GNG1103

Final Design Report

[OP-Watch - Opioid Overdose Detection Device]

Submitted by

[Supreme Designers. Team 7]

[Abdel Baig, 300121134]

[Bilal Ahmad, 300125852]

[Ali Al-Zaidi, 300082526]

[David Onoruvwe, 300144303]

[Yazan Elmasry, 300136709]

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University of Ottawa

Abstract

This user manual will provide accessibility to the reader of all project documentation and will allow him or her to maintain, integrate, or configure our entire design project. This project focuses on the development of our opioid overdose detection device, entitled, “OP-Watch.” This prototype predominantly involves the usage of electrical components such as the Arduino ESP-32 Bluetooth microcontroller and the Sensor MAX30100. For our device, we have produced a physical prototype and a mobile application. The main objective of this design project is to provide emergency assistance to an individual in the event that he or she has undergone an opioid overdose. The device utilises a watch design which accurately measures the user’s heart rate and oxygen saturation levels, and has a built-in GPS tracking system. When the user has overdosed, these numerical values are recorded on the mobile app to which then, a phone call is made to the user’s emergency contact who is able to pinpoint the person's exact location, and can then forward the call to emergency services if additional assistance is required. Our device will help save many lives and rescue others from potential life-threatening circumstances.

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List of Acronyms

Acronym	Definition
CEED	Centre for Entrepreneurship and Engineering Design
LED	Light Emitting Diode
OLED	Organic Light Emitting Diode
LCD	Liquid Crystal Display
GPS	Global Positioning System
BOM	Bill of Materials
CAD (in context of prototyping)	Computer-Aided Design
CAD (in context of money)	Canadian Dollar
BPM	Beats Per Minute
SpO2	Peripheral Capillary Oxygen Saturation
IDE	Integrated Development Environment
STEM	Science, Technology, Engineering and Mathematics
UX	User Experience
COVID-19	Coronavirus Disease 2019
3D	Three Dimensional

1 Introduction

The first step of the design thinking process is empathize. In order to empathize one must be able to create a device that is suitable to the needs of the user. In other words, it's about getting in the "shoes" of the user, and really understanding their emotions towards something. With this notion, our team was able to determine the target specification for our opioid overdose emergency device. With the help of Tali, a nurse who works at the Sandy Hill Community Centre located in Ottawa, Ontario, during our first client meeting, she shared with us her knowledge on the types of people who take opioids. The types of opioid users include the following; most users are in a trade-based industry, about 75% of these people were men (between ages 20-30), and homeless people were also a large demographic affected by this crisis. Another vital aspect of this list is that most users reported a form of discrimination and stigma for using opioids. Keeping this information in mind, our team was presented with the challenge of creating a device that not only detects when the user is experiencing an overdose, but also ensuring the device is discreet as possible.

As aforementioned, there are multiple needs of the user that must be taken into consideration. Firstly, the device must be user-friendly so the individual is not discouraged by the complexity of the design. Secondly, the device must be non-intrusive as in to not interfere with the user's daily activities. Thirdly, the device must be low-cost. It is very important for the device to be at a low price-point due to the fact that some individuals (i.e. homeless) might not be able to afford a high-budget electronic device. Because of this, our team must remain respectful to the $100 budget.

There are various aspects to our device that will make it much more appealing to the user than other devices currently on the market. The main reason is that our team will implement a GPS tracking system that tracks the user's exact location at all times. This is created to ensure the user's safety and wellbeing. This concludes the Empathize stage and now we will move onto the second stage of the design thinking process, Define.

2 Needs Identification and Product Specification Process

2.1 User Needs and Design Criteria

The defining stage of the design process is quintessential when interpreting the needs of the user. After our team gained an understanding of who we were creating this device for (during the empathize stage), we were able to synthesize what we learned into user interpreted needs. These user interpreted needs are displayed on the left-hand side of **Table 1**. Keeping the needs of the users in mind, this gave us an intuitive idea of what the design criteria will be. Each need is paired with a specific design criterion that is implemented in our device, which is represented by the right-hand side of **Table 1.**

Table 1: User Interpreted Needs and Design Criteria

#	Need	Design Criteria
1	The device is discreet	Watch size (mm^3) GPS tracking system Weight (Ibs) Watch shape Optical sensor
2	The device is user-friendly	Weight (Ibs) Watch shape Optical sensor
3	The device is non-intrusive	GPS tracking system
4	The device is low cost	Cost ($)
5	The device is waterproof	Watch material

In order to really understand the users' needs, we must compare them with the design criteria because this will make the device optimal for them. The design criteria includes functional and non-functional requirements of our users' needs. These requirements are accompanied by a set of constraints which increases the risk of contingencies for the device being produced. The following pointers show the constraints, followed by the functional/non-functional aspects for the device being developed.

2.2 Constraints and Design Criteria

Constraints:

- Weight (Ibs)
- Cost ($)
- Size of watch (volume in mm^3)

- Operating conditions: temperature in °C
- Material type of watch (dependent on heat resistance)

Functional requirements:

- Sends a notification to nearby paramedic to inform that an opioid overdose has occurred using GPS tracking system
- Weight supported (Ibs)
- Quick response time (min)
- Measuring range (BPM)
- Optical sensor to display accurate readings for pulse and SpO2 rates
- Safety readings for when oxygen saturation levels are excessive or insufficient
- Charging capability (i.e. wireless or battery-powered)

Non-functional requirements:

- Aesthetics
- Product life (years)
- Corrosion from rust
- Reliability
- Compatibility (i.e. Bluetooth technology)
- Screen Display (i.e. LCD or LED)
- Day-to-day water resistance

After separating the design criteria into its functional and non-functional components, we observed that the implementation of these specific criteria will be a challenge given the list of constraints. Our team worked on a plan and formulated a contingency plan that will accommodate for the constraints that are imposed on our device. This will be detailed later when we discuss the project planning and execution for our device.

2.3 Problem Statement

Analyzing the first two steps of the design thinking process helped us generate the following problem statement;

"Opioid users are in a need for a device that will monitor the possible risk of an overdose. It is discreet, durable, and sends out an emergency response to local paramedics indicating the current location of the user in the event of an overdose." This problem statement was based on the amalgamation of the user interpreted needs. The problem statement is the definition of this entire project, and it was vital that our team stayed methodical to this notion.

3 Conceptual Designs

For the Ideate stage of the design thinking process, each team member brainstormed a set of designs for the opioid detection device. These ideas were amalgamated into three global conceptual designs, as illustrated in **Figure 1**.

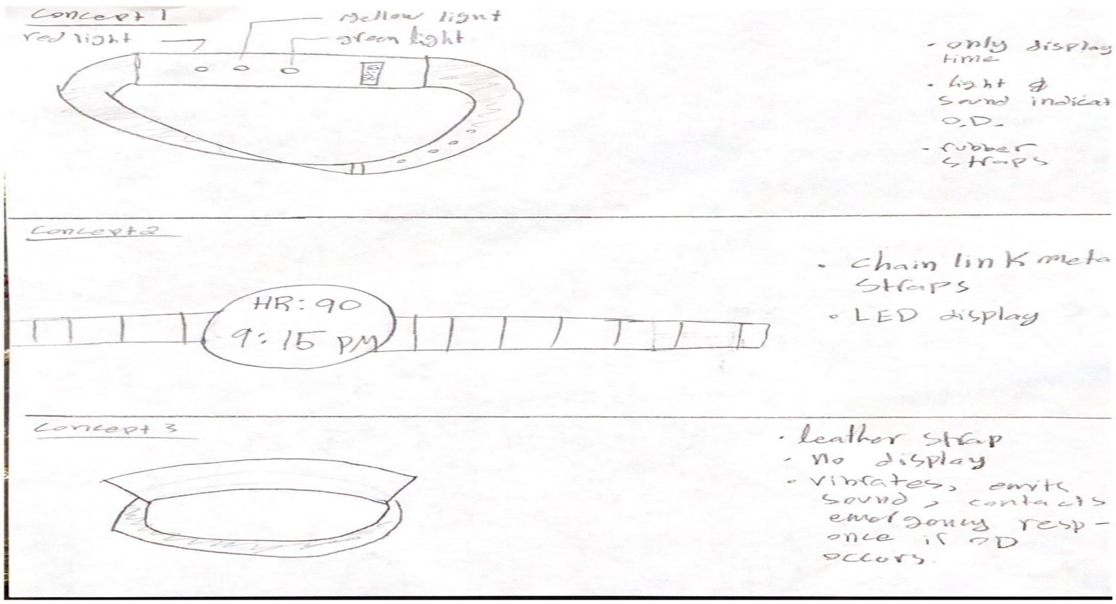


Figure 1: Three Global Concepts

The first concept displays a modern design with rubber straps and cuboid shape which displays the current time. Rubber is used for the straps because it is a very comfortable and durable material for the user to wear and is durable as well. The device encompasses an LED light system that reflects heart rate normality. This is based on a colour scale in which green indicates a normal heart rate, yellow indicates an unusual heart rate, and red indicates a drastically low heart rate which implies that the user is potentially suffering through an overdose. Whenever the red light flashes, this alerts the nearby emergency response team that one has overdosed. This method makes the device very discreet because there is no display of any rate and no one around the individual will question why there are lights present on the watch display. All in all, this is a very futuristic design which many users will find it to be a lavish accessory.

