GNG1103

**Deliverable D: Conceptual Design**

**3D Printer Monitoring System**

Submitted by

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# Introduction

The objective of this deliverable is to develop an overall design concept for our project by categorizing and ranking various ideas that will allow us to design an ideal prototype. Each concept will be created using the problem statement as a foundation. Through the use of a previously formulated needs identification, each team member generates three to four different ideas that they will then evaluate using design criteria that has already been developed by the team. The use of a numerical index scale with weighted criteria allows all ideas to be effectively evaluated by the same scale. In the end each member’s highest ranked concept will be compared with all the other highest ranked concepts in order to select one final concept.

The purpose of a problem statement is to outline the problem at hand and is based off of customer’s needs. To develop concepts that are viable, it is essential that they are based off the problem statement. As a team, a problem statement was created using the identified customer needs and is as follows: “*CEED facility users need to remotely monitor available devices in the Makerspace and Brunsfield Centre with a device that can accommodate a changing workspace. They need to access this information with a user-friendly and attractive interface.”*

The team previously developed a list of functional and non - functional requirements that the final prototype would require to encapsulate. Some of the functional requirements that were taken into account when creating concepts include the real - time tracking of 3D printer usage, and the ability to display this information remotely. Some non - functional requirements include having a long product life as well as being easy for all CEED facility users.

In addition to the requirements created, a set of identified needs were also factored in to account when creating said ideas. The highest ranked needs for our project are that the product is maintainable, it’s user - friendly, it’s automated, safe for the surrounding environment, and affordable. Using these needs as well as design criteria such as user interface, safety, and cost, all team members were able to formulate ideas. A ranking system of 1-5 was used throughout this process, where 5 was ideal, 4 was very good, 3 was manageable, 2 was presenting problems, and 1 was counterproductive based on user needs.

# Team Member Concepts

## Amesh’s Concepts

**Concept 1**: The utilization of a motion sensor attached to the frame of a 3d printer that will sense movement of the nozzle and the plate to detect if the printer is in use. This information will be relayed to a microcontroller (arduino) that will be accessed by Ross dashboard and then view by users.

*Pros: Easy to use; easy set up.*

*Cons: Combined price of sensors and microcontroller.*

**Concept 2**: Using a pressure sensor on the inside of an sd card holder in order to sense if the sd card for various printers is there (not in use) or has been taken (in use). This information is then sent to a microcontroller for interpretation and then to Ross Dashboard for users.

*Pros: Simple; requires no additional user input.*

*Cons: Difficult to set up; Cost; Would require a new SD card holder to be designed.*

**Concept 3**: Manual entry system by a third party individual (CEED employee) that would input which 3D printers are available and which ones are in use. This will be accessed remotely and then broadcasted so users can see the available 3D printers.

*Pros: Easy to setup and use; cost efficient.*

*Cons: Requires a third - party user input; possibility of human error.*

### Evaluation of Amesh’s Concepts

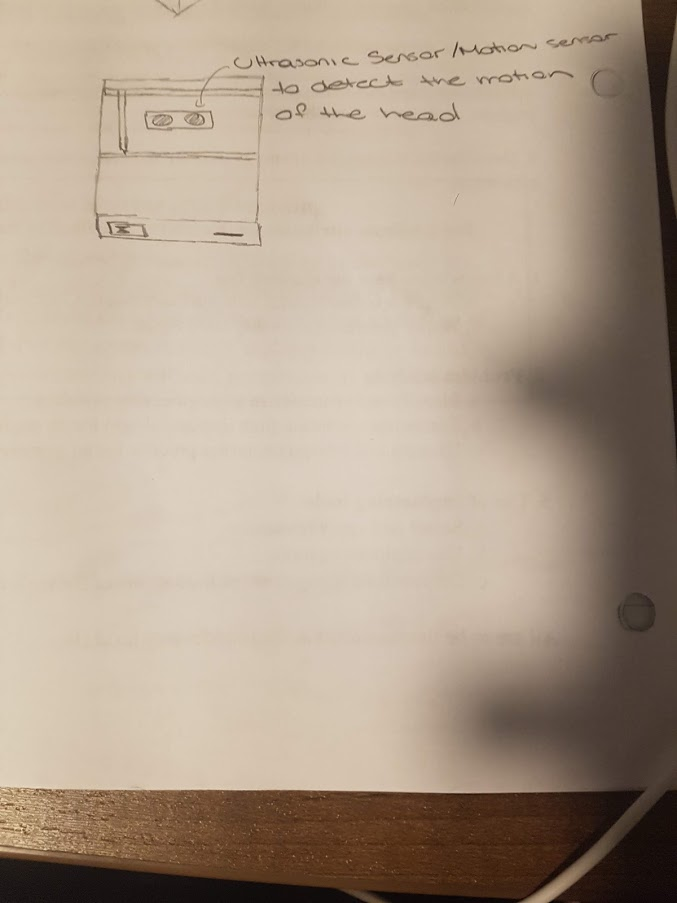
|  |  |  |  |
| --- | --- | --- | --- |
| **Criteria** | **Concept 1** | **Concept 2** | **Concept 3** |
| **Ease of Use** | **3** | **4** | **2** |
| **Product Life** | **2** | **4** | **3** |
| **Cost** | **1** | **3** | **4** |
| **Is it realistic?** | **3** | **3** | **2** |
| **Automation** | **4** | **3** | **1** |
| **Total:** | **13** | **17** | **12** |

