School Security System

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Executive Summary

This project sought to create value by defining and exploring a unique engineering challenge faced by the team's user group, high school administrators. By evaluating end user needs and market dynamics, the team developed, prototyped, and tested an innovative solution that would create positive socioeconomic impacts.

To begin, an interview was conducted with a high school administrator, and it was discovered that a primary user concern revolved around monitoring when all individuals entered/exited the school while keeping unauthorized individuals out. To address this concern, the team conducted research into existing school security solutions and high school administrators' perceptions of them. Key factors considered in research included school budget constraints and impacts on students and faculty. Through their research, the team found that a lack of effective security measures to monitor student entry/exit in schools often creates extra work for administrators and faculty, taking away time and resources that could be dedicated to improving student education. Another important takeaway is that security concerns among students and parents can negatively impact learning and morale in schools and communities. The biggest drawbacks administrators face in implementing improved security measures are that they can be expensive, or too complex to maintain and integrate smoothly. Based on these research results and user interviews, the team determined that to create value for the end user, they should focus on coming up with a simple, reliable, cost-effective, and efficient solution.

Three potential solutions were brainstormed by the team: face scanners, license plate scanners, and student/staff ID card readers. The team determined that the face scanners could be seen as invasive towards student privacy, and that the license plate scanners did not thoroughly meet the user needs as they would not accurately track nondriving students that enter and exit the building. Therefore, the team designed a compact device equipped with a screen and an RFID sensor that reads valid school ID cards to unlock school doors, simultaneously recording the date and time for attendance purposes. If an invalid ID card is scanned, the user is prompted to go to the attendance office and be manually checked in. The team utilized an Arduino Mega 2560 board, several Arduino components such as an LCD and lay and MFRC522 RFID sensor, and hardware from the tools shop to create this device. By requiring individuals to use this device to both enter *and* exit the facility, high school administrators can effectively keep unauthorized individuals out and prevent students from leaving when they should not be due to the automated attendance tracking.

In conclusion, this project successfully addressed the need for enhanced school security and attendance tracking among high school administrators. After thorough research and iterative prototyping, the team was able to create the device to scan student and staff ID cards and record attendance. The results of this work highlight the significance of user-centered design and incorporating end-user feedback into engineering solutions. In the future, based on the fabrication process of the prototype, the team recommends access to more advanced tools/resources and time when creating the final product design.

Problem Definition Review

1. Introduction

The team was tasked with designing a project that creates value for a user group and their identified problem. In this problem definition review, user interviews were conducted by each team member and the user group high school administrators was chosen to focus on. The team focused on a high school administrator's task of managing building safety and security. Research and user interviews outlined in this document show that a problem faced by high school administrators is not having a way to track the flow of students, staff, and visitors into and out of the building. With rising concerns for student safety in America, it is imperative that this problem be addressed.

2. Problem Definition

a. User Group Selection

The team individually interviewed people from the user groups undergraduate researchers, software developers that work from home, nurses, and high school administrators. Pros and cons of selecting each user group were considered but the team chose to focus on high school administrators due to time and budget constraints. Since the team is expected to complete this project by the end of the semester, designing for school administrators seemed more attainable than the other user groups that were interviewed. The team determined that prototyping solutions for problems that high school administrators face as a user group would be more cost effective than prototyping for the other user groups that were reviewed. Potential gains for users and stakeholders, and impacts on secondary markets are discussed.

b. User Persona

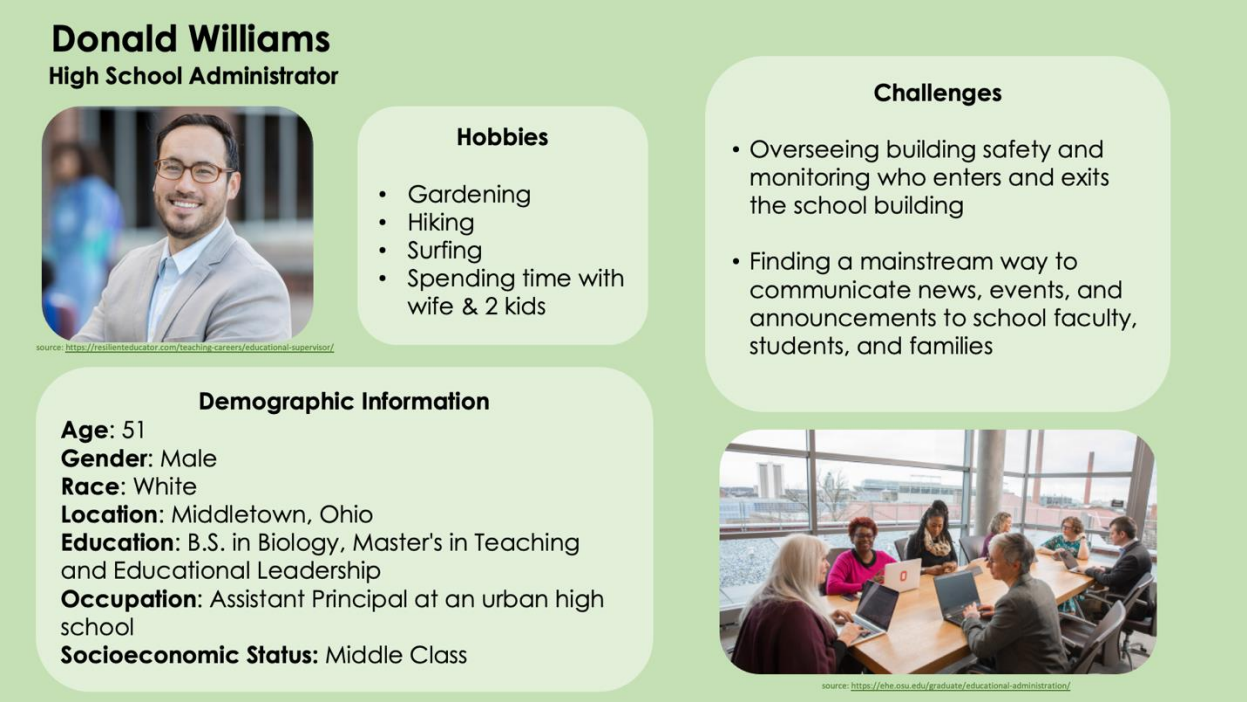

Figure 1: User persona for a possible end-user

c. Pains and Tasks

Task 1: Overseeing building safety at the high school
Pains:

1. Administrators cannot track who comes in and out of the building unless it is through the main entrance.
2. Students and staff open/hold doors for other people to let them in resulting in unauthorized individuals entering the building.
3. There is not enough space in severe weather shelter areas to fit all students at the school.

Task 2: Communicating news/events/announcements to faculty, students, and families
Pains:

1. Many students and families speak languages other than English.
2. Some people do not check their emails regularly resulting in miscommunications.
3. The school communicates on many different forums, so information is not always communicated.

Summary:

The tasks high school administrators oversee surrounding building safety and communication between staff, students, and families were discussed in the most detail. The interviewee mentioned that there are screening systems to get into the building's main entrance but there is currently no system that keeps track of who enters and leaves the building through other doors. Another pain regarding building safety is students and staff holding outside doors open for others. This can result in unauthorized individuals entering the building undetected. The interviewee also voiced concerns about not having enough room for all students and staff in severe weather shelter areas, leaving some people at a higher risk during weather threats. There are also multiple systems that the district uses to communicate with students, staff, and families which can sometimes lead to confusion. In urban districts, many students and families do not speak English. Language barriers can cause misunderstandings and make attending school increasingly difficult. The interviewee mentioned that one of the biggest frustrations in combating these pains when working in an urban school district is the lack of staff and funding.

3. Research Plan

The goal of this research plan is to gain further insight into the various security methods used by schools, as well as to develop an understanding of how school administrators feel about these security systems, and the overall impact that they have had on schools and their employees. The research questions outlined in the table below consider aspects of school security such as the costs of relevant security technologies, administrator perceptions of safety systems, and the benefits and drawbacks of certain security methods. Journal articles, news articles, surveys of teachers and school districts, and interviews with students and administrators can be used to obtain both qualitative and numerical data relating to these topics. This information can reveal which security methods have been working for schools and which have not, the importance of effective security, and what issues may be holding administrators back from implementing the safest and most efficient security methods in their schools. Note that some administrator interviews or surveys may contain personal information about the interviewee's experiences. Researchers should make sure that the interviewee's identity remains anonymous, and that any information that is shared or used is done so with their consent.

Table 1.
A chart with a list of research questions and data that may answer it

Research Question	Qualitative Data Collection	Quantitative Data Collection
(**RQ1.1)** What security measures do schools currently have in place? **(RQ1.2)** How effective are these measures and how do the administrators and students feel about them?	Recorded interview with a 9th grade student about current school safety [5].	Online article about current security mechanisms adopted in schools and details how widely adopted they are [2]. Numerical survey of school administrators on the effectiveness of certain school security measures [10].
(RQ2.1) How do urban schools track who enters/leaves the building? **(RQ2.2)** How do urban schools ensure unauthorized individuals cannot enter?	Journal article about a biometric recognition system for letting authorized individuals into school buildings in New Jersey schools [11].	
(RQ3.1) Do parents feel safe sending their children to school with the current security system? **(RQ3.2)** How will schools get parents on board with new forms of security measures?	Discusses the debate regarding the privacy of students when taking new/advanced security measures [1], [3].	Provides analysis and trends of statistics from surveys conducted to gauge parent school safety concerns [4].
(RQ4) What are the potential effects associated with an unauthorized individual entering the building?	Interview with students who experienced the Parkland mass shooting [7].	
(**RQ5)** Do urban schools have the money to ensure their building is safe for their students/faculty?	A school district responding to frequent questions regarding current security mechanisms in place and how effective they are [8].	Dissertation on the effects of a school shooting on security budgets and practices [6].
(**RQ6)** How much does it cost for a school to implement new forms of security systems (scanners, CCTV, etc.)?	A recorded interview with a superintendent of multiple school districts discussing the challenges of public-school funding [12].	Analysis of the costs of school security tools used by a Texas public school district [9].

4. Research Results

a. Creating User Value

Task in Focus: Overseeing building safety in the high school

i. Pains

1. Administrators cannot track who comes in and out of the building unless it is through the main entrance.
2. Students and staff open/hold doors for other people to let them in resulting in unauthorized individuals entering the building.
3. There is not enough space in severe weather shelter areas to fit all students at the school.
4. Cincinnati school district found that many of their students were losing student ID cards used to facilitate the school security system [3]. It can be expensive to replace these.
5. Certain security measures may result in pushback from parents, as a school district San Antonio was taken to federal court by a student's family for using GPS tracking to monitor attendance [3].
6. Completely digital security systems are at risk of being hacked – parents are concerned about where their children's personal information is going [1].
7. Certain current security measures may lead schools to feel like prisons. [8]

To maintain building safety, administrators must track who is entering and exiting the building during school hours. But at some urban high schools, administrators can only track who is coming in and out of the school's main entrance [A.2]. Students and staff often open and hold doors for other individuals to come into the school building [A.2]. There is no way to ensure these individuals are authorized to enter which puts a threat to building safety. Another pain high school administrators must handle is keeping students and staff safe during severe weather threats. However, with the current building layout and high student population, there is not enough space for all students to fit in severe weather shelter areas [A.2].

Upon conducting further research, the team discovered several new pains associated with the task of implementing building security. The most pressing of these was the privacy concerns of parents regarding their students' personal information being recorded by security systems. If a student were to lose their student ID, anyone who found it would have access to an alarming amount of information, and it would also be costly for the school to replace them. School administrators will have to take on the additional task of creating opt-out protocols to avoid any controversy surrounding privacy concerns [3].

ii. Gains

1. Parents will feel safer sending their kids to school, as they will be able to keep track of when their children have made it to school and are notified sooner if an incident occurs [3].
2. Staff will also feel safer going to work, creating a more positive workplace attitude.
3. Administrators can direct their focus onto pressing issues alongside building safety.
4. School will get better press and positive social influence in the community.
5. Students will be prepared and safe in the event of danger.
6. A safer environment with an organized attendance system will positively impact student education – especially for high school students who have been known to leave school without permission.
7. Students will be able to have more fun while learning, and it would also lead to students being less tense and feeling safer [5].
8. Safety risks like shootings will be denormalized, receive less press, and therefore would occur less [5].

If a high school building is safe, there will be many benefits to student education and the peace of mind of parents and staff. The consequences of an insecure building can be detrimental. For example, after the Parkland school shooting, Hogg a student at the high school described it as "sheer terror" [7]. If building security is maintained, staff and students will not have to worry about the chance of an unauthorized individual entering the school with malicious intent. This will allow students to focus on their studies and teachers to focus on teaching. Maintaining building safety is also only one of many issues which administrators deal with. If a better solution for building safety is implemented, administrators would be able to dedicate their time to other pressing issues.

iii. User Needs Chart

Table 2.
A chart with determined user needs, the description of the need, supported research if applicable, and the team's predicted ranking of each need.

User Need	Description	Predicted Rank (1 = Best)
Simple	It should be simple enough for administrators to be able to delegate the task of implementing the system, so that they may focus on improving other areas of the school.	5
Reliable	It should consistently work correctly and should remain functional long term, so that administrators do not have to worry about constant repairs.	2
Efficient	The design should be systematic and work quickly.	3
Affordable	The design should fit within a high school's budget so that the school can afford the technology without sacrificing other programs important to student success at the school [12].	4
Ethical	The implemented technology/design should not violate any individual's privacy/rights [1].	1
Accessible	The design of the security system should accommodate any students/faculty with disabilities.	7
Adaptable	The security system should be easily updated to accommodate new students/changes in the school. Schools continue to grow, with enrollment in public schools increasing by 11% from 2021 to 2023 [19].	6

User Needs Chart Discussion:

The team developed a list of 7 user needs which, if fulfilled, would allow high school administrators to implement a school security system that effectively monitors the individuals entering/leaving the building without resulting in excessive work from the administrators. As shown in the chart above, the team determined that the most important user need is that the security system is ethical, such that students and parents are willing to comply with the system's requirements. Several attempts at school security systems in the past have been too invasive, and consequently, students were not willing to participate [3]. For the security system to be as effective as possible, there should not be resistance from students/staff to the new protocols. The team also ranked efficiency and reliability high in importance, because the new security system should consistently function correctly, and should not take a significant time out of the school

day. Finally, the team initially predicted that affordability and accessibility should not be as significant because it seemed more important to have a fully functional security system. However, this was changed when the pairwise-comparison algorithm was used to rank the user needs.

iv. Pairwise Comparison Chart

Table 3.
A comparison chart which compares the user needs to determine the most important need

	Simple	Reliable	Efficient	Affordable	Ethical	Accessible	Adaptability	Total	Normalized	Predicted
Simple		0	0	1	0	0	1	1	**1.0**	2
Reliable	1		0	1	0	0	0	2	**2.3**	4
Efficient	1	1		1	0	1	1	4	**5.0**	3.5
Affordable	1	0	0		0	0	0	1	**1.0**	3
Ethical	1	1	1	1		0	0	4	**5.0**	4
Accessible	1	1	0	1	1		0	4	**5.0**	1
Adaptability	0	1	1	0	1	1		4	**5.0**	2

Pairwise Comparison Discussion:

The predictions the team had initially made ranked accessibility as one of the lowest priority user needs, and reliability as one of the highest. The rationale behind this was that a security system should primarily be able to do its job correctly and do so consistently. However, during the actual process pairwise comparison, the team's discussion around the topic revealed that that implementing a security system that could not be used by students/faculty with disabilities was impractical because the purpose of a security system is to protect *all* individuals in a building.

After research, the team found that for many schools, the funding received is dependent on the area in which the district is located. This has resulted in disproportionate funding to districts, even forcing schools to make staff cuts. Making staff cuts then leads to increased class sizes, which decreases the teacher-to-student ratio, effectively reducing the quality of education being received by each student [12]. Using school funds to implement an efficient and reliable security system should not diminish the quality of education and opportunities available to students, which is why affordability will be prioritized more in the team's design moving forward.

b. Market Characteristics

v. Stakeholders

Table 4.
A visual representation of how various demographics may be impacted by the product design.

Stakeholder	Positive Impacts	Negative Impacts
Parents	Parents will have a sense of security sending their children to school knowing that they will be safe	Tuition may increase for private schools which are not funded by taxpayer money.
Students	Students will feel safer while in school, which improves their focus towards their education	Freedom within the school may be limited, it may be a larger hassle to enter school.
Teachers	Teachers will be able to focus on educating and mentoring students rather than spending extra time dealing with student safety issues	Teachers may have to be trained how the design works and may be an increased workload for them to tend to the system
Security company manufacturers	Their business will gain recognition and will lead to more profit. Currently, only 3% of schools' nationwide implement systems by the company Zonar Systems. An increase in schools using this technology would result in much needed recognition [3].	Manufacturers will have to find more resources / money to spend on developing security technologies to supply to the schools.
Taxpayers	Increased property value because more people will want to move and send their kids to that school district	Taxes may rise to accommodate the new security system in the school budget (in the case of Public Schools).
Local Police Departments	Will have a larger presence in the community as they will interact daily with school faculty/students.	May have to add extra work hours/create new positions if the school security system involves an on-call officer.

vi. Market Size

Size of Market: 59,522 high school administrators

Between 2019 and 2020, there were a total of 23,519 public and 3,626 private high schools in the United States [15]. Depending on the size of the high school, a school can have between 2-6 principals/administrative staff. In the case of public schools, there were a total of 226,300

primary & and secondary administrators [17] and 22.8% of these individuals worked at the high school level [16]. Thus, the team concluded that the market size for public high school administrators is approximately 51,597 individuals. Using the ratio of public to private high schools (23,519:3626), the team derived the market size of private high school administrators to be 7,955 individuals. Thus, the total market size of high school administrators is approximately 59,522. This means there is an even larger market of teachers, parents, and students impacted by school safety policies. If more solutions to protect high school buildings are designed, it would create positive effects for the entire market.

Trends Within Population: +/- 1% change in the next 10 years

From 2022-2032, employment for primary through secondary education administrators is predicted to remain within 1% of the current employment [18].

Secondary Markets:

1. Airports: Although airports already have extensive security procedures, a new design could increase the efficiency of security checks, resulting in shorter wait times at TSA.
2. Hospitals: Hospitals should be secure institutions so that medical personnel may treat patients without worrying about their own safety. There may be situations in which security technology is required either to keep certain threats out, or even to keep certain patients from leaving.
3. Labs: Sensitive and essential information is kept in several labs, along with experiments and set ups which can be very delicate and prone to damage if even the slightest disturbance occurs. Therefore, many scientists may benefit from security systems in their labs to ensure that no information/experiments are tampered with.
4. Government Buildings: Similar to labs, sensitive information essential to the country's wellbeing is contained in several government buildings. Additionally, the safety of government employees is also a concern, given certain events in the history of the United States in which many government employees were put in harm's way.
5. Banks: Banks require several layers of security due to the valuable assets contained in their chambers such as currency and important documents, which are at risk of being stolen without strong security.

vii. Current Alternatives

Table 5.
Comparison of user needs and whether they meet specific criteria

User Needs	Microchip Student IDs	Biometrics	Metal detectors	Secured vestibule	Security Staff
Simple	✕	✕	★	★	★
Reliable	★	★	✕	✕	✕
Efficient	★	★	✕	✕	★
Affordable	✕	✕	★	★	✕
Ethical	✕	★	★	★	★
Accessible	★	✕	✕	★	★
Adaptable	★	✕	✕	✕	★

The current alternative matrix shows there is no existing form of school security that meets all user needs. One trend that can be seen is that affordable solutions are not reliable and efficient. In an interview about school safety policies, police response time to school-related incidents is reported to be under three minutes [8]. This level of efficiency is great in maintaining school safety. However, security personnel are one of the leading expenses in school security measures [6]. Schools have limited budgets and can only allocate a portion of that to security purposes. To maximize school security, it is ideal to have a solution that is both affordable and reliable. Also, all the current solutions which are reliable and efficient are either unethical or inaccessible. A study found that an estimated two-thirds of school districts had facilities that posed physical barriers for students or teachers with disabilities. However, 70% of schools reported that while they had planned upgrades or renovations geared towards improving accessibility, they were facing issues with securing adequate funding for these projects [20]. In the team's research, they have discovered in an interview with a school district that metal detectors are not reliable or effective. Instead, it is important for students to regularly practice drills and emergency protocols [8]. Based on this, a more refined goal for the team will be to create a design that will be affordable and efficient at the same time.