The second concept displays a design similar to that of a digital watch. The casing is enclosed by a rounded shape and there are also two LED displays; one for the time and the other to display the user's heart rate level. The device also has chain link metal straps which make the watch look very resplendent and extremely durable. All in all, this is a very simplistic design that users will find easy-to-use.

The third concept displays a rudimentary design but with very sophisticated functionality. The casing is enclosed with a squircle shape and contains leather straps with no screen display. This means that there is no time, heart rate, or SpO2 sensor. Leather is used because it is a comfortable material for the user to wear thereby increasing its durability as well. This device uses a different technique than that of the first two designs in determining if one has overdosed. When an individual overdoses, the device emits a sound and sets off continuous loud vibrations, thereby contacting an emergency response team to come to the person's aid. Due to the functionality of the watch, it is very discreet because as already stated, there are no features displayed on the device thus no user interaction occurs. All in all, this is a very minimalist design that users will find accessible and convenient to wear.

Table 2: Benchmarking of Three Global Concepts

Concept	1	2	3
Cost	$100 (CAD)	$100 (CAD)	$100 (CAD)
Estimated Weight (g)	145	125	175
Material of Case	Metal	Metal	Metal
Material of Straps	Rubber	Metal	Leather
Shape of Case	Cuboid	Cylinder	Curved

Pulse Range	25 BPM-250 BPM	25 BPM-250 BPM	25 BPM-250 BPM
Pulse Accuracy	+/- 2 BPM	+/- 2 BPM	+/- 2 BPM
Safety	Yes	Yes	Yes
Optical Sensor	Yes	Yes	No
Power	Replaceable Battery	Replaceable Battery	Replaceable Battery
Tracking System	GPS	GPS	GPS
Heart Rate Display	No	Yes	Yes
Display Time	Yes	Yes	No

The table below is color-coded with (green = 3, yellow = 2, red = 1). The purpose of this is to determine which of the three solutions best fits the user's needs based on the provided sketch diagrams.

Table 3: Selection of Benchmarking of Three Global Concepts

Concept	1	2	3
Cost	$100 (CAD)	$100 (CAD)	$100 (CAD)
Weight (g)	145	125	175
Material of Case	Metal	Metal	Metal
Material of Straps	Rubber	Metal	Leather
Shape of Case	Cuboid	Cylinder	Curved
Pulse Range	25 BPM-250 BPM	25 BPM-250 BPM	25 BPM-250 BPM
Pulse Accuracy	+/- 2 BPM	+/- 2 BPM	+/- 2 BPM
Safety	Yes	Yes	Yes
Optical Sensor	Yes	Yes	No

Power	Replaceable Battery	Replaceable Battery	Replaceable Battery
Tracking System	GPS	GPS	GPS
Heart Rate Digital Display	No	Yes	No
Display Time	Yes	Yes	No
Sum of Values	35	33	27

Concept 1

- Sum of Values = 35

Concept 2

- Sum of Values = 33

Concept 3

- Sum of Values = 27

Concept 1 wins as the user's most beneficial product when compared to the other concepts. This was done through utilising the design criteria's functional requirements as well as keeping the user's needs intact. The sum of values was calculated using the predetermined colour scale (green, yellow, red). We then use the design from Concept 1 to create a final concept for our opioid overdose detection device which is illustrated below.

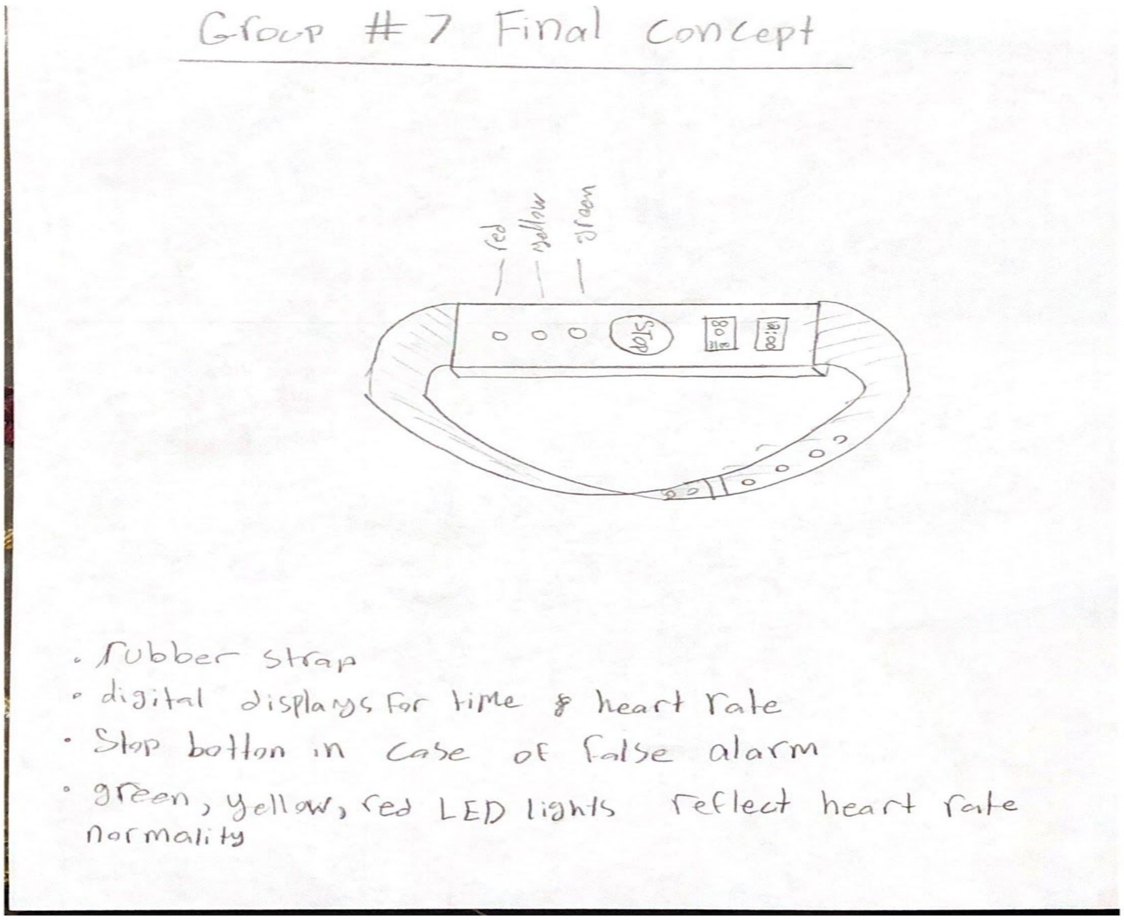


Figure 2: Final Concept

The above sketch is the diagram for what the device that our group will create. This final concept is very similar to Concept 1 with the addition of a STOP button in the event of a false alarm, which occurs when the user does not undergo an opioid overdose but the device mistakenly interprets that he or she is going through one. This is a very useful feature because the device cannot accurately determine whether one is experiencing an overdose at all times. One's heart rate can be less than the normal amount (attributed to frequent inhalation and slow exhalation) but that does not necessarily mean that they have overdosed. The other features of the device are that first and foremost, it has rubber straps because rubber is an inexpensive material and these straps allow for greater comfort on the user's wrists. It is also lightweight and durable. Secondly, there are digital LED displays for both the time and heart rate. The displaying of time is a vital component of the device because it is the quintessential aspect of any watch. The heart rate is an integral part of the device due to the fact that one of the prevalent symptoms of an opioid overdose is that one's heart rate slowly decreases as time progresses. In some cases of overdoses where the effects are gradual and prolonged, a person may notice his heart rate decreasing and start taking steps to obtain medical aid. In addition to this, there is a built-in LED light system which displays different coloured lights that reflect the user's heart rate normality. As aforementioned, green light indicates normal heart rate, yellow rate indicates questionable heart rate (less than normal), and red light indicates very low heart rate which implies that the user is experiencing an opioid overdose, thus triggering an emergency response. This will commence by the device emitting a loud emergency noise and sound vibrations to alert those around the opioid user of the situation. In the scenario where the emergency is a false alarm (which may occur with heart rate detection devices), the user may press the "STOP" button to indicate that he or she is not undergoing an overdose. The device utilises replaceable batteries as some users may not have a place to safely charge the device by using a wire.

