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Conceptual Design Specification (CDS)

St. Lawrence College Project 1

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Executive Summary

The project's goal is to develop an engineering design to manage the loud behaviour of Megan, an 8-year-old girl with Attention Deficit Hyperactivity Disorder (ADHD) and a visual-learning disability. Megan's loud voice disrupts the classroom and harms her relationships with her peers. There are currently no designs for managing loud behaviour in elementary school students with ADHD. The design should alert Megan when she raises her voice and operates within her immediate surroundings, in classrooms, and on the school playground.

The physical environment includes the climate which has a wide range of temperatures and weather conditions from summer to winter, including precipitation, humidity, and wind. The physical environment also considers vibrations from instruments and the classroom sound level. The living environment includes animals, plants, and people, both indoors and outdoors and the element in the virtual environment is Wi-Fi. There are a handful of groups and individuals that will influence or be affected by the design. The high-interest and high-influence stakeholders are Megan's peers and teachers. These individuals are situated in the same environment as Megan, thus affected by her disruptive behaviour.

The design solution's primary function is to transmit information to Megan about an increase in her volume level by reducing Megan's noise level, detecting the volume level at Megan's location, and identifying and distinguishing Megan's voice from her surrounding environment. The objectives are prioritized as follows: discrete, child-friendly, durable, lightweight, and water-resistant. The solution must have an emergency clasp, be unrestrictive, have no loose or hanging parts, not use active technology, not be discriminatory to Megan, and not collect personal information without parental consent.

The idea generation process consisted of both free and structured brainstorming using Blue Sky Thinking and SCAMPER to determine a hundred ideas. Multi-voting was employed to determine the best ten solutions after conducting a feasibility check based on functions, constraints, and reality-checking. A graphical decision chart using the discreet and child-friendly objectives determined the top three solutions. These include (1) the Heads-up Glasses, which displays Megan's volume level on the inside of a clear lens, (2) the Foot Compression Shoe that tightens the velcro on her shoe to subtly alert Megan when she is too loud, and (3) the Alerting Bracelet which has a colour and vibration system which employs multi-modally to notify Megan of her increasing volume level.

The proposed conceptual design is the Alerting Bracelet that amassed the most points in the Pugh chart— which compared the three solutions to a Soft-Talker datum. In the upcoming three weeks, the bracelet prototype will be created using Myhal's facilities and tested on its speech recognition function and the discreetness objective. The team's prospective plans include testing the other functions, objectives, and the emergency clasp along with a user observation stage with Megan to ensure aesthetic choices and ease of use.

1.0 Introduction

The clients, Elizabeth Minnis and Becca Hole are students pursuing their Honours Bachelor of Behavioural Psychology at St. Lawrence College. They seek aid for an eight-year-old student, Megan, who experiences atypical challenges in class due to her Attention Deficit Hyperactivity Disorder (ADHD) and visual-learning disability (Appendix A). Megan has strengths in auditory learning and struggles with reading, causing her to unintentionally process her thoughts aloud. In combination with her loud voice, Megan has begun to disrupt her classroom and strain her social relationships with peers [1]. This document will highlight the problem, service environment, stakeholders, and design criteria necessary to accomplish the idea generation and selection process. The measures of success will detail testing the proposed design according to select features in the detailed requirements.

2.0 Problem Statement

The client statement demonstrates that Megan has difficulty processing her thoughts and speaks out loud at a high volume [1]. This distracts her peers in the classroom and strains her social relationships, as others assume she is yelling at them. Megan is not on medication and is not currently utilizing any methods to address this situation (Appendix B).

The current world lacks an engineering design that manages impulsive loud behaviour in elementary school students with ADHD. The client needs a solution that alerts Megan of increased volume.

The scope of the project is limited to the classroom and the school playground (Figure 1), with the design implemented within Megan's immediate surroundings. Megan's home or school commute is out of the scope. The solution should improve Megan's behavioural impulses over time to make her aware of her volume and self-regulate accordingly (Appendix B).

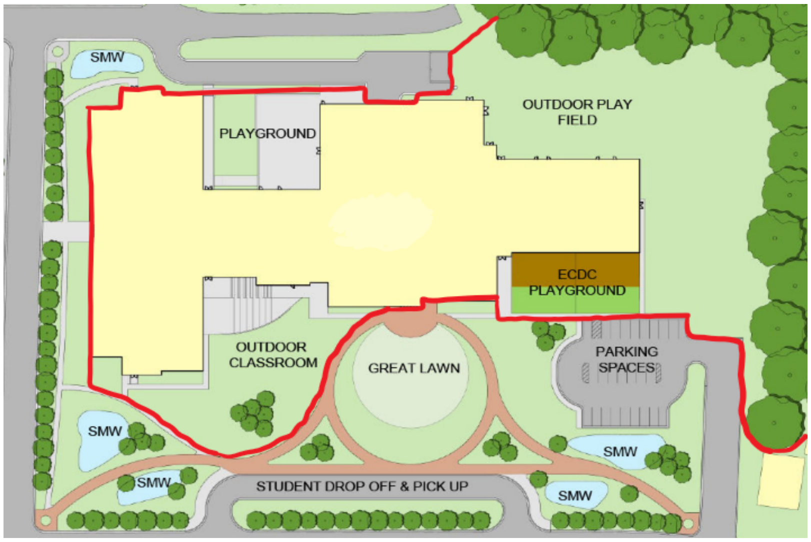

Figure 1. A schematic of elementary school grounds, with the physical scope outlined in red [2].

3.0 Service Environment

This section describes and justifies the elements in the physical, living, and virtual environment where the solution will function.

3.1 Physical Environment

Table 1 describes and rationalizes the features of the physical environment.

Table 1. Physical environment

Element	Description	Justification of Impact
Humidity (Relative Humidity)	Indoors: 30-50% [3] Outdoors: 10-90%	Design will be implemented and used in locations with varying humidity.
Precipitation (mm)	Rainfall: ● September 2021 to June 2022: 78.55[3] ● Average: >= 1 Snowfall Accumulation: [4] ● Winters Average: 630 ● Summers Average: < 30	Precipitation may decrease the durability, in terms of water resistance (Appendix C).

Light Intensity (lux)	• Ambient daylight - 10 000 • Dark day - 107 • Twilight - 10.8 [5]	Varying lighting can decrease the durability and visibility of certain materials, depending on if indoors or outdoors.
Temperature (ºC)	Outdoor Average: [6] • Range: -11 to 25 • Winter Lowest: <-22 • Summer Highest: >28 Indoor Average: • Indoors: 18ºC	Temperature can impact functionality during fluctuations between indoor and outdoor settings.
Wind (km/h)	Wind Speed: • Average: 11.2 • Maximum: 25.9 • Winter Average: 14 • Summer Average: 8 [4]	Wind gusts can decrease the functionality in detecting sound when outdoors.
Vibrations from musical instruments (Hz)	Piano frequencies: 27.5 to 4186; Covers the range of frequencies used in music classes. [7]	The frequency of sounds could disrupt the ability to recognize Megan's sounds.
Sound intensity (dB)	Average noise level of a classroom with students is 60.	Surrounding noise levels can decrease the detection of sound.

3.2 Living Environment

Table 2 defines and justifies key constituents of the living environment.

Table 2. Living environment

Element	**Description**	**Justification**
People Indoors	Classroom culture [9] • Individual and group tasks • Quiet environment • Up to 23 students in a class, 7-9 in age [10]	The classroom environment, in Figure 2, may influence sound detection.
People Outdoors	Recess Culture [11] • Use of playground or sports equipment • Peer-to-peer games • Children run at speeds of 20km/h [12]	The spontaneous activities of children may decrease sound detection and durability.

Animals	Eastern Gray Squirrels, Song Sparrow, and Dogs	Animals with notable sound emissions can decrease sound detection [13].
Plants	Trees and Bushes	Plants can decrease sound detection (ex. rustling of leaves) [14].

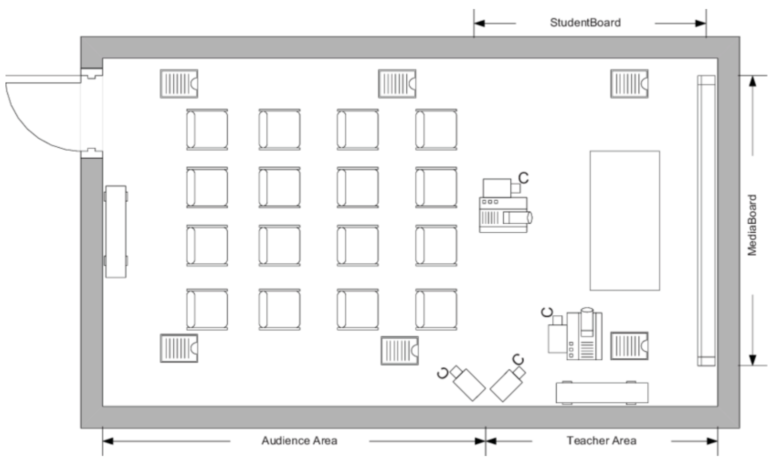

Figure 2. Layout of a standard Canadian classroom [8].

3.3 Virtual Environment

Table 3 lists and justifies the components of the virtual environment.

Table 3. Virtual environment

Element	Description	Justification of Impact
Wi-Fi (Mbps)	Fourth Generation technology. Speeds ● Download: 50 ● Upload: 10 [15]	Solutions may utilize internet connectivity available on school property.

4.0 Stakeholders

This section identifies and justifies the individuals and organizations impacted or influenced by this project, categorized in Table 4.

Table 4. Stakeholders and their Interest/Influence

Stakeholder	Interest
High Interest & High Influence	
Megan's Peers	Interest: Peers are directly impacted by Megan's impulsive and loud behaviour, disrupting their learning environment. Influence: The design must blend in with Megan's environment and be socially acceptable to her peers, without distracting aesthetics.
Megan's Teachers	Interest: Teachers are directly impacted by Megan's impulsive and loud behaviour, disrupting the learning environment for other students. Influence: The design should respect the teacher's expectations and not be distracting to the flow of teaching or other students in the class.
High Interest & Low Influence	
Megan's Parents	Interest: The parents are responsible for Megan's well-being and succession in emotional, physical, and academic aspects. Influence: The design is tailored to aid Megan at school and has minimal use at home.
Low Interest & Low Influence	
Centre for ADHD Awareness, Canada (CADDAC)	Interest: A possible solution could also benefit other individuals with similar experiences Influence: CADDAC has published research with recommended classroom accommodations which can be implemented in our final design [16].