5. Value Proposition

Ensuring the safety of students and faculty in the school building is important to high school administrators. After conducting a user interview and research, the team determined that administrators are concerned student and faculty safety is put at risk due to insufficient security protocols. This is because it is hard to keep track of who is entering/leaving the school buildings [A.2] and districts do not have enough funding to implement proper security solutions [12]. The team plans to create a security product for high school administrators that is reliable, efficient, and simple to implement while also being affordable and non-invasive. Although the team's target user group is high school administrators, research shows that improved security solutions could also benefit other institutions with strong security needs. This could include airports, banks, labs, hospitals, government buildings, and other establishments where valuable information is kept.

6. Design Focus

The team plans to create a product that makes it easy for high school administrators to guarantee building security in high schools. After conducting research, the team determined that the design should be within a high school's budget and should not violate a student's privacy and rights [12] [1]. Current security solutions are resulting in pushback from parents due to being invasive of the privacy of students, making schools feel like prisons, and expensive to maintain [3][8][4]. The team wants to create a design that is both reliable, efficient, and affordable. The design should guarantee the safety of students while also promoting a nurturing environment so that students are eager to learn. A successful design should also generate enough positive discussion within the community so that taxpayers are satisfied with the reallocation of funds towards security in a school district's budget. After conducting user interviews, the team originally decided to select high school administrators as the user group of focus. The pains associated with managing school security in high schools is a relevant and pressing issue in the current state of the country. Originally the team identified that high school administrators face difficulty tracking students entering and exiting the building. After conducting research, the team examined current security measures high school administrators take. It was concluded that current measures that are affordable lack reliability and effectiveness. Now, the team aims to create a solution that is reliable, affordable, ethical, and cost effective.

Concept Development Review

7. Concept Brainstorming and Ideation

a. Process Description

To begin the brainstorming process, the team first spent about five minutes creating bad ideas to help high school administrators manage who leaves and enters the school building. The team's bad ideas consisted of invasive measures like microchipping students and scanning QR codes that could be accessed by anyone. Next, each team member developed a rough sketch of a potential design. The designs were passed in a circle and each team member took turns adding their input and concerns to the designs. Additionally, each team member spent time designing an individual sketch. The team focused on making designs that were efficient, ethical, and accessible since these user needs were determined to be the most important. To ensure efficiency, the concepts are designed to allow many students to sign into and out of the school building at the same time. Ethics were considered in the design process by brainstorming ideas that were noninvasive and could have simple opt-out measures for students and parents. The planning of the concepts featured accessibility in that most students could use the systems. One of the team's main priorities was to make an affordable design. This means that the team is constrained by a budget. Schools have limited funding, so it is important for the team's design to be affordable.

b. Brainstorming Results

The results of the brainstorming session had similar concepts, as all designs incorporated some form of scanning to allow access to the school. The team ended the brainstorming process with three potential ideas:

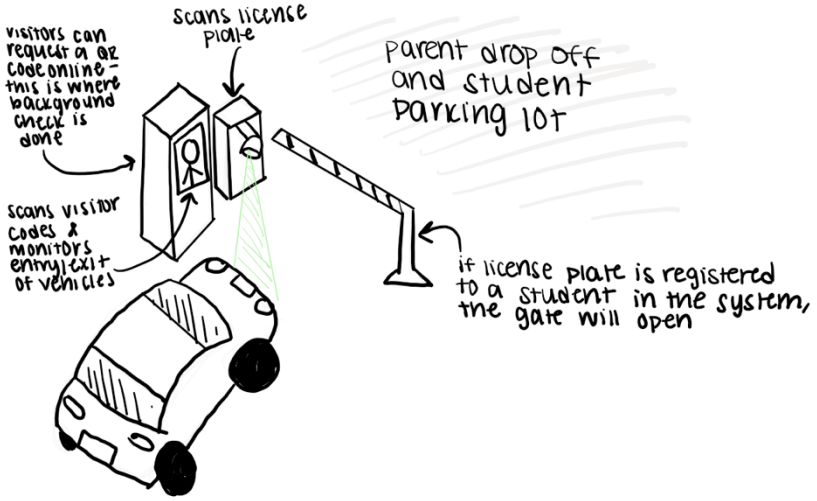

Figure 2: Concept drawing of license plates being scanned to allow access into the facility

1. **Facial Recognition Software:** The first idea was facial recognition software used to monitor individuals going in and out of the building [See A.4 for visual representation]. Students would first enter the secured vestibule, where their faces would then be scanned by cameras equipped with facial recognition technology. If their faces are recognized by the system, the students are marked present and may proceed through the second set of doors. If there is an unfamiliar face, all doors will automatically lock. Any visitors will have to go through the office, where there will be a background check done. This addresses the user needs of being reliable, efficient, and simple to maintain because all the work is being done by the cameras, so the office and administrative staff will have to do little work themselves in terms of tracking attendance and monitoring security. This is also accessible to all individuals, as it does not involve fingerprint scanning or metal detectors, which may be inaccessible to disabled individuals. However, parents may not be comfortable with their children's faces being scanned every day, so this solution is not entirely ethical. Additionally, facial recognition cameras may be expensive to implement, leaving the user's need for affordability unaddressed.

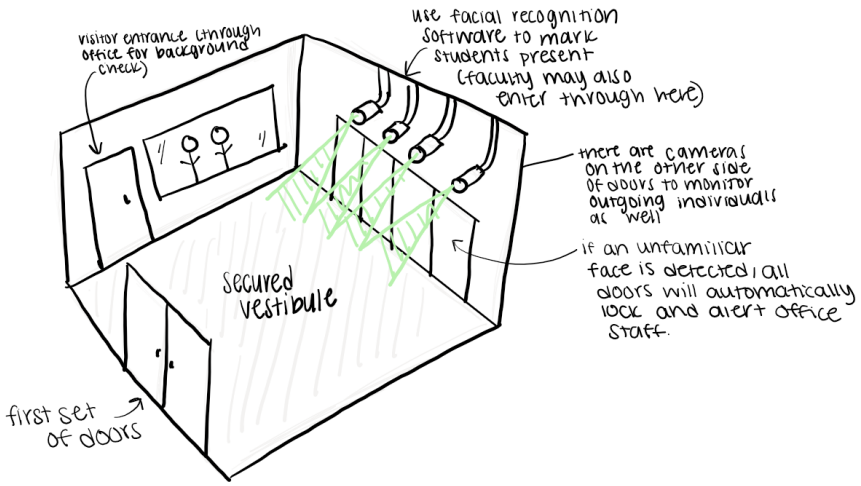

Figure 3: Concept drawing of a facial recognition system to allow access into the facility

2. **License Plate Scanning:** In this design, the school system has a license plate registered under each student if they have opted out of riding the school bus [See Figure A.3 for visual representation]. A camera will scan the car's license plate, and the bar will lift to allow access to the parking lot if the license plate is recognized. Any visitors will have to request a QR code online ahead of time, which will be scanned by the attendant. This design addresses the user needs to be reliable and simple to maintain, however, it may not be the most efficient as it will result in long lines of cars waiting to enter the school's

grounds. This design is noninvasive to a certain extent, as certain individuals may not be comfortable with their license plates being scanned.

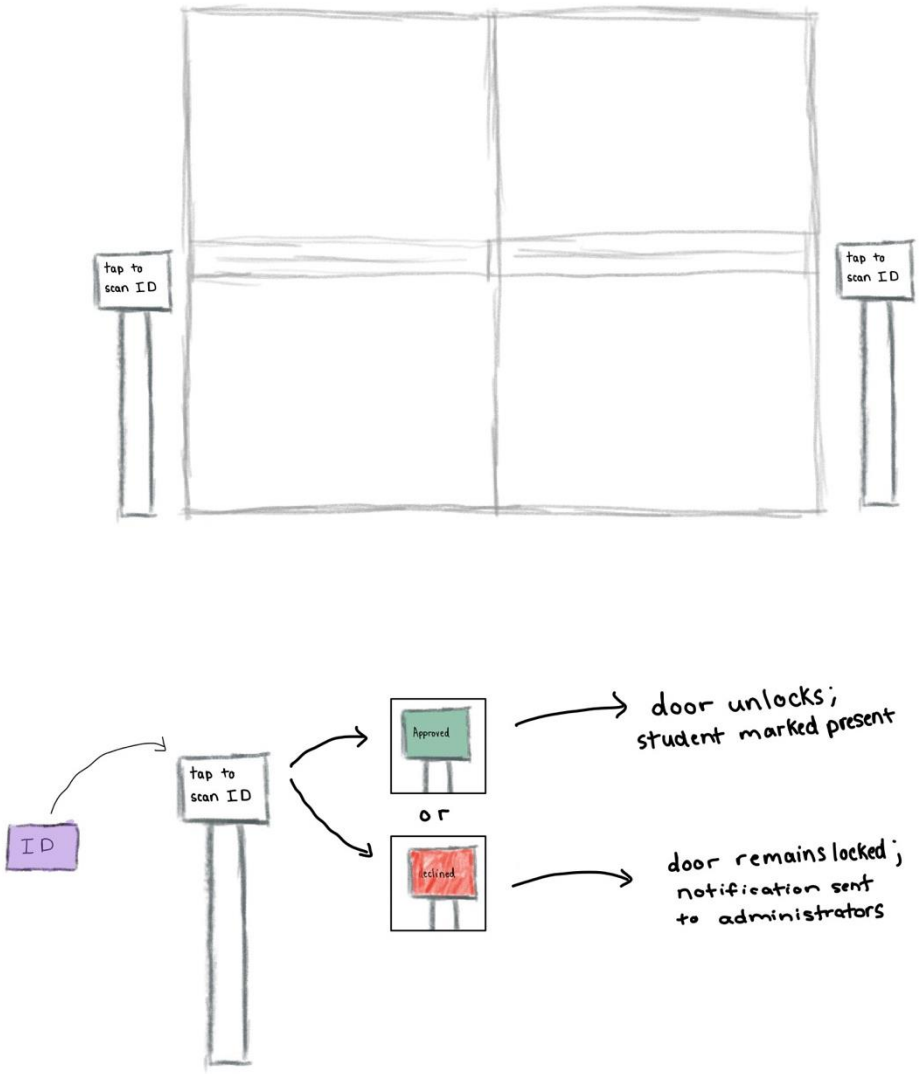

Figure 4: Concept drawing of a system which allows student IDs to be scanned to allow access into the facility

3. **ID Card Scanning:** This design utilizes a system of locked doors which will only unlock when a valid student/staff ID card is scanned [See Figure A.5 for visual representation]. The IDs will be configured in a way such that students may not lose them. When the ID is scanned, the time of the scan is recorded, and the student/faculty member is marked present. The same system will be in place on the outgoing side of the doors as well, to monitor exactly which individuals are in the building and when they arrived/left. This design meets the user needs of being accessible, efficient, affordable, and ethical.

Administrators will spend less time manually entering attendance information, so building efficiency will increase and they can spend more time addressing issues elsewhere. Since the system only requires an ID to scan, it is accessible to all students. IDs are noninvasive and cost-effective to manufacture, making this design ethical and affordable.

8. Concept Selection

a. Down-Selecting to Two Concepts

The team determined that out of the brainstorming results, the two most viable design concepts were the student ID scanners and the facial recognition software in school doorways. According to user feedback, administrators are looking for security solutions that efficiently track who enter and leaves a school building and can be effective without taking up excessive resources. Having staff members spend more time on building security takes away from the time dedicated to students' learning [A.2]. They also want solutions that fit within the school budget. Often, a result of trying to accommodate more expensive security technologies is that schools are forced to cut funding and resources from other valuable school programs [12]. The team needed to choose design concepts that would effectively keep students and teachers safe without sacrificing the quality of their educational experience. Based on this, the team decided that the ID scanners and the facial recognition technology were the best design concepts because they streamline the process of tracking student and visitor entry, and do not require as much work on the part of school staff such as security guards or office attendants. Facial recognition is mostly an automated process and would track student or visitor entry and would only require staff intervention in particular cases (such as an unauthorized individual trying to come into the building). These systems would also be much more reasonable to implement compared to alternatives like license plate scanners in the parking lot. Since most schools already have IDs for students, incorporating an ID scanning system would not require schools to expend many additional resources. However, something like scanning license plates would require each student's car to be registered manually, which may not be as adaptable.

b. Pugh Scoring Matrix

Table 6.
A Pugh scoring matrix which weights user needs and uses them to rank different concepts

		Reference		Concept 1		Concept 2	
User Needs	Weight (1-5)	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Simple	1	4	4	3	3	2	2
Reliable	2.3	1	2.3	4	9.2	4	9.2
Efficient	5	3	15	4	20	4	20
Affordable	1	2	2	3	3	1	1
Ethical	5	5	25	5	25	3	15
Accessible	5	4	20	4	20	5	25
Adaptable	5	3	15	4	20	3	15
TOTAL			83.3		100.2		87.2

Pugh Scoring Matrix Description:

The Pugh scoring matrix uses the determined user needs and their weights generated from the Pairwise Comparison chart (Table 3, page 12) to rank different concepts. For this chart, the reference concept was security staff. It was chosen as the reference because it met the most user needs in the current alternatives chart (Table 5. page 15). “Concept 1” was the ability to scan student IDs at the front door to allow access into the building and “Concept 2” was the idea of facial recognition software at the front door which will conduct a silent alarm if an unrecognized individual enters the building. From the Pugh Scoring Matrix, it can be determined that the strongest concept is the ability to scan IDs. But both concepts are ranked higher than the reference solution.

c. Final Concept Selection

Based on the results from the Pugh scoring matrix (Table 6, page 19), additional end user feedback, and enterprise risk factors, the team has determined that the design concept to move forward with is the idea of students and staff scanning their IDs when entering the facility. One reason the concept was chosen was because it was ranked as the strongest concept on the Pugh scoring matrix as it scored significantly higher than the facial recognition concept and the reference concept. Additional end user interviews also favored this concept over the facial recognition idea. Although the team faced some criticism as school IDs can easily be lost or damaged, the end users stated that it is the best solution for the problem as it would satisfy all the user needs. These risk factors and enterprise needs were also considered in making this decision. The concept picked will meet all the needs of the enterprise including being cost-effective and reliable. An enterprise needs something that works effectively, has little downtime, and has little maintenance. The chosen concept of ID scanners track attendance meets all those objectives.

9. Grand Concept Design

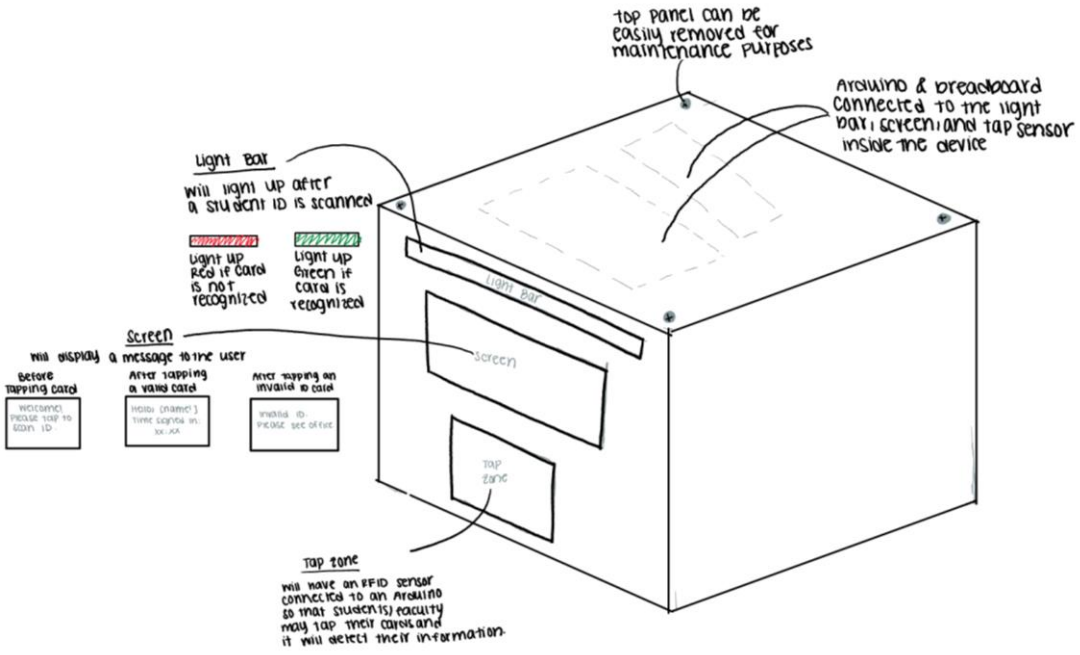

Figure 5: Detailed drawing of preliminary prototype design with descriptions of each component

The team's design mainly focuses on a housing unit for all the internal components. The front of the design has three cut outs. The top cut out would be a light bar which can illuminate either white, red, or green. The middle cut out would feature a screen with instructions or detailed information, and the bottom cut out would be a section for the student to tap to scan their ID. The total size of the housing would be about 5 inches long, 5 inches tall, and 4 inches deep and the design would ideally either be mounted on a wall or propped onto a stand. Our design's purpose is for housing to be near the school's front doors. When a student comes up to the door, the screen would illuminate a welcome message instructing the user to tap their ID. When the student taps their ID two scenarios could occur. Either the ID will be accepted, which would result in the light bar illuminating green, the front door unlocking, and the screen will be displaying their sign in time, or the ID would be denied. If the ID is denied, the light bar will illuminate red, screen will display that access is denied, and the front office would be notified. Our design is unique compared to others because whenever a student signs in, their sign in time would be logged in a database which can be accessed by administration. This will allow administrators to know if a student is in the building. Another unique feature would be the front office being notified if a student who is suspended or expelled attempts to enter the building. To develop this idea into a fully realized product, there are some challenges which the team must overcome. There will be technical challenges in creating a system which would accept certain student IDs while denying others, as well as logging student entries and exists. For the design to gain traction in the market, it must be reliable, unlock the door quickly, accurately log student attendance, and the entire process must be efficient. Originally, the team wanted to create a system which scanned the person's iris when they tapped their student ID to ensure the ID was

theirs. But, based on end user feedback, the team decided it would be best to instead implement a system which building access can be turned off for lost IDs due to privacy concerns [3].

10. Prototyping Design

a. Description of Prototype

The team's grand concept prototype models the structure where the circuit board and sensors that control the school security system will be kept. The prototype is a box with the top face split into three labeled areas – a screen, an area to tap student IDs, and a light bar which will turn either green or red depending on whether the scanned ID is valid or not [See Figure C.1 in Appendix C for visual representation] The screen will display a welcome message to students who scan their valid student ID to enter the building. The light bar will turn green if access is granted, and red if access is denied. The prototype will be constructed by building a box out of cardboard, and taping sheets of multi-colored paper on top to represent the screen, tap region, and light bar. The Arduino and breadboard with sensors will eventually go inside the box, with the sensor at the tap area so that it can detect when a student taps their ID to scan. Some resources from the preliminary R&D labs that will be useful in testing the prototype in the future will be the Arduino board, and an RFID sensor to model the ID scanning system. The biggest limitation the team faced in prototyping was that the physical prototype doesn’t contain the Arduino board and sensors or demonstrate how they function within the school security system. Eventually, the final product should be able to unlock a door once a valid ID is scanned. However, the team's first prototype is a low-level mockup, scaled down in functionality from the grand concept to model just the physical appearance of the concept, not the software aspects of the design that come from the circuit boards and sensor. The mockup includes physical representations of all the key features that will be included in the final product to allow the team to prove the feasibility of their concept and evaluate or refine the effectiveness and functionality of their design.

b. Prototype Design Requirements

Table 7.
Table of design requirements with measurable range and ideal value for each requirement.