As is this the case with most designs, there are limitations which must be kept in mind. With the global concept illustrated, there is a glowing issue that, in some rare instances, an individual may be experiencing an overdose but is in complete and utter denial and wishes to not be disturbed. He or she may still have the ability and bodily control to cancel the emergency response, thus cancelling the compulsory medical aid. However, there must be a system to prevent false alarms, which are much more likely to occur, and this is the best solution proposed, since infrared oxygen saturation levels are hard to read at the wrist. This drawback should be kept in mind during further development to lessen its probability of occuring. Another drawback is that some users may neglect to replace the batteries once their lifespan is ended, putting them at risk if they overdose. This can be potentially resolved by adding a “low battery” indicator to warn them ahead of time.

Through amalgamating our group members’ sketches together into three conceptual designs, and then benchmarking these three solutions based on the design criteria requirements, one final design concept was formed for the device that our group will aim to produce. The first prototype will be as close as possible to the sketch presented above as we now move onto the development of the project plan and creating cost estimates for the design of the watch.

4 Project Plan, Execution, Tracking & Bill of Materials

The opioid overdose detection device that our group was tasked with creating involved many consequences which could have affected the safety of the user. Given that we were working with such a high stake (i.e. a person's life) it was our team's responsibility to ensure that our design would be safe and foolproof. In order to monitor the potential risks and fidelity in the production of our emergency detection device, we constructed a full project plan. In our project plan, we have mapped out certain guidelines that our team must respect and stay coherent to during the design process of our device. This project plan includes a list of tasks and the team member whom it depends on, task durations, multiple contingency plans to cope with potential risks and a bill of materials which will track our team’s overall budget.

The following tables display the task ID number, its description, estimated duration, the owner of the task, and the dependencies associated with each specific task.

Table 4: Prototype I Tasks, Durations, Owners.

Task ID	Task Description	Estimated Duration (days)	Owner	Depends on task ID:
1.1	Make the list of components and materials that must be approved by the PM/TA (will be required for all prototypes)	7	Abdel	None
1.2	Simplified version of the conceptual design made from the collection of house materials to create the casing of the watch	1	Yazan	None
1.3	Assembling the components and material based on the conceptual design	2	Ali	1.1, 1.2
1.4	Analyzing the prototype design	1	David	1.3
1.5	Receiving feedback from potential customers	1	Ali	1.4
1.6	Adjusting the prototype design based on the analysis and feedback	1	Bilal	1.3
1.7	Finishing the analysis of Prototype I and completing Deliverable F	2	ALL	1.5, 1.6

Table 5: Prototype II Tasks, Durations, Owners.

Task ID	Task Description	Estimated Duration (days)	Owner	Depends on task ID:
2.1	Make necessary adjustments to the subsystem from feedback of prototype 1	1	Abdel	1.6
2.2	Create a functional design, including the subsystems of the device using solidworks	1	Yazan	2.1
2.3	Using Arduino to code make the subsystem	3	Abdel	2.2

2.4	Determining the analytical behavior of the device (e.g. dimensions)	1	Bilal	2.2
2.5	Assemble the subsystem	2	All members	2.2. 1.1,
2.6	Analyze the functionality of the subsystem	1	Ali	2.5
2.7	Receive feedback from potential clients/users to improve the functionality of the device	2	David	2.5
2.8	Adjust the design based off the feedback and completing project Deliverable G	2	ALL	2.6, 2.7

Table 6: Prototype III Tasks, Durations, Owners.

Task ID	Task Description	Estimated Duration (days)	Owner	Depends on task ID:
3.1	Implementing the feedback of the client/user from prototype II into prototype III to the design	1	Abdel	1.6, 2.7
3.2	Assembly of all components to create a fully functional device	3	ALL	1.1, 3.1
3.3	Diagnostic testing of the device	1	Bilal	3.2
3.4	Final adjustments to improve success rate	2	ALL	3.3
3.5	Feedback from clients/users of the fully functioning device	1	David	3.2
3.6	Documenting the feedback received and the entirety of the test plan	2	ALL	3.5
3.7	Analyzing Prototype III and finish project Deliverable H	2	ALL	3.2, 3.5, 3.6

Table 7 represents a specific set of risks and their contingencies, as well as their respective risk levels (i.e. low, medium or high).

Table 7: Risks vs Contingencies

Risks	Contingency Plans	Risk Level
Insufficient battery power where it cannot supply enough current for all the components	Replace the current battery with a battery that has a higher voltage supply. This indicates that the battery will be more costly and the current budget will also have to be taken into consideration when purchasing this new item.	Medium
The circuit of the device does not function	Create a new circuit for the device and ensure that each component matches with its specific power capacity. This avoids the possibility of a short circuit.	Medium
Various parts of the design do not fit together after 3D printing the watch's casing	Make adjustments to the CAD design in Solidworks to account for the newly found dimensions of the different components	High
The change of components depending on the prototypes	Only use the most essential components first and then use the less needed components afterwards so as to not waste more time for completing the prototypes.	Low
MIT App Inventor, the web-based application used to create the GPS tracker, does not function very well (i.e. does not accurately track the user's location)	Change the code used to create the GPS tracker app and verify that the bluetooth module can maintain a strong connection with the GPS tracker	High
Arduino program does not work (i.e. code does not run)	Many things can be done including verifying that the correct ports are implemented in the code, the correct pins are used for the specific components, etc.	High

Table 8 displays the BOM for our final prototype. This includes all of the components purchased as well as ones given to us from the Makerlab, which our team will present the device on Design Day. The total cost of the device is $55.86 which clearly displays that our team has remained respectful to the project's $100 budget.

Table 8: BOM For Final Prototype

Item #	Item Description	Quantity	Unit Price	Amount
1	Vibrational Motor DC 1.3V (Bought)	1	$2.878	$2.878
2	Push Button Tactile Switch (SMD) (Used from Makerlab)	1	$0	$0
3	OLED Display Module DC 3-5V (Bought)	1	$4.90	$4.90
4	Sensor MAX30100 (Pulse Oximeter and Heart Rate) (Bought)	1	$11.50	$11.50
5	Arduino ESP32 Wi-Fi + Bluetooth 2-in-1 Microcontroller (Bought)	1	$13.99	$13.99
6	Drone Charging Station with Two 3.7V Batteries (Bought)	2 (Minimum Quantity of Batteries)	$3 (Price of one battery)	$17.99

7	USB 2.0 Cable Type A/B (Used from Makerlab)	1	$0	$0
8	Rubber Straps (from an old watch)	1	$0	$0
9	5Ft Hook-Up Wire 22AWG (Red) (Used from Makerlab)	1	$1.60	$1.60
10	4.3K Ohm Resistor (Used from Makerlab)	10	$0	$0
11	RGB LED (Used from Makerlab)	6	$0.5	$3.00

5 Analysis

After constructing the project plan that our team was committed to follow, we experienced some difficult obstacles which affected our original plan to complete the opioid overdose detection device. During the final stretch before Design Day, the team had agreed to physically meet every weekday for at least an hour, and weekends if necessary, to achieve a fully functioning prototype for Design Day. With this highly discouraged during the COVID-19 outbreak causing the facilities to close, as well as Design Day being cancelled, it was no longer possible to achieve the goal, and the team lost its sense of direction and focus/clarity, having to adjust to new deadlines and expectations. We were able to follow the original project plan until our team's second prototype, however the planning changed once Canada declared COVID-19 a national health crisis. The following Gantt chart displays a day by day plan of how the team would have completed the tasks for the third prototype:

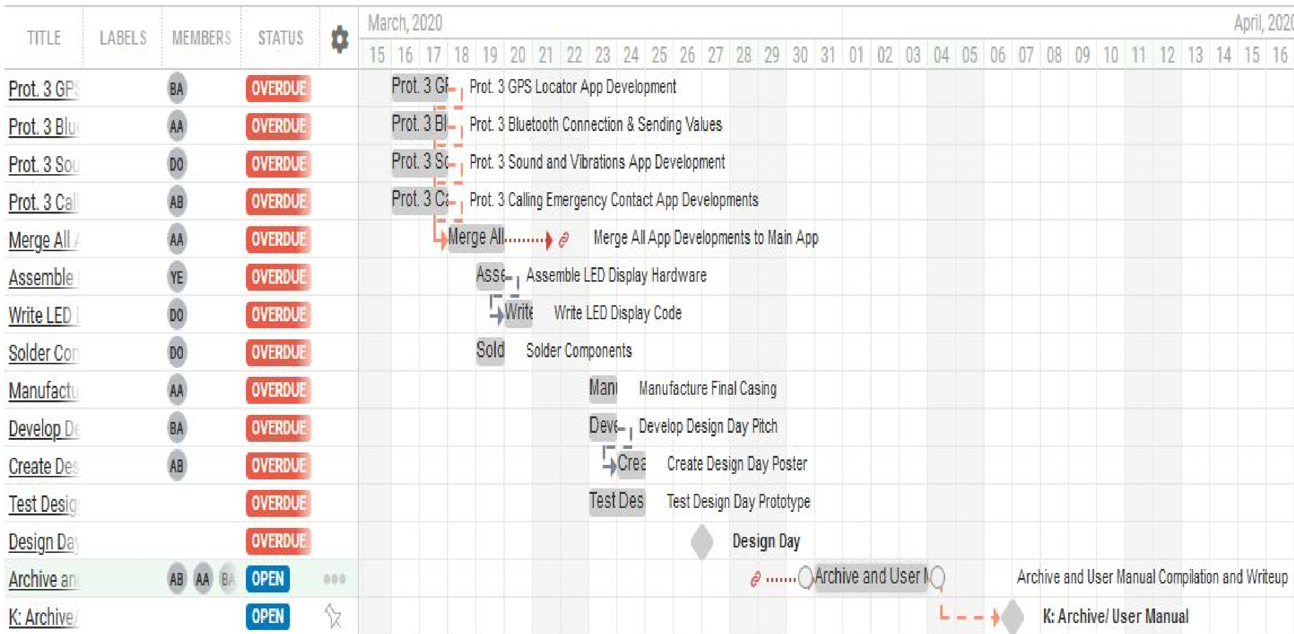


Figure 3: Gantt Chart of 1.5 Weeks Before Design Day

In addition to our modified project plan, we also created an updated list for the BOM which helps us keep track of how much we spent towards buying components and the components that were not used during the design process. The final cost of our device is $25.49 which indicates that we respected the budget of $100 that was allocated to our team and the potential refunds we would receive for the unnecessary utilities. The following table displays the final BOM:

Table 9: BOM For Breadboard Prototype

Item #	Item Description	Quantity	Unit Price	Amount
1	Sensor MAX30100 (Pulse Oximeter	1	$11.50	$11.50

	and Heart Rate) (Bought)			
2	Arduino ESP32 Wi-Fi + Bluetooth 2-in-1 Microcontroller (Bought)	1	$13.99	$13.99
3	Arduino Mini Breadboard (Used from Makerlab)	1	$0	$0
4	USB 2.0 Cable Type A/B (Used from Makerlab)	1	$0	$0
5	4.3K Ohm Resistors (Used from Makerlab)	3	$0	$0
6	Hook-Up Wire 22AWG (Orange, Green, Grey)	4	$0	$0

6 Prototyping, Testing and Customer Validation

After the first three steps of the design thinking process (Empathize, Define, Ideate) were complete, our team proceeded with the prototyping for the OP-Watch. In the prototyping stage, we wanted to create a real life design from the global concept that our team decided on during the ideation process.

6.1 Prototype I

The first prototype was the simplest out of the three prototypes we completed, but it was also the trailblazer for our device. In our first prototype we only cared about the aesthetics and the physical features. The entire manufacturing of the prototype took place on Monday, February 24, 2020 at the Brunsfield Centre located in the STEM complex. Team members Ali and Abdel were assigned the responsibility for this task and completed it within a time frame of approximately 5 hours (this included the planning and dimensioning, which are dependencies of the manufacturing process). The result required from this prototype test was an understanding of the comfort, durability, aesthetics, and discreteness of the watch, so that appropriate adjustments could be implemented. We wanted to ensure that our device was aesthetically pleasing and very comfortable for the user to wear.

The following three figures display the orthographic projections of Prototype I:

Figure 4: Top view of Prototype I

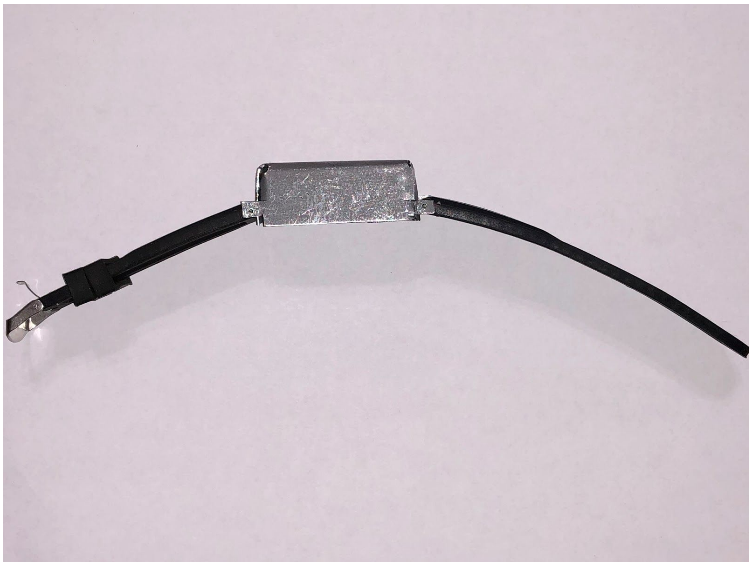


Figure 5: Front view of Prototype I

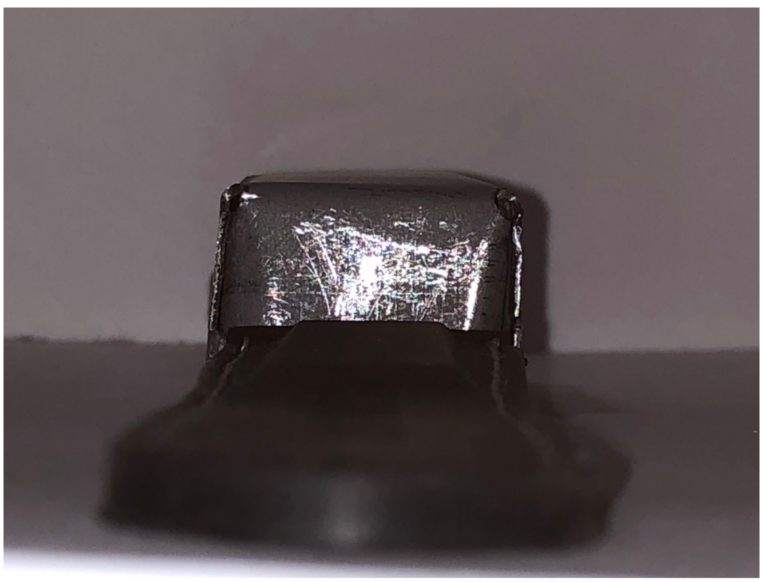


Figure 6: Right side view of Prototype I

6.1.1 Testing and Customer Feedback

For this prototype we asked a tester to wear the physical model of our device for the entire day (24 hours). We have decided as a group that one cycle (full 24 hours) is enough testing for this prototype. The reason being that in 24 hours, a person should have had enough experience wearing the device to know the conceptual faults present that can be problematic.

After we had the tester try our device, we were provided with the following set of information and data:

- The watch is very bulky and restricts movement of the wrist, which is irritating
- The metal case is simplistic and feels classy, but also futuristic.
- The bottom of the case has exposed metal sheet edges which can be irritating to the skin
- The rubber straps look and feel very durable, but the metal buckle rubs against the skin and is irritating
- Due to the size of the wristwatch, wearing and taking off clothes is doable but very challenging and one grows tired of this
- The corners of the metal case are rough and sometimes get caught on clothing, such as on a winter jacket. This can potentially cause damage.
- The metal case is lightweight and feels very sturdy. One does not fear it will chip or break.
- The size of the case is large enough that it is not discrete and attracts privy eyes. Almost everyone asks “What are you wearing?”. One may become extremely cautious or paranoid from these persistent questions.

6.1.2 Analysis of Prototype I

The prototype consists of a metal box and rubber straps. It utilises the exact form and materials that the final prototype is expected to take, so at first one may think that the degree of fidelity is high. However there are some important distinctions that can be made including the fact that there are no cutouts in the box for buttons and displays, which may affect the UX as well as the aesthetics, durability, and discreteness of the device. The contents of the case are also non-present, which means that the prototype will be significantly lighter than in reality, and will disrupt the comfortability of the watch. The dimensions used were also estimates of the final ones and, and our team has discovered after the manufacturing of the prototype that the final one will be larger, due to the internal mechanism. The assumptions that were made regarded the aesthetics, weight, and dimensions of our device. With this in mind we decided that this prototype has a medium degree of fidelity.

We gained key pieces of information about the wearability of the prototype, including aesthetics, comfort, discreetness, and durability, as well as other interesting pieces of information we were not specifically looking for.

