants/class $\times$2 classes = 60 participants

Observations

1. Students wanted to keep the material or screen close to themselves when they tried to read it, and it happened even when they explained it to someone. They wanted to use a finger to point the area (text line or figure) they were describing while explaining something.
2. Students used many hand gestures when they presented their opinions, even when the gestures were obstructed by a laptop monitor in front of them so that the other students could not see them.
3. Students turned their head to an uncomfortable posture to see materials or screen in the forward direction.
4. When they put the screen in the center, those who sit behind the screen were alienated.
5. There was a need of “transferring” information from screens to paper (as the answer needed to be handwritten).
6. According to the results of the survey, the main reasons that students want to collaborate are: Discussing solutions, Cross checking results, and Offering help to peers. Dividing works and Reviewing materials are not considered as important, which means collaborative learning is more meaningful in learning new concepts.



Requirements

User Requirements:

1. All users should be able to view the shared content without any obstructions.
2. Users should be able to view a 3D model of the shared object.
3. The system should enable the driver to manipulate 2D and 3D models with gesture interactions to avoid difficulties faced with traditional keyboard and mouse.
4. The system should allow the passengers to track which part the driver is talking about or looking at (ex: pointer or marker).
5. The system should accommodate 2 to 10 users with one user as the driver.
6. The system should enable the driver to pull up more information about an object.

Functional Requirements:

1. The system should provide users a large shared display that makes information visible to all users.
2. The system should be able to show 3D objects.
3. The system should have a gesture sensor.
4. The system should have a cursor that can point to a specific area on the screen.
5. The system should allow user to bring up a 3D object in hologram.
6. The system should allow user to remove an existing 3D object in hologram.
7. The system should allow user to zoom-in and out the 3D object in hologram.
8. The system should allow user to rotate the 3D object in hologram.
9. The system should allow user to pull up more information of an object on the large display.

10. The system should provide a common shared view and a dedicated individual view of content for each user.
11. The system should allow user to have freedom to pull up content in an individual view.
12. Gestures (including gestures using leap motion) and keyboard and mouses interactions should be easily discoverable.

Non - Functional Requirements:

1. Movement and zooming of the 3D model with hand gestures should be smooth and hassle free.
2. Different hand gestures should be defined for the 3D model.
3. The large display should be a size that 2-10 people can see at the same time.
4. The 3D model should be properly visible to all participants.
5. There should not be any obstruction for human-to-human interaction among participants.
6. Users should be able to control large display efficiently without trouble.
7. Content in the large display should be arranged properly to improve effectiveness.
8. The 3D model should be appropriate for the topic and should have proper details.

Usability Requirements:

1. Easy Installment: The setup of this system should be easy.
2. Accurate Gesture Recognition: The system should make sure the user's intended gesture is applied well.
3. Constant Feedback: The system should constantly give feedback about whether user's finger posture is well recognized.
4. Quick Response Time: The system should respond fast enough so that user does not feel the delay.
5. Easy to Use: The user interface should be intuitive and easy to learn.

Instructor Feedback:

1. Need to explicitly mention the instruments of the user studies.
2. Need to mention number of participants of each user study.

Design Challenges:

How to display a 3D object to a group of learners?