5.0 Detailed Requirements

This section contains a comprehensive overview of the functions, objectives, and constraints of the solution.

5.1 Functions

The primary and secondary functions, outlined in Table 5, explain what the design should do to fulfill clients' needs.

Table 5. Primary and Secondary Functions

Primary Functions *Functional Basis (Appendix D)*	**Secondary Functions** *Black Box Method (Appendix E)*
Transmit information to Megan about her volume	• Reduce Megan's volume • Detect volume level at Megan's location • Identify and distinguish Megan's voice in the surrounding environment

5.2 Objectives

The objectives highlight what the design should be, outlined in Table 6.

Table 6. Ranked Objectives

Ranked Objectives **(Appendix F)**	**Objective Goals**	**Metrics** **(Appendix G)**
1. Discreet	• Minimal sound and light emitted. • Blends into the school environment.	• Maximum sound produced within 10-20 decibels. [17]
2. Child-friendly	• Age Appropriate • Easy to use and efficient • Tailored to Megan's interests	• Prompt a positive reaction by utilizing happy colours (pink, red, yellow, blue, etc) [18]. (Appendix I) • 4-5 star verbal rating regarding user satisfaction from Megan after initial testing of the design.

3. Durable	• Low maintenance. • Long-lasting materials.	• Water and dust rating of at least IP64 [19] • Withstand regular wear and tear [20] (Appendix I)
4. Lightweight	• Easy to carry and store.	• Megan's bag should remain less than 10% of her body weight when the design is added [21].
5. Water resistance	• Endures sweat and water splashes.	• Should withstand up to 3 bars = 44.1 PSI [22].

5.3 Constraints

The constraints reflect the limitations of the design and are determined by the client (Appendix H) and laws and regulations.

Table 7. Detailed specifications of each constraint.

Constraints from Clients	Description
Emergencies	Must have an emergency fail-safe.
Safety	Must not be restrictive, tight-fitting or contain loose parts that can result in safety hazards.
No Active Technology	Must use passive technology, without constant interaction or awareness from the user. Active technology is not permissible for this solution [23].
Constraints from Government	
The Personal Information Protection and Electronic Documents Act (S.C. 2000, c. 5)	Must not collect and use personal information without parental approval [24].
The Ontario Human Rights Code (Code 1.1.1)	Must not discriminate against Megan based on her age, education, or learning disability and ADHD [25].

6.0 Alternative Design Generation, Selection and Description

The section describes the processes utilized during the idea generation and selection and subsequently compares the three leading solutions.

6.1 Idea Generation Process

The team used an iterative process consisting of SCAMPER, structured, free brainstorming, and benchmarking to generate 100 possible solutions which alert Megan (Appendix J).

The common approaches included implementing technologies based on detecting, reducing and identifying Megan's volume, within the surrounding environment.

6.2 Alternative Design Selection Process

The design selection process involved comparing designs against the primary function of alerting Megan and the client's constraints of including a fail-safe mechanism, having no loose components, and no active technology. Designs that couldn't be used indoors and outdoors were not feasible. After multi-voting, the top ten ideas were analyzed based on secondary functions and compared against the objectives of discreet and child-friendly. Hence, the top three results are Heads-Up Glasses, Foot Compression Shoe, and Alerting Bracelet. The process is outlined in Figure 3 and Appendix J.

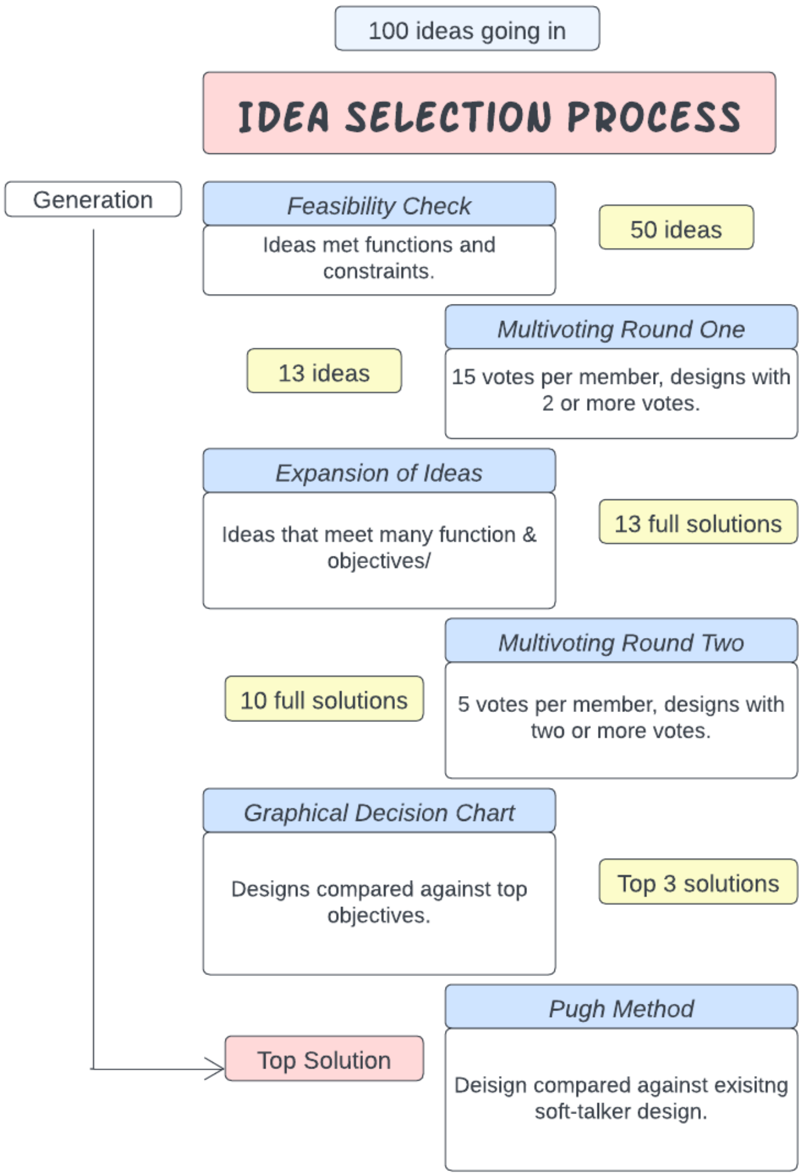

Figure 3. Represents the different phases of the idea selection process.

6.3 Alternative Designs

The team has developed three solutions that activate when Megan's volume reaches 70 decibels and the surrounding environment is 60 decibels or less [27]. These designs meet all the required functions, constraints, and objectives as listed in Table 8.

6.3.1 Alternative design 1: Heads-Up Glasses

This design consists of an advancement on glasses that can transmit information on the inner lens. The frame of the glasses will be built from titanium [28] and will house a micro Arduino [29], microphone [30], vibrating motor [31], and a power source. The right lens will contain a heads-up display unit which will only be visible to the user. The stem houses all the technical components and power is controlled by a button on the top right of the frame. The glasses can be powered down and easily removed in emergency situations.

The Arduino will be linked to a microphone unit housed near the bottom of the frame to better receive sound. A battery cell unit which operates from rechargeable coin cell batteries will power the system [32]. The display will have simple traffic lights-like graphics which will indicate whether or not Megan's current volume is above or below 70 decibels [33] (red is loud, green is appropriate). The design will weigh 20-40 grams [34]. The Arduino will only process current inputs and will not save any data for the future. Additional pictures: Appendix L.

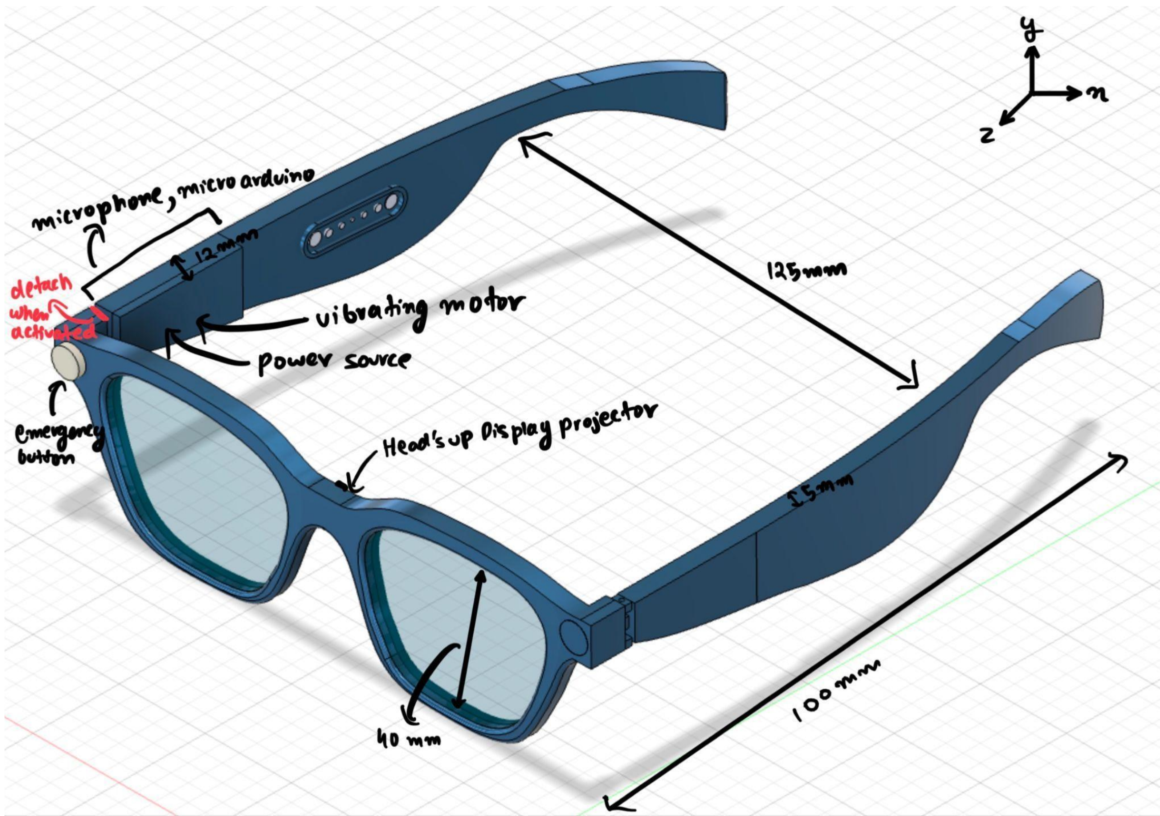

Figure 4. 3-D model of the Heads-Up Glasses, see Appendix K for detailed measurements.