The fact that some features of the watch caused irritation was certainly alarming and must be addressed. Luckily, this could be fixed by altering the way that the metal sheet is folded into the case so that there are no exposed edges directly facing the user's skin. In addition to this, the manufacturing process of the case could be changed to reduce the sharpness of the corners, removing the possibility of damaging the user's clothing.

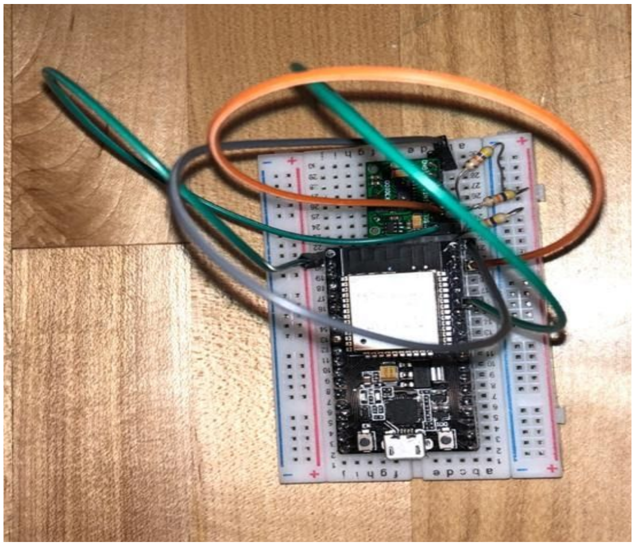
Unfortunately, certain other problems found in the feedback are very difficult to address, namely the bulkiness of the wrist watch which restricted wrist movement and greatly reduced discreteness, to the point where other people in public asked about the device. Once potential users discover these faults, they will certainly decide to not use the device. We will simply have to optimise the positioning of the components to make it as small as possible, while keeping this restriction in mind when working on our final prototype.

Now that our team has gathered sufficient data about our first prototype, we will proceed with the second prototype, which focuses on creating the most critical subsystem of the device; the measurement of the heart rate and oxygen saturation levels of the user.

6.2 Prototype II

The second prototype is much more complex to make than the first prototype, albeit not very difficult to produce. In this prototype, our team decided to test and analyse the most important subsystem of our device, the heart rate and SpO2 levels of the user. This was done through implementing an Arduino ESP-32 microcontroller and Sensor MAX30100, with the latter effectively storing the heart rate and SpO2 information. The creation of the prototype took place over the course of five days, from Monday, March 1, 2020 to Saturday, March 7, 2020 at the Makerlab located in the STEM complex. The result required from this prototype test was an understanding of how the device will function in a real-world setting and to observe the accuracy of the Sensor MAX30100 and how efficiently it monitors one's health and safety.

The following two figures display the orthographic views of the circuit diagram for Prototype II:



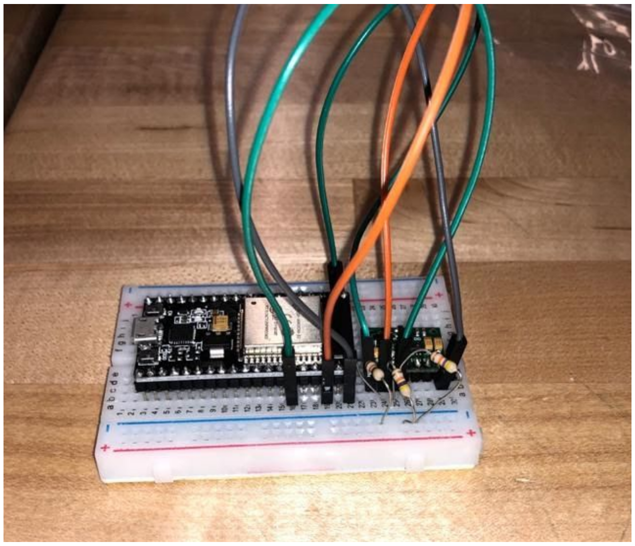


Figure 7: Top view of Prototype II **Figure 8: Front view of Prototype II**

The following two figures display the Arduino serial monitor which showcases the heart rate and oxygen saturation values that are sent from the MAX30100 sensor.

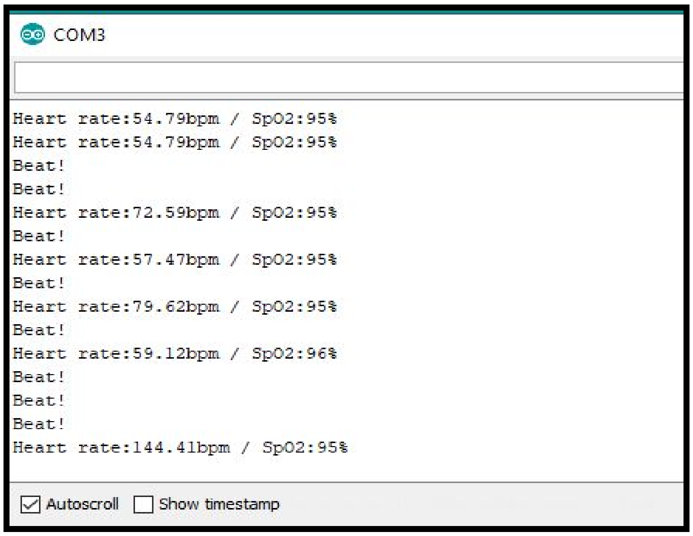


Figure 9: Serial monitor displaying fluctuation in heart rate

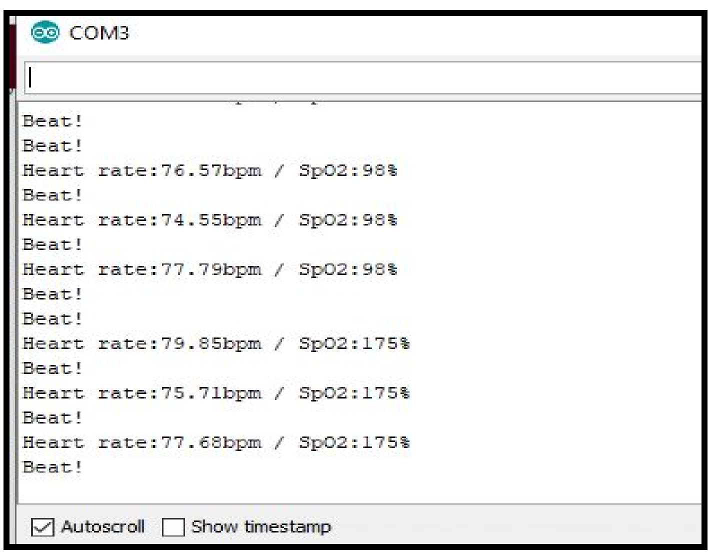


Figure 10: Serial monitor displaying fluctuation in oxygen saturation levels

6.2.1 Arduino Testing

The testing process is a simple one, but with multiple steps that must be taken into consideration. Firstly, for the MAX30100, the three ohmic resistors that are mounted onto the part must be desoldered, and specific pins on it must be soldered. The reason for desoldering is because the default resistors are not powerful enough to withstand high-powered microcontrollers such as the ESP-32, which also has built-in bluetooth functionality. The pins that must be soldered are VIN, SCL, SDA, INT and GND. Once these tasks have been completed, the sensor can be placed onto the breadboard, alongside the ESP32. Then, one must attach 4.7K ohmic resistors to the SCL, SDA and INT pins (see **Appendix 3.2**). The information that is being measured and observed is the heart rate and oxygen saturation levels. The Arduino IDE was used to help record these values and we utilised source code that was on a GitHub repository to help read the sensor's data. The values are clearly recorded and displayed on the Arduino serial monitor. Most of the materials required for prototype II were given to our team from the Makerlab, so it did not go towards our total budget.

6.2.2 Customer Feedback

After our testers interacted with the prototype, we asked them to share their thoughts on the user interface and to give any feedback that they had. It is important to note that they were shown the data collected in live time. We received the following information:

- The values don't seem stable and constantly jump around a lot. The user would not feel comfortable using this device since false alarms could easily occur.

- The oximeter (which was on and sending infrared waves over the one minute duration of testing) was getting very warm. The tester stated that he would feel uncomfortable wearing it all day, especially during hot weather.
- A user mentioned that they would have concerns over the health effects caused by a constant infrared light penetrating the skin and subsequently the bloodstream.

6.2.3 Analysis of Prototype II

The results obtained for this prototype were not what our team had hoped for. As can be noted in **Figure 9** and **Figure 10** the heart rate and oxygen saturation levels of the user were mostly uniform, however there were instances of fluctuation that occurred. The reason for the fluctuation might be attributed to the manufacturing of the MAX30100 sensor. The only ways that we can try to rectify this problem is to fix any faulty wiring on the Arduino circuit and improve the source code if need be.