## Qaiz’s Concepts

**Concept 1**: Using an ultrasonic sensor to detect the motion of the head of the 3D printer in order to detect if it is in use or not. This information could then be relayed with the use of an Arduino or a Raspberry Pi.

*Pros: Detects when the machine is in use.*

*Cons: Bulky, would not cover the entire space (might misread based on position of printer head), total price could exceed budget.*



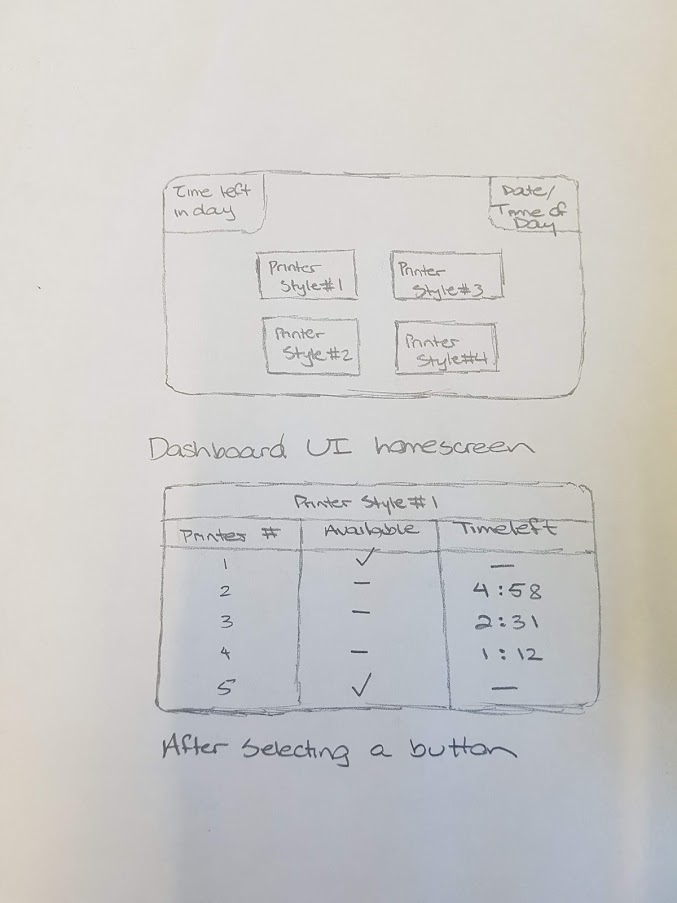
**Concept 2:** Octoprint / Cura. Using a USB connection to pull data on if the printer is being used and time left in a print.

*Pros: Provides information on whether or not a printer is in use with time left, accounts for printers in maintenance.*

*Cons: Steep learning curve with regards to software and external required hardware (multiplexer) in a short timeframe.*

**Concept 3:** Using pressure plate sensor on the printing surface to detect a shift in weight on the plate. This information would then be relayed back to an Arduino or Raspberry Pi to determine whether a printer is in use or not.

*Pros: Determines if the printer is in use or not.*

*Cons: Does not gather the time left information, could be very expensive, bulky.*

**Software Concept:** Idea for the front page for dashboard UI - displaying time of day, date and time left in the Makerspace/Brunsfield day.