6.3.2 Alternative Design 2: Foot Compression Shoe

This design modifies any velcro-based shoe to tighten on command. A motor with an eight-centimeter long shaft with a ceramic coating is attached to velcro strips fastened to the shoe. When turned on, the rod rotates, tightening the velcro and the fit of the shoe (Figures 5, 6). To pick up the user's volume, a neck microphone is implemented on Megan's neck and is plugged into the motor to isolate and transmit the information.

The shoe will be powered by a AAA battery connected to the motor. The additional weight due to modifications is 42g (Appendix K). This adds 6% to the weight of a typical 680g children's shoe [35]. The wire connecting the shoe to a microphone can be unplugged to turn the motor off and loosen the shoes in emergencies.

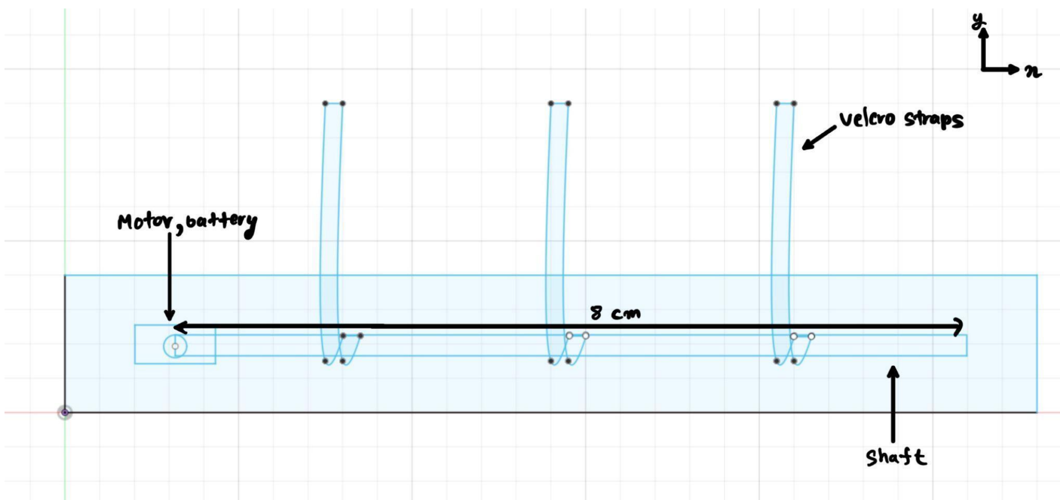

Figure 5. A two-dimensional schematic of the tightening mechanism

Figure 6. A three-dimensional schematic of the design, detailed measurements in Appendix K.

6.3.3 Alternative Design 3: Alerting Bracelet

This design contains components responsible for the detection of volume and transmission of information through an LED, a vibrating motor, and a microphone (see Figure 7). The bracelet band will resemble a watch band but will be interchangeable with customizable bands. A mini Arduino will be powered by LR44 batteries which will power the microphone, LED indicator, and vibrating motor.

The microphone will detect noise through frequencies and will compare the value with a predetermined threshold of 70 decibels. The LED indicator will turn red for sound levels over 70 dB, yellow for levels between 60 and 70 dB, and green for levels below 60 dB. The motor will vibrate the device when exceeding the 60-dB threshold. The technology will be housed in a 3-D printed casing which will be (41 to 45 mm) and will rest on top of Megan's wrist [46], Appendix K for detailed measurements. The safety clasp will be implemented with the strap with a button that dislodges the bracelet during emergencies. The design weighs approximately 52 grams [37]. Additional pictures can be found in Appendix L.

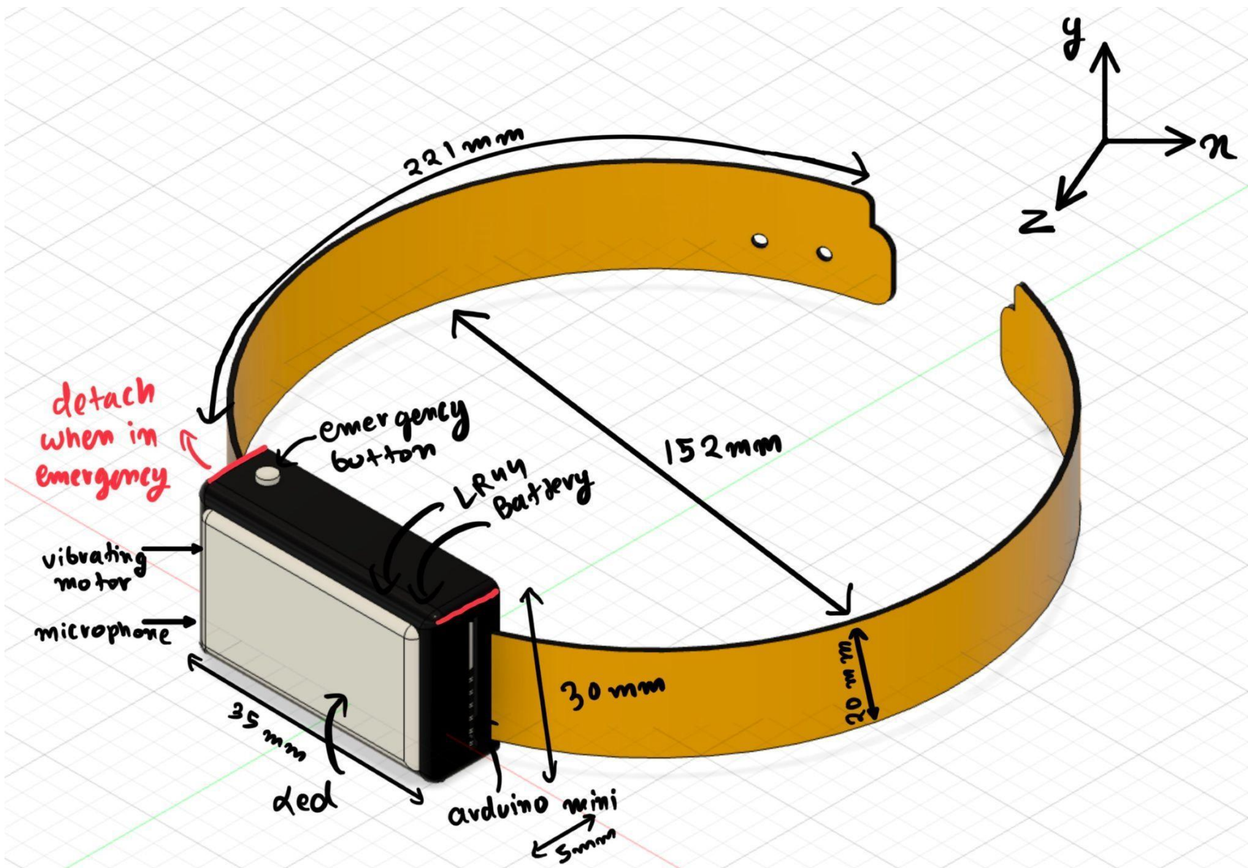

Figure 7. 3-dimensional annotated design.

Table 8. Descriptions of which aspects of the designs meet each objective.

Objectives	Heads-Up Glasses	Foot Compression Shoe	Alerting Bracelet
Discreet	- 21.9% of Canadian children wear glasses making it common [38].	- Design is a shoe and worn by everyone in school [42].	- Bracelets are common in elementary schools.
Child-Friendly	- Non-constraining and easy to put on and off.	- Normal use of a customized shoe with velcro.	- Changeable band to match Megan's interests and trends.
Durable	- Frame of the glasses is constructed from titanium [28]. -Scratch-resistant coating on polycarbonate lens [39].	- Rubber soles that have shock absorption under various conditions [43].	- Polycarbonate casing will protect circuit components. - Silicone bands will sustain wear and tear [45].
Lightweight	- Will be supported by Megan's ears and is between 20-40 grams [34].	- 6.28% of additional weight added to both shoes (Appendix K).	- Will be approximately 52g. [46] - The material is lightweight
Water Resistant	- The lens [40] and the frame [41] are both water resistant.	- A ceramic coating on the shoes will give a water repellent property [44].	- The strap is a waterproof silicone-based material. The circuit is in a waterproof casing.

7.0 Proposed Conceptual Design

Design three, a vibrating bracelet with colour-changing features, was selected by the team as it best meets the aforementioned objectives and clients' needs. The Pugh method was used to compare the top three designs against the pre-existing Soft-Talker design (Appendix M), with the bracelet receiving the highest rating in terms of improving discreetness, child-friendliness, and durability (see Appendix J).

Megan will be notified of her increasing volume through the vibratory and visual effects provided by the motor and LED light. The traffic light system will facilitate Megan in maintaining her volume through green, yellow, and red LED coloured lights. The yellow light will inform Megan that her volume is gradually increasing, helping Megan self-regulate before reaching an unacceptable sound level. The motor provides vibratory feedback when Megan is outside or engaged in other activities and cannot directly look at the bracelet.

The device's microphone will detect Megan's sound level and distinguish her volume from her surroundings. The bracelet will be specific to Megan by utilizing speech recognition, setting a modifiable threshold of 70 decibels. The design will be discreet and child-friendly—personalized to Megan's preferences and environment with interchangeable bands, with a button that can dislodge the bracelet in emergencies. Silicone and polycarbonate withstand regular wear and tear, and their properties provide water resistance in low volumes of water.

8.0 Measures of Success

The Alerting Bracelet will be prototyped and assessed in the following three-week timeline.

The week of March 27th will involve completing further calculations and research on technical components and aesthetics (Appendix N). All team members have completed the online training and will attend the in-person training in the Myhal Light Fabrication Facility (LFF) on March 30th [47]. The team will establish the materials available for students and order the remaining equipment necessary.

In the week of April 3rd, all team members will return to the LFF to create the prototype by coding the Arduino, building the circuit, 3-D printing the case, and combining each element alongside the LR44 battery. Once the emergency clasp mechanism is attached to the silicone bands and fastened to the box, the prototype is complete.