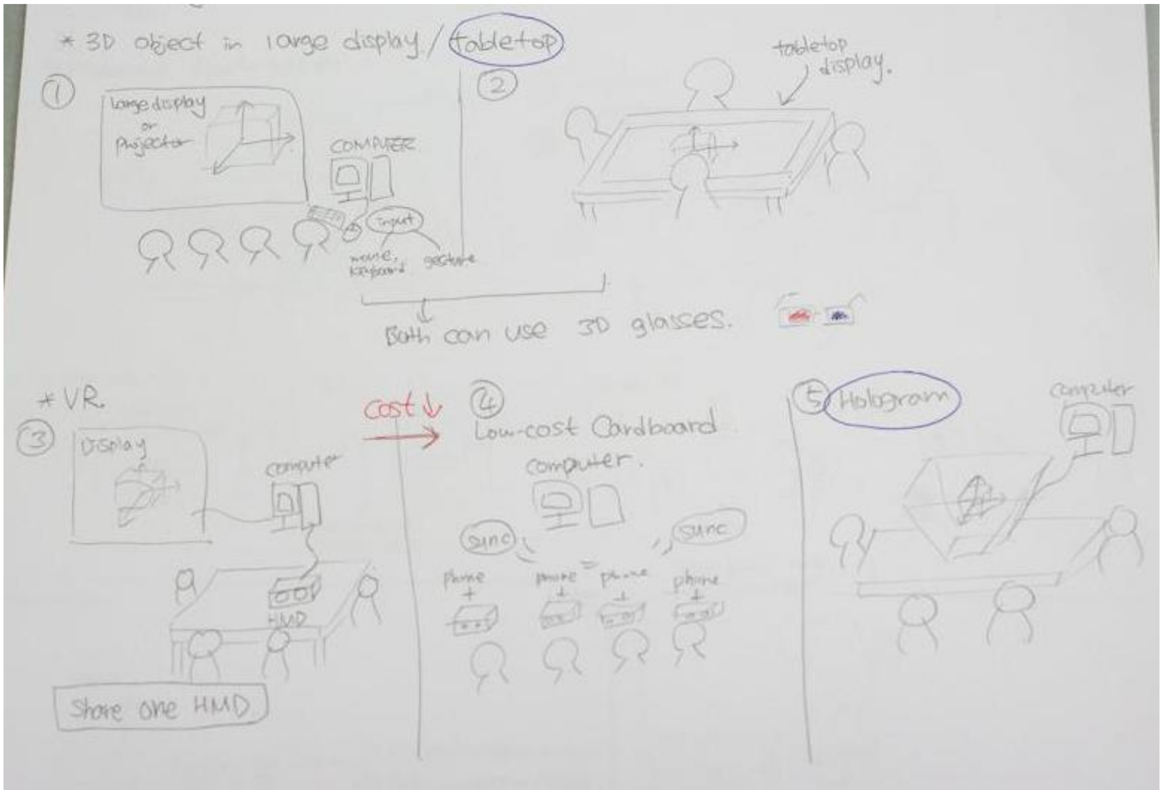


Fig 5: Different options that we considered

In this challenge discarded a few options that we had at the beginning: cardboards/3D glasses or head-mounted displays. We also explored mirascope, a device comprised of two parabolic reflectors which creates a 3D illusion of the (physical) object put at the bottom of the device. However, since the object that we would like to display is not physical, this option was also rejected.

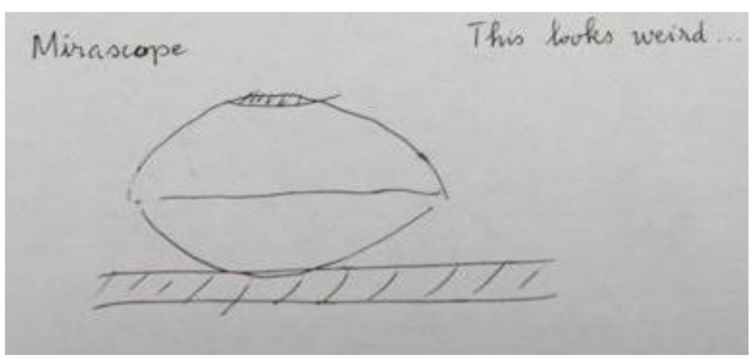


Fig 6: How a Mirascope looks like

After eliminating the above options, we all agreed to pick the *holographic projector* as our medium to display 3D objects. In that case, a display under the projector is needed. The tabletop display was considered but then rejected because it is difficult for a tabletop display to accommodate more than 4 users.

How can users interact with the 3D visualization?

In the user studies, we observed that participants had a hard time when manipulating the 3d object with the mouse. They wanted a more natural way to interact with the object. One of the study participants suggested using voice commands, but since human-to-human conversations are an important part of collaborative learning, it was not ideal to let the computer guesses the commands. Instead, we wanted to incorporate another type of natural communication medium: *hand gestures*. Kinect and Leap Motion were considered beside the traditional mouse and keyboard. Since Leap Motion provides a better precision and has a lower price, it was picked as our medium to interact with the 3D visualization. Through this device, we will provide just as much interaction as needed: pointing, selecting, rotating, zooming in/out.