Need	Requirement Threshold	Goal
Device can accurately record student attendance	Accurately records attendance 40% of the time	Accurately records attendance 90% of the time
Device reliably reports security issues to attendance	An invalid ID scan will alert the attendance system within 15 seconds	An invalid ID scan alerts the attendance system within 5 seconds
Device works fast enough to accommodate the number of students entering the school	Logs one student's attendance in less than 30 seconds	Logs one student's attendance within 5 seconds
Device is affordable for schools	Device contains no more than 10 components	Can be assembled using 10 or less components
Device does not take up too much space	Device is no larger than 24x24x24 inches	Is no larger than 6x6x6 inches
Device is easy to disassemble	Can be partially disassembled with a screwdriver	Can be completely disassembled with a screwdriver

Design Requirements Discussion:

The design requirements outlined in the table above reflect the team's user needs by specifying characteristics of the prototype that can be measured in a way to ensure the user needs are being met. Affordability is one of the main user needs the team has been focusing on, and thus it is of great importance that the prototype is as inexpensive to fabricate as possible. The team is working to meet this user need by minimizing the components used in the design, hence the design requirement of 10 or less components. Additionally, school administrators need a device that is both reliable and efficient, which is why the team plans to test both the device's reporting time (ideally under 5 seconds) and its reporting accuracy (ideally 90% accurate).

c. Testing Methodology and Verification Plan

Table 8.
A visual representation of each design requirement and its corresponding testing methodology.

Design Requirement	Testing/Verification Plan
The device correctly records attendance/building entrance at least 90% of the time	A valid ID card will be scanned 10 times, and the device should record at least 9 of the scans. This will be determined by the number of times the MATLAB program prints a statement indicating the computer received the correct signal from the Arduino.
The device logs one student's attendance within 5 seconds.	Multiple time trials will be performed during which a valid ID card will be scanned, and an iPhone timer will be used to measure the prototype's reaction time. The tic/toc functions on MATLAB will also be used as another measure of time to ensure accuracy. cy.
The device consists of 10 or less components.	A component is a constituent part that may be connected to other parts to form something more complex. For this design, screws, wires, and any other objects that serve to act as connectors between two components will not be considered components themselves. To verify this design requirement, each component will be labeled and recorded on a separate sheet. The components on this sheet will be counted to determine the number of components used in the prototype.
The device is less than 6x6x6 inches.	The device's dimensions will be measured by a ruler in inches.
The device can be completely disassembled with a Philip's head screwdriver.	A team member will obtain Philip's head screwdriver and attempt to remove the top panel of the device by unscrewing all 4 screws. If the top panel can be completely removed, allowing full access to the Arduino inside, the design requirement will be met.
Device will alert attendance within 5 seconds if an invalid ID card is scanned.	An invalid ID card will be scanned, and then the print function on MATLAB will be used to represent a signal being sent from the Arduino to the computer. The computer should receive this signal within 5 seconds, so an iPhone timer and the tic/toc MATLAB functions will be used to record the time taken to "alert attendance".

d. Correlation Matrix and Verification Scorecard

Table 9.
A correlation matrix which shows the relationships between design requirements and user needs

Design Requirements / User Needs Correlation Matrix								
	Device correctly records attendance/building entrance at least 90% of the time	Device logs one student's attendance within 5 seconds	Device consists of 10 or less components	Device is less than than 6x6x6 inches	Device can be disassembled with a Philip's head screwdriver	Device will alert attendance system within 5 seconds if an invalid ID card is scanned		User Need Weight
Simple	1	3	1	9	9			1
Reliable	9	9	1		3	9		2.3
Efficient	3	9		3	9	9		5
Affordable			9	1	3	1		1
Ethical		1		1	1	1		5
Accessible	1	3	1	9	3	3		5
Adaptable	1	3	1	3	9	3		5
Importance ->	46.7	103.7	22.3	90	128.9	101.7	0	493.3

Correlation Matrix Discussion:

The top requirement based on the weighted importance on the correlation matrix is that the device can be disassembled with a Phillip's head screwdriver. In the design prototype the team will address device disassembly by making the box that holds the Arduino component out of plywood. If the box is plywood, screw holes can easily be added to ensure the top of the box can be removed completely and the device maintenance can be performed easily. Other top requirements identified by the correlation matrix are that the device logs one student's attendance within 5 seconds and the device will alert the attendance system within 5 seconds if an invalid ID card is scanned. To account for this in the design prototype, the team will rely on a MATLAB code that runs quickly and effectively. Since these requirements have the highest importance, tradeoffs can be made with the design requirements with less importance. For example, the least important requirement is that the device consists of fewer than 10 components. This means that if it is necessary to have more than 10 components to ensure the device can be disassembled or logs attendance within 5 seconds, it would be more beneficial for the team to add more components.

Table 10.

A scorecard which defines our design requirements, a range of the possible scores, and a score rubric.

Scorecard			
Requirement	**Range**	**Score Rubric**	**Score**
Device correctly records attendance/building entrance at least 90% of the time	0-2	0: Device never correctly records attendance/building entrance 1: Device correctly records attendance/building entrance 40% of the time 2: Device correctly records attendance/building entrance 90% of the time	0
Device logs one student's attendance within 5 seconds	0-5	0: Device logs one student's attendance within 30 seconds 2: Device logs one student's attendance within 15 seconds 3: Device logs one student's attendance within 10 seconds 5: Device logs one student's attendance within 5 seconds	0
Device consists of 10 or less major components	0-1	0: Device contains more than 10 components 1: Device contains of 10 or less components	1
Device is less than than 6x6x6 inches	0-5	0: Device is greater than 24x24x24 inches 2: Device is between 18x18x18 inches and 24x24x24 inches 3: Device is between 12x12x12 inches and 18x18x18 inches 5: Device is less than 6x6x6 inches	3
Top panel of the device can be removed with a Philip's head screwdriver	0-7	0: Top panel of device cannot be removed 5: Top panel of device can be partially removed with only a Philip's head screwdriver 7: Top panel of device can be fully removed with a Phillip's head screwdriver	0
Device will alert attendance system within 5 seconds if an invalid ID card is scanned	0-5	0: Device does not alert attendance system 2: Device will alert attendance system within 15 seconds if an invalid ID card is scanned 3: Device will alert attendance system within 10 seconds if an invalid ID card is scanned 5: Device will alert attendance system within 5 seconds if an invalid ID card is scanned	0

Scorecard Discussion:

The scorecard's purpose is to list the team's design requirements and utilize the scores generated in the correlation matrix to create a score rubric and range of scores which will be used when testing the prototype. The scorecard allows the team to evaluate and refine the prototype. The total score which the prototype can achieve is 25 points. When the team begins testing the prototype, the rubric's purpose is to score how well the device functions and how effective it is in meeting the team's design requirements. If the total score is less than 25, the team will improve on the prototype to ensure all the design requirements are met. For example, if the prototype does not correctly record attendance, it will not achieve the full 25 points, so the team will analyze the software and hardware to determine and rectify the issue. This may involve fixing an error within the prototype's MATLAB code or adjusting the wiring between the sensors and Arduino.

e. Protype Preliminary Design and Mock-up

Figure 6: Inside of preliminary mockup showing an Arduino and breadboard

Figure 7: Preliminary mockup before a user scans their identification

Figure 8: Preliminary mockup after a user successfully scans their identification

Figure 9: Preliminary mockup after a user's identification is invalid

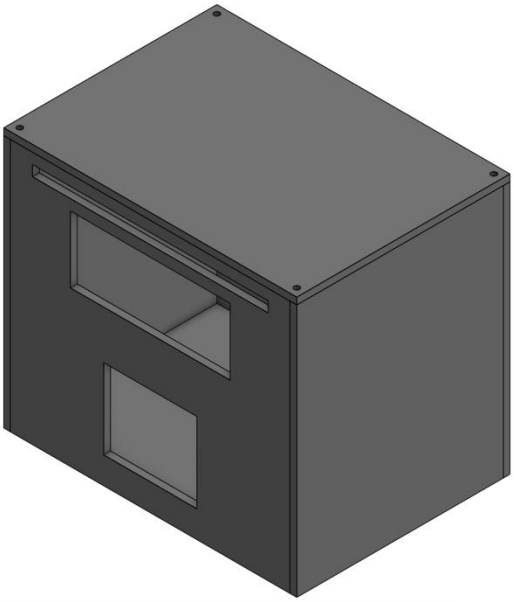

Figure 10: Preliminary CAD model of prototype created using Onshape

Preliminary Prototype Discussion

One of the team's takeaways after building a preliminary mockup of the design is that a laser cutter would be a useful tool during the prototyping phase. The design features many flat edges since it will hold an Arduino and a breadboard. The laser cutter is a useful tool to cut pieces with flat edges. The team plans to make the box that holds the Arduino and breadboard out of plywood. The plywood will provide structural support for the Arduino component inside the box. Another takeaway is that the team will rely more on coding the prototype with Arduino than building with power tools. As the team continues to develop the prototype in Onshape, unique features that will require the use of power tools will be designed. After building the preliminary prototype, the team decided to add a mount to the back of the prototype so it can sit on the walls by entrance doors for easy access to users. Having one scanner by each door would improve the efficiency of the device. The team also intends to make the top panel of the scanner removable with Philip's head screwdriver. This will make maintenance easier so unexpected problems with the device can be quickly assessed and resolved.

Detailed Design Review

11. Prototype Fabrication and Evolution

The team's original prototype design involved a box housing for components and an Arduino, light bar, screen, and RFID scanner. The original had modifications made as issues arose. For example, one issue that the team noticed was there was no hole for wires to come out to power the Arduino. To rectify this issue, the team added a small hole at the back of the housing to allow wires to exit. The team also made the overall housing size larger due to the components needing much more wiring than initially expected. The front panel dimensions were also modified to ensure that each component can easily slot into the holes. While testing our prototype, the team encountered issues with connections between components being incorrect and therefore the team would have to rewire the component and ensure it matches up in the code.

During the team's preliminary testing, the device failed nearly every test and earned a 3/25 on the verification scorecard. The Arduino enclosure was larger than the allotted 6x6x6 inches in the design requirements. To remedy this, the team used plywood provided from the wood shop and a bandsaw to prototype a box that is 5x5x5 inches. The prototype also failed to log student attendance. The team is working on the programming aspect of the prototype and got the screen to display writing. A delimitation the team chose to make is making the box out of plywood. The plywood was provided to the team for no cost in the wood shop, so it saved both time and money.

The team used the information from the preliminary testing to improve on the existing prototype. One of the tests that the prototype failed during the preliminary testing is that the device correctly records attendance 90% of the time. This test failed due to the sensor not correctly detecting when an ID card was scanned. The team soldered the wires to the RFID sensor board and reworked the code base and was able to fix this issue in the final prototype. This change also allowed the prototype to pass the remaining design requirements including the prototype alerting the attendance system and the device logging one student's attendance within 5 seconds. A design trade off which the team had to make was not wiring the LED in the front of the box. This is because although the team wired the component as described in the component's documentation, the LED would still not light up when an ID was scanned. The team determined that as the LED was not involved in any of the design requirements it is non-essential for final testing and that the team should proceed without it. This was also a delimitation as the decision not to wire the LED allowed the team to instead prioritize essential functions over aesthetic features.