The final week, April 10th, will focus on testing the prototype with supervised, drop-in sessions at Myhal's Rapid Prototyping Facility [48].

Table 9. Procedures to be conducted.

Noticeability (Discreet)	Justification

1. Have a user wear the bracelet for a week.
2. Have another member document how often people look at the bracelet and the reasoning. For example:
    a. Is the vibration too loud?
    b. Is the colour of the bracelet conspicuous?
    c. Are the changing lights too bright?
3. Repeat the test in differing social situations (classrooms, social outings, etc.)
4. Evaluate the level of discreetness by the frequency of people's reactions to the bracelet.
	The design should integrate into Megan's school environment and not distract her peers.

Vibration (Functional)	

1. Download a sound level meter app (ex. NIOSH or Decibel X).
2. Set up the bracelet in a quiet environment without any external noise that might interfere with the microphone.
3. Create a noise, observe, and document if the device vibrates in the following condition:
    a. Under 60 dB.
    b. Between 60 dB and 70 dB (inclusive).
    c. Greater than 70 dB.
4. Repeat the test in different environments of ranging noise levels (classroom, outdoors, cafeteria, etc.).
5. Analyze the results to determine if the vibration feature only activates above a 70 dB volume threshold.
	The design should only notify Megan when she is too loud through vibrations, in varying environments.

The team's future endeavours prioritize testing other objectives and functionalities (Appendix O) and calculating battery life, estimating 460 hours (76 school days) (Appendix N). For example, durability cannot currently be tested within the given budget and resources, because it is unfeasible to iterate a new prototype within a week if the design breaks. The team will test the child-friendly objective with Megan to ensure the device is tailored to her voice and interests (Appendix O) and make a final user-centred design to optimize the prototype.

9.0 Conclusion

After analyzing the problem statement and identifying the detailed requirements, service environment and stakeholders, the team established a proposed conceptual design: the Alerting bracelet. The design contains a silicone band, emergency button, LR44 battery, and polycarbonate casing housing the microphone, Arduino board, LED light and motor. This design will alert Megan through coloured lighting and vibrations. It will be discreet and not attract attention in school environments. The team's immediate course of action includes testing the design for discreetness and its vibrational functionality. Future plans include testing for remaining functionalities and objectives to create a final user-centred design for Megan.

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11.0 Appendices

Appendix A: Client Statement

The statement provided by the client regarding Megan's problem, gives insight into the client's wants, needs, gaps, and scope.

Table 1. Client Statement

Project Title:	Project 1 – St. Lawrence College
Project Description:	Megan is an eight-year-old child with ADHD and a visual learning disability (She has deficits in reading and strengths in auditory learning). Megan is very impulsive and has a very loud voice. In class, she often speaks her thoughts out loud. This occurs during academic independent work. It does not appear to be to get attention but rather, she seems to be thinking and processing out loud in order to complete work. Megan is also very loud when she talks to peers during free time. The teacher feels that this is not only disruptive to the class but also, classmates have begun to make fun of Joey and it seems to be affecting her social relationships.

Appendix B: Client Meeting Summary

The initial client meeting can be summarized in the table below which discusses both technical and non-technical information about the project. The clients also expressed their implied solution during the meeting which will be marked with an *. Currently, they should be disregarded when considering the design solution.

Table 2. Meeting Summary Topics

Topic	Detail
Technical Information	● A Bracelet-like voice volume-detecting device. * ● Must vibrate when hearing Megan's voice at elevated levels. * ● Lights up upon detection of loud voice, preferably gradually based on voice level. * ● It must have an emergency clasp for safety ● Registers only Megan's voice and ignore surrounding noise ● The design can be used both indoors and outdoors. ● It must be lightweight and comfortable to wear. ● It should preferably not have any loose components ● The overall design of the solution should be symmetrical and uniform looking ● Design should preferably not be a necklace or a watch ● Solution should not be active technology which can be distracting to student *
Non-Technical Information	● The design should be attractive yet simple and not distracting to her and her peers. ● Megan has no allergies/restrictions which allows for some freedom in choosing materials. ● The material should have longevity and sustain wear and tear. ● Material should be water and sweat resistant. ● The design must be age appropriate and safe.
Megan's Preferences	● Megan enjoys arts and crafts and many colours. ● Megan is not interested in any specific tv shows.

	● Megan is quiet while on the bus because she is not processing information that requires her to think out loud.
Environment	● Megan is in a closed classroom, with about 23-28 students. ● The students sit less than 6 feet away from each other. ● Aside from being indoors at school, Megan also goes to the playground area for recess. ● Megan lives within walking distance away from school and bikes or walks to school while supervised. ● The design does not need to be used at home.

Appendix C: Service Environment

This section shows the environmental data of the physical service environment.

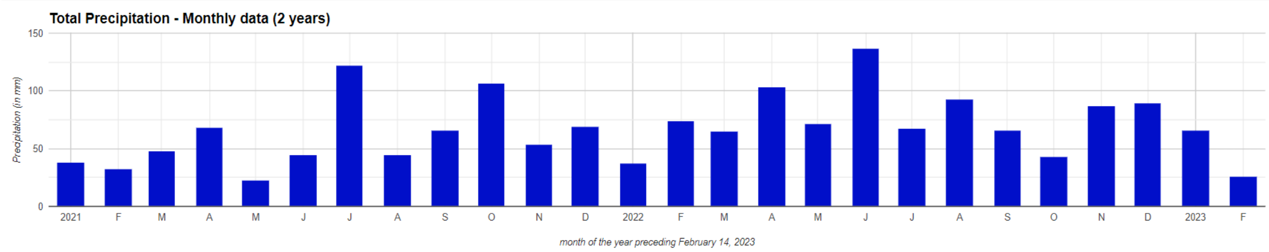


Figure 1. Monthly data of precipitation in Kingston, Ontario over the past two years. [3]

Appendix D: Functional Bases Breakdown

Figure 1 describes the process of breaking the problem into the functional basis of the design.

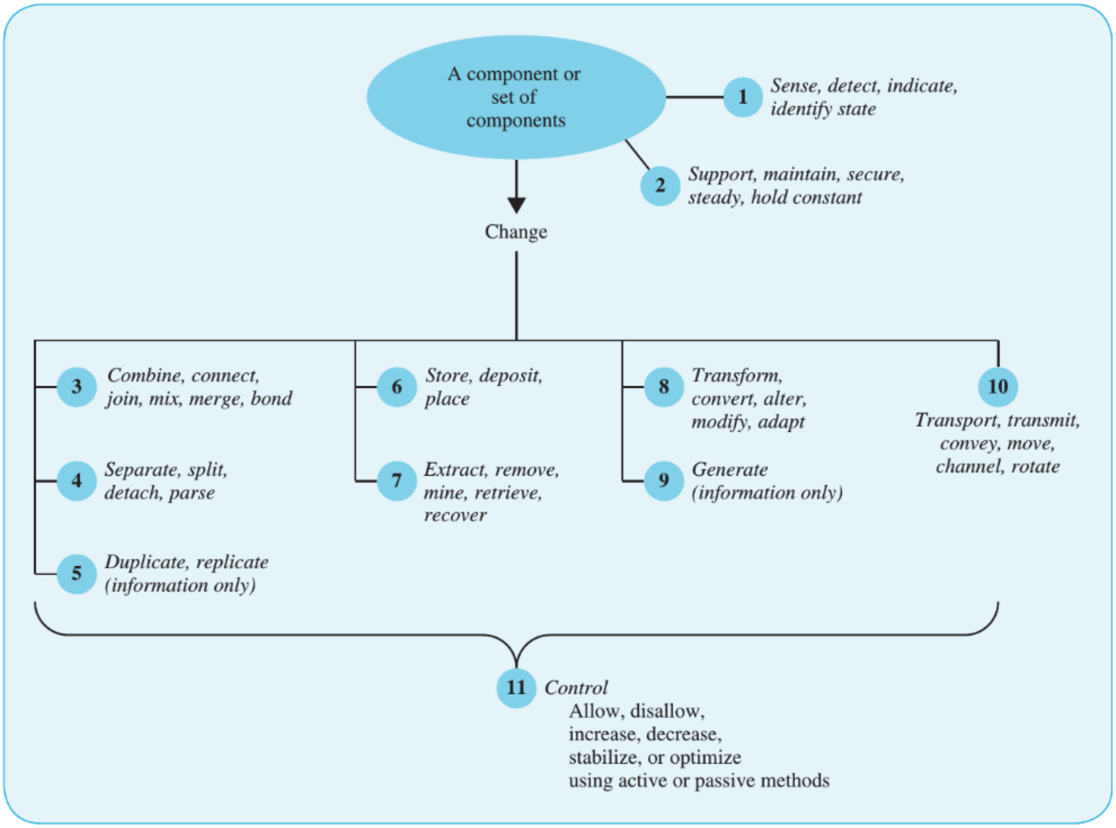


Figure 2. Functional Basis Generation Process [26].