The main assumption that was made in testing this subsystem was determining the location of the measurement of the heart rate and SpO2 levels. The testers were asked to place their finger on the sensor, however our design involves reading measurements from the user's wrist. Although we were unable to perform the latter, we assumed that the measurement values would behave the same, thus yielding the results to be identical as well. The second assumption that was made was that the measurement values would behave the same way for every activity that the user is doing (i.e. writing, running, laying down). However in reality, the sensor may behave differently depending on the current situation. With these assumptions in mind, our team has rated the fidelity of this prototype to be medium.

The testing method could also have been improved by comparing our device's results to that of a pulse oximeter currently on the market. The user would have worn both devices at the same time, thus yielding a detailed comparison between both products. This would also have given a great insight into the accuracy of our device, specifically the precision (uniformity) of our results compared with that of a more reliable device.

A major concern that was brought up by the test subjects was the heat caused by the MAX30100 sensor and the serious health effects of the infrared light being constantly aimed at the skin during the prototype's usage. In order to combat this issue, we will configure the sensor in a way that it will only turn on at specific intervals to measure the heart rate and SpO2 values, rather than being on at all times. This should reduce the heat emitted and lessen concerns about the infrared light. Our team will conduct extensive research on the quantity of infrared light that is safe to be directed towards the skin. This will allow us to determine a safe method to effectively identify opioid overdoses.

Now that we have completed the testing process of the prototype, and have gathered the positive and negative aspects of the subsystem, we will now move onto the third and final prototype. In this prototype, we will assemble all of the components together to create the final solution to the opioid overdose crisis.

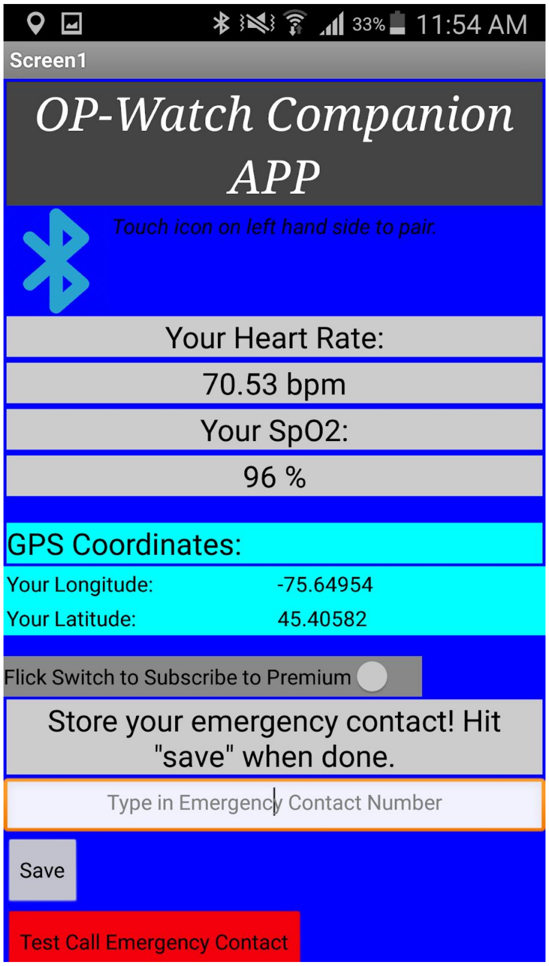
7 Final Solution

The third prototype is our team's final solution to the opioid overdose crisis. Given the complexity of the second prototype, we already had established a strong base in the serial monitor that displays the SpO2 and heart rate levels. However we needed a way to combine the two components with a fully functional app that would trigger an emergency response to the user's loved ones and local health authorities. This app would be paired with a complete, fully functional and physical prototype which would be ready for potential users to wear.

Our team was on track to completing the third prototype by Design Day which was supposed to be held for March 26, 2020. However due to the COVID-19 outbreak our plan had been altered. Considering that the CEED facilities at the University of Ottawa had shut down, the physical aspect of our final prototype was impossible to complete, as the equipment required (i.e solder, drill press, 3D-printer, etc) to finish it was located in the facility. With team members unable to work together on tasks, productivity was greatly reduced. Given the unfortunate circumstances, our team decided to shift the focus towards completing a fully functional app that would be showcased during the online presentations which was set for Tuesday, March 24th, 2020.

On the physical side, we successfully activated the MAX30100 heart rate and SpO2 sensor through the ESP32 board and had it send values through Bluetooth or to the Arduino serial monitor. These are the only two components that were setup. The device, however, has to be connected to a power source, since the planned battery was not added. The app which was developed is called "OP-Watch Companion App", and can be downloaded from the MakerRepo link located in **Appendix II**. Note that this app only runs on the Android operating system. It is able to receive sensor readings from the physical device, and display them for the user on the app. In addition to this, the app receives GPS coordinate locations from the host device, and is able to make calls using its cellular network. While these subsystems are all working individually and can be tested on an individual basis, they have not yet been combined into a fully functional system.

During the course of the semester, the team struggled with one particular area of the solution. We knew that the app could not contact emergency response directly, but contacting a relative can be unreliable as there are many times in our day-to-day lives when we will not receive a phone alert. Having the device call a control centre, however, would be costly and would make the product less desirable, so it was debated whether to prioritize reliability or cost. For the final solution, it was decided to let the user choose between the two models, either to have an emergency contact saved on the app or subscribe to a service that would alert a control centre in case of an emergency. **Figures 11** and **12** show the main screen of the OP-Watch Companion App under two different modes:



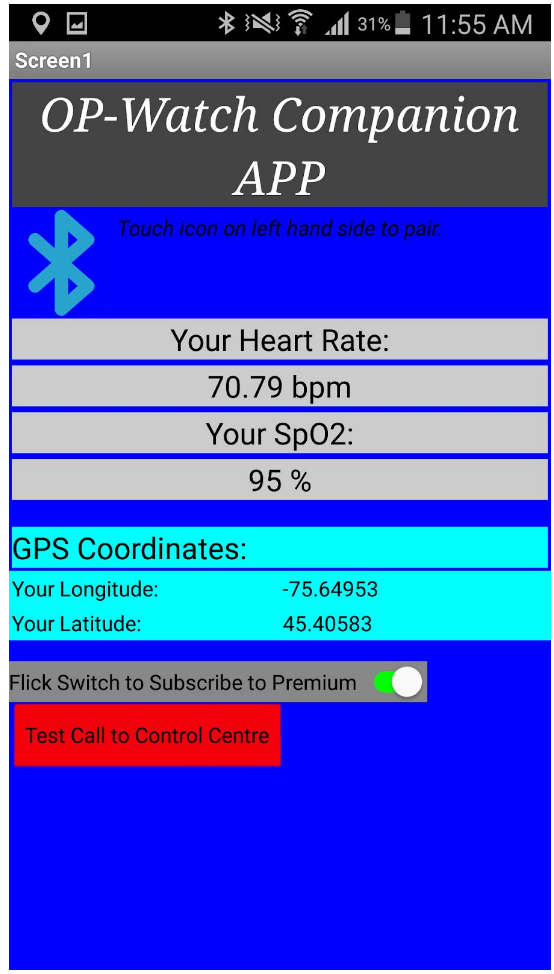


Figure 11: App without subscription

Figure 12: App with subscription

Figure 11 displays the app without the subscription, where the user inputs an emergency contact number and saves it to the app. This is ideal for users who wish to have a relative or friend alerted, understanding the risks. **Figure 12** shows the app with the subscription, where it will contact the control centre in case of an emergency. This is ideal for users who wish for the utmost reliability, or who do not have anyone to ask or do not wish to burden others.

8 Conclusions and Recommendations for Future Work

Though this class encountered challenges not seen by a class in the memorable past, and faced unprecedented circumstances that hindered further work, the project was very beneficial in its own unique ways. In addition to the implementation of the design process, each team member learned valuable characteristics of themselves and how they interact with other team members, as well as how they can improve to avoid any problems that may have occurred during the semester. The main lessons our group learned were in areas such as organization, time management, and contingency planning. Having a big hurdle in the global pandemic present at the end of the term especially enhanced lessons in these areas. With the world in a state of chaos and circumstances unpredictable, organization was key to keep the group constantly on task. With members unable to meetup and work together, work had to be divided strategically among members and durations set, keeping in mind dependencies. Furthermore, with changes in circumstances unpredictable, there was a need to be very flexible at times with our plans and take into account different scenarios that might unfold. These are lessons which can be applied in the real world of engineering jobs, specifically in the engineering design and entrepreneurship sector.

Since the solution was not fully assembled and tested in a comprehensive way, there are clearly set plans for what can be developed next. On the physical side, what remains is the assembly and coding of the OLED screen for displaying time and measurement of the heart rate and SpO2 levels, the battery to power the device, and the vibration system to be activated in an emergency situation. The app contains all fundamental components and subsystems, but these remain to be merged into a fully functioning system.