Figure 11: Top view of Arduino enclosure prototype

Figure 12: Isometric view of Arduino enclosure prototype

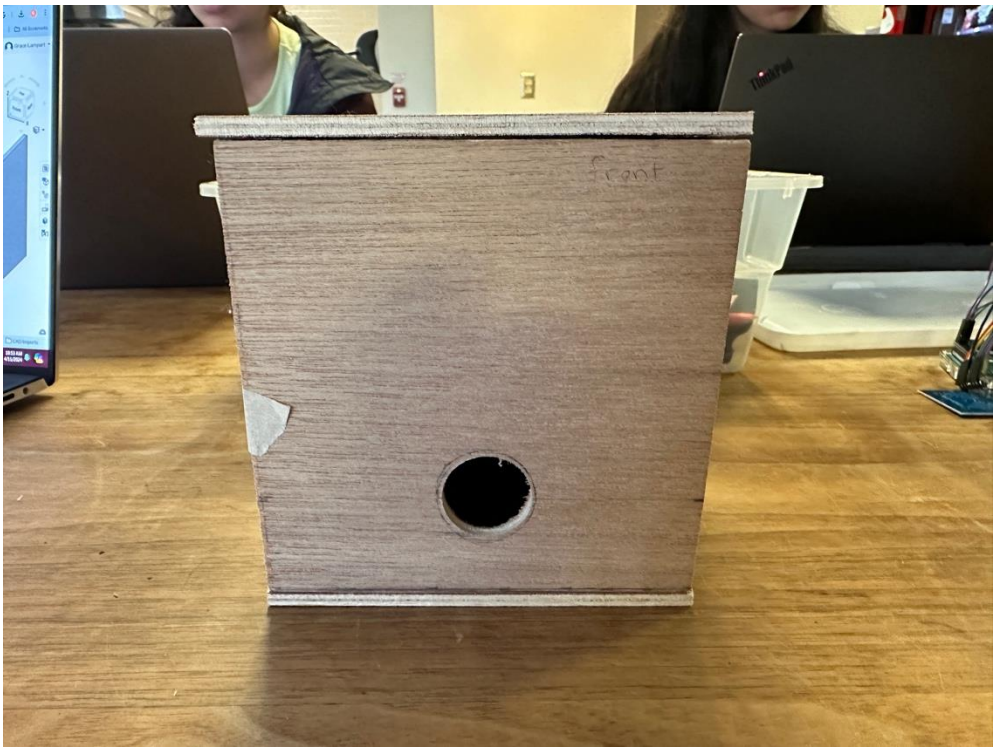

Figure 13: Front view of Arduino enclosure prototype

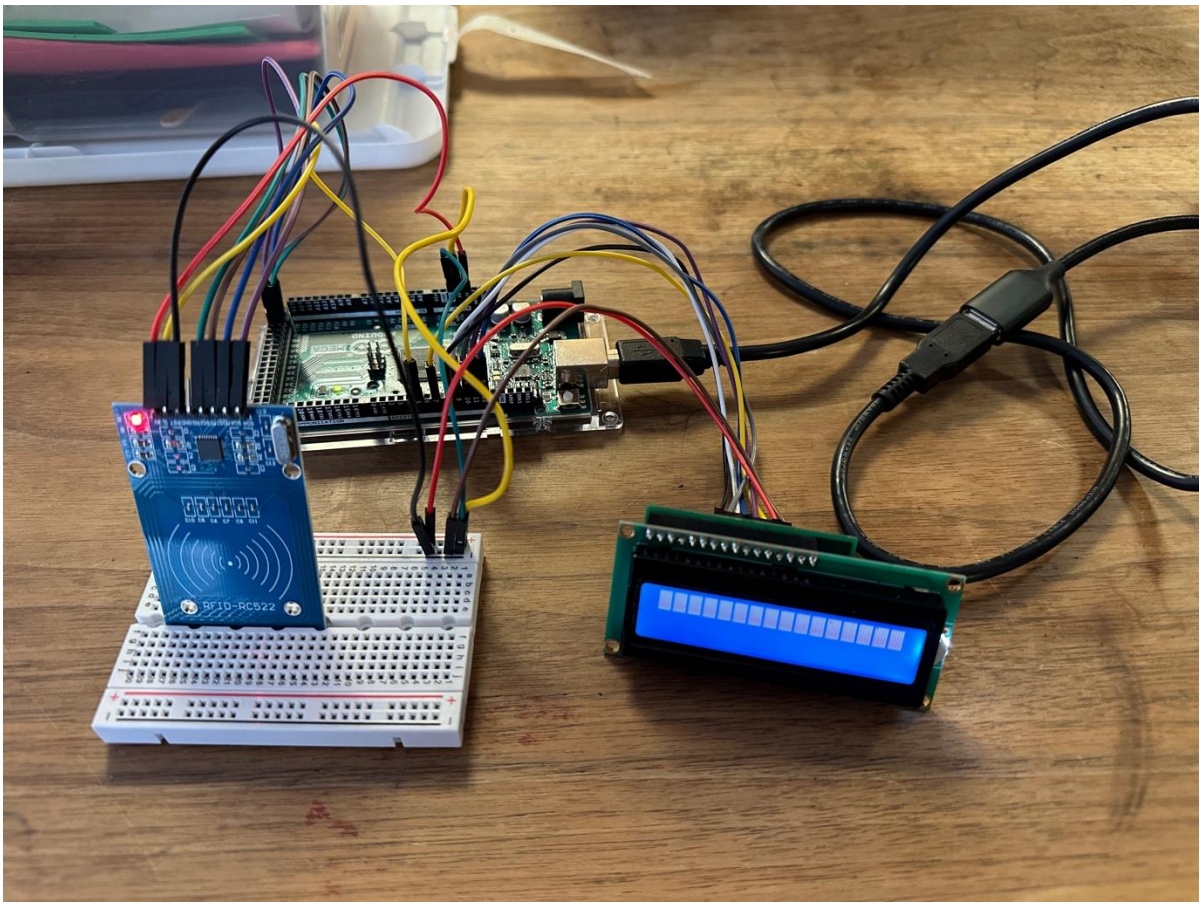

Figure 14: Wired Arduino and Breadboard

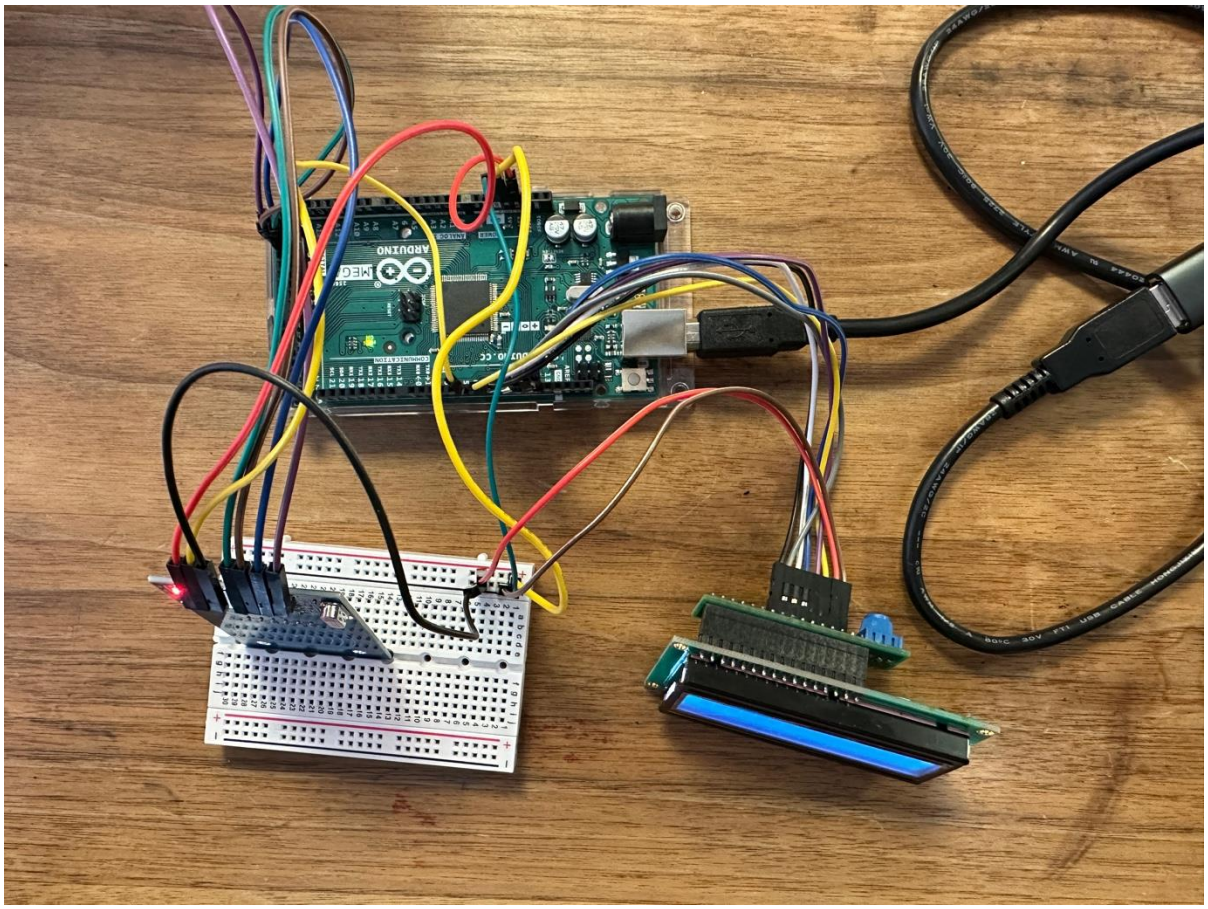

Figure 15: Top view of wired Arduino and Breadboard

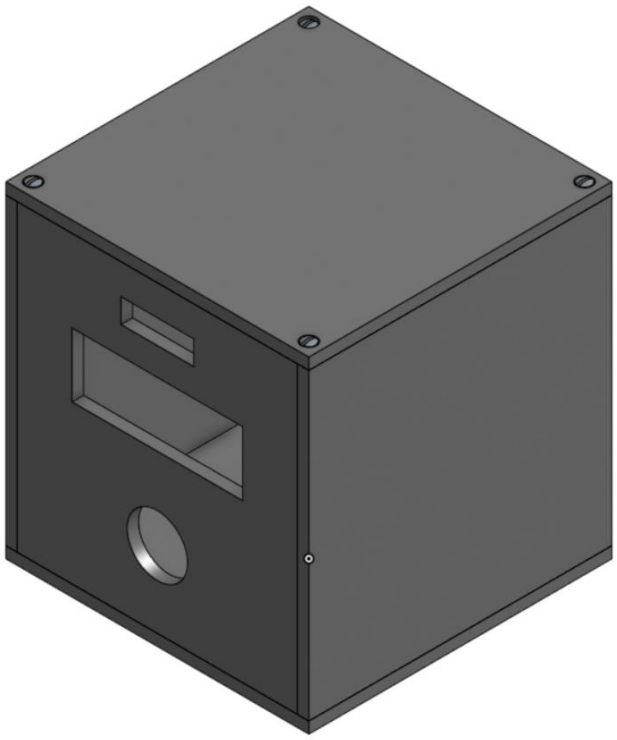

Figure 16: Updated isometric view of prototype in CAD

12.Detailed Design

a. Final Prototype Design

Final Prototype and Research and Development Findings

During the research and development phase, it was determined that certain school districts use handheld and mobile ID scanners to keep track of students getting on and off school buses [1]. To model the convenience of smaller ID scanning devices, our final attendance tracker prototype includes an enclosure for the Arduino components that is sized 5x5x5 inches. This makes it easy to maintenance and transport for school administrators to use in many different locations and entrances. In addition, certain school bus systems began using RFID technology to send a message to parents that notifies them when their student gets on the bus [3]. The team's decided to use an RFID scanner alongside an Arduino to help notify school administrators when students sign into school. This will maintain the flow of students into and out of the building while promoting safer security measures. It would also allow the school to more easily log student attendance as the attendance office would be notified when a student enters or leaves the building. Furthermore, in the team's research it was found that 38% of parents fear for their child's safety while they are in school [4]. If this prototype is incorporated, it would allow parents to feel more at ease when sending their students to school due to the security benefits the prototype poses.

Non-standard Parts

The only non-standard part within the design is the enclosure. The front panel of the team's enclosure for the Arduino component includes a circular cutout for the RFID scanner and a rectangular cutout for the light bar and screen. The RFID scanner cutout will allow students to tap their school IDs so attendance can be tracked. The screen will show messages about whether the ID scan was accepted and instructions on how the student should proceed. The light bar cutout allows the light bar to display a green color when the student ID is accepted and a red color when the ID is rejected. The back panel of the enclosure is fitted with a smaller hole for a wire to connect the Arduino to the computer. The top panel will be screwed onto the enclosure so it can be removed for easy maintenance and access to the Arduino.

Future Design Considerations

One anticipated difference between the current prototype and final product is that the final product will include a mount on the Arduino enclosure. This will increase the versatility of the device and allow it to be mounted near any entrance or exit. Another difference is the material on the device. Our current prototype enclosure is composed of plywood due to availability of materials and team members' previous experiences. In the final product, the enclosure will be made from cheap and accessible plastic. This will improve the visual appearance of the device, so it is more appealing to the public. To manufacture our product, the team recommends using repetitive processing. This would allow the device to be produced quickly and efficiently so a multitude of school districts around the nation could implement the technology in their school.

b. Revised Grand Concept Design

Figure 17: Final Prototype Image

The team's final prototype has a few differences from the original grand concept design. In the original grand concept design, the team originally had the idea of having a stand on the bottom to hold the enclosure. The team decided not to go through with this idea to allow school administrators to have more flexibility in deciding how they want to integrate the system into their schools. Instead, the team would add mounting holes to the back of the unit so school administrators can choose whether they want to mount the prototype to the wall. In addition, while creating the original prototype the team realized the components did not all fit inside the enclosure. To fix this, the enclosure was made an inch and a half deeper to be able to hold all the necessary components. Finally, the team decided that install of using screw holes at the top of the enclosure to disassemble the box, two hinges would be a better replacement to easily allow the team to maintain the device and swap components as necessary.

13.Final Prototype Verification

Table 11.

An empty scorecard which tests the prototype against design requirements during Final Verification Testing.

Scorecard			
Requirement	**Range**	**Score Rubric**	**Score**
Device correctly records attendance/building entrance at least 90% of the time	0-2	0: Device never correctly records attendance/building entrance 1: Device correctly records attendance/building entrance 40% of the time 2: Device correctly records attendance/building entrance 90% of the time	
Device logs one student's attendance within 5 seconds	0-5	0: Device logs one student's attendance within 30 seconds 2: Device logs one student's attendance within 15 seconds 3: Device logs one student's attendance within 10 seconds 5: Device logs one student's attendance within 5 seconds	
Device consists of 10 or less major components	0-1	0: Device contains more than 10 components 1: Device contains of 10 or less components	
Device is less than than 6x6x6 inches	0-5	0: Device is greater than 24x24x24 inches 2: Device is between 18x18x18 inches and 24x24x24 inches 3: Device is between 12x12x12 inches and 18x18x18 inches 5: Device is less than 6x6x6 inches	
Top panel of the device can be removed with a Philip's head screwdriver	0-7	0: Top panel of device cannot be removed 5: Top panel of device can be partially removed with only a Philip's head screwdriver 7: Top panel of device can be fully removed with a Phillip's head screwdriver	
Device will alert attendance system within 5 seconds if an invalid ID card is scanned	0-5	0: Device does not alert attendance system 2: Device will alert attendance system within 15 seconds if an invalid ID card is scanned 3: Device will alert attendance system within 10 seconds if an invalid ID card is scanned 5: Device will alert attendance system within 5 seconds if an invalid ID card is scanned	

Table 12.

Table displaying itemized expenses for design prototype and the total cost of materials.

Item	Additional Notes	Cost
Arduino Mega	Materials Library stock material	$15.00
Medium breadboard	Materials Library stock material	$4.00
LED bar graph	Materials Library stock material	$5.00
Servo Motor	Materials Library stock material	$3.00
RFID Starter Kit	Amazon RFID Starter Kit	$7.00
LED Screen	Materials Library stock material	$5.00
Arduino Wires (x15)	Materials Library stock material	$1.50
Plywood	Recycled material	$0.00
Hinges (x2)	Recycled material	$0.00
Screws (x12)	Recycled material	$0.00
	TOTAL:	$40.50

Table 13.

A complete scorecard from the Final Verification Testing.

Scorecard			
Requirement	**Range**	**Score Rubric**	**Score**
Device correctly records attendance/building entrance at least 90% of the time	0-2	0: Device never correctly records attendance/building entrance 1: Device correctly records attendance/building entrance 40% of the time 2: Device correctly records attendance/building entrance 90% of the time	2
Device logs one student's attendance within 5 seconds	0-5	0: Device logs one student's attendance within 30 seconds 2: Device logs one student's attendance within 15 seconds 3: Device logs one student's attendance within 10 seconds 5: Device logs one student's attendance within 5 seconds	5
Device consists of 10 or less major components	0-1	0: Device contains more than 10 components 1: Device contains of 10 or less components	1
Device is less than than 6x6x6 inches	0-5	0: Device is greater than 24x24x24 inches 2: Device is between 18x18x18 inches and 24x24x24 inches 3: Device is between 12x12x12 inches and 18x18x18 inches 5: Device is less than 6x6x6 inches	5
Top panel of the device can be removed with a Philip's head screwdriver	0-7	0: Top panel of device cannot be removed 5: Top panel of device can be partially removed with only a Philip's head screwdriver 7: Top panel of device can be fully removed with a Phillip's head screwdriver	7
Device will alert attendance system within 5 seconds if an invalid ID card is scanned	0-5	0: Device does not alert attendance system 2: Device will alert attendance system within 15 seconds if an invalid ID card is scanned 3: Device will alert attendance system within 10 seconds if an invalid ID card is scanned 5: Device will alert attendance system within 5 seconds if an invalid ID card is scanned	5

Final Prototype Verification Discussion: The team successfully met all the design requirements and obtained all the points possible. The team mostly followed the final prototype plan though made slight deviations to the plan to stay on track which was a large factor in the team's success. For example, the team successfully created an enclosure for the Arduino and its components using plywood but determined that screw holes would not be feasible due to the thinness of the plywood. Instead of screw holes, the team decided to instead use hinges for the top panel so the enclosure could easily be opened and closed. This would also allow the design requirement to still be met. For the final prototype, the team was able to create a plywood enclosure which held all the Arduino components and was able to create a program which

accurately logged all student attendance with no errors. The key part of the team's success was dividing work based off the strengths of the team members. The team would meet twice a week and talk about accomplishments and struggles and team members would offer feedback to ensure that all the members are on track.

14. User Validation

Top Three User Needs

The top three user needs based on the pairwise comparison chart are efficiency, adaptability, and accessibility (Table 3, page 12). To achieve efficiency, the ID scanner security system must be able to quickly output attendance data to school administrators with a minimal input of tapping an ID to the sensor. To reach the adaptability user need, the device must be able to undergo maintenance and updates effectively to accommodate for bugs and changes in the school's system. To achieve accessibility, the ID scanner security system must be able to accommodate students and faculty with disabilities.

Goals

To investigate whether the team's top three user needs are met, the team aims to gather qualitative data from an end user by conducting an interview. The goal of this interview is to get detailed feedback on:

1. How the team's product might improve student flow management and security at schools.
2. Whether recording student attendance in this manner is more efficient for administrators.
3. How the students will receive a new implementation like this product in their schools.
4. Areas where the product may fail to deliver a resolution to any of the user needs, and what the team can do about it.

All the data collected in this interview will be qualitative, as many responses will be based on the interviewee's opinion and their life experiences as a high school administrator. By asking the questions listed in the section below, the team will be able to gauge how the device would perform in a high school realistically and how this device would impact the routines of the high school administrators.

Methodology

To ensure that our top three user needs are met, the team will interview high school administrators at a local school district either in-person or virtually. A member of the team will be designated to ask the interview questions. The designated member will first greet the end-user, ask if they consent to an interview, and inform them that their responses will be recorded but their personal information will remain confidential. The team will first show the end-user the video of the prototype functioning and explain the features of the design. The team will then ask the following questions:

1. Do you believe that the prototype would be able to effectively handle traffic before and after school without causing a large backflow of students?
2. Do you believe that there will be issues regarding efficiency if the prototype is stationed on both sides of the door and must be used to both exit and enter the building?
3. Do you believe that this design reasonably accommodates students with both physical and psychological disabilities?
4. Do you believe that the prototype can easily be restationed if changes to the building occur?
5. Do you believe that at your school district, the prototype will be able to handle the flow of the traffic during any time of day effectively and efficiently?
6. Do you think students would be receptive if this prototype is installed or do you believe there may be backlash?
7. Do you will that this prototype will help support your role in ensuring school safety?

Depending on the end-user's responses to these questions, the team will be able to gauge if the prototype successfully meets the top three user needs and determine whether the prototype creates value to the end-user.

User Validation Interview Summary

After conducting a second interview with a high school administrator and presenting the final prototype, the interviewee believed that if there were multiple scanners for students at the doors, then it would effectively handle traffic before and after school. The interviewee believes it is better to just track students entering the building rather than entering and exiting. While it would be useful to track students exiting the building for certain occasions, it would reduce overall efficiency. The interviewee does not think the prototype would make it easier for students with disabilities but also does not think it would make it harder. This means the prototype meets our user need of accessibility because it does not make it more difficult for a student with disabilities to use the device. The interviewee believes that the prototype is an appropriate size to be restationed to different parts of the building if changes to the building occur. This would fulfill the user need of adaptability. If there are enough units installed near the school doors, the interviewee believes it would be able to successfully handle the traffic of students. The interviewee thinks most students would be receptive to the prototype and its benefits for promoting fairness and consistency. Overall, the high school administrator the team interviewed believes that the prototype would support their role in ensuring school safety.

Ethics

When conducting research for end user validation, there are some ethical considerations that the team should account for. The team will make it a priority to inform their end user that their information is being recorded and obtain their permission to do so. The team will also not use or share any personal information about the end user not relevant to their research about the prototype's effectiveness. This is to make sure that the privacy of the end user is being respected.

15. Value and Impact

Table 13: Value categories and stakeholders, with positive and negative impacts in each category for each stakeholder

	Value Categories	
Stakeholders	Economic	Social
High School Admin (End User)	**Positive**: Since the security device is automated and records attendance as students/staff enter and exit the building, School Administrators will no longer need to spend as much money on hiring staff dedicated to monitoring attendance. **Negative:** School Administrators will have to initially make a relatively large investment of money into purchasing and installing the device, which will simply have to be accounted for when the school's administrative team drafts the annual budget and projections for the years to come.	**Positive:** The security device will improve safety in schools, giving the school a good reputation within the community. This benefits administrators because it will boost enrollment in schools and their credibility as an administrator. **Negative:** Enforcing the new security system might result in pushback from students, which might disrupt the relationship between administrators and students at first.
Parents	**Positive:** In addition to keeping unauthorized individuals out, the device also prevents students from sneaking out of school early to partake in various activities that are most likely frowned upon. This can be dangerous and has often resulted in negative criminal and medical consequences, which can be a large monetary burden on parents. Since the device prevents students from being able to leave when they are not supposed to, Parents no longer have to worry about any monetary expenses that could come from their child sneaking out and finding trouble. **Negative:** In the case of private schools, the cost of implementing the new device into the school may raise tuition since private schools are not funded by taxpayer money.	**Positive**: Parents will benefit from being assured that they are sending their kids to a safe and secure school with a strong security system, and not having to worry about the safety of their children throughout a school day. **Negative**: Having enhanced security measures in schools would require more elaborate protocols for parents picking up their children from school early, and also for parents gaining access to the school for special events during school hours. This may result in inconvenience to parents who are already balancing busy work schedules and commitments.
Students	**Positive:** With manual attendance systems, there is a lot of room for error and it is not common for students to be wrongfully charged/threatened with truancy when in reality, teachers are so busy that they forget to take attendance. According to Columbus City Schools, students charged with truancy can face up to a $500 fine. With this new automated attendance system, students will no longer have to worry about being wrongfully fined/charged. **Negative:** If a student loses their ID card, the cost to replace it will be more than a regular ID card because these must be equipped with microchips for the RFID sensor.	**Positive:** Being part of a more secure school environment can help students feel safer at school and improve their learning experience. Not having to worry about their safety will allow students to focus more on their education while in class **Negative:** Students may initially feel that the new security systems restrict their freedom too much, which could result in resentment or unwillingness to cooperate with administrators on the implementation of the new systems
Teachers	**Positive:** Insurance providers such as The Hartford, Chubb, and Liberty Mutual provide insurance premiums for schools with robust security systems, including anti-theft measures. This greatly reduces replacement costs for teachers, who often have to buy everything in their classrooms. **Negative:** When budgeting to implement the new security devices, school administrators may have to reduce some teachers' wages or cut some altogether. Part-time and substitute teachers are especially at risk of receiving a wage cut or termination in cases like this.	**Positive:** Teachers will also feel safer in a school with better security, which will allow them to dedicate more time and energy into providing their students with the best possible learning experience. Also, with the attendance process being more automated, the job of monitoring student attendance won't fall to the teachers as much, which frees up time and attention they can dedicated towards teaching instead. **Negative:** Teachers might need additional training on how to work with the new attendance system, which could add too much to their workload on top of having to deal with their classes. This might initially cause a drop off in the quality of their teaching when the security systems are first implemented
Security Tech Manufacturers	**Positive:** The succesful integration of a security system in schools will lead to increased recognition and profits for the company that developed them. If their product is effective, other schools, or other potential end users with similar security needs will be more willing to do business with them **Negative:** Manufacturers will have to spend additional money and resources on developing security technology to supply to schools. They may have to restructure their budget plans to accomodate their clients if they get a large influx of customers.	**Positive:** If the tech manufactureres create a security system that is succesfully implemented in schools, it could improve the company's reputation within the industry, and make them more appealing to other potential consumers for the future. **Negative:** Any negative repercussions of the security systems in the schools may also reflect badly on the company that developed those technologies
Taxpayers	**Positive:** Having a school with enhanced security measures in the area will increase property values, so taxpayers will be able to sell their houses at higher prices in the future. **Negative**: The cost of implementing this security system may be funded by increases taxes or levies on the local taxpayers/residents.	**Positive:** Having better security in local schools results in better education and having a more educated population can lead to overall improvements in a community. This benefits taxpayers because they would get to be part of a more educated workforce **Negative:** This may cause debate amongst taxpayers in the community regarding resource allocation. Some community members may express concerns about not allocating these resources towards other infrastructure or social services instead.

Economic & Social Impacts Discussion

Overall, the team's security solution would have positive impacts both within the school it is implemented in, as well as in the broader community. For teachers and students, safer schools would result in improved educational experience with less concerns about security throughout a school day. For parents and taxpayers, safer schools mean safer communities, with overall improvements to the well-being of a population. There are also unintended possible negative repercussions that the security system could have on society. If the security system is not smoothly and successfully integrated, pushback from students and parents is a possibility, which could have negative impacts on the social environment of a community. For example, for parents

a social negative impact be if they want to pick up their child from school early, it may lead to a longer and more difficult pickup process due to the security system. For taxpayers, a possible negative impact is that by implementing this security system, it may cause debate between taxpayers and the government where their money should be allocated as some taxpayers would rather have their money used for social services or infrastructure. The team also considered the economic impacts of the solution, such as how it would generate additional costs for taxpayers, end users, and technology manufacturers. However, the solution would generate economic revenue as well, as having safer schools can lead to better education, and more educated workforces in a community leads to higher employment rates and salaries. While the initial costs of setting up security systems in schools may have negative economic impacts, there are overall economic benefits of increased security that will balance these costs out in the long run.

16. Project Recommendations and Next Steps

Looking holistically at the project, for the next steps, the team recommends creating an additional prototype that has a functional lightbar and does not require a computer connected. In this new prototype, the team recommends also having dedicated spots inside the enclosure for each of the components. After the second prototype's creation, the team recommends revising the grand concept design with user feedback from it. To help fund the project and bring it into market, the team recommends finding an investor who will give it $500,000 to help further its development. The team should also find employees and contractors with necessary skills in product design, sales, and marketing. Finally, with the funds from the investor, the team should acquire manufacturing facilities that would specialize in creating the product. With these resources, the team would be able to continue prototyping and improving product design based off user feedback, promote and build awareness of the product, ensure efficient production and timely delivery of high-quality products.