### 

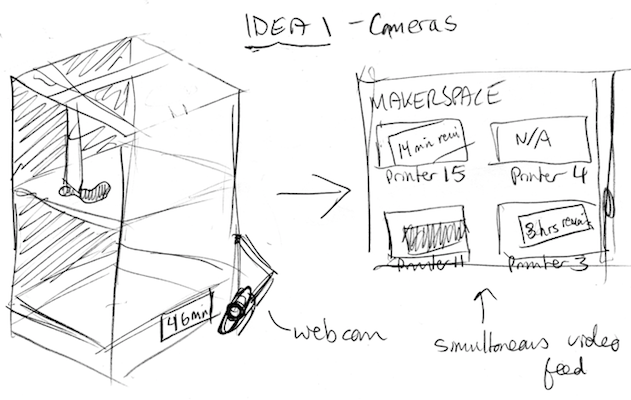
### 

### 

### Evaluation of Qaiz’s Concepts

|  |  |  |  |
| --- | --- | --- | --- |
| **Criteria** | **Concept 1** | **Concept 2** | **Concept 3** |
| **Ease of Use** | 4 | 4 | 4 |
| **Product Life** | 2 | 3 | 2 |
| **Cost** | 1 | 2 | 1 |
| **Is it realistic?** | 2 | 1 | 3 |
| **Automation** | 4 | 5 | 4 |
| **Total:** | 13 | 15 | 14 |

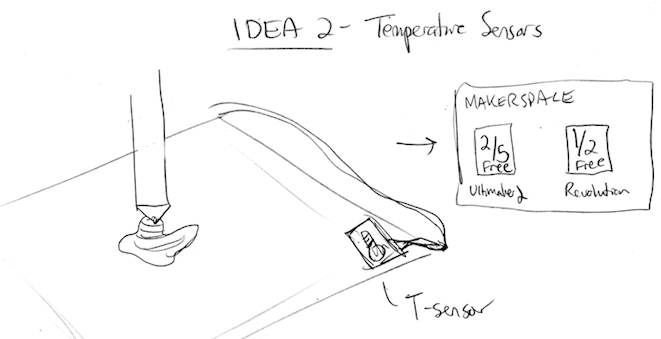
## Magdalena’s Concepts

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**Concept 1:**  Setting up a webcam to monitor the LCD screen of each 3D printer. This video feed will be constantly streamed on a website and users will be able to see if each printer is on, if each printer is functional, and how much time is remaining for each printer.

*Pros: Straight-forward system. Provides information given by printer.*

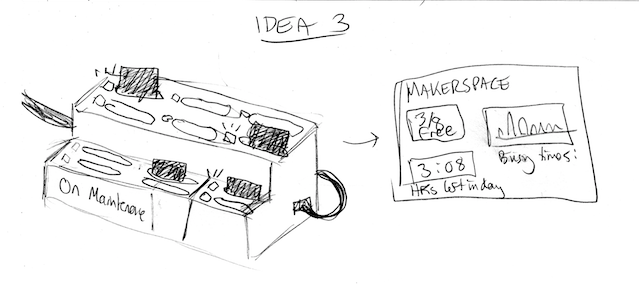
*Cons: Difficult maintenance and much staff intervention required. Information must be hunted down by the user. Cost of materials would inhibit scalability.*



**Concept 2:** Temperature sensors on the beds of the printers would indicate which machines are in use.

*Pros: Unobtrusive and easy to set up. Temperature information is easy to calibrate and interpret.*

*Cons: Difficult to troubleshoot. Would not provide information about time remaining or information about the printer.*



**Concept 3:** SD card holder where slots read if card is inserted and LED indicate that info is being read. Machines on maintenance get an unconnected row of slots. If card is present in slot, machine is being used. Could connect to pre-existing database for info on colour / current user.