How to bring an object from the 2D screen to the 3D display (and vice versa)?

Our initial idea was to let users operate hand gestures to “carry” the displayed object from one display to another. However, we could foresee a lot of possible difficulties in this option -- precision of the movement, we need to track the position and size of every component in the system, etc. Therefore, we went for a safer path which is approximately as convenient as the initial idea: make use of the GUI. GUI design will prevent users from making errors as compared to gestures..

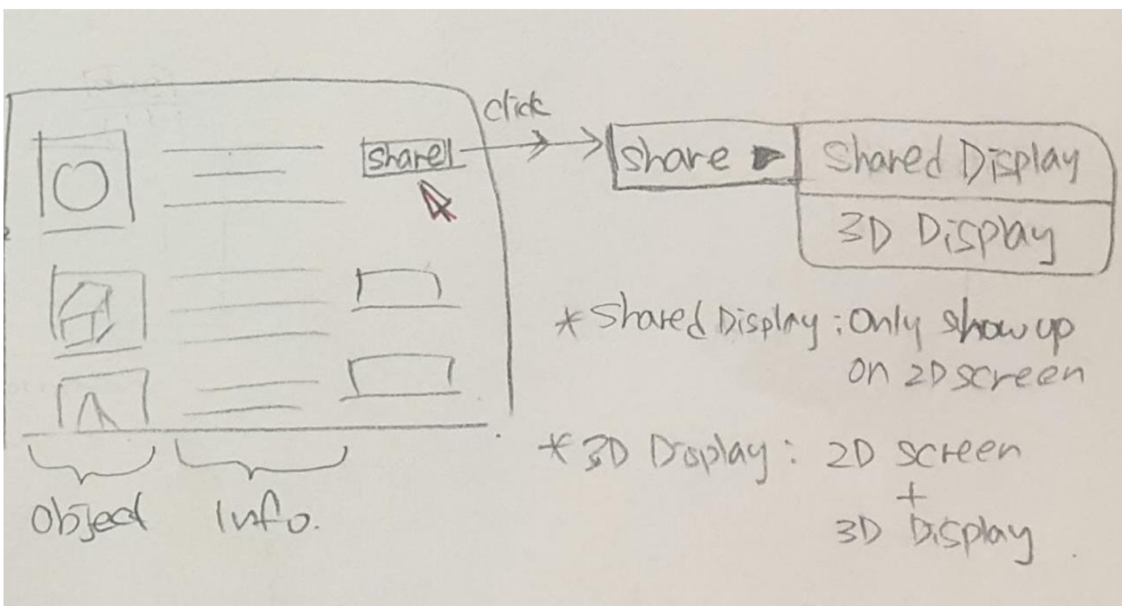


Fig 7: The system lets user decide which display should the object appears in

How can group members share/transfer control of the 2d screen?

We started our concept with two distinct roles: driver who is in charge of both the shared screen and the 3D display, and passenger who does not have control over the two displays. This idea actually went against the goal of collaborative learning, therefore we decided to give every member of the study group the same freedom of control: The group members can all have access and pull up information from their personal individual display to the shared display as well as the 3D projector. However, only the person who is occupying the Leap Motion is able to interact with the 3D visualization.

Should the system provide users with an individual view of the content?

One of the problems we observed during our requirement gathering phase was that individuals learn in different ways and at different paces. Even though the instructor may be explaining a concept by referring to an object or information on the shared screen, a learner may still want to view information, another object, or the same object in a different way, which may not be visible on the shared screen at the time. Instead of interrupting the instructor for providing appropriate content, we considered it important for each learner to have an individual view of the content. One of the counter arguments for not having a individual view was that we also found that adding an individualized view will cause the learners to get distracted resulting in reduced attention which would hamper collaboration in the learning environment.

We considered many sketches which provided learners with an individualized view of the content and some sketches which did not provide any individualized view of the content. We concluded providing users control and freedom over the content and the system important and narrowed down our sketches to ones which minimized learner distraction yet still providing learners with an individualized view of the content.