1. **Detect Energy**
   - Detect changes in sound energy in the immediate surroundings
2. **Transmit Information**
   - Notify users of their voice level
3. **Store Information**
   - Capture the volume to process into comprehensible information

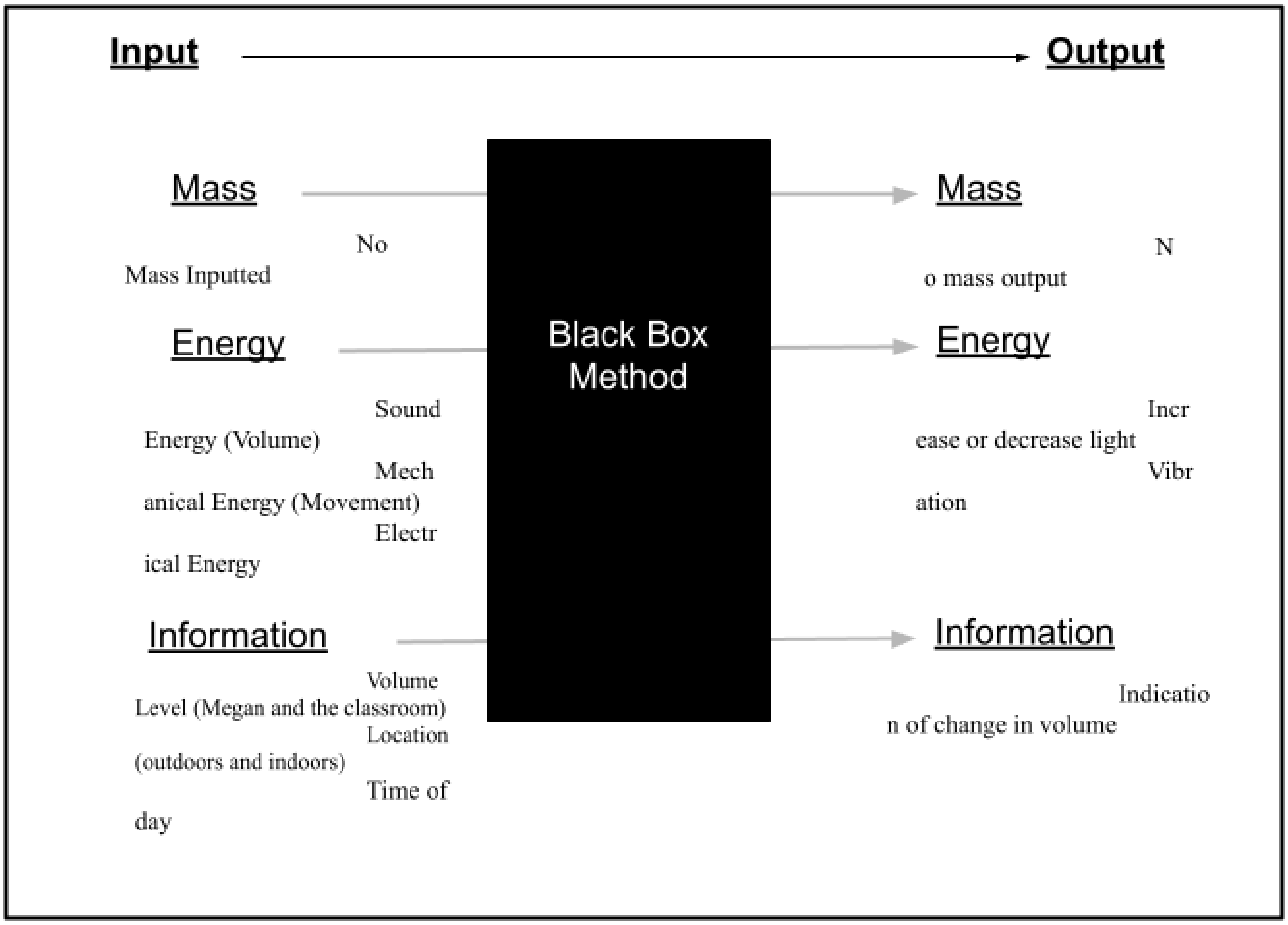
Process of Generation for Functions, Objectives, and Constraints

The following section will describe the process and steps used to develop the functions, objectives, and constraints (FOCs) of the project.

Appendix E: Black Box Method for Function Generation

The black box method was used to break down the problem into components to determine the inputs and outputs of a design, independent of the solution.

Figure 3. Black Box Method



The secondary functions below were created using the black box method.

- Reduce Megan's Noise Level
- Alert Megan of her Noise Level
- Detect Volume Level where Megan is located
- Recognize Megan's Volume in the surrounding environment.
- Detect the Environment of Megan (indoors and outdoors).

The objectives below were brainstormed from the client statement and meeting.

- Child-friendly interactive design
- Light-weight and small
- Durable
- Smooth surface
- Waterproof or Sweatproof
- Discreet/subtle design

● Easy to use ● Close proximity to Megan	● To support Megan's learning style by taking into account her strengths in auditory learning and her deficits in reading

Appendix F: Pairwise Comparison

A pairwise comparison technique was utilized to rank the objectives in order of precedence.

Table 1. Pairwise Function

	Child-friendly design	**Light Weight**	**Durable**	**Waterproof or Sweatproof**	**Discreet/ subtle design**	**Total**
Child-friendly design		1	1	1	0	**3**
Light Weight	0		0	1	0	**2**
Durable	0	1		1	0	**2**
Waterproof or Sweatproof	0	0	0		1	**1**
Discreet/ subtle design	1	1	1	0		**3**

Justifications on categories in the pairwise comparisons:

1. Child Friendly versus Light Weight
    a. The design must be applicable and safe for children because the user, Megan, is an 8-year-old. The design will also function around many other children because it will be used on school property. Although the design should be effortless for Megan to carry, it is possible that the design could remain stationary. Safety and usability, in the form of child-friendliness, were chosen over lightweight.
2. Child Friendly versus Durable
    a. The design could last forever, however, it must be in use for Megan to benefit from it. If the design is not implemented, it will not solve the problem. As a result, a Child-Friendly design is more important than durability.
3. Child Friendly vs Waterproof
    a. A solution being resistant to water is important to ensure that the solution can be implemented and used in the rain and activities evolving water. However, to ensure the successful implementation of the design, it must be child friendly and appropriate for children. As a result, a design being child friendly is more important than being waterproof.

4. Child Friendly versus Discreet and Subtle.
    a. The solution must not disturb others. Megan's condition already disrupts the learning environment of her classmates. In order not to cause any more issues or alienate Megan, it is essential that the solution is discrete. As a result, a discreet design is more important than a child-friendly design.
5. Lightweight versus Durable
    a. The design should be for long-term use and therefore durability was prioritized over lightweight. This design is meant to help Megan until she can detect her increase in volume without it. It is essential that the design itself is easy to maintain and will last Megan through elementary school.
6. Lightweight versus Waterproof
    a. The design should be a comfortable weight for Megan to potentially carry and to be portable as she goes around the school and the playground. Megan should be comfortable with using the design or else she potentially will not use it or benefit from it. As a result, lightweight was chosen over waterproof.
7. Lightweight versus Discreet and Subtle
    a. The design should blend in with Megan's environment to ensure minimal distraction in the classroom. It would be beneficial for the design to be easy to carry. However, if the design creates additional disruptions to the classroom, it defeats the purpose of Megan's aid. Ultimately, a discreet design is placed higher than a lightweight design.
8. Durable versus Waterproof
    a. The design is meant for long-term use and therefore durability was prioritized over waterproofing. Megan's environment would have minimal water exposure through washing hands, sweat and rain. However, the design should maintain its integrity at all times.
9. Durable versus Discreet
    a. The design itself should not be a distraction and should blend into Megan's school environment. If the design is not discreet it will add to the distractions and can potentially further strain Megan's social relationships with her peers. As a result, discreetness took precedence over durability.
10. Waterproof versus Discreet
    a. One constraint is that the design must work in rain and when sprinkled with water. If water impedes or disables the solution, then the solution would not be able to be implemented. As a result, having a waterproof design is more important than the design being discrete.

Appendix G: How-Why Tree

The How-Why Tree was utilized to analyze the objectives and pair them with appropriate metrics.

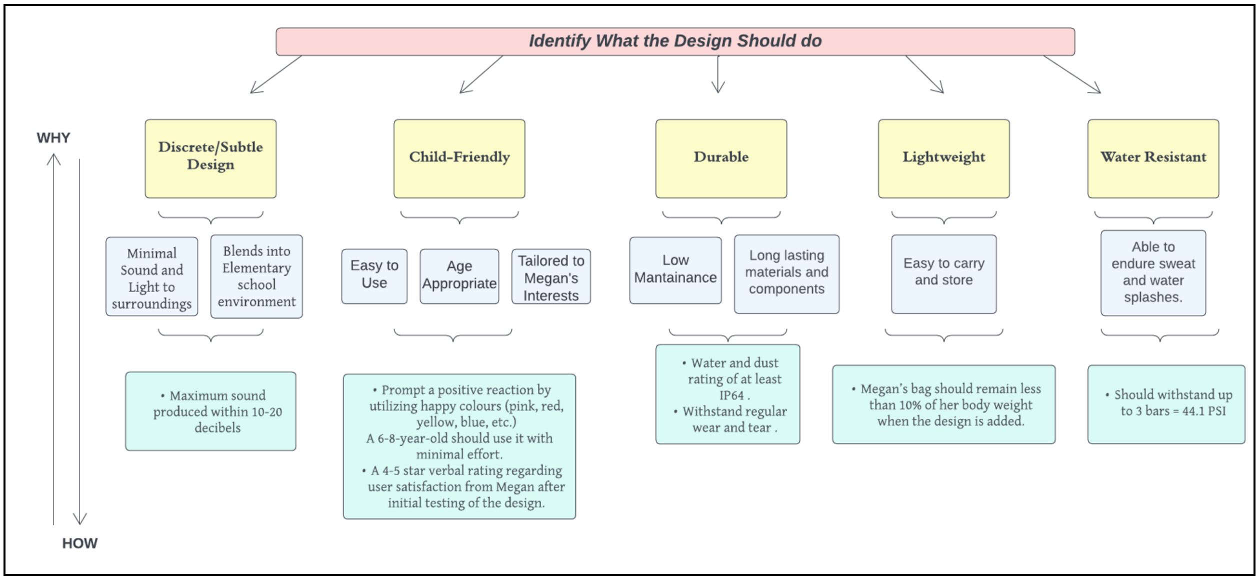


Figure 4. How-Why Tree is used to identify the objective goals and metrics.

Appendix H: Constraints

The constraints were mainly provided by the client and adhered to their requirements. The table below justifies them.

Table 2. Constraints and Justification

Constraints	Justification
Emergency Clasp	The client outlined the requirement of an emergency clasp on the design. This ensures that if the design is restrictive it can be removed immediately.
No Restrictive Solutions	The design must not be restrictive in any shape or form as it can be a safety hazard. Specifically, the client expressed that a necklace must not be a design solution.
No Loose Components	The design must not have any loose components that can get caught on objects or break off. This can be a potential safety hazard for Megan and those around her.
No Active Technology	The design must not implement active technology only passive technology must be used. This would mean that there must be minimal to no interaction between Megan and the design solution. The solution should adhere to privacy standards (not tracing location, no recordings etc.)

Appendix I: Metric Breakdown

Wear and Tear: Normal wear and tear caused by kids can vary in intensity depending on the type of material. What will be included in normal wear and tear in terms of our client's need: regular exposure to water, rubbing against harsh/soft fabrics and materials (brick, clothes, backpack), sweatproof, non-toxic paint splatter, food particles, and minor impact with surfaces [23].