*Pros: Takes up the least amount of space and set-up. Integrates well into existing system. Base it on the work that already went in to designing the current SD card organizer.*

*Cons: No immediate information on time remaining.*

### Evaluation of Magdalena’s Concepts

|  |  |  |  |
| --- | --- | --- | --- |
| **Criteria** | **Concept 1** | **Concept 2** | **Concept 3** |
| **Ease of Use** | 1 | 3 | 4.5 |
| **Product Life** | 2 | 4 | 5 |
| **Cost** | 1 | 3 | 5 |
| **Is it realistic?** | 3 | 5 | 5 |
| **Automation** | 3 | 5 | 4 |
| **Total:** | 10 | 20 | 23.5 |

## Lucas’s Concepts

**Concept 1:** A motion sensor could be installed inside the printers given that it does not interfere with the proper functioning of the device. When a printer is being used, the moving parts (the printing table, cables and nozzle), would trigger the motion sensors and by connecting those to Dashboard with an Arduino, we could create a system that lets users know which printers are being used.

*Pros: Non-invasive technology that could easily be applied to 3D printers but also other technologies that use moving parts. It would be easy to use and would not require much attention after the initial installation is complete.*

*Cons: High-fidelity, durable and high-quality motion sensors are expensive. Also, it would provide no information on how much time there is left for each printing. Also, wiring inside the printer could get complex given the high number of moving parts that need to be avoided.*

**Concept 2:**  A “sign in” system could be installed on every machine. Users would simply sign in by scanning their student card on a device similar to the one already in place in the Makerspace. By linking the device to an online platform using Dashboard, users would be able to see which machines are “signed in” and thus in use. Users would have to scan their card once again to sign out.

*Pros: It would very user-friendly. Also, the technology already exists in the Makerspace, we would just need to apply it to the 3D printers and link it to Dashboard.*

*Cons: Not very practical since users also have to sign out. People tend to forget about signing out, so without any supervision machines could remain “signed in” even if no one is using them.*

**Concept 3:** Another potential concept is a modified SD card reader inside of the machine itself. When users insert their SD card to begin printing, a pressure sensor at the back of the SD card slot would then be linked to a microcontroller.

We could link those to an online interface through Dashboard. If the pressure sensor is activated, meaning the card is inserted, the machine is being used. If it is not activated, then the machine is not in use since no SD card is inserted.

*Pros: Very reliable and easy to use once installed. Would require minimal support from CEED staff. Takes human error out of the equation since it removes any potential human intervention.*

*Cons: It would be very complicated to install since we would basically be modifying an already existing SD card reader design for every machine. This would create scalability and cost issues.*

### Evaluation of Lucas’ Concepts

|  |  |  |  |
| --- | --- | --- | --- |
| **Criteria** | **Concept 1** | **Concept 2** | **Concept 3** |
| **Ease of Use** | 4 | 4 | 4 |
| **Product Life** | 3 | 4 | 4 |
| **Cost** | 1 | 4 | 1 |
| **Is it realistic?** | 2 | 4 | 2 |
| **Automation** | 4 | 1 | 5 |
| **Total:** | 14 | 17 | 16 |

## 

## 

## Midas’s Concepts

**Concept 1**



(Fig 13. A proposed adaptable hardware and software design to add and remove SD cards).

The design of the SD card holder and the user interface must be easy to modify and use. With this in mind, the 3D printed card holder will be designed to have 3 slots per column and each column has an interlocking tab on one side and then a groove on the other to accept similarly printed another column. This would help facilitate an increase or decrease in SD cards available by simply reducing or increasing the size of holder. On the software end of this design, there will be buttons available to add or remove a column to integrate the same idea from hardware to software. This will help keep things simple as what will be presented in hardware will be observed in the user interface of Rossvideo’s Dashboard.

|  |  |
| --- | --- |
| *Pros:*   * Easy to modify on the fly to fit the available printers in Makerspace * Integrates well with Dashboard | *Cons:*   * Increased complexity in design * Not an essential component for the client(low priority) * May have lower durability with tabs and grooves |

**Concept 2**



(Fig 14. Laser/Sensor Reading attached to each printer).

This system would rely on a laser attached to the body of the printer and pointed towards the interior of the 3D printer. It would then detect movement of the nozzle based on if the laser was crossed to check if the printer is in use.

|  |  |
| --- | --- |
| *Pros:*   * Easy to visualize and understand | *Cons:*   * Will increase bulkiness * Will increase cost and maintenance |

**Concept 3**



(Fig 15. A webcam system used to monitor the space within the 3D printer. This will serve 2 functions: allow users to understand which printer is in use, and displaying a live feed to dashboard for people to view). This system would rely on a webcam and a live feed to Dashboard. The idea is that it will provide useful information to the available users on which printers are in use and how the projects are coming along. Furthermore, it may provide some entertainment to users as they view projects grow in the 3D printer.

|  |  |
| --- | --- |
| *Pros:*   * Simple concept to grasp and visualize * Provides a view into print job progress * Will also allow users to get a rough estimate on time left | *Cons:*   * Expensive to purchase cameras * Will require extensive troubleshooting and modification if any issue arises * Will require a larger power source |

**Concept 4**



(Fig 15. Basic homepage for Dashboard user interface).