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Appendix A. Evidence of Brainstorming

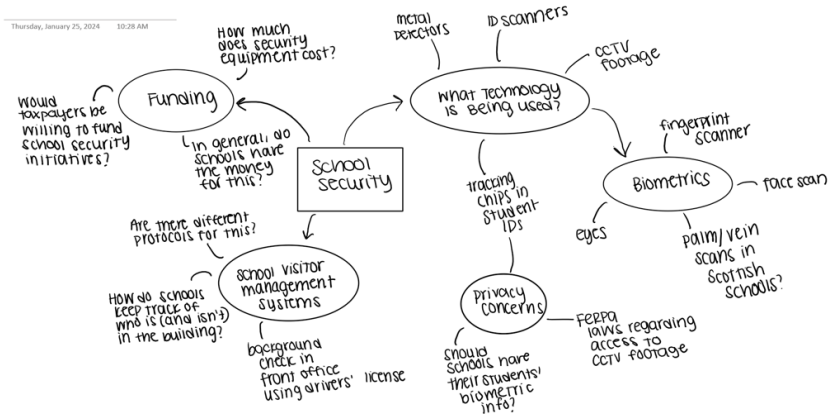

Figure A.1: Concept map of brainstorming

PD0 – Practice Interview

ENGR 1182.02 – Dr. Braaten
Team N
01/18/24

Description of Interviewee

I interviewed a middle-aged white male who fits into the user group of school administrators. He works as an assistant principal at an urban high school in Ohio and has both a science teaching license and a principal's license. He earned a bachelor's degree in biology and a master's degree in teaching and educational leadership. His hobbies include running, working out, gardening, hiking, and spending time with his family. He has a wife and two kids, and his socioeconomic status is middle class.

Interview Summary

In the interview we discussed the important tasks of an assistant principal and aspects that contribute to a school district's success. The interviewee mentioned that one of the biggest frustrations about working in an urban school district is the lack of staff and funding. The students' needs for support tend to outweigh the funding provided by the district. Staff members are underpaid for amount of work they do which is causing a staff shortage in the district. Building safety and communication between staff, students, and parents/guardians were discussed in the most detail. There are screening systems to get into the main entrance but there is currently no system that keeps track of who enters and leaves the building through other doors. There are also multiple systems that the district uses to communicate with students, staff, and families which can sometimes lead to confusion. The interview went well and multiple tasks and pains for the school administrator user group were detailed. One thing I would have done differently is prepare more guided questions. When the interview would go off topic, it would be useful to have more specific questions to get it back on track.

Tasks and Associated Pains Uncovered in the Interview

Task 1: Overseeing building safety at the high school

Pains:

- Administrators can't track who comes in and out of the building unless it's through the main entrance.
- Students and staff open/hold doors for other people to let them in resulting in unauthorized individuals entering the building.
- There is not enough space in severe weather shelter areas to fit all students at the school.

Task 2: Communicating news/events/announcements to faculty, students, and families

Pains:

- The school communicates on many different forums, so information is not always streamlined.
- Many students and families speak languages other than English.
- Some people don't check their emails regularly resulting in miscommunications.

Attendance: the school is woefully understaffed; interviewee must call home for truancy issues but there is not enough time to call; truancy officer on maternity leave; emails blow up.
Building safety: there isn't an efficient way to track who enters and leaves the building; during a tornado drill, the tornado shelters are bathrooms, but 1600 students don't fit in the bathrooms.

7. **Is there anything that would make it easier or more enjoyable to perform these tasks?**
Meeting students' needs: teachers need to be paid better so staff will want to work there
Discipline: If staff were less stressed, had better compensation, and had a better communication system (everyone communicates different ways so it would be easier if information was streamline).
Building safety: need adequate spaces to put people when there's inadequate weather; need a way to track if unauthorized people are entering/leaving the school building.

8. **Do any of the products you use lack certain features or could those products be improved?**
Building safety: Fire bars are supposed to be on exit doors, but they aren't; the school's safety system is not 100% activated.
Communication: if the systems the district buildings used were compatible with each other; if everything (athletic/district offices) was on the high school campus. Having a bigger site would reduce the number of staff needed.

9. **Of the problems/frustrations/pains you've described, are there any that really stand out?**
    a. poor communication
    b. not having equipment/systems in place for safety

a) Why is this a significant problem?
    a. Communication: People can't get on the same page because information is communicated on many different platforms. Many families in the district speak languages other than English.
    b. Building safety: Faculty can't keep track of who is entering/leaving the building and if they're supposed to be there.

b) What are you currently doing to alleviate this problem?
    a. Communication: Announcements are through email, Schoology, Progress Book, phone calls, Facebook, and Twitter.
    b. Building safety: Students use badges to enter building; visitors need their ID to badge in and can't leave the main office.

c) What do you like about how you currently handle this problem?
    a. Communication: Monthly meetings with staff to talk to everyone; admin works well as a team; secretaries are helpful; good work atmosphere
    b. Building safety: The school has two school resource officers and an administrative team that works together to keep the building safe for staff and students.

d) What isn't working about how you currently handle this problem?
    a. Communication: People are stretched to complete more tasks than they can handle when teachers are absent and staff miscommunicate.
    b. Building safety: Not everyone follows the safety policies regarding hall passes and opening outside doors leading to a less safe environment.

e) What products do you wish existed that currently do not?
Communication: Something that would efficiently tie together all the systems that the buildings use to prevent miscommunications.
Building Safety: Something to ensure only authorized people are in the building and that students don't leave the building before the school day is over.

Figure A.2: User Interview & Notes

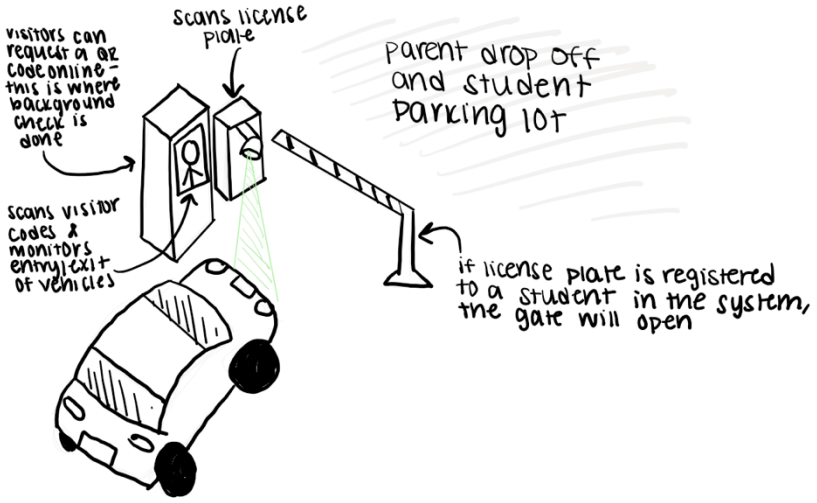

Figure A.3: Concept drawing of license plates being scanned to allow access into the facility

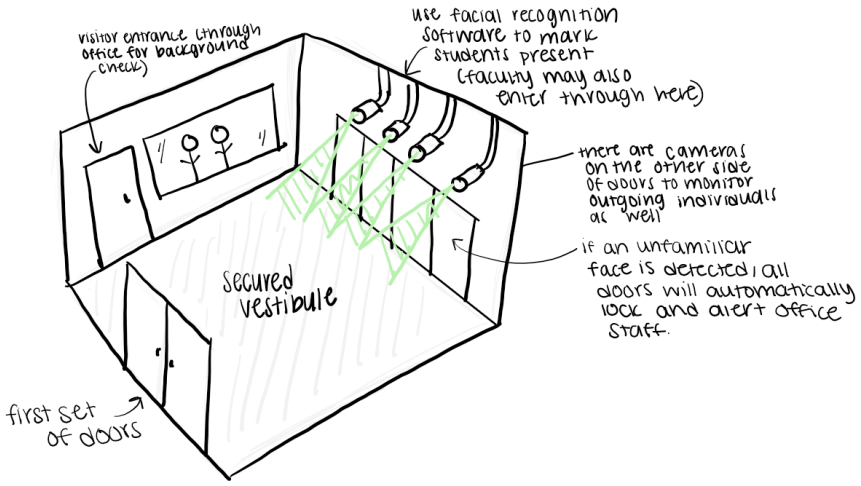

Figure A.4: Concept drawing of a facial recognition system to allow access into the facility

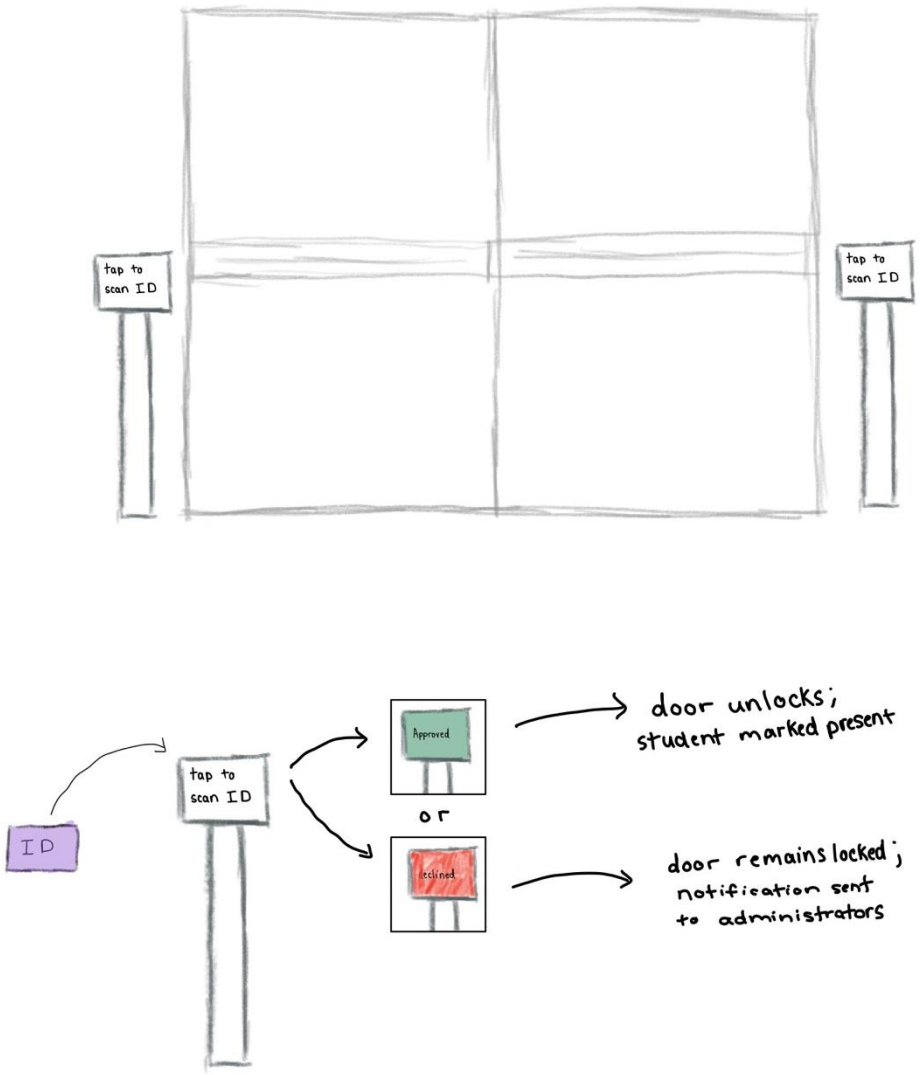

Figure A.5: Concept drawing of a system which allows student IDs to be scanned to allow access into the facility

Appendix B. Research Methodologies

	Value Categories	
Stakeholders	Economic	Social
High School Admin (End User)	**Positive**: Since the security device is automated and records attendance as students/staff enter and exit the building, School Administrators will no longer need to spend as much money on hiring staff dedicated to monitoring attendance. **Negative:** School Administrators will have to initially make a relatively large investment of money into purchasing and installing the device, which will simply have to be accounted for when the school's administrative team drafts the annual budget and projections for the years to come.	**Positive:** The security device will improve safety in schools, giving the school a good reputation within the community. This benefits administrators because it will boost enrollment in schools and their credibility as an administrator. **Negative:** Enforcing the new security system might result in pushback from students, which might disrupt the relationship between administrators and students at first.
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Teachers	**Positive:** Insurance providers such as The Hartford, Chubb, and Liberty Mutual provide insurance premiums for schools with robust security systems, including anti-theft measures. This greatly reduces replacement costs for teachers, who often have to buy everything in their classrooms. **Negative:** When budgeting to implement the new security devices, school administrators may have to reduce some teachers' wages or cut some altogether. Part-time and substitute teachers are especially at risk of receiving a wage cut or termination in cases like this.	**Positive:** Teachers will also feel safer in a school with better security, which will allow them to dedicate more time and energy into providing their students with the best possible learning experience. Also, with the attendance process being more automated, the job of monitoring student attendance won't fall to the teachers as much, which frees up time and attention they can dedicated towards teaching instead. **Negative:** Teachers might need additional training on how to work with the new attendance system, which could add too much to their workload on top of having to deal with their classes. This might initially cause a drop off in the quality of their teaching when the security systems are first implemented
Security Tech Manufacturers	**Positive:** The succesful integration of a security system in schools will lead to increased recognition and profits for the company that developed them. If their product is effective, other schools, or other potential end users with similar security needs will be more willing to do business with them **Negative:** Manufacturers will have to spend additional money and resources on developing security technology to supply to schools. They may have to restructure their budget plans to accomodate their clients if they get a large influx of customers.	**Positive:** If the tech manufactureres create a security system that is succesfully implemented in schools, it could improve the company's reputation within the industry, and make them more appealing to other potential consumers for the future. **Negative:** Any negative repercussions of the security systems in the schools may also reflect badly on the company that developed those technologies
Taxpayers	**Positive:** Having a school with enhanced security measures in the area will increase property values, so taxpayers will be able to sell their houses at higher prices in the future. **Negative**: The cost of implementing this security system may be funded by increases taxes or levies on the local taxpayers/residents.	**Positive:** Having better security in local schools results in better education and having a more educated population can lead to overall improvements in a community. This benefits taxpayers because they would get to be part of a more educated workforce **Negative:** This may cause debate amongst taxpayers in the community regarding resource allocation. Some community members may express concerns about not allocating these resources towards other infrastructure or social services instead.

Table B.1: A table showing the economic and social values of different stakeholders.

Appendix C. Prototype Working Drawing Packet

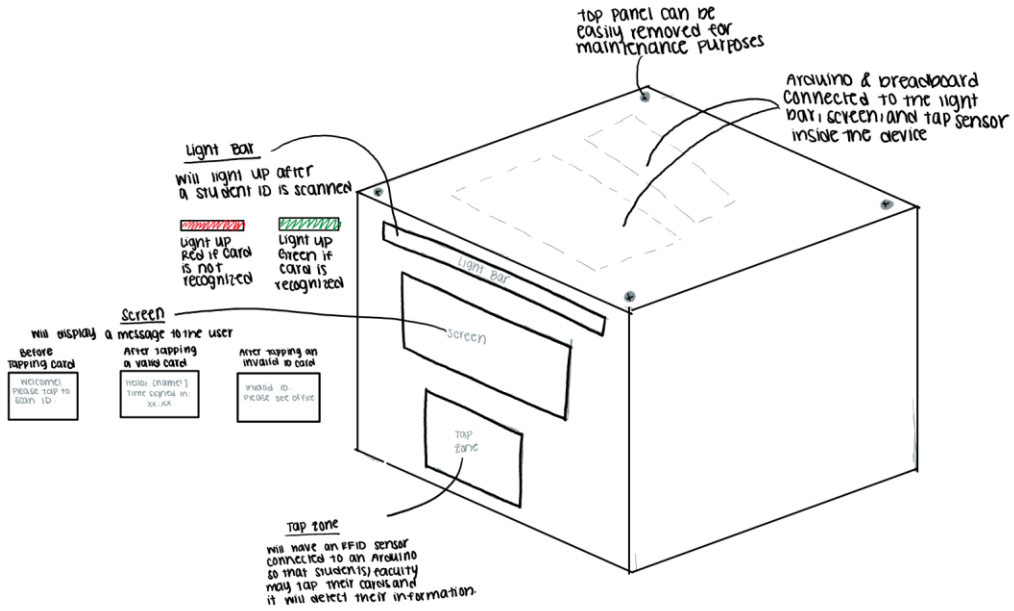


Figure C.1: Detailed drawing of preliminary prototype design with descriptions of each component

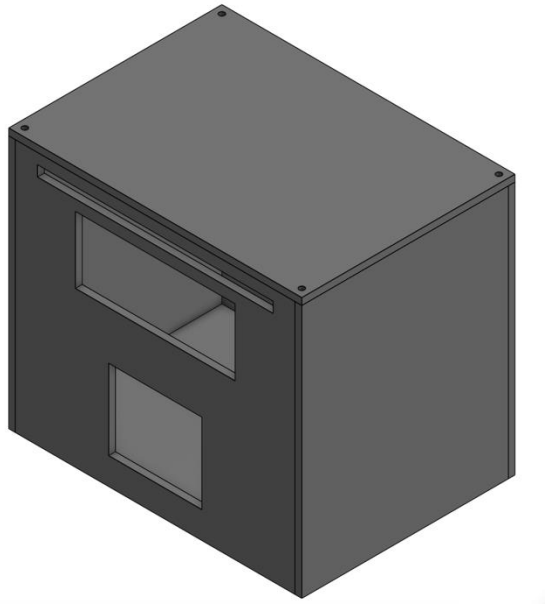


Figure C.2: Preliminary CAD model of prototype created using Onshape

Figure C.3: Inside of preliminary mockup showing an Arduino and breadboard

Figure C.4: Preliminary mockup before a user scans their identification

Figure C.5: Preliminary mockup after a user successfully scans their identification

Figure C.6: Preliminary mockup after a user's identification is invalid

Design Requirement	Testing/Verification Plan
The device correctly records attendance/building entrance at least 90% of the time	A valid ID card will be scanned 10 times, and the device should record at least 9 of the scans.
The device logs one student's attendance within 5 seconds.	Multiple time trials will be performed during which a valid ID card will be scanned, and an iPhone timer will be used to measure the prototype's reaction time. The tic/toc functions on MATLAB will also be used as another measure of time to ensure accurate
The device consists of 10 or less components.	A component is a constituent part that may be connected to other parts to form something more complex. For this design, screws, wires, and any other objects that serve to act as connectors between two components will not be considered components themselves. To verify this design requirement, each component will be labeled and recorded on a separate sheet. The components on this sheet will be counted to determine the number of components used in the prototype.
The device is less than 6x6x6 inches.	The device's dimensions will be measured by a ruler in inches.
The device can be completely disassembled with a Philip's head screwdriver.	A team member will obtain Philip's head screwdriver and attempt to remove the top panel of the device by unscrewing all 4 screws. If the top panel can be completely removed, allowing full access to the Arduino inside, the design requirement will be met.
Device will alert attendance within 5 seconds if an invalid ID card is scanned.	An invalid ID card will be scanned, and then the print function on MATLAB will be used to represent a signal being sent from the Arduino to the computer. The computer should receive this signal within 5 seconds, so an iPhone timer and the tic/toc MATLAB functions will be used to record the time taken to "alert attendance".

Table C.1: Testing Methodology and Verification Plan for each Design Requirement.