Age Appropriate: A clinical trial conducted on 60 children (30 boys and 30 girls) showed a positive reaction 69% of the time when exposed to bright colours such as pink, red, yellow, green, purple, and blue. [18]

Appendix J: Full Idea Generation and Selection process

The idea generation process began with blue sky thinking. The team generated 100 ideas by looking at existing solutions for different problems, and adapting them to Megan's case, or simply innovating out of thin air different ways to solve the various problems. Table 3 contains a full breakdown of the 100 ideas.

The following step was a feasibility check to see if the ideas followed the constraints and functions, and were possible to implement. For instance, if an idea did not work in all aspects of the service environment, or failed to alert or silence the user, they were found to be unfeasible and marked as such.

Table 3 illustrates the feasibility check undertaken. Ideas highlighted in red were deemed to be infeasible, ideas highlighted in gray were found to be duplicate ideas and ideas highlighted in orange were found to be infeasible ideas which could easily be iterated into fully functioning designs. Ideas without highlights were ideas that passed the feasibility check and advanced to the next stage of idea generation.

Table 3. Blue sky thinking; ideas generated.

Sl No.	**Idea**	**Description**
1	Noise-Canceling Headphones for classroom	Provide earplugs to every student to ensure that they do not hear Megan speak loudly during quiet time, and alert Megan/ of her sound
2	Noise Canceling Mask	Dampens/softens the sound when the mask in use, reducing overall volume, alerted by teacher
3	Drop down Cubicle	Drop-down cubicle to isolate Megan and her sound during quiet time.
4	Noise Canceling Bubble	Use high tech noise cancelling technology, create a virtual bubble of isolation around Megan.
5	Remove Quiet Time	Remove "quiet time" from classroom activities; no longer a need to be silent in class.
6	Focus Group	Provide Megan with a focus group containing other students like her so that she has the opportunity to make friends outside the classroom. Whatever she does at school does not affect her social life.
7	Box with sound meter	Wearable small speaker like design which would display her decibels in relation to acceptable levels
8	Throat Implant	Chip implanted inside her throat. Vibrates when she is too loud encouraging her to quiet down.
9	Ice pack Clothing	Mix ammonia and water to create a cold pack sensation attached to Megan. Release chemical when detecting loud behaviours
10	Ear Implants	Implants on Megan's ears. When they detect that Megan is speaking too loudly, they send a signal directly to the brain (similar to how hearing aids work), to inform Megan.
12	App that can scan and read things out loud to her	This app can be used by Megan to listen to assignments and handouts she gets in class by taking a picture and having a text to speech mechanism. This can help Megan battle her weakness in visual learning.
13	Colour-changing ring	Change into noticeable colours upon detection of an increase in volume
14	Providing a journal or another mechanism to help her organize her thoughts	The journal will read and analyze each journal entry and provide a brief summary of the situation and possible solution to mitigate the intensity.
15	An app that provides a set of vocal exercises.	Vocal exercises can be a great tool to maintain volume levels and train yourself to speak softer. Some of the vocal exercises include humming, yawning, lip buzzing etc. Megan can practice these daily at home to improve her voice and this can easily be done through an app that lists

		these exercises, shows how to do them and also times Megan.
16	Soft-talker like design TM	Used for deaf people to monitor their volume level. Wear on the wrist and uses microphone, amplifier, signal rectifier and a level detector
17	Water-Bottle that lights up when it detects an increase in sound	Megan can use a simple object like a water bottle to alert her when there is an increase in volume. The water bottle can slightly light up and can blend into the school environment.
18	A pen that has a small blinking light that activates when it senses an increase in volume. Also vibrates.	Using something like a pen or pencil that can easily alert Megan and can also blend into the school environment. The pencil/pen can light up and little or blink to alert Megan of her volume level
19	Colour changing socks which also compress and decompress to alert her	Shoes get heated when volume increases and then socks change colour to alert Megan of her increase in volume.
20	Fidget toy	Both help her stay calm and can vibrate/light up when there is an increase in volume.
21	Automatic sequence changing pencil case	Create a pattern when too loud from the sequence changing material
22	Scheduling Talk-Out Loud Time Periods	Before individual work, students can have 5-10 minutes to talk through their ideas to themselves or with friends
23	Hand Signal	Create a hand signal in the classroom to ask/remind people to lower their voices
24	A colour changing & vibrating bracelet	A watch that vibrates and lights up when a loud noise is detected from Megan. This idea was suggested by the clients (without the vibrations).
25	Concealable ear piece	Earpiece that vibrates to inform Megan
26	Vocal cord manipulation	Tighten the vocal cord to increase sound frequency and decrease sound intensity. This is done by making the cords stiffer so that higher pitched (and quieter) volumes exits Megan.
27	Muzzle redirecting sound	Muzzle on mouth contains sound within Megan. Tubes from mouth to ears direct sound to Megan for her to hear. Circular tubing resting on head to circulate cold air or fluids when Megan is too loud. Helmet contains the technological equipment for the machine to operate.

28	Vibrating pen	Writing utensil that Megan uses for school work. When she is too loud, it vibrates and a panel on it emits a light. When she is thinking and not holding the pen, its vibrations make the table vibrate and cause a lot of noise audible to her. When on the playground, Megan can wear the pen in her hair or on her ear like cool people.
29	Nail backed chair	A normally functioning chair with nails embedded in the back. If a certain vibrational pattern in Megan's back is detected (she is speaking loudly) and the surroundings are quiet, nails slowly advance from the chairs back until Megan quiets down. In other words, nails deploy when loud, retract when quiet. Additional option for electric current to be embedded into the nails for additional encouragement to Megan to be quiet.
30	Electric Chair	When the user is loud, a stream of electric current is directed to the user to provide a shock and inform them that they are too loud. When the user is quiet, electricity turns off.
31	Compressive shoe	Custom made shoe that compresses when Megan is loud to physically notify her of her noise level. This is accomplished by pumping compressed air into a chamber to make the fit on the shoe tight until reaching a predefined limit, or Megan silences herself.
32	Mustache pumping fluid	Fluid filled false mustache resting on upper lip. When Megan is too loud, droplets of fluid are pumped at a non constant rate into her nose, triggering an immediate gag reflex which forces her to comply with demands. This solution alerts her of her loud volume until she quiets down. Mustache style would be replaceable ensuring a variety of options for artistic expression.
33	Fidget spinner	Megan can use a small, handheld device that can be spun around in the fingers to help provide a calming and distracting sensory experience.
34	Noise-cancelling headphones	Headphones can help block out distracting sounds and provide a more peaceful auditory environment.
35	Speech monitoring device	A wearable device that measures the volume and frequency of the wearer's speech and vibrates or provides an alert when the volume or frequency is too high.
36	Calming scents diffuser	Disperses scents that Megan is trained to associate with being quiet
37	Stress ball that lights up when she is loud	A squishy ball that can be squeezed and manipulated to help release nervous energy and reduce tension. This would help Megan calm down.
38	Mindfulness app	Apps available that offer guided meditations, breathing exercises, and other mindfulness techniques that can help promote calmness and focus.
39	Reminder app	A device that provides reminders to the wearer to stay quiet or listen more often.
40	White noise machine	Devices can help mask out distracting sounds and create a more peaceful environment.

41	Personal planner	A planner or notebook specifically designed for ADHD individuals can help with organization and reduce anxiety related to forgetfulness or time management.
42	Sound wave cancellation	Use a small microphone/speaker combination attached to Megan's desk. When she is loud, the microphone picks up the increase in volume and then the speaker plays a sound wave that cancels out the noise.
43	Electronic mask	Mutable mask which literally puts Megan on mute, controlled by the teacher, the teacher can also set a volume
44	Vibrating clippable device	Bracelet like solution in different form that clips like a pin
45	Pulsating Earing	Bracelet solution in different forms that can be either a piercing or a magnetic earring.
46	Heating Bracelet	Same as 45 but in a bracelet form.
47	Bone Pullsing Implant	An implant that will vibrate a bone when it detects an increase in volume, alerting Megan.
48	Vocal Cord Numbing Spray	Numbing spray that will numb the vocal cords allowing Megan to not talk at maximum volume.
49	Portable Microphone Studio Isolation Setup	Portable studio setup which can process her voice before being heard by others and output a quieter message back at acceptable levels. Iron man like mask setup with built-in bootleg JARVIS
50	Sound Dampening Face Mask	Covid-type face mask which will soften the tone of her voice when increased volume is detected.
51	Glasses that Show Volume Level	Something like google glass or iron man glasses from Spider-Man Far from Home
52	Temperature Changing Headband	Heats up or cools down to cold level upon loud volumes from MEGAtron
53	Colour projecting band	Wristband projects colour illuminating her arm when she is loud.
54	Slap-on Bracelet	Old school type bracelets from when we were young. Same as other bracelets
55	Drone	A drone that follows Megan around to pick up her volume level, connected to an ear piece that will remind her to quiet down.
56	Implementation on Neck	Implement a chip on Megan's neck to sense when there are vibrations occurring. When Megan speaks, it will detect vibrations and, after comparing Megan's time speaking with the surrounding noise, will determine if it should inform Megan to quiet down. If it is decided that Megan should be quiet, a secondary device will

		inform Megan of her noise level.
57	Duct tape	To shut her down, and not speak, whenever teachers allow, she will remove the duct tape.
58	Heat detecting unit	Detects the amount of heat exiting Megan's mouth.If an abnormality of heat is exciting and the surroundings are silent, sends a signal to another component.
59	Personal AI	AI that informs Megan that she should keep her volume down.
60	Noise Cancelling earbuds	Noise cancelling gets more intense as she gets loud ultimately isolating her from the class, forcing her to quiet down.
61	Retainer that injects liquid in mouth	Liquid can be something like water that gets released into her mouth to alert her of increase in volume
62	Visor sprays vapor	Wearing a glasses or spectacle like thing which would either fog up or spray a mist of water when too loud, could be like faux glasses
63	Talking hat	Has a sound/signal that alerts Megan of when shes loud
64	Spray that makes Arm hair that stands up when loud	Arm on hair stands up to visually indicate that she is loud.
65	Medication	Provide Megan with pharmaceuticals which could help deal with her issues.
66	Placebo	Provide Megan with a placebo solution.
67	Scrunchie	same as bracelet, possibly tighten as well when loud
68	Silent Treatment from Teacher	Teacher informs Megan of her sound by being silent when Megan is too loud.
69	Medications	Provide Megan with a prebuilt physical solution to solve her problem.
70	Hoodie with strings that tighten when she is loud	Draw strings in hoodie pulsate by tightening and loosening when she is loud.
71	Anklet with charms that change colours	Band worn on her ankle with beads that lights up. Similar to an ankle monitor.
72	Eraser cover that changes colour	Colour changes when she is loud
73	A headband that tightens when Megan is loud	Tightens around her head when she is loud