While incomplete, our team's solutions are a stepping stone for anyone looking to tackle the problem, and can be completed fully or parts of it can be used as inspiration to create other technological devices. There are plenty of ways in which our solution can be improved and polished, and we as a group bid the best of luck to anyone who wishes to build upon the available ideas present in order to create a reliable, and affordable solution to the ever-growing opioid overdose crisis present within Canada.

9 Bibliography

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APPENDICES

APPENDIX I: User Manual

The current solution features the capabilities of measuring heart rate, SpO2 levels, GPS coordinates, and making phone calls. **Appendix 1.1** shows the parts necessary to assemble the final solution, which can be done using **Figures 7** and **8** of this document. The required code that must be uploaded to the ESP32 board is available for download from the MakerRepo webpage whose link is provided in **Appendix II**.

Appendix 1.1: **Parts and Quantities for Breadboard Prototype**

Part	Quantity
ESP32	1
MAX30100	1
Mini Breadboard	1
Hook-Up Wires	5
Resistors	3
USB-C to USB 3.0 Cable	1

Appendix 1.2 displays the various problems that our team encountered when using the prototype, well as the solutions that we implemented to help resolve these problems.

Appendix 1.2: Problems and Solutions for Breadboard Prototype

	Problem Observed	Solution
1	Sketch fails to upload to ESP32 board.	The BOOT button on the ESP32 must be

		pressed and held at the same time as the sketch is uploaded.
2	MAX30100 sensor does not detect heart beat.	The sensor received was defected, and the skin contact had to be made in a very specific way for the sensor to detect beats. The sensor must only be partially covered, with the middle being uncovered.
3	MAX30100 turns off after functioning.	It is common for the sensor to turn off after some time. First try pressing the EN button on the ESP32 board. If the sensor does not turn on, disconnect power sources and reconnect.

The mobile app is available to download on Android phones only from the MakerRepo webpage in **Appendix II.** The app immediately starts tracking the GPS location upon launching, however it must be paired to the ESP32 before it will start displaying heart rate and SpO2 levels. To pair, tap the Bluetooth icon located on the top left-hand side of the mobile app screen, and select the device "ESP32TEST". **Appendix 1.3** displays common problems encountered with the operation of the app and their solutions.

Appendix 1.3: Problems and Solutions for the OP-Watch Companion App

	<u>Problem Observed</u>	<u>Solution</u>
1	Mobile phone blocks installation of app	Before the app can be installed, the settings of the mobile phone must be configured to allow apps from unrecognized sources to be installed. Reference phone manual for further instructions.
2	Phone does not pair with ESP32	It takes a few seconds after ESP32 activation to initialize the Bluetooth.

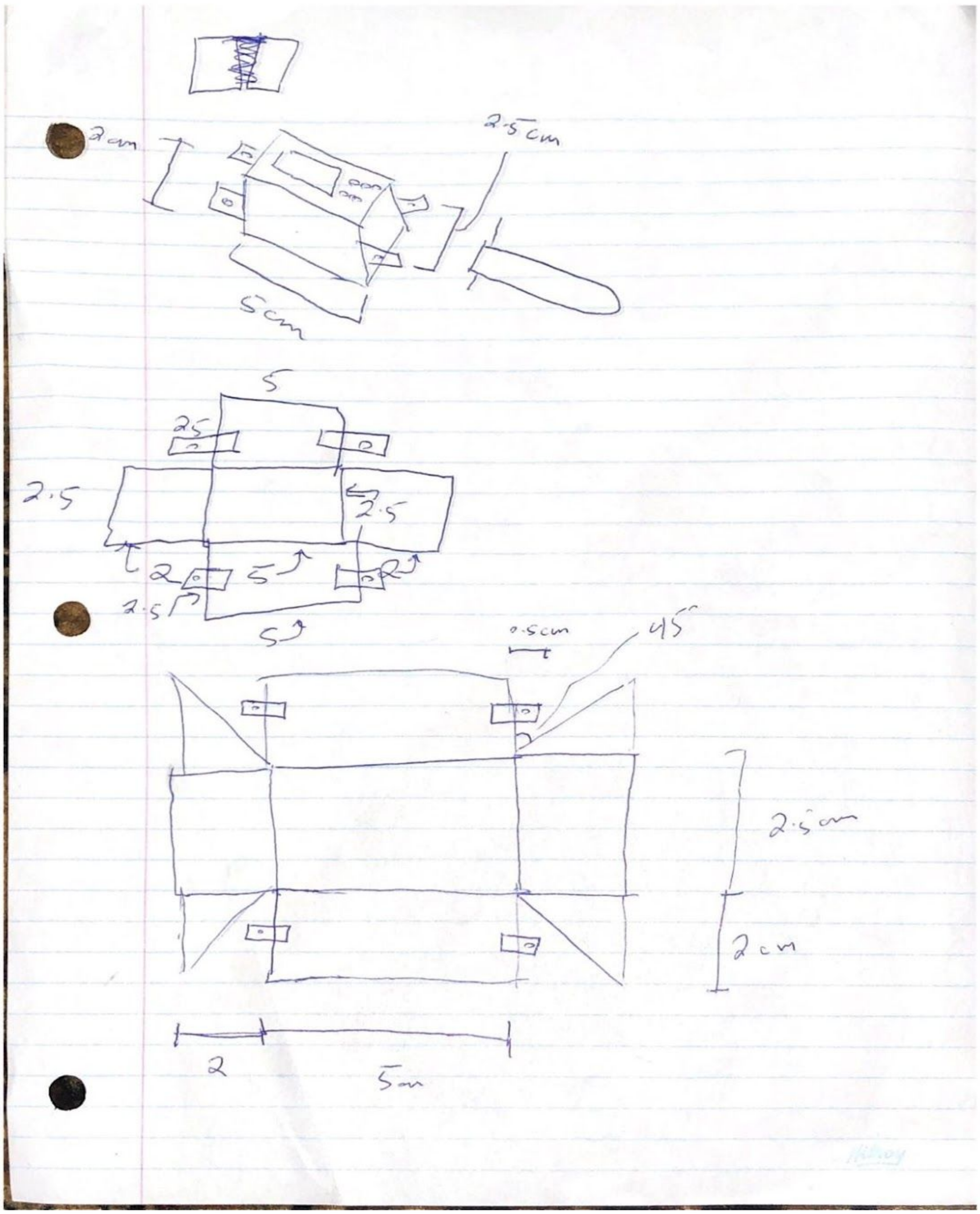
		Simply wait a few seconds and attempt again. If the problem persists, restart the ESP32 by pressing the "EN" button.

APPENDIX II: Design Files

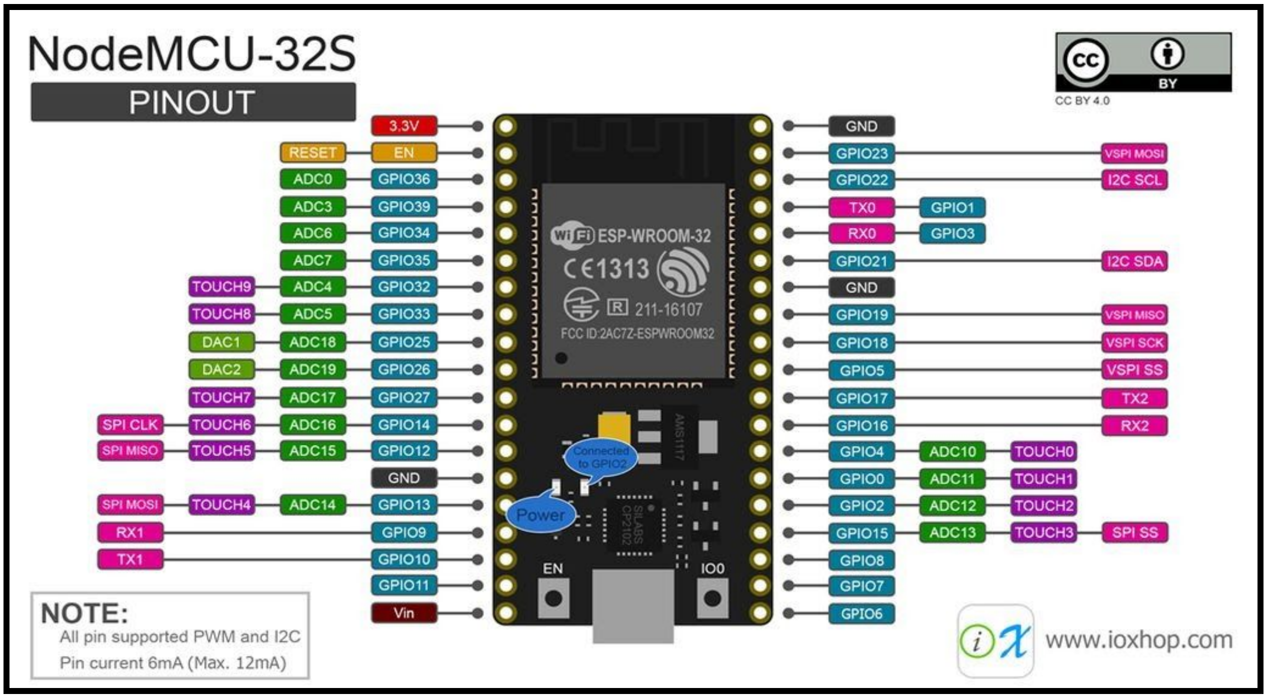
No design files were needed for the making of this document. All of the previous deliverables, source code, as well as other important documents are listed on our team's MakerRepo webpage. The link is as follows; https://makerepo.com/AbdelSB/c7-opwatch.