It will display all active and inactive 3D printers sorted by type in a table of buttons. There will be a legend used to sort the type of printers and then an outline around the buttons to indicate if it’s in active or inactive use.

|  |  |
| --- | --- |
| *Pros:*   * All information is easily visible and summarized on one page * A lot less effort is required to see all the information one would seek for regular use | *Cons:*   * May be difficult to create an easily adaptable design. * If done wrong, it will feel cluttered and messy |

### Evaluation of Midas’ Concepts

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Criteria** | **Concept 1** | **Concept 2** | **Concept 3** | **Concept 4** |
| **Ease of Use** | ***4*** | ***2*** | ***3*** | ***5*** |
| **Product Life** | ***3*** | ***2*** | ***2*** | ***5*** |
| **Cost** | ***2*** | ***1*** | ***1*** | ***4*** |
| **Is it realistic?** | ***5*** | ***3*** | ***4*** | ***4*** |
| **Automation** | ***~~NA~~*** | ***4*** | ***4*** | ***4*** |
| **Total:** | ***14*** | ***12*** | ***15*** | ***22*** |

# Evaluation of concepts

After analyzing each concept provided by our team, we have chosen 5 of the best performing concepts to further analyze . Using the same values found earlier, we created a new decision matrix only containing our highest scoring ideas. Some of the concepts found during individual brainstorming had things in common, but our top ideas were all different.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Selection Criteria** | **Option 1**  **Amesh’s**  **Concept #2** | **Option 2**  **Qaiz’s Concept #2** | **Option 3 Magdalena’s Concept #3** | **Option 4**  **Lucas’s**  **Concept #2** | **Option 5**  **Midas’s**  **Concept #4** |
| **Ease of Use** | 4 | 4 | 4.5 | 4 | 5 |
| **Product Life** | 4 | 3 | 5 | 4 | 5 |
| **Cost** | 3 | 2 | 5 | 4 | 4 |
| **Is it realistic?** | 3 | 1 | 5 | 4 | 4 |
| **Automation** | 3 | 5 | 4 | 1 | 4 |
| **Total** | 17 | 15 | 23.5 | 17 | 22 |

#### Option 1 - Pressure-Sensing SD Card Holder (Amesh)

Amesh’s idea of an SD card holder is a promising one since it would provide quick and automatic information on which printer is being used through a Dashboard interface but also in person at the lab, where users would pick up the SD card from the holder. Disadvantages noted were cost and setting up the new card holder.

#### Option 2 - USB Printer Reader (Qaiz)

Qaiz’s idea of using a software such as Octoprint or Cura to gather information on all the 3D printer is a great one. By pulling out information about time remaining, which machine is in use and potential issues with the printer through a USB port would provide a solution that is the most complex of all the ones we have found. It would also provide a lot of information easily displayed to potential users. However, there would be a steep learning curve to master the use of such softwares and external required hardware, such as a multiplexer, and this course’s timeline might not allow for that.

#### Option 3 - SD Card Holder (Magdalena)

Magdalena’s concept is a very user friendly and easy to use idea that would require minimal installation and rely on pre-existing Makerspace technology and adding LEDs powered by Dashboard to it in order to enhance the user’s experience. It would also allow users to quickly see which machines are undergoing maintenance, which is convenient. However, the biggest flaw in this design is the lack of information on remaining printing time while the machine is in use.

#### Option 4 - Card Reader Sign-In (Lucas)

Lucas’s idea of a card reader similar to the one already in place inside the Makerspace is a very user friendly solution to the problem. It uses a technology already used in all of the CEED spaces, which more simplify its installation and scalability. However, it is not the most practical concept, since it requires that users tap in and out of the machine. This amplifies the risk of human error, as people could forget to do so.