74	Device that plays music in a low volume when Megan is too loud	Headphones/hearing pieces that play music when an increase in sound is detected.
75	Sensor that put on her wrist to sense sound level and vibrates	Sensor senses a change in a certain body feature when she is loud. This would be comparable to a blood pressure monitor that senses an increase, and reacts accordingly.
76	Stress ball that lights up when she is loud	Stress ball that is kept on Megan's desk that lights up on command. Acts as a stress ball as well.
77	Hair clip/ brooch that would shoot out mists of scents to calm her down	Brooch with a tank of a certain liquid with a scent and pump. Pumps out the liquid when Megan is loud to create a trigger for Megan to react to be quiet.
78	Silencer like mask	Similar to gun silencers, it contains several chambers with a volume 20 times greater than Megan's mouth, slowing down gas exiting her mouth to decrease the sound emissions.
79	Compressive Armband	The arm band can sense if Megan is talking too loud/much with a spike in her blood pressure. Then it will compress to remind her to lower her voice. (Similar to a blood pressure monitor)
80	Firing projectiles	Fixtures on the ceiling of the classroom aimed straight at Megan contain projectiles made of soft rubber. When it detects a loud noise, it discharges the projectiles, hitting Megan and thus informing her that she is loud.
81	Finger ring	Finger ring that will change spin around upon detecting loudness (fidget ring)
82	HUD (head-up display) contact lens	Display that shows her and only her the level of her volume
83	Rocking chair	Megan's chair is smart; when it detects loud noises coming from her, it begins to oscillate back and forth, physically informing her that she is loud by causing a sea sickness type reaction.
84	Compressive joggers	The jogger strings tighten when Megan is being too loud and alert Megan of her increase in volume
85	Compressive hair tie	It tightens Megan's ponytail when there is an increase in volume detected
86	High altitude bubble	An airtight helmet fitted to Megan's head. When it detects an abnormal amount of volume exiting her mouth, it slightly increases the air pressure in the helmet similar to being in an airplane. When

		Megan quiets down, it drops the air pressure. Megan is able to communicate with others through a speaker and microphone setup fixed on her ear, and exterior of the helmet.
87	Smart wearable device	Device that senses if people are using their vocal cords too much, if it needs rest, and if it will cause vocal fatigue. Uses bluetooth to send notifications to a device.
88	A self destructing fixture	A box fitted onto Megan's desk. When it detects that she is loud, it disassembles itself in a violent, explosive fashion, so that she can observe it. When she quiets down, it peacefully builds itself back.
89	Colour changing wall/projector	Projector/Cat light that turns on whenever she is loud and alerts her
90	Earpiece holding sounds of a formula one car's engine and the doppler effect	Megan has an earpiece in her ear. This keeps it hidden and discreet. When the microphone picks up that she is too loud, it plays the sounds of a formula one car at a certain distance away from her. Using the doppler effect noises of changing intensities based on her volume, this will give her a place to compare her volume level.
91	A digital ruler that displays volume levels	The ruler will have a small rectangle in the corner that changes colour based on volume- green if okay, yellow if borderline loud and red if too loud
92	AlterEgo device	Wearable tech that detects the signals sent to vocal cords from the brain when someone speaks to themselves. AI reads these signals and turns them into words and reads the words back to the user, without the user needing to speak out loud.
93	Blood pressure monitor	Setup a blood pressure monitor on Megan's arm. The technological aspects can be held in a fanny pack. When it detects that she is loud, it compresses the cuff to take her blood pressure and let her know that she is too loud at that instant.
94	In built - fan in her fanny pack	The fan can turn on when she is being too loud (sort of like a heating jacket with an inbuilt heater) but it will release cold air to alert Megan that she is being loud. Megan will also be able to hear the mechanical whirring of the fan.
95	Patch on neck/chest	The patch can sense the vibration in vocal cords or movement of the chest when Megan speaks. The patch can change temperature to alert Megan of her volume.
96	A device that blows bubbles when she is loud	Small bubbles released when she is loud and can alert Megan of her volume levels (bubbles can be small and unnoticeable?)

97	Nail Polish	Microchip under acrylic nails that can detect an increase in volume and an led that flashes light on those nails for them to change colour and for Megan to notice.
98	Shoelaces/velcro that tighten	Megan's shoelaces tighten and alert her when there is an increase in volume
99	A ring which works like a traffic light based on volume	Reflects green when ambient volume, yellow when increase detected, red when too loud
100	artificial mole that beeps and illuminates	Similar to a birthmark or natural occurring on skin

Ideas were found to be fitting into categories outlining the secondary functions. Figure 4 below outlines the functions and operations that the ideas fit into.

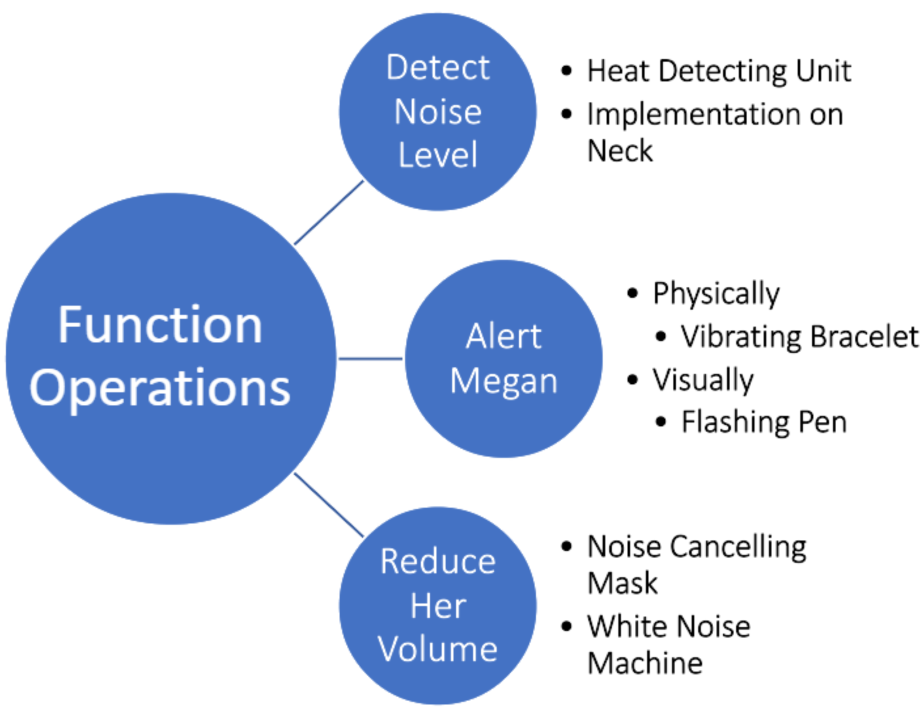


Figure 5: Different categories of functions that the feasible ideas fit into.

The next step in the ideation phase was a recorded vote to narrow down the ideas. Each member was given 15 votes to pick ideas that they thought fit the design specifications the best. Table 4 is an image of the recorded results of the vote. The ideas highlighted in green received two or more votes and advanced onto the next stage in the ideation process.

Table 4. Record of multivoting to narrow down ideas. Team member votes are based on their initials (YP - Yashvi Patel, DA - Danielle Akinlalu, MH - Max Haim, AS - Aaryaman Singh, PK - Paarth Kashyap).

Idea	Description	YP	DA	MH	AS	PK	Total
Noise-Canceling Headphones for classroom	Provide earplugs to every student to ensure that they do not hear Megan speak loudly during quiet time, and alert Megan/ of her sound						0
Noise Canceling Mask	Dampens/softens the sound when the mask in use, reducing overall volume, alerted by teacher	1		1	1	1	4
Noise Canceling Bubble	Use high tech noise cancelling technology, create a virtual bubble of isolation around Megan.						0
Box with sound meter	Wearable small speaker like design which would display her decibels in relation to acceptable levels						0
Ice pack Clothing	Mix ammonia and water to create a cold pack sensation attached to Megan. Release chemical when detecting loud behaviours	1				1	2
Colour-changing ring	Change into noticeable colours upon detection of an increase in volume		1		1	1	3
Providing a journal or another mechanism to help her organize her thoughts	The journal will read and analyze each journal entry and provide a brief summary of the situation and possible solution to mitigate the intensity.		1				1
Soft-talker like design TM	Used for deaf people to monitor their volume level. Wear on the wrist and uses microphone, amplifier, signal rectifier and a level detector	1	1				2
Water-Bottle that lights up when it detects an increase in sound	Megan can use a simple object like a water bottle to alert her when there is an increase in volume. The water bottle can slightly light up and can blend into the school environment.						0
A pen that has a small blinking light that activates when it senses an	Using something like a pen or pencil that can easily alert Megan and can also blend into the school environment. The pencil/pen can light up and little or	1		1	1	1	4

increase in volume. Also vibrates.	blink to alert Megan of her volume level						
Colour changing socks which also compress and decompress to alert her		1	1	1	1		4
Automatic sequence changing pencil case	Create a pattern when too loud from the sequence changing material						0
A colour changing & vibrating bracelet	This idea was originally suggested by the client (vibrating aspect was added by the team).	1	1	1	1	1	5
Concealable earpiece	Earpiece that vibrates to inform Megan					1	1
Compressive shoe	same concept as socks			1	1	1	3
Calming scents diffuser	Disperses scents that Megan is trained to associate with being quiet			1			1
Electronic mask	mutable mask which literally puts Megan on mute, controlled by the teacher, the teacher can also set a volume	1	1			1	3
Vibrating clippable device	Bracelet like solution in different form that clips like a pin						0
Pulsating Earing	Bracelet solution in different form that can be either a piercing or a magnetic earing		1				1
Portable Microphone Studio Isolation Setup	Iron man like mask setup with built-in bootleg JARVIS						0
Glasses that Show Volume Level	Something like google glass or iron man glasses from Spider-Man Far from Home	1	1	1	1		4
Temperature Changing Headband	Heats up or cools down to cold level upon loud volumes from MEGAtron	1					1
Colour projecting band	Wristband projects colour illuminating her arm when she is loud.			1	1	1	3
Implementation on Neck	Implement a chip on Megan's neck to sense when there are vibrations		1	1			2