APPENDIX III: Other Appendices

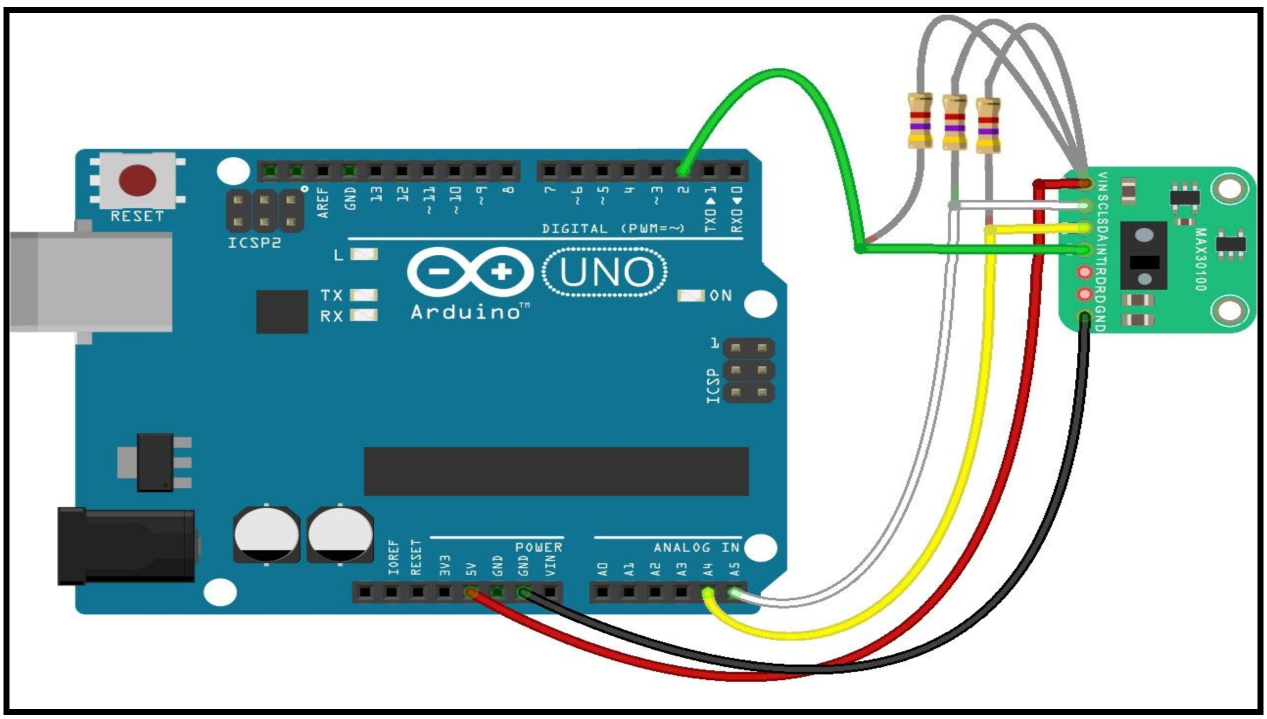
Appendix 3.1: Sketches created before manufacturing of Prototype I



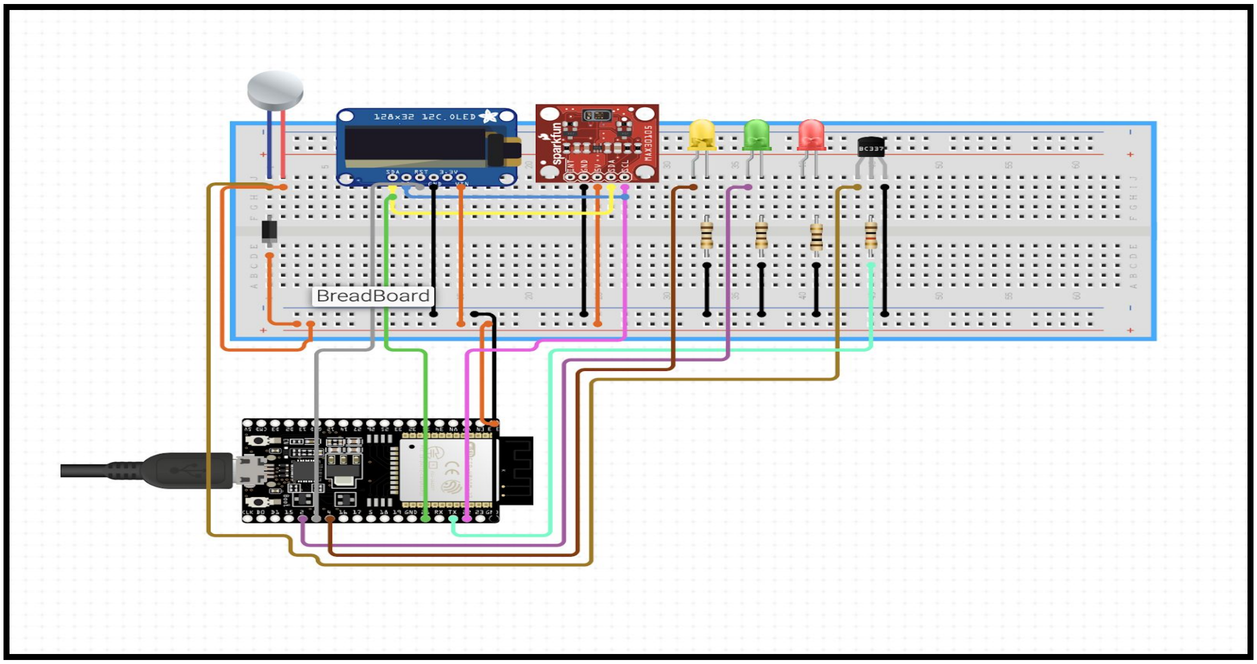
Appendix 3.2: Development Board of Arduino ESP32-S Microcontroller



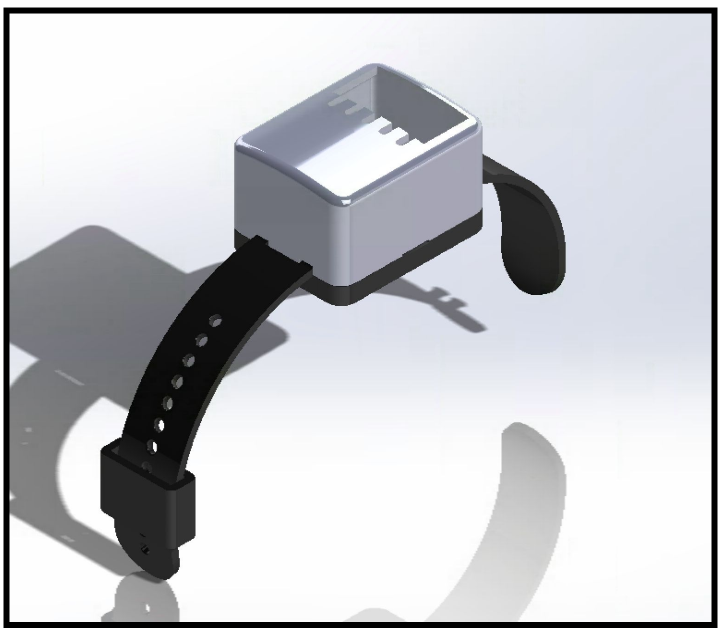
Appendix 3.3: Circuit Diagram of Arduino Uno with MAX30100



Appendix 3.4: Electric Circuit Diagram of all Components Needed for Prototype III (Note: the heart rate sensor used in this diagram is different than the one our group used)



Appendix 3.5: Analytical model of Prototype III



Appendix 3.6: MIT App Inventor Code for OP-Watch Companion App