Sample Sketches:

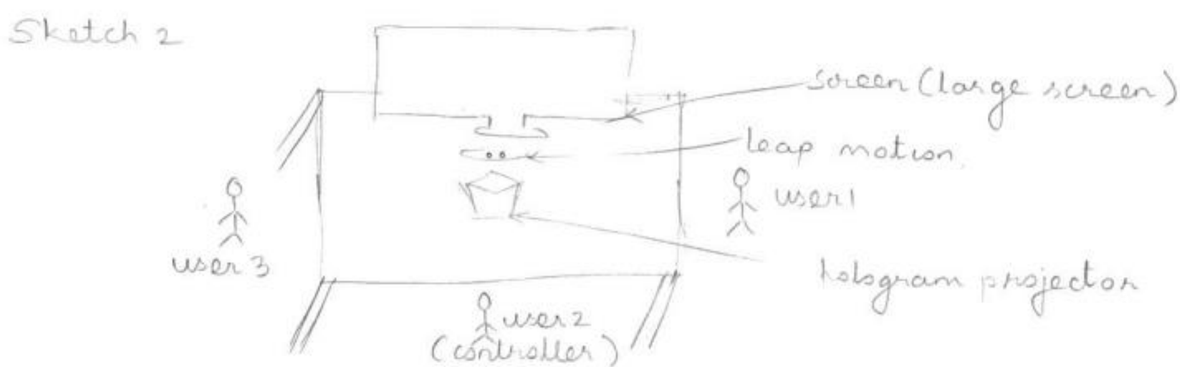


Fig 8: Eliminated Sketch of the Design Challenge 5

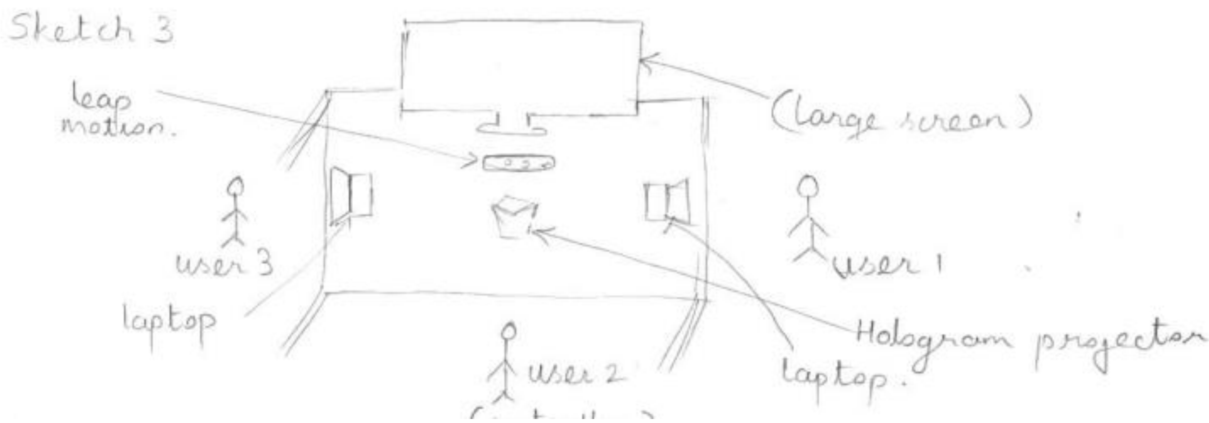


Fig 9: Final Sketch of Design Challenge 5.

How will the system allow learners to see an individualized view of the content and a shared view of the content being discussed?

Based on our user studies, we observed that for collaborative learning, the ability to clearly view common content is necessary. Having access to common content helps users discuss common points, perform common tasks, and more importantly, clearly understand what is being discussed or taught. Based on reasoning in design challenge 5, our team decided that having an individual view too is necessary in a collaborative learning environment. We considered various options which included HMD's, tabletops, large screens for shared content and laptops, dedicated areas in tabletops, tablets etc. for providing users individualized view of the content.

Design options with HMD's were rejected because HMD's do not encourage human interactions, cost too much, and may cause discomfort after being worn for a long time. For study groups, HMD's do not enable users to easily perform traditional group learning activities like taking notes.

Design options using tabletops were eliminated due to high costs. The tabletop we have access to was not big enough to effectively provide a group of learners with the ability to simultaneously view shared content, individual content and view of the hologram. Due to the lack of space, users would have to recall information from the shared content or individual content, depends on which content they are accessing.