Design Requirements / User Needs Correlation Matrix								
	Device correctly records attendance/building entrance at least 90% of the time	Device logs one student's attendance within 5 seconds	Device consists of 10 or less components	Device is less than than 6x6x6 inches	Device can be disassembled with a Philip's head screwdriver	Device will alert attendance system within 5 seconds if an invalid ID card is scanned		User Need Weight
Simple	1	3	1	9	9			1
Reliable	9	9	1		3	9		2.3
Efficient	3	9		3	9	9		5
Affordable			9	1	3	1		1
Ethical		1		1	1	1		5
Accessible	1	3	1	9	3	3		5
Adaptable	1	3	1	3	9	3		5
Importance ->	46.7	103.7	22.3	90	128.9	101.7	0	493.3

Table C.2: A correlation matrix which shows the relationships between design requirements and user needs

Scorecard			
Requirement	Range	Score Rubric	Score
Device correctly records attendance/building entrance at least 90% of the time	0-2	0: Device never correctly records attendance/building entrance 1: Device correctly records attendance/building entrance 40% of the time 2: Device correctly records attendance/building entrance 90% of the time	0
Device logs one student's attendance within 5 seconds	0-5	0: Device logs one student's attendance within 30 seconds 2: Device logs one student's attendance within 15 seconds 3: Device logs one student's attendance within 10 seconds 5: Device logs one student's attendance within 5 seconds	0
Device consists of 10 or less major components	0-1	0: Device contains more than 10 components 1: Device contains of 10 or less components	1
Device is less than than 6x6x6 inches	0-5	0: Device is greater than 24x24x24 inches 2: Device is between 18x18x18 inches and 24x24x24 inches 3: Device is between 12x12x12 inches and 18x18x18 inches 5: Device is less than 6x6x6 inches	3
Top panel of the device can be removed with a Philip's head screwdriver	0-7	0: Top panel of device cannot be removed 5: Top panel of device can be partially removed with only a Philip's head screwdriver 7: Top panel of device can be fully removed with a Phillip's head screwdriver	0
Device will alert attendance system within 5 seconds if an invalid ID card is scanned	0-5	0: Device does not alert attendance system 2: Device will alert attendance system within 15 seconds if an invalid ID card is scanned 3: Device will alert attendance system within 10 seconds if an invalid ID card is scanned 5: Device will alert attendance system within 5 seconds if an invalid ID card is scanned	0

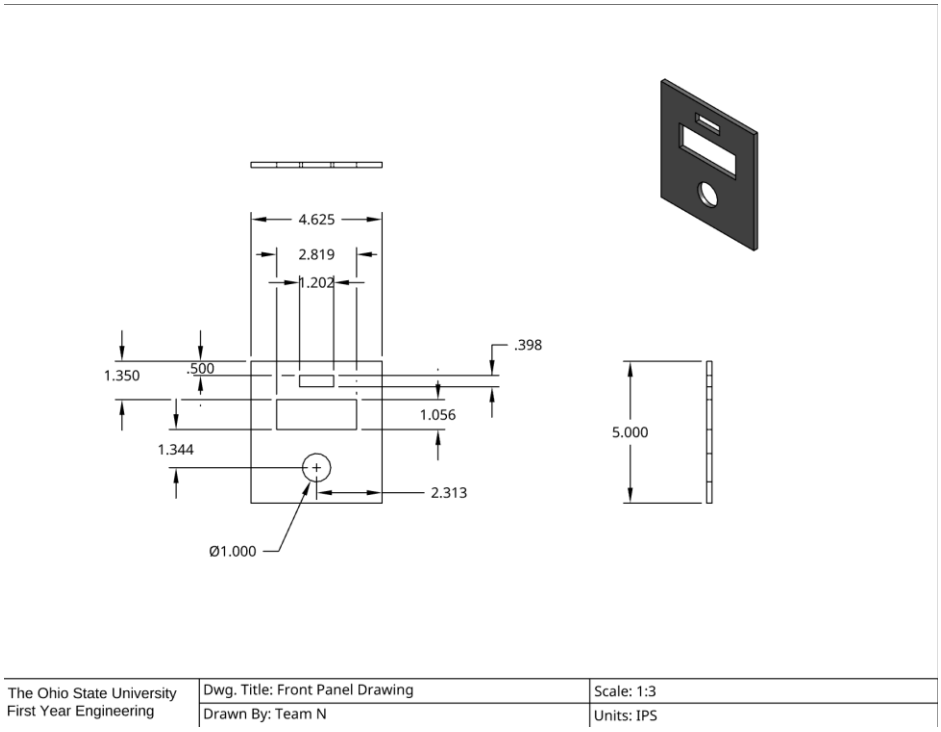
Table C.3: A scorecard which defines our design requirements, a range of possible scores, and a score rubric.

Scorecard			
Requirement	**Range**	**Score Rubric**	**Score**
Device correctly records attendance/building entrance at least 90% of the time	0-2	0: Device never correctly records attendance/building entrance 1: Device correctly records attendance/building entrance 40% of the time 2: Device correctly records attendance/building entrance 90% of the time	2
Device logs one student's attendance within 5 seconds	0-5	0: Device logs one student's attendance within 30 seconds 2: Device logs one student's attendance within 15 seconds 3: Device logs one student's attendance within 10 seconds 5: Device logs one student's attendance within 5 seconds	5
Device consists of 10 or less major components	0-1	0: Device contains more than 10 components 1: Device contains of 10 or less components	1
Device is less than than 6x6x6 inches	0-5	0: Device is greater than 24x24x24 inches 2: Device is between 18x18x18 inches and 24x24x24 inches 3: Device is between 12x12x12 inches and 18x18x18 inches 5: Device is less than 6x6x6 inches	5
Top panel of the device can be removed with a Philip's head screwdriver	0-7	0: Top panel of device cannot be removed 5: Top panel of device can be partially removed with only a Philip's head screwdriver 7: Top panel of device can be fully removed with a Phillip's head screwdriver	7
Device will alert attendance system within 5 seconds if an invalid ID card is scanned	0-5	0: Device does not alert attendance system 2: Device will alert attendance system within 15 seconds if an invalid ID card is scanned 3: Device will alert attendance system within 10 seconds if an invalid ID card is scanned 5: Device will alert attendance system within 5 seconds if an invalid ID card is scanned	5

Table C.4: The team's scorecard after final verification testing

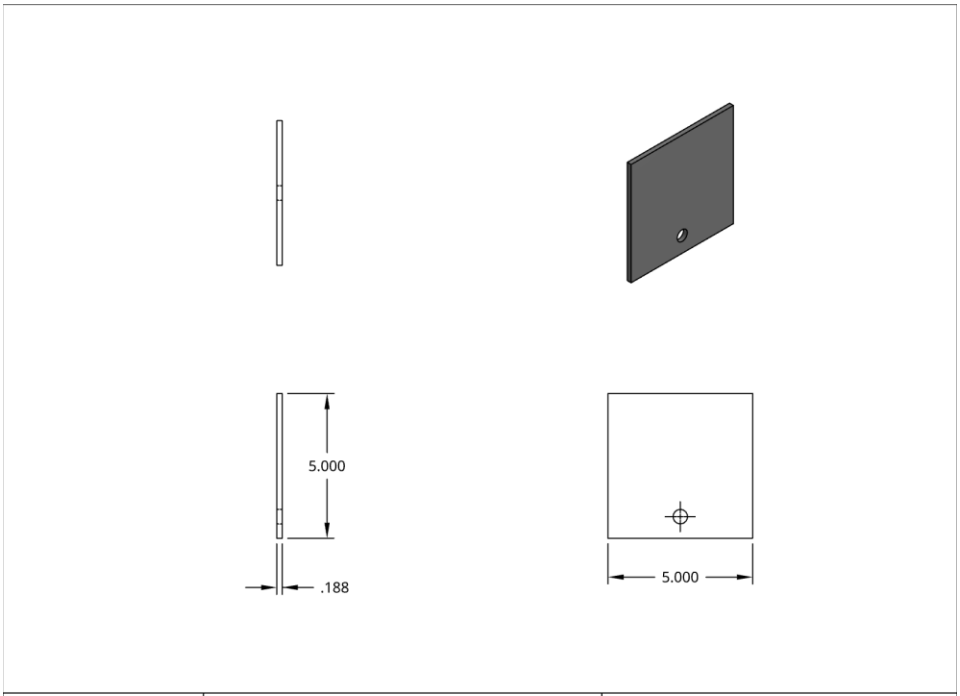
Need	Requirement Threshold	Goal
Device can accurately record student attendance	Accurately records attendance 40% of the time	Accurately records attendance 90% of the time
Device reliably reports security issues to attendance	An invalid ID scan will alert the attendance system within 15 seconds	An invalid ID scan alerts the attendance system within 5 seconds
Device works fast enough to accommodate the number of students entering the school	Logs one student's attendance in less than 30 seconds	Logs one student's attendance within 5 seconds
Device is affordable for schools	Device contains no more than 10 components	Can be assembled using 10 or less components
Device does not take up too much space	Device is no larger than 24x24x24 inches	Is no larger than 6x6x6 inches
Device is easy to disassemble	Can be partially disassembled with a screwdriver	Can be completely disassembled with a screwdriver

Table C.5: Table of design requirements with measurable range and ideal value for each requirement.



The Ohio State University First Year Engineering	Dwg. Title: Front Panel Drawing	Scale: 1:3
	Drawn By: Team N	Units: IPS

Figure C.7: Front panel drawing of prototype



The Ohio State University First Year Engineering	Dwg. Title: Left Side Panel Drawing	Scale: 1:3
	Drawn By: Team N	Units: IPS

Figure C.8: Left Side panel drawing of prototype

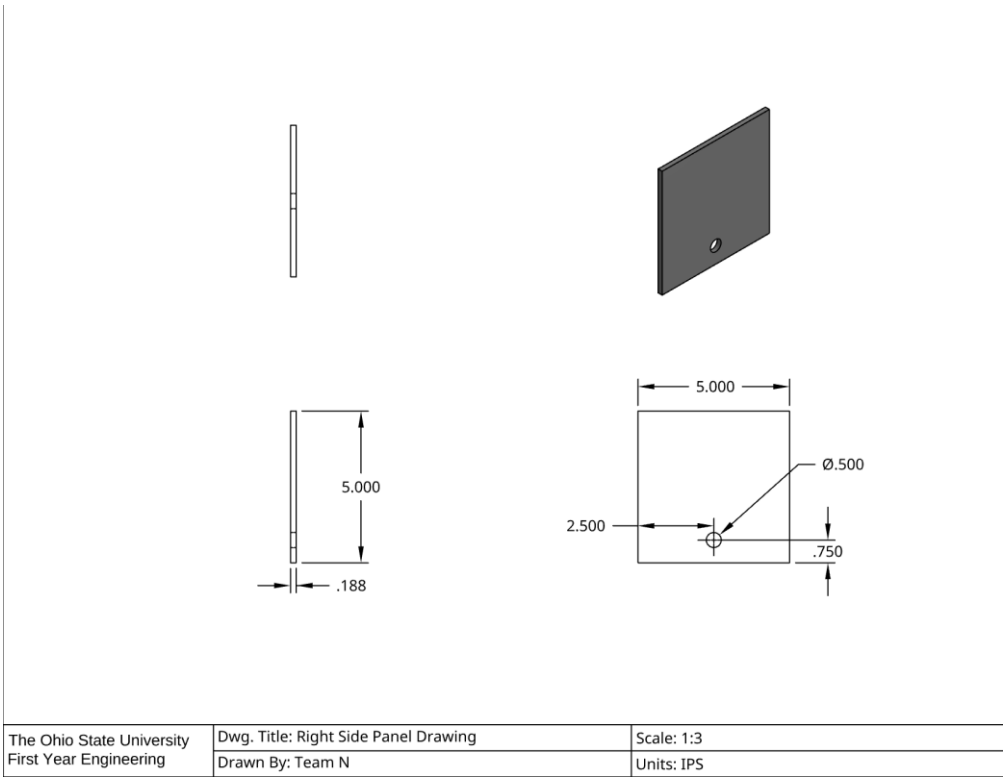


Figure C.9: Right Side panel drawing of prototype

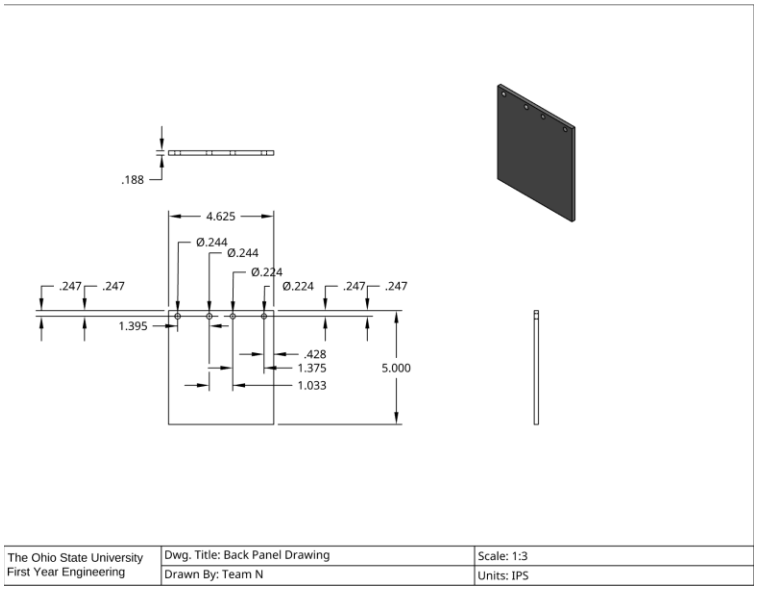


Figure C.10: Back panel drawing of prototype

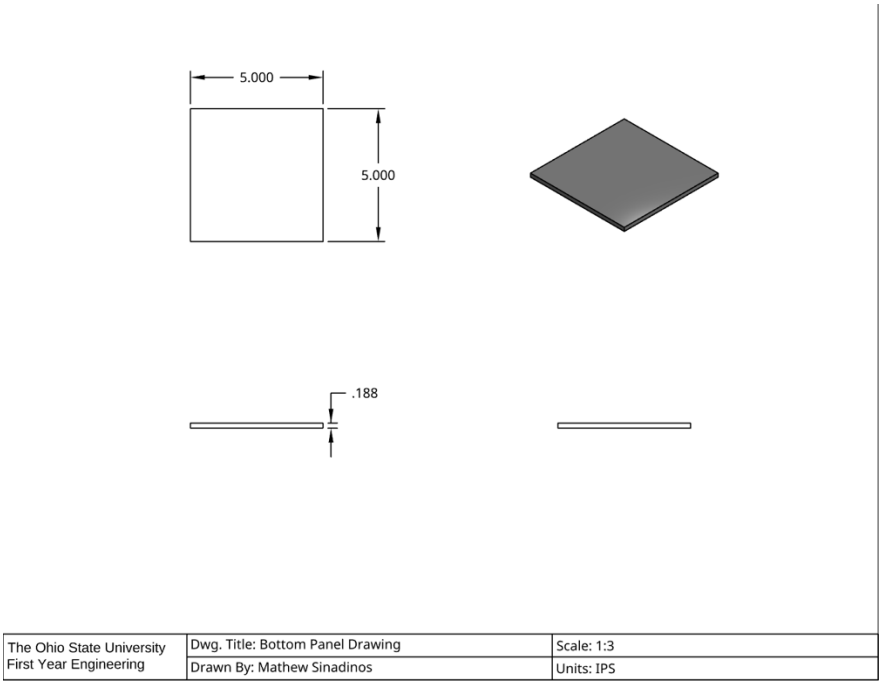


Figure C.11: Bottom panel drawing of prototype

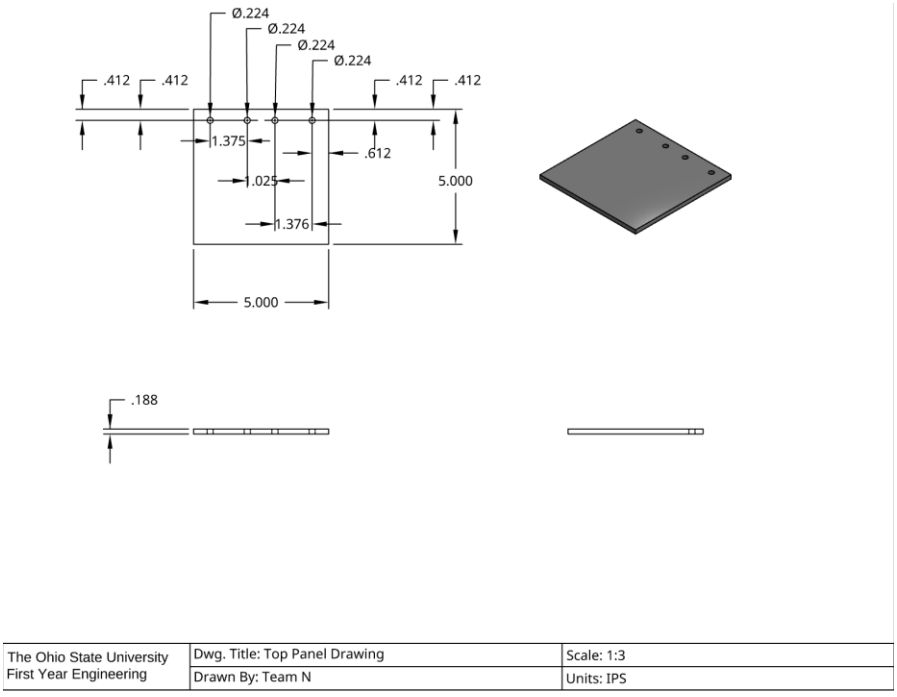
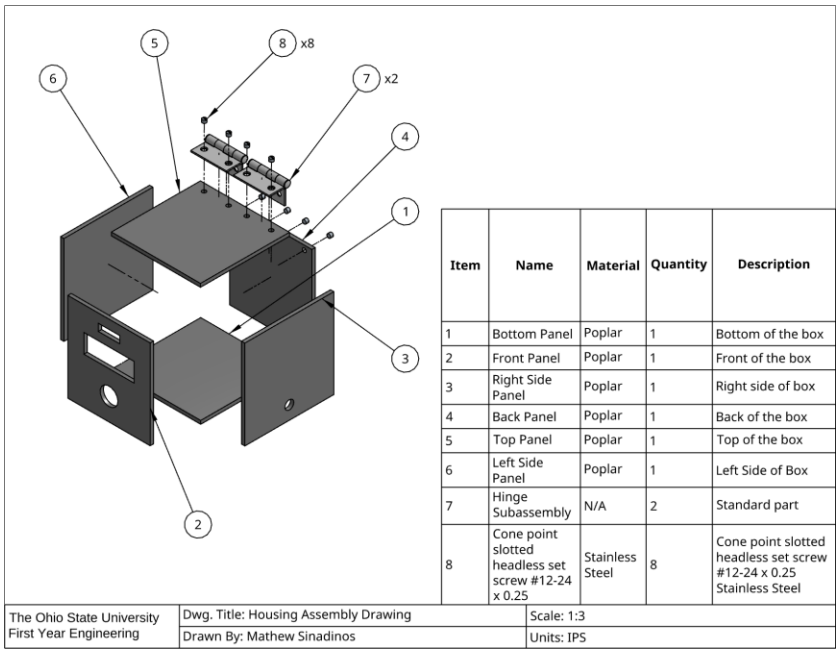


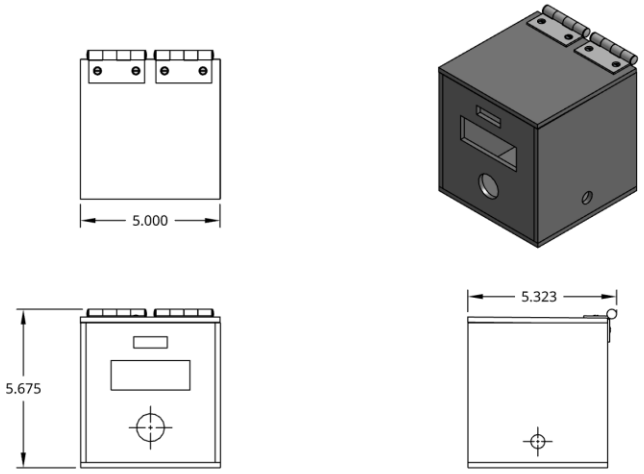
Figure C.12: Top panel drawing of prototype



Item	Name	Material	Quantity	Description
1	Bottom Panel	Poplar	1	Bottom of the box
2	Front Panel	Poplar	1	Front of the box
3	Right Side Panel	Poplar	1	Right side of box
4	Back Panel	Poplar	1	Back of the box
5	Top Panel	Poplar	1	Top of the box
6	Left Side Panel	Poplar	1	Left Side of Box
7	Hinge Subassembly	N/A	2	Standard part
8	Cone point slotted headless set screw #12-24 x 0.25	Stainless Steel	8	Cone point slotted headless set screw #12-24 x 0.25 Stainless Steel

The Ohio State University First Year Engineering	Dwg. Title: Housing Assembly Drawing	Scale: 1:3
	Drawn By: Mathew Sinadinos	Units: IPS

Figure C.13: Exploded assembly drawing of prototype



The Ohio State University First Year Engineering	Dwg. Title: Housing Assembly Drawing	Scale: 1:3
	Drawn By: Mathew Sinadinos	Units: IPS