#### Option 5 - Visual Interface (Midas)

Midas’s idea of a user interface displaying all available printers and indicating which ones are in use is a great idea. It would be very simple to use and users would not have to look very far to find the information that they need. Potential downsides to this solution are the difficulty to implement a system that would work well and be adaptable without feeling too cluttered and messy.

# Synthesis of Ideas

After going through our ideas and combining positive features that worked well together, we synthesized our ideas into 3 fully-functional solutions. Although we had a lot of overlap in certain types of ideas (ex: we had several ideas to use webcams on the printers, or motion sensors on the printer heads, or pressure sensors on the printer beds), we ultimately rejected these ideas as being unrealistic to use reliably in the Makerspace as they would require too much maintenance and interference on the part of staff. We felt that this did not match the spirit of the project, which was to automate a process to improve the experiences of all makerspace users, staff and students alike. We favoured ideas that took advantage of pre-existing technology in the makerspace as staff already have familiarity with how to use these devices and it will take up less space and create less work to use.

### Solution 1 - Interlocking SD Card Holder

This solution would involve a physical SD card holder similar to the one already in place inside the Makerspace, however it would detect if the SD card is in place and cross-reference this with information about the printer to determine how many printers are in use at any given time. This solution would integrate well with the existing system, meaning it would require little additional effort on the part of staff.

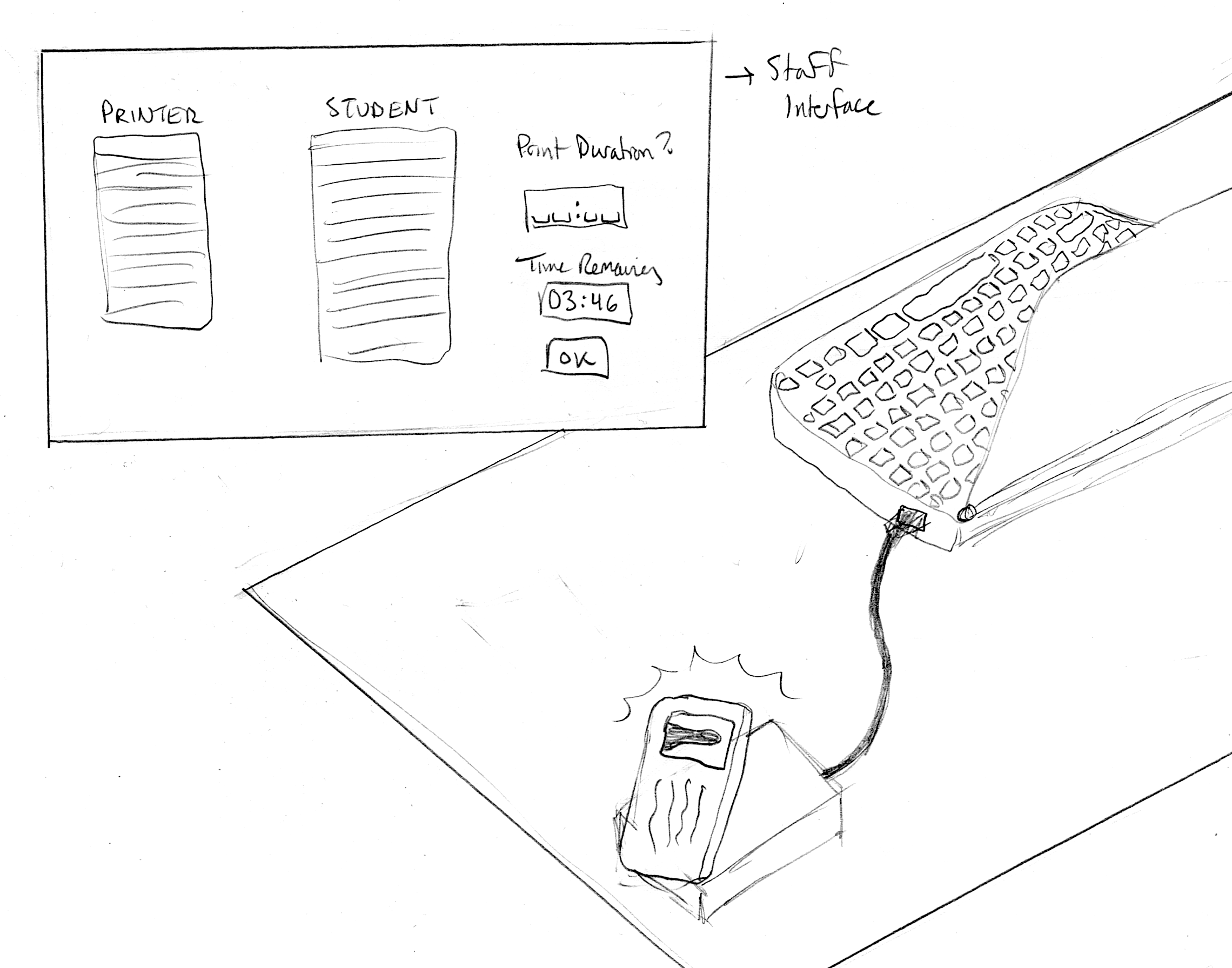
Features integrated from brainstorming sessions:

* Staggered card holder (Magdalena). This would make our system very similar to what is in place in the Makerspace, making it easy to navigate and easy to use by staff.
* Interlocking structure (Midas). This would mean this system could be scaled for however many printers exist in the Makerspace at any given time. We would need to make sure our code could handle additional pieces.
* Pressure sensor for cards (Amesh & Lucas). By using a binary sensor, we have an easy procedure to determine if the card is present in the holder.

Possible downsides:

* This system would not be able to detect or calculate the time remaining on the current print jobs, which is a feature that the staff have said would be useful. We might be able to build in the capability for the printer to connect to a database in the future.

Things to think about:

* We would need to determine how we could incorporate this system’s modularity in our code. This might require using multiplexers in each segment that attach to a processor.
* Feasibility of syncing data with user/time/printer data. We would need to investigate what exist architecture exists in the Makerspace, specifically how their databases work and how we could access this information on the fly through DashBoard.
* We would need to think of a clever way to get all the segments to work with our processor with little to no coding input from the staff.
* We would need to think of how the card slots would get printer information assigned to them.

### Solution 2 - Printer-Linked Card Reader

This solution would create a fillable form for staff to use when students want to take out a printer. It would connect to the existing card reader that is used to sign students in and out of the Makerspace. To take out a printer, the student would have to provide the estimated project duration to the staff member when they went to get the SD card and this would be updated on the UI. When the student leaves and signs out, the printer will automatically be made free.

Features integrated from brainstorming sessions:

* Student card reader (Lucas). This infrastructure and knowledge exists within the Makerspace and would not require us to reinvent the wheel for the RFID mechanism.
* Manual CEED staff entry (Amesh). By manually updating information like project duration, user, and printer number, there is a low chance of incorrect sensing along the way, plus the staff already fill out a comparable form when they sign out a printer.

Possible downsides:

* This system includes the least amount of automation. It would require the most staff intervention.
* This system might not account for when staff cancel a job because of printer failure and the student is not present to restart their job.
* This system might not accurately reflect project duration as a student may print consecutive prints or spontaneously change their print time. They would likely not return to the staff to update this information.

Things to think about:

* We would need to determine how to differentiate between when a student leaves the CEED centre for a few hours vs. when the student leaves the Makerspace for the day, either because they forgot about their project or because their project is finished.
* Database architecture. We would need to determine what infrastructure already exists..

### Solution 3 - USB-Connected Printer Status Reader

This solution would involve connecting to the back of the printers to obtain the g-code and status of each printer and then using multiplexers to process all this information with a single processor. It would be able to access all information about print duration and printer status with instantaneous accuracy and would require minimal input from the staff and users to upload to the UI. This would be the most software- and code-intensive option but provide all the data requested by the Makerspace.

Features integrated from brainstorming sessions:

* USB pull to get information straight from the printer (Qaiz). All the required information could be taken from one source without needing to sync up many devices just to read one printer.

Possible downsides:

* After a preliminary test in the Makerspace and several hours of looking through forums on the Cura, Octoprint and Ultimaker websites, we determined that with our current level of software knowledge, this project might require a lot of intermediate steps between different software. For example, we would need to learn how to connect to a Raspberry Pi with multiplexers, then we might need to pull the g-code using Cura or Octoprint which might require connecting Dashboard to a third-party app or website. As we would be learning how to use all of these programs and devices at once, this solution might have an enormous learning curve and we might not be able to learn everything we need within the given time frame.