Designs which included large screens and laptops placed on a table were chosen due to the following:

1. Large screens monitors or TV's are relatively affordable.
2. All users can comfortably view shared content on the large screen if placed at the edge of the table. Users can access individualized content on a laptop which is a common device used.
3. Users have simultaneous access to shared and individual content without both the content interfering with each other.
4. This setup enables learners to access all content and also perform human interactions while using the system.

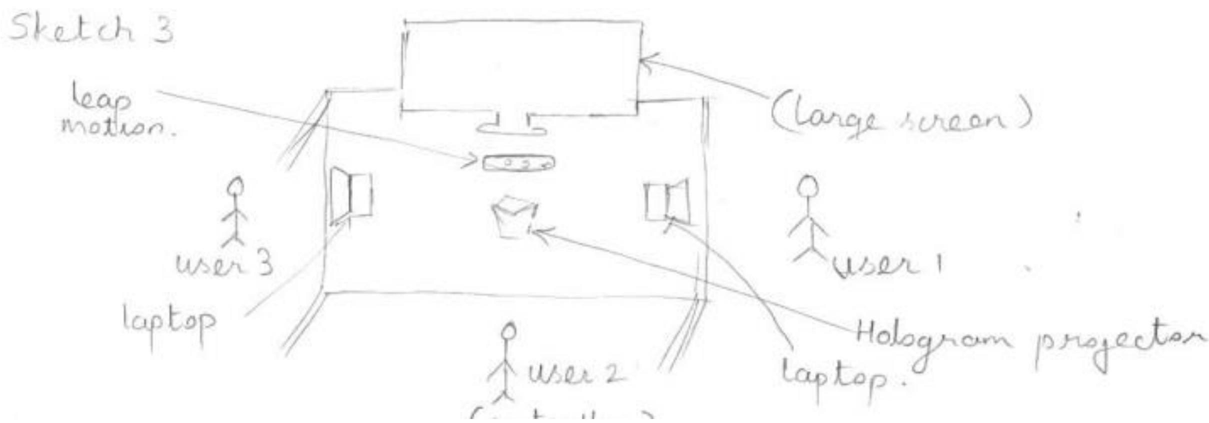


Fig 10: Final Sketch Design Challenge 6

How to display object parts which can be marked and how a driver can mark or point to an object part which is currently being explained?

In order to help group members, follow what the driver is talking about during a discussion, we plan to support a marking/pointing feature that follows the speaker's finger and highlights the corresponding area of the object on the shared screen and/or the 3D visualization.

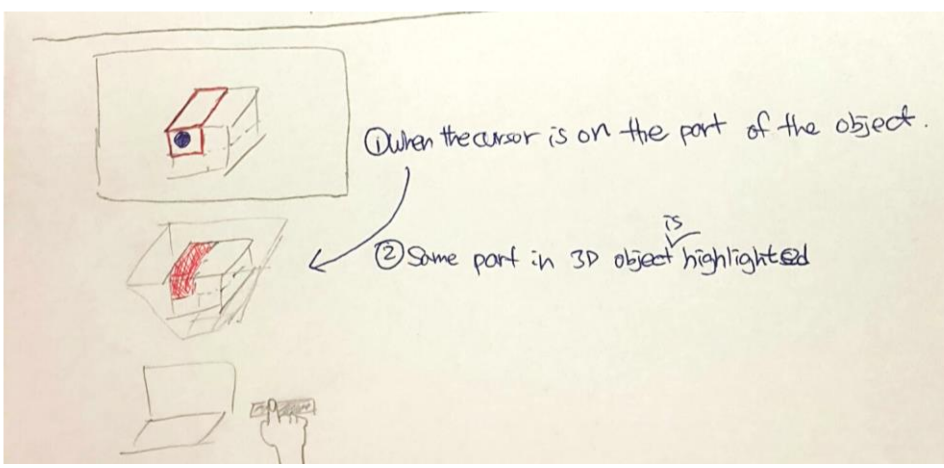


Fig 11: Our concept of marking/pointing. When the driver points to at the 2D object, the corresponding part of the 2D and the 3D visualizations will be highlighted.