Figure C.14: Assembly drawing of prototype

Figure C.15: Top view of Arduino enclosure prototype

Figure C.16: Isometric view of Arduino enclosure prototype

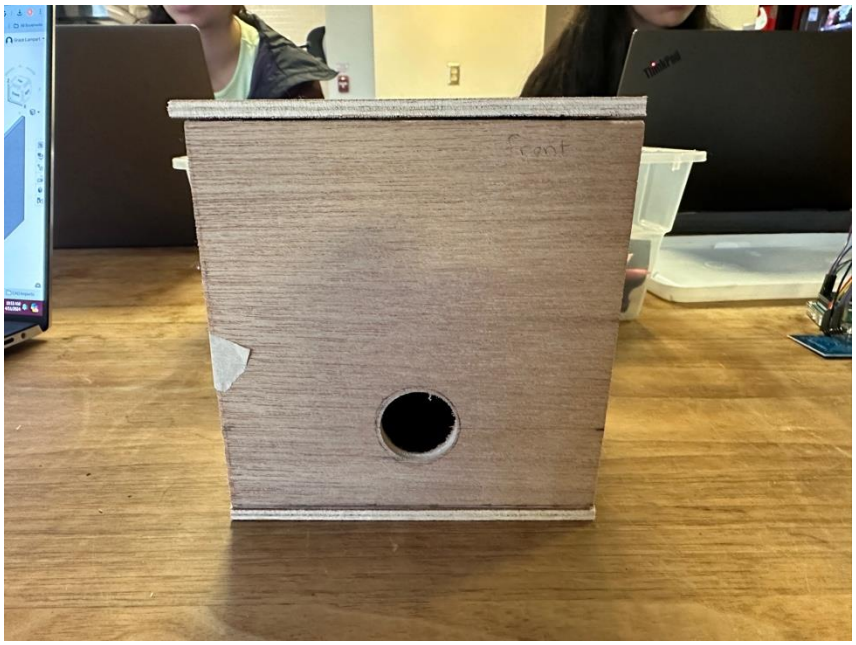


Figure C.17: Front view of Arduino enclosure prototype

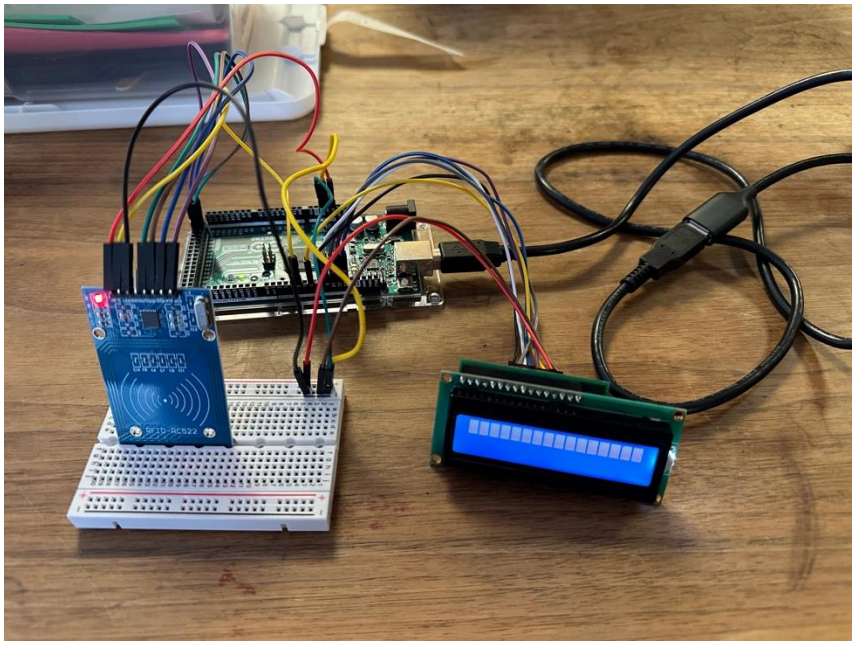


Figure C.18: Wired Arduino and Breadboard

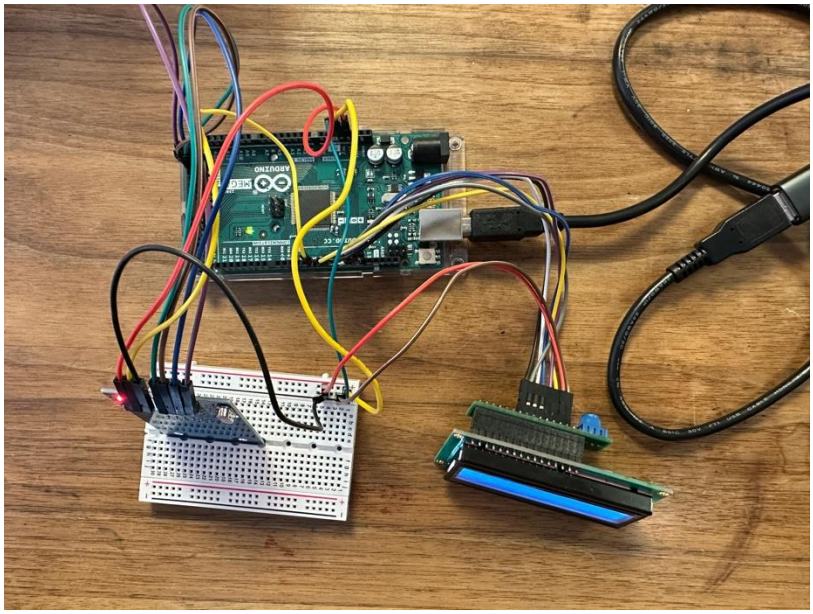


Figure C.19: Top view of wired Arduino and Breadboard

Figure C.20: Final Prototype Image

Appendix D. Software Code

```
#include <SPI.h>
#include <MFRC522.h>
#include <LiquidCrystal.h>

#define SS_PIN 53
#define RST_PIN 5
MFRC522 mfrc522(SS_PIN, RST_PIN);  // Create MFRC522 instance.
byte accessUID[4] = {0xE3,0x41,0x7A,0x35};

// initialize the library by associating any needed LCD interface pin
// with the arduino pin number it is connected to
const int rs = 12, en = 11, d4 = 6, d5 = 4, d6 = 3, d7 = 2;
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

int readsuccess;
byte readcard[4];
char str[32] = "";
String StrUID;

void setup() {
  lcd.begin(16,2);
  // Print a message to the LCD.
  lcd.print("Hello! Please");

  // set the cursor to column 0, line 1
  // (note: line 1 is the second row, since counting begins with 0):
  lcd.setCursor(0, 1);
  // print the number of seconds since reset:
  lcd.print("scan your ID");

  Serial.begin(9600); // Initialize serial communications with the PC
  SPI.begin();      // Init SPI bus
  mfrc522.PCD_Init(); // Init MFRC522 card
  delay(1000);

  Serial.println("CLEARDATA");
  Serial.println("LABEL,Date,Time,RFID UID");
  delay(1000);

  Serial.println("Scan PICC to see UID...");
```

```
  Serial.println("");
}
// ----------------------------------------------------------------
void loop() {
  readsuccess = getid();

  if(readsuccess){
    Serial.println( (String) "DATA,DATE,TIME," + StrUID );
  }
}
// ----------------------------------------------------------------
int getid(){
  if(!mfrc522.PICC_IsNewCardPresent()){
    return 0;
  }
  if(!mfrc522.PICC_ReadCardSerial()){
    return 0;
  }


  Serial.println("THE UID OF THE SCANNED CARD IS:");
  if(mfrc522.uid.uidByte[0] == accessUID[0] && mfrc522.uid.uidByte[1] ==
accessUID[1] && mfrc522.uid.uidByte[2] == accessUID[2] &&
mfrc522.uid.uidByte[3] == accessUID[3] && mfrc522.uid.uidByte[4] ==
accessUID[4] && mfrc522.uid.uidByte[5] == accessUID[5] &&
mfrc522.uid.uidByte[6] == accessUID[6])
  {
    for(int i=0;i<4;i++){
      readcard[i]=mfrc522.uid.uidByte[i]; //storing the UID of the tag in
readcard
      array_to_string(readcard, 4, str);
      StrUID = str;
      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("Welcome Niha!");
    }
  }else
  {
    StrUID = "NOTVALID";
    lcd.clear();
```

```
    lcd.setCursor(0,0);
    lcd.print("Invalid ID");
    delay(1200);
    lcd.clear();
    lcd.setCursor(0,0);
    lcd.print("Go to main");
    lcd.setCursor(0,1);
    lcd.print("office");

  }
  delay(1500);
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Hello! Please");
  lcd.setCursor(0,1);
  lcd.print("scan your ID");
  mfrc522.PICC_HaltA();
  return 1;
}
// ------------------------------------------------------------------
void array_to_string(byte array[], unsigned int len, char buffer[])
{
    for (unsigned int i = 0; i < len; i++)
    {
        byte nib1 = (array[i] >> 4) & 0x0F;
        byte nib2 = (array[i] >> 0) & 0x0F;
        buffer[i*2+0] = nib1  < 0xA ? '0' + nib1  : 'A' + nib1  - 0xA;
        buffer[i*2+1] = nib2  < 0xA ? '0' + nib2  : 'A' + nib2  - 0xA;
    }
    buffer[len*2] = '\0';
}
```

Figure D.1: Arduino code

Appendix F. Project Management Schedule and Meeting Minutes

17.Project Schedule

Finalized Prototyping Plan

The team plans on prototyping the final design by creating a case/enclosure that will house the Arduino and its components, and one face of the case will be equipped with a screen, lightbar, and RFID sensor where ID cards may be scanned. The top face of the case will be designed so that it can be easily removed using a simple screwdriver, allowing for easy maintenance of the electronic components inside. The design will also have a mount on the back so that it may be easily fitted to walls and other areas. To achieve this, the team initially planned on utilizing a laser cutter due to the many flat edges that the design features. However, the team decided to opt for using manual tools like a band saw to cut the plywood that will be used to make the box/case in the interest of time and money. The team will then utilize a threading tool available in the workshop to create threads in 4 corners of the case's top face where screws will be placed. Finally, a circular opening will be made in the side face of the box so that wires may be fed through to the Arduino. After building the case, the team will assemble the Arduino and use MATLAB to write and test programs. The team acquired an RFID Arduino sensor along with 2 cards that the sensor can read, and those will also be used to test the device. The limitations of this prototype plan are mainly time and budget, however, the team also discovered that only 2 individuals can simultaneously work on the prototype. Furthermore, none of the team members currently have any woodworking experience, which will be crucial to creating the case of the prototype.

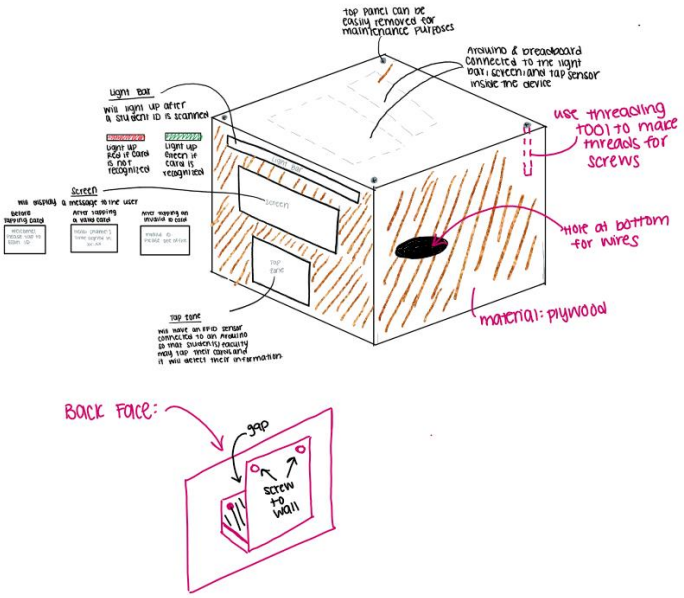


Figure F.1: Table of project schedule the team plans to follow with timelines for each component of the prototyping design process.

Major Deliverables

The final product the team will create is a working school security device that records student attendance from an ID scan within with 90% accuracy and notifies the system within 5 seconds if an invalid ID is scanned. The device will be composed of fewer than 10 components, be less than 6x6x6 inches, and be disassembled with a screwdriver. These requirements will be tested during the final verification. The team will also deliver a technical review of the engineering design process in assignment FD4 and a final product pitch in assignment FD2.

Gantt Chart Template			
	Project Start Date	Project End Date	Today's Date
	3/25/24	4/22/24	4/10/24
Task Description & Lead Initials	Start Date	End Date	% complete
Pick up Materials (MS)	3/26/24	3/31/24	100
Order Arduino Sensor on Amazon (MS)	3/27/24	3/28/24	100
Begin Prototyping Case/Enclosure (GL)	3/29/24	4/3/24	25
Draft Pseudocode (AJ)	4/1/24	4/3/24	0
Complete Arduino code (NT)	4/3/24	4/7/24	10
Develop Configuraiton for Wires/Components on Breadboard and Arduino (GL)	4/3/24	4/5/24	100
Develop a Testing Plan for the Code (AJ)	4/5/24	4/8/24	0
Develop Testing Plan for Physical Prototype + Code (MS)	4/6/24	4/9/24	0
...	4/8/24	4/20/24	0
...	4/12/24	4/17/24	0
...	4/14/24	4/19/24	0
...	4/16/24	4/21/24	0
	4/17/24	4/22/24	0
Task X (YZ)	4/17/24	4/22/24	0

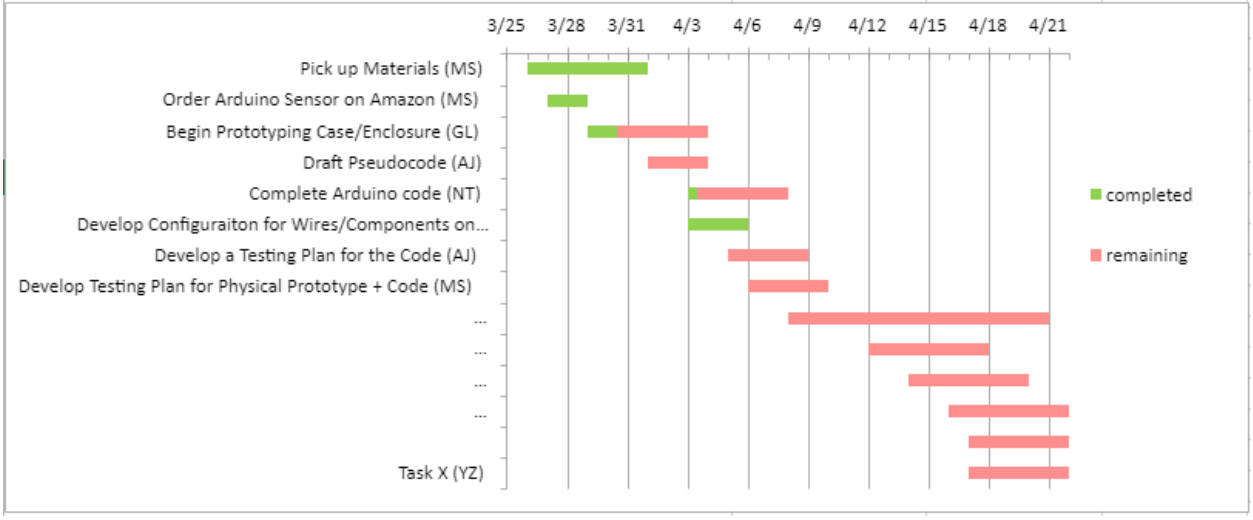


Table F.1: Table of project schedule the team plans to follow with timelines for each component of the prototyping design process.

Detailed Schedule Discussion

The schedule outlined in the Gantt Chart outlines the order of tasks and designates a team lead for each task. The team will first order and pick up materials for the Arduino component. During the class lab time, the team will work in Smith lab to build the enclosure box for the Arduino and sensors. Next, the team will write the code for Arduino in MATLAB. A configuration for the wires on the breadboard and Arduino will be developed. The MATLAB code and physical prototype will be tested by the team before the final verification to ensure all requirements are met and any bugs in the device can be resolved. A critical path in the team's schedule is drafting pseudocode, writing the final MATLAB code, developing wire configurations for the Arduino, and implementing a testing plan for the code. This sequence of tasks will most likely be the most time-consuming and technically complex to get done, so the team will have to have to plan many other tasks in the prototype development process around the completion of these tasks. The software aspects of the team's prototype are a key part of the device's functionality. For the prototype to meet most of the design requirements for this project, the Arduino components need to be working properly, which is dependent on the coding tasks being completed in a timely manner. This could be a potential bottleneck in the project because without the software code being completed, the rest of the prototype development process will be stalled.

18. Prototyping Workday 1 Meeting Minutes

3/29/2024, 11:30AM, Hitchcock 308

Members Attended: Niha Talele, Grace Lampart, Mathew Sinadinos, Avani Jagdale

Objective Statement:

To continue working on R2 and develop a plan to begin prototyping our design.

Completed Tasks:

- Scheduled a team meeting for Monday, April 1st at 1st floor at 6 PM (Mathew, Niha, Grace, Avani)
- Delegated Mathew to pick up prototyping materials from Smith Lab 0094 (Mathew, Niha, Grace, Avani)
- Added missing improvements made to Grand Concepts Design for R2 (Mathew, Niha, Grace, Avani)
- Created Gantt chart (Mathew, Niha, Grace, Avani)

Tasks to be completed:

- Complete DD1 Project Management (Mathew, Niha, Grace, Avani)
- Complete P2 - Grand Concept & Prototype Plan (Questions) (Mathew, Niha, Grace, Avani)
- Complete R2 - Concept Development Review (Mathew, Niha, Grace, Avani)
- Complete TM8 - CATME Team Evaluations 2 (Mathew, Niha, Grace, Avani)
- Begin prototype development in preparation for testing on Project 22 - Initial Verification (Mathew, Niha, Grace, Avani)

Decisions:

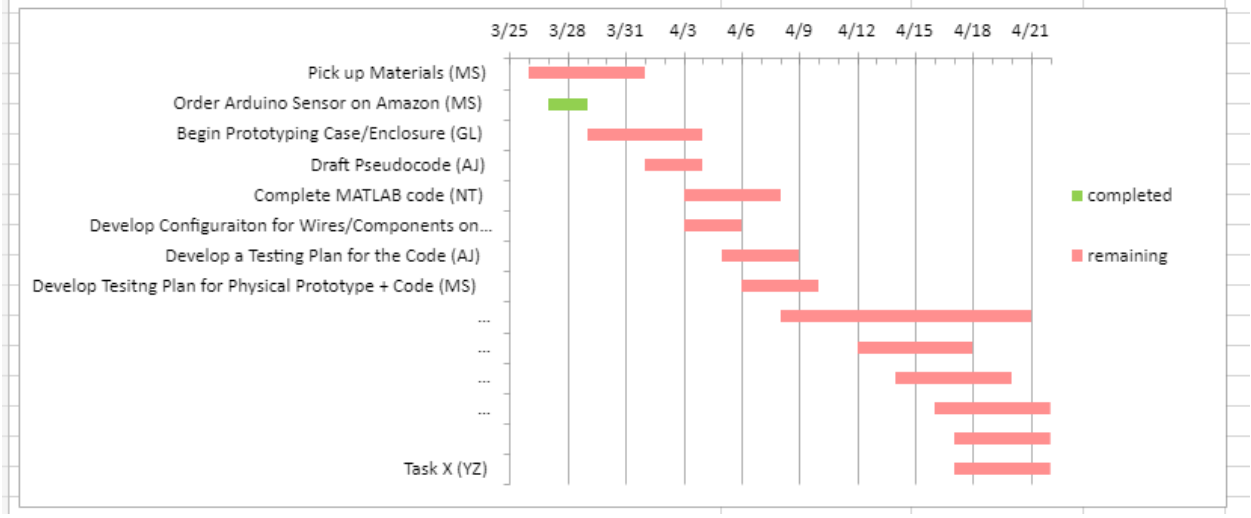
The team assigned leads for different portions of the prototyping process in the Gantt chart based on team member strengths. Niha, Mathew, and Avani will take the main leads when it comes to programming Arduino because they are CSE majors and have experience coding. Grace will take the lead on building the enclosure for the Arduino.