Things to think about:

* We would need to determine how to get the g-code from the SD card using the USB-B port.
* We would need to learn how to integrate multiplexers with a Raspberry Pi (chosen over Arduino because of it’s improved processing power).
* We would need to determine how to make this scalable - how to build-in the capability to connect more printers in the future.
* We would need to determine how this solution could work with the printers in the Makerspace that aren’t the Ultimakers.

### Final Ranking

As stated in the introduction, the ranking system we are using is a scale of 1-5, where means the solution matches the criteria perfectly, 4 is a very good fit, 3 is manageable, 2 means the solution presents problems, and 1 means the solution is counterproductive based on user needs.

We are evaluating ‘Ease of Use’ based on how easy it will be for staff to use on a regular basis and how easy it will be for students to use. We are evaluating ‘Product Life’ based on how long we believe the parts will withstand repeated use and how long we think the solution will work with changing Makerspace conditions. We are evaluating ‘Cost’ based on how well we think this project will fit into a $100 budget if scaled to all the printers in the Makerspace. We are evaluating ‘Is it realistic?’ based on how likely it is that we can finish this product given our current skill levels and time restrictions. We are evaluating ‘Automation’ based on how well it conforms to the spirit of this design project.

|  |  |  |  |
| --- | --- | --- | --- |
| **Criteria** | **Solution 1** | **Solution 2** | **Solution 3** |
| **Ease of Use** | 4 | 3 | 5 |
| **Product Life** | 5 | 5 | 3 |
| **Cost** | 4 | 5 | 4 |
| **Is it realistic?** | 5 | 4 | 1 (Note 1) |
| **Automation** | 4 | 1 (Note 2) | 5 |
| **Total:** | 22 | 18 | 18 |

*- Note 1:* We gave this solution a 1 for realistic because with our current skill level, we do not think that we will be able to complete this project within the given time frame.

*- Note 2:* We gave this solution a 1 for automation because it does not seem to create less work for staff and users.

### Synthesized User Interface

We have also combined our ideas for our final UI. This UI will include a visual account about current printer status that uses colour-coding to represent both how many printers are functional in the Makerspace and how many of those printers are currently available (Midas Concept 4). We will also include a summary table that can build in future functionality of ‘time remaining’ and that will automatically scale to the number of printers in the space (Qaiz Concept 3). This interface will also contain information such as the time remaining in the day and the types of printers in the space (Midas, Qaiz, Magdalena).

# Final Design

After evaluating our designs, we have decided to pursue Solution 1: Interlocking SD Card Holder. We believe that this project is scalable, cost-effective, easy to use, and will be possible to finish with our skill set and time constraints. Most importantly, it fulfills our problem statement of being able to monitor 3D printer use while also being adaptable to a changing Makerspace. While this solution does not allow us to display the remaining time on current print jobs, something that was brought up as useful by the Makerspace staff, we have decided to investigate ways to build in this capability for the future. This might involve connecting to a database that has yet to be created or designating space on the UI for this information that can be filled in at a later time, or some other option that we have not found yet.

### Final UI

This interface will be constructed using Ross Video DashBoard. It will contain both attractive and easy-to-understand visual elements as well as a summary table for those looking for more specific information. We will need to determine what information we can incorporate as we determine what kind of information we will have access to, but we will also build in capabilities that we are not yet equipped for, such as time remaining on individual print jobs.



### Information Flow

We predict that the primary algorithm to be used in this design will resemble the following.



# Next Steps & Continued Learning

Now that a final design has been outlined, a future plan must be made in order to ensure that the project moves forward on task and on schedule. To achieve an effective final product, we need to be able to learn and understand a variety of things. To start, we need to decide how exactly we are doing to detect whether or not the SD card is in it’s holder. Research needs to be done on the following:

* What type of sensor would be the most optimal way to detect the position of the SD card
* How is the information being relayed back to a server and then displayed on Dashboard
  + Microcontroller (Arduino or Raspberry Pi) that will read the value and relay the information
* Familiarizing ourselves with the Dashboard software in order to create the appropriate UI
* What type of power source is going to be used to power the microcontroller and the sensor
* How to integrate all of the data into the Dashboard Software
* Familiarizing ourselves with software that can be used to 3D print aspects of our project

Looking forward, our next steps include performing the above research in order to create the ideal solution to our problem in the given timeframe, creating a bill of materials / estimated overall cost for the project including each prototype and looking to begin creation of our first prototype.