8. How will the gestures made using leap motion and mouse and keyboard interactions with the system be made discoverable to the drivers?

Discoverability is a major issue with gesture based interactions. After iteration one, our team decided that this system will include a Leap Motion to recognize hand gestures. Our system will also provide users with mouse and keyboard interactions to enable participants to perform various functionalities. Hence one of the important design challenges we were faced with is discoverability of gestures.

To make gestures more discoverable we came up with and considered various sketches which included following aspects:

1. Shadow screens tutorials on startup.
2. Videos and help documents.
3. Access to gesture and interaction tutorials at any time while using the system.
4. Showing prompts on available gestures and how to perform the gesture when the user is in the vicinity of the object while using the system etc.

The designs in point 4 were discarded due to the fact they were found to be intrusive to the user while using the system. Video help designs were also discarded as they did not allow users to practice the gestures.

The design which included an option where the user is given an option to walk through a shadow screen tutorial when the application is started for the first time was considered. This designs enabled users disable this tutorial as per need. The user also could access this tutorial at any point while using the application. Choosing this design option enables user freedom, control, and flexibility over the system and provides users accurate help and guidance in practically practicing the gestures and keyboard and mouse interactions on dummy objects. In the shadow tutorial, the user has an option to select the gesture or keyboard and mouse interaction which can be performed by choosing from a menu.

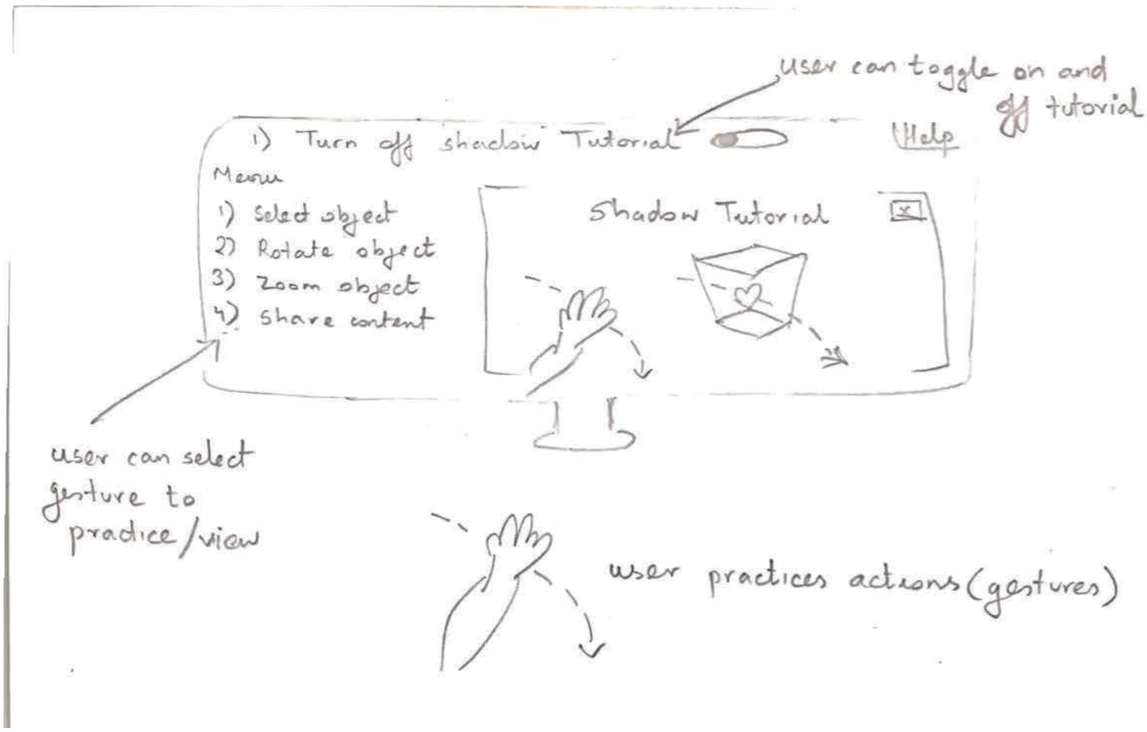


Fig 12: Final Sketch for Design Challenge 8