Project Timeline:

Gantt Chart Template

	Project Start Date	Project End Date	Today's Date
	3/25/24	4/22/24	3/29/24

Task Description & Lead Initials	Start Date	End Date	% complete
Pick up Materials (MS)	3/26/24	3/31/24	0
Order Arduino Sensor on Amazon (MS)	3/27/24	3/28/24	100
Begin Prototyping Case/Enclosure (GL)	3/29/24	4/3/24	0
Draft Pseudocode (AJ)	4/1/24	4/3/24	0
Complete MATLAB code (NT)	4/3/24	4/7/24	0
Develop Configuraiton for Wires/Components on Breadboard and Arduino (GL)	4/3/24	4/5/24	0
Develop a Testing Plan for the Code (AJ)	4/5/24	4/8/24	0
Develop Tesitng Plan for Physical Prototype + Code (MS)	4/6/24	4/9/24	0
...	4/8/24	4/20/24	0
...	4/12/24	4/17/24	0
...	4/14/24	4/19/24	0
...	4/16/24	4/21/24	0
	4/17/24	4/22/24	0
Task X (YZ)	4/17/24	4/22/24	0



19.Prototyping Workday 2 Meeting Minutes

4/10/2024, 12:45PM, Hitchcock 308

Members Attended: Niha Talele, Grace Lampart, Mathew Sinadinos, Avani Jagdale

Objective Statement:

To continue working on DD3 and finish building a prototype of design.

Completed Tasks:

- Scheduled a team meeting for Thursday, April 11th on 1st floor at 10:15 AM (Mathew, Niha, Grace, Avani)
- Picked up prototyping materials from Smith Lab (Mathew)
- Successfully wired the Arduino and its components (Mathew and Niha)
- Completed Tool Shop Training (Grace and Avani)
- Updated Gantt chart (Mathew, Niha, Grace, Avani)

Tasks to be completed:

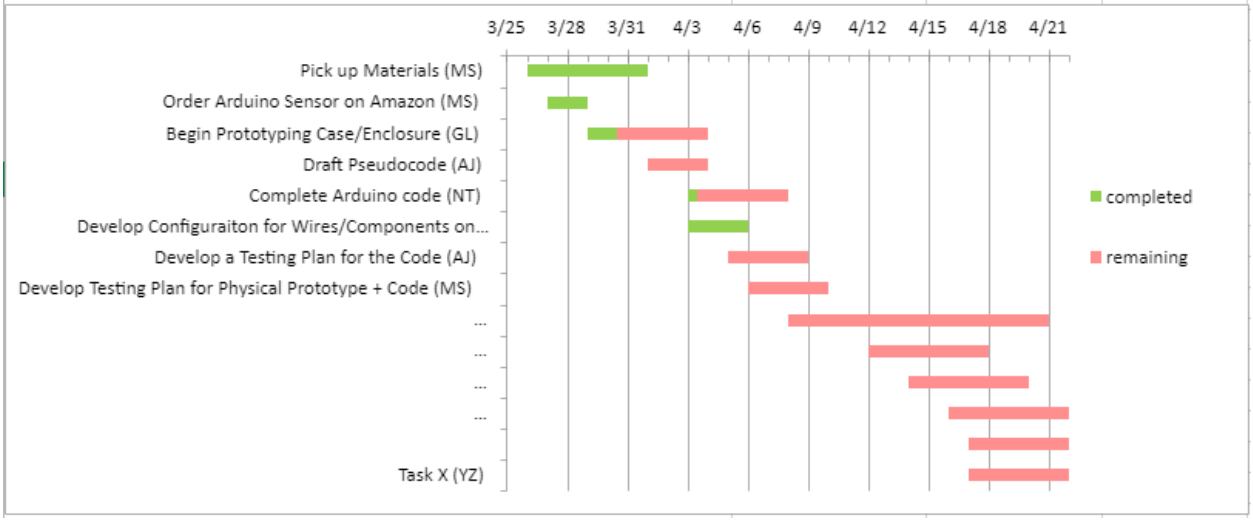
- Complete DD3 - Communicating Value & Determining Next Steps (Mathew, Niha, Grace, Avani)
- Complete code for prototype (Mathew, Niha)
- Complete box enclosure for prototype (Grace, Avani)
- Begin testing prototype (Mathew, Niha, Avani, Grace)

Decisions:

The team assigned leads for different portions of the prototyping process in the Gantt chart based on team member strengths. Niha, Mathew, and Avani will take the main leads when it comes to programming Arduino because they are CSE majors and have experience coding. They decided it would be best to code in the Arduino language over MATLAB because the RFID sensor library is not compatible with MATLAB. Grace will take the lead on building the enclosure for the Arduino.

Project Timeline:

Gantt Chart Template			
	Project Start Date	Project End Date	Today's Date
	3/25/24	4/22/24	4/10/24
Task Description & Lead Initials	Start Date	End Date	% complete
Pick up Materials (MS)	3/26/24	3/31/24	100
Order Arduino Sensor on Amazon (MS)	3/27/24	3/28/24	100
Begin Prototyping Case/Enclosure (GL)	3/29/24	4/3/24	25
Draft Pseudocode (AJ)	4/1/24	4/3/24	0
Complete Arduino code (NT)	4/3/24	4/7/24	10
Develop Configuraiton for Wires/Components on Breadboard and Arduino (GL)	4/3/24	4/5/24	100
Develop a Testing Plan for the Code (AJ)	4/5/24	4/8/24	0
Develop Testing Plan for Physical Prototype + Code (MS)	4/6/24	4/9/24	0
...	4/8/24	4/20/24	0
...	4/12/24	4/17/24	0
...	4/14/24	4/19/24	0
...	4/16/24	4/21/24	0
	4/17/24	4/22/24	0
Task X (YZ)	4/17/24	4/22/24	0



20.Prototyping Workday 3 Meeting Minutes

4/12/2024, 11:30AM, Hitchcock 308

Members Attended: Niha Talele, Grace Lampart, Mathew Sinadinos, Avani Jagdale

Objective Statement:

To continue working on completing a prototype of our design.

Completed Tasks:

- Scheduled a team meeting for Monday, April 15th on 1st floor (Mathew, Niha, Grace, Avani)
- Completed DD3 assignment (Mathew, Niha, Grace, Avani)
- Picked up prototyping materials from Smith Lab (Mathew)
- Successfully wired the Arduino and its components (Mathew and Niha)
- Completed Tool Shop Training (Grace and Avani)
- Updated Gantt chart (Mathew, Niha, Grace, Avani)

Tasks to be completed:

- Solder pins to fix wiring issues
- Finish coding for the servo motor on the Arduino
- Complete code for prototype (Mathew, Niha)
- Complete box enclosure for prototype (Grace, Avani)
- Begin testing prototype (Mathew, Niha, Avani, Grace)

Decisions:

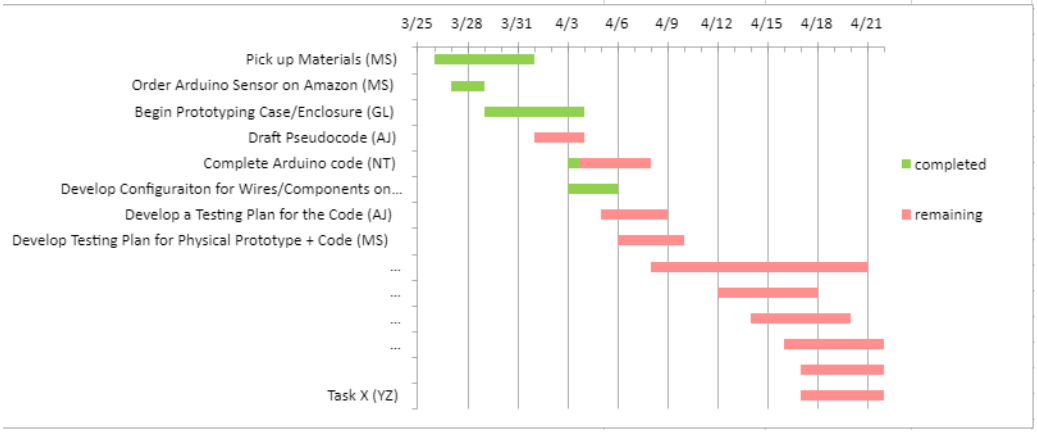
The team assigned leads for different portions of the prototyping process in the Gantt chart based on team member strengths. Niha, Mathew, and Avani will take the main leads when it comes to programming Arduino because they are CSE majors and have experience coding. They decided it would be best to code in the Arduino language over MATLAB because the RFID sensor library is not compatible with MATLAB. The team encountered some errors with getting the sensor to successfully connect, which led to the decision to solder the pins in order to get the Arduino to stop giving an error when the code is run. Grace will take the lead on building the enclosure for the Arduino.

Project Timeline:

Gantt Chart Template

	Project Start Date	Project End Date	Today's Date
	3/25/24	4/22/24	4/12/24

Task Description & Lead Initials	Start Date	End Date	% complete
Pick up Materials (MS)	3/26/24	3/31/24	100
Order Arduino Sensor on Amazon (MS)	3/27/24	3/28/24	100
Begin Prototyping Case/Enclosure (GL)	3/29/24	4/3/24	100
Draft Pseudocode (AJ)	4/1/24	4/3/24	0
Complete Arduino code (NT)	4/3/24	4/7/24	15
Develop Configuraiton for Wires/Components on Breadboard and Arduino (GL)	4/3/24	4/5/24	100
Develop a Testing Plan for the Code (AJ)	4/5/24	4/8/24	0
Develop Testing Plan for Physical Prototype + Code (MS)	4/6/24	4/9/24	0
...	4/8/24	4/20/24	0
...	4/12/24	4/17/24	0
...	4/14/24	4/19/24	0
...	4/16/24	4/21/24	0
	4/17/24	4/22/24	0
Task X (YZ)	4/17/24	4/22/24	0



21.Prototyping Workday 4 Meeting Minutes

4/16/2024, 12:45PM, Hitchcock 308

Members Attended: Niha Talele, Grace Lampart, Mathew Sinadinos, Avani Jagdale

Objective Statement:

To finish wiring and writing code for the Arduino component of the prototype. To finalize our enclosure for the Arduino component and prepare for final verification testing.

Completed Tasks:

- Scheduled a team meeting for Tuesday, April 16th on 1st floor at 6:30 PM (Mathew, Niha, Grace, Avani)
- Completed box enclosure for prototype (Grace)
- Tested Arduino component enclosure using the Verification Scorecard (Grace)

- Soldered wires to RFID chip (Mathew and Niha)
- Successfully coded LED screen and RFID (tap) sensor (Mathew and Niha)
- Updated Gantt chart (Grace)

Tasks to be completed:

- Code Arduino to interact with an Excel document to record attendance (Avani and Niha)
- Code the light bar so it lights up when an ID is accepted (Mathew)
- Begin Final Pitch Presentation (Grace, Mathew, Niha, Avani)
- Update Prototype Working Drawings Packet (Grace)
- Complete Technical Design Review (Grace, Niha, Mathew, Avani)
- Complete code for prototype (Mathew, Niha, Avani)
- Test final prototype using design requirements (Mathew, Niha, Avani, Grace)

Decisions:

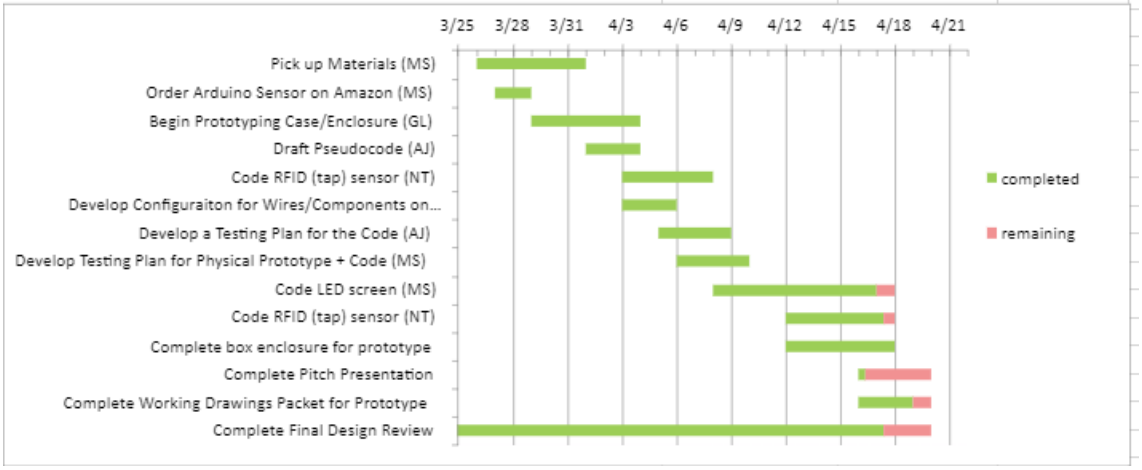
Based on user feedback, the team decided to have the box for the Arduino open with a hinge rather than being screwed in. The size of the box was decided on to make mass manufacturing more efficient and cost effective. The team developed a plan to finalize the prototype before testing based on team member strengths. Niha, Mathew, and Avani will take the main leads when it comes to programming Arduino because they are CSE majors and have experience coding. They decided it would be best to code in the Arduino language over MATLAB because the RFID sensor library is not compatible with MATLAB. Grace will take the lead on adding final touches to the enclosure for the Arduino and update the Technical Design Review Document according to the changes the team has made. The team may fall short when it comes to getting the door to lock/unlock when IDs are scanned due to time and money constraints.

Project Timeline:

Gantt Chart Template

	Project Start Date	Project End Date	Today's Date
	3/25/24	4/22/24	4/16/24

Task Description & Lead Initials	Start Date	End Date	% complete
Pick up Materials (MS)	3/26/24	3/31/24	100
Order Arduino Sensor on Amazon (MS)	3/27/24	3/28/24	100
Begin Prototyping Case/Enclosure (GL)	3/29/24	4/3/24	100
Draft Pseudocode (AJ)	4/1/24	4/3/24	100
Code RFID (tap) sensor (NT)	4/3/24	4/7/24	100
Develop Configuraiton for Wires/Components on Breadboard and Arduino (GL)	4/3/24	4/5/24	100
Develop a Testing Plan for the Code (AJ)	4/5/24	4/8/24	100
Develop Testing Plan for Physical Prototype + Code (MS)	4/6/24	4/9/24	100
Code LED screen (MS)	4/8/24	4/17/24	90
Code RFID (tap) sensor (NT)	4/12/24	4/17/24	90
Complete box enclosure for prototype	4/12/24	4/17/24	100
Complete Pitch Presentation	4/16/24	4/19/24	10
Complete Working Drawings Packet for Prototype	4/16/24	4/19/24	75
Complete Final Design Review	3/25/24	4/19/24	90



Appendix G. Team Working Agreement

Term Spring 2024
Created Date: 1/16/24 Revised Date: 2/26/24

1. Team Information

Course Section # - 8117
Team Designation - N
Instructor and GTA - Dr. Braaten (Instructor) & Simon Pusateri (GTA)
Team Name (Optional) - Team Nachos

Contact Information:

Name	Email Address	Phone Number
Niha Talele	talele.5@osu.edu	614-808-6442
Mathew Sinadinos	sinadinos.1@osu.edu	+1 (331) 425-3449
Avani Jagdale	jagdale.9@osu.edu	513-909-5915
Grace Lampart	lampart.3@osu.edu	(513)-567-6520

2. Team Values & Goal

What are the team's top 5 values?

1. Family
2. Friends
3. Kindness
4. Perseverance
5. Communication

What are the team's expectations of quality level? Top goals? Minimum acceptable goals?
We want to achieve an A in the overall course and a minimum of an A- on all team assignments. To accomplish this, all teammates will adhere to the posted rubrics.

Include at least 1 goal regarding psychological safety, belonging, and inclusion.
We want to create a judgement-free zone; thus, teammates should be open-minded to all ideas.

3. Communication and Meetings

What are your team's preferred method(s) of contact and expected response time(s)?
We will communicate using an iMessage group chat. Teammates are expected to respond to text messages within 4 hours from 8am-10pm.

How often do you plan on meeting to achieve your goals? (Do you anticipate this changing throughout the semester?)
We will meet twice a week as a team in about 2-hour time blocks. On of our team meetings will take place in open lab so we can ask Tas questions and get clarifications about assignment guidelines. During this time, we will meet our goals this semester by collaborating effectively through team assignments, delegating the workload amongst the team members, and double checking each other's work.

Primary and Secondary Meeting Day/Time/Location

Meeting Location: Hitchcock 308 during open lab; First floor of Drackett Tower
Primary Day/Time: Tuesdays after 5:00 pm.
Secondary 1st Day/Time: Monday at 6:30 pm in Hitchcock 308.
2nd Day/Time: Thursday at 10:15am on Drackett 1st floor

Individual(s) in charge of agendas, reminders, minutes
We will rotate these duties amongst us for every meeting.

4. General Expectations and Group Norms

How are team members expected to behave? What are the group norms?

- Be respectful
- Open minded
- No talking over each other
- Completing assigned work on time

What are acceptable/unacceptable types of interaction?
Acceptable: being kind, encouraging, managing your time, open-minded
Unacceptable: yelling, doing work last minute, not collaborating, being stubborn

What are team member expectations regarding attendance?
Team members are expected to attend every class/meeting. If they are unable to attend, they should let the group know ahead of time. If the team member is out of town, they will be able to FaceTime into the meetings.

How are team members expected to behave during lab/class periods?
Pay attention to the instructor and following group norms set forth.

What are team members meant to do between classes? Lab/class preparation?
Complete all pre-class preparation, communicate with your team, and stay on-top of workload.

How are team members meant to ensure the team stays on track?
Checking in during meetings and set soft deadlines for assignments to have them done before the actual deadline. Additionally, the team will check grades for the last week's assignments together and discuss how the team can improve/learn from the feedback received.

How are documents expected to be shared? (e.g. OneDrive, Google Docs, etc.)
OneDrive through the Team N folder

How many days before an assignment is due should everybody have their portion completed for review?
1-2 days

When should team members first notify the group if they are struggling?
If the task at hand is taking longer than it should, notify the team as soon as possible. They can also bring up the question at Open Lab during Monday meetings so a TA can assist

5. Individual Team Member Responsibilities

When/how will individual tasks/responsibilities be assigned? How will the team ensure work is fairly divided and that everyone participates equally?
Individual tasks/responsibilities will be assigned in-class and at team meetings. Tasks will be assigned on a rotation with group members' strengths and weaknesses in mind.

Are there specific roles that all team members have?
All teammates will have the opportunity to both lead and follow when completing assignments. Roles will be shared and delegated at team meetings accordingly.

What specific tasks are team members in charge of?
Depending on the project, each team member will be assigned a task that caters to their strengths.

How often will these roles/task rotate?
The roles delegated to group members will rotate after each assignment. We will take turns submitting the team report out and assignment documents.

6. Conflict Resolution

Once the Team Working Agreement is established, open and honest discussions must occur within the group when the agreed-on expectations are not being met.

When there is disagreement amongst members, how will the team make decisions?
Each member involved in the disagreement should be presented with the opportunity to communicate their feelings and ideas. Based on these ideas, the team will decide after everyone has been heard out.

How will team members above be held accountable (be specific!)? How will team members that are not meeting expectations (not contributing to the team effectively) be addressed? How will team members that are not interacting appropriately with team members be addressed?
Team members will be held accountable through team evaluations and through expressing concerns when an issue arises.

How will the team handle resolving issues when a team member is not acting inclusively?
The team will have an open and honest discussion, and if this is not effective, the team will go to the instructors.

What are the consequences for violating this agreement (be creative!)?
Realistically, the consequences will be to remind the team members of the evaluations' impact on their final grades and then to get instructors involved.

When is it okay to redefine goals, expectations, and responsibilities?
If the current expectations aren't being met and if all team members agree to adjust expectations and goals.

When will UTAs, GTAs, or the instructor become involved?
If a team member is in consistent violation of the team working agreement (such as never showing up to meetings or completing their assigned work).

7. Expectations of Faculty and GTAs

If a member within the group consistently violates the Team Working Agreement, they may be reported to a UTA, GTA, or instructor. Regardless of the outcome, the team will still be responsible for completing the assignment.

8. Team Signatures

___Mathew Sinadinos_____
Name

___Grace Lampart_____
Name

__Niha Talele_____
Name

__Avani Jagdale_____
Name