	occurring. When Megan speaks, it will detect vibrations and, after comparing Megan's time speaking with the surrounding noise, will determine if it should inform Megan to quiet down. If it is decided that Megan should be quiet, a secondary device will inform Megan of her noise level.						
Noise Cancelling earbuds							0
Retainer that injects liquid in mouth	Liquid can be something like water that gets released into her mouth to alert her of increase in volume						0
Visor sprays vapor	Wearing a glasses or spectacle like thing which would either fog up or spray a mist of water when too loud, could be like faux glasses						0
Talking hat	Has a sound/signal that alerts Megan of when shes loud						0
Scrunchie	same as bracelet, possibly tighten as well when loud						0
Hoodie with strings that tighten when she is loud	Draw strings in hoodie pulsate by tightening and loosening when she is loud.						0
Eraser cover that changes colour	Colour changes when she is loud						0
A headband that tightens when Megan is loud	Tightens around her head when she is loud				1	1	2
Device that plays music in a low volume when Megan is too loud	Headphones/hearing pieces that play music when an increase in sound is detected.						0
Sensor that put on her wrist to sense sound level and vibrates	Sensor senses a change in a certain body feature when she is loud. This would be comparable to a blood pressure monitor that senses an increase, and reacts accordingly.						0
Compressive Armband	The arm band can sense if Megan is talking too loud/much with a spike in her blood pressure. Then it will compress to remind her to lower her		1				1

	voice. (Similar to a blood pressure monitor?)						
Finger ring	Finger ring that will change spin around upon detecting loudness (fidget ring)	1	1	1	1	1	5
HUD (head-up display) contact lens [this is cool]	Display that shows her and only her the level of her volume	1		1		1	3
Compressive joggers	The jogger strings tighten when Megan is being too loud and alert Megan of her increase in volume	1					1
Compressive hair tie	It tightens Megan's ponytail when there is an increase in volume detected						0
High altitude bubble	An airtight helmet fitted to Megan's head. When it detects an abnormal amount of volume exiting her mouth, it slightly increases the air pressure in the helmet similar to being in an airplane. When Megan quiets down, it drops the air pressure. Megan is able to communicate with others through a speaker and microphone setup fixed on her ear, and exterior of the helmet.						0
Smart wearable device	Device that senses if people are using their vocal cords too much, if it needs rest, and if it will cause vocal fatigue. Uses bluetooth to send notifications to a device.		1				1
Colour changing wall/projector	Projector/Cat light that turns on whenever she is loud and alerts her	1		1	1	1	4
Earpiece holding sounds of a formula one car's engine and the doppler effect	Megan has an earpiece in her ear. This keeps it hidden and discreet. When the microphone picks up that she is too loud, it plays the sounds of a formula one car at a certain distance away from her. Using the doppler effect noises of changing intensities based on her volume, this will give her a place to compare her volume level.						0
A digital ruler that displays volume levels	The ruler will have a small rectangle in the corner that changes colour based on	1	1		1		3

	volume- green if okay, yellow if borderline loud and red if too loud						
AlterEgo device	Wearable tech that detects the signals sent to vocal cords from the brain when someone speaks to themselves. AI reads these signals and turns them into words and reads the words back to the user, without the user needing to speak out loud.					1	1
In built - fan in her fanny pack	The fan can turn on when she is being too loud (sort of like a heating jacket with an inbuilt heater) but it will release cold air to alert Megan that she is being loud. Megan will also be able to hear the mechanical whirring of the fan.						0
Patch on neck/chest	The patch can sense the vibration in vocal cords or movement of the chest when Megan speaks. The patch can change temperature to alert Megan of her volume.		1	1			2
A device that blows bubbles when she is loud	Small bubbles released when she is loud and can alert Megan of her volume levels (bubbles can be small and unnoticeable?)	1		1			2
Nail Polish	Microchip under acrylic nails that can detect an increase in volume and an led that flashes light on those nails for them to change colour and for Megan to notice.				1		1
artificial mole that beeps and lights up slightly	similar to a birthmark or natural occurring on skin			1	1	1	3
		15	14	15	14	15	

The selected ideas were then fully developed by individual team members seen in table 5.

Table 5. Fully developed ideas after multivoting 1.

Ideas	Description
Noise Canceling Mask	Megan's teacher asks Megan to wear this mask thus it alters her that she is loud. The mask itself dampens and/or softens Megan's volume as she talks

	so it does not distract her classmates and allows Megan to lower her volume over a small interval of time rather than instantly
Ice pack Clothing	Mix ammonia and water to create a cold pack sensation attached to Megan. This works like cold packs that can be cracked in order for the water to be mixed with the chemical and start to cool down. Release chemical and automatically break when detecting Megan's loud behaviours and also allow for re-freezing after a short interval when volume decreases to be used again.
Colour-changing ring	Change into noticeable colours upon detection of an increase in volume, will detect volume through using a microchip that can distinguish Megan's volume increase and reflect a change in temperature which can allow thermotropic crystals to move and bend in order to change colour this is fairly similar to the mechanism of a mood ring, these colours should be clearly visible (ex. yellow, red, orange).
Soft-talker like design TM	This device is currently used for those who are deaf and involves multiple components which include a microphone, amplifier, signal rectifier, smoothing and a level detector that provides feedback to this bracelet which vibrates as a result of the feedback from voice level. The microphone detects the sound level and amplifier increases the sound intensity for the signal to be stronger allowing the device to successfully send back vibratory feedback to the user.
A pen that has a small blinking light and vibrates	A discreet and practical way to monitor Megan's volume level at school is by using a pen or pencil with a built-in LED light or blinking mechanism. There will be a microchip inserted inside the pen that will detect Megan's increase in volume. For outdoor environments the pen can be placed in a fanny pack and vibrate in order to alert Megan. This alert system can signal to Megan when she's speaking too loudly without drawing attention or disrupting the classroom.
Colour changing socks which also compress and decompress to alert her	Socks contain an adjustable ring with LED lights along the upper edge. This keeps the lights from the socks visible. The sock also contains a thread woven around the foot horizontally fixed to a small motor. The motor attached thread would be 5 cm wide. Megan would have the option of having a throat microphone affixed to her throat under her clothes and a wire running down her shirt and leg to the sock, or a wireless connection between a microphone fixed on her collar sending a signal to the sock. When it detects a loud noise from Megan, and the surroundings are quiet, a signal would be sent for the sock to activate, turning on the motor to compress her foot, as well as lighting the LED's up visibly so that she can see as well as

	feel that she is loud. Since the design is under her clothes, it would ensure the discreteness that she so loathes.
A colour changing & vibrating bracelet	The bracelet will have a colour changing LED light that can switch between happy colours to indicate when Megan is speaking too loudly. The bracelet will also have a vibration function that can provide a discreet reminder to Megan to lower her voice. With its versatile and customizable signaling capabilities, this bracelet can help Megan stay informed and focused without drawing unwanted attention from others.
Compressive shoe	The system is broken down into two parts; one part detecting Megan's volume and her surroundings' volume, and a second part of her shoe compressing to physically alert her of her volume level. The shoe would be designed as follows; a normal shoes' exterior, and an interior section consisting of a custom designed velcro for her foot which tightens upon detection of raised volume. When a loud noise from Megan is detected, motors attached to each velcro strap would rotate and tighten the shoe to indicate to Megan. This would physically alert her of her loud noise volume. The design is discreet since it is contained in her shoe, away from where her peers are looking. The shoe would be designed to be fashionable and look cool. Additionally, it would be child friendly since it would interact with Megan in the same way that she interacts with a shoe.
Electronic mask	A mask Megan can wear that will detect Megan's volume with a hidden microphone, which will differentiate Megan's voice from her surroundings due to close proximity. The teacher, or any approved staff member, can control the output of the mask. They will be able to mute the mask, preventing noise leak, and also set a standard volume level which will modulate the sound leaking out of the mask.
Glasses that Show Volume Level	Glasses with a small, embedded microphone to detect Megan's volume. As she speaks, the ranging decibels of her volume level will be displayed on the corner of the glasses, with changing colours to depict Megan's volume range and ultimately, inform Megan of her volume level. For example, when her volume is at an acceptable level, the small meter will be green. As her volume increases, it changes to yellow, then if she is too loud, the glasses show she is in the red zone. Megan will be the only person to see her volume level, which will be hidden in an everyday item, which creates a discreet design.
Colour projecting band	A wristband that alerts Megan of her loud volume by projecting an illumination on her arm. The design illuminated will be fun and child-friendly, like a doodle of a flower, sun, butterfly etc. This wearable

	technology functions with two microphones, one that strips away surrounding noise and analyzes only Megan's volume level, and another to measure the volume level of the environment around Megan. The wristband, when Megan is not loud, is a discreet, everyday accessory, which Megan can simply put on when she arrives at school and remove when the school day is over.
Implementation on Neck	This design features a chip or sticker implemented on Megan's neck, which detects her volume level by sensing the vibrations from her throat that occur when one speaks. A small microphone will be used to detect the sound in the surrounding area, while alienating and analyzing Megan's voice due to close proximity. Once the difference is compared, and found to be too large, the device will alert Megan to lower her volume with a slight vibration. The device will be easily wearable and removable by using adhesive technology.
A headband that tightens when Megan is loud	Megan will be wearing a headband or bandana with a piston embedded on them with an air compressor feeding the piston. It would also have a throat microphone on her neck with a thin wire running to the headband. When the fixture to the neck determines that she is being significantly louder than her surroundings, it would send a signal to the piston for air to be compressed and push the piston onto her head, leading her headband to compress thus physically alerting her of her volume. This design would be discreet because it will look inline to everything girls wear on a daily basis. Additionally, it would offer Megan artistic flexibility by allowing her to change the design of the head band that she chooses to wear on a daily basis.
Finger ring	This finger ring monitors Megan's volume level using a microphone and LED light. It alerts her discreetly with a flashing red light and gentle vibration to remind her to lower her voice. With this finger ring device, Megan can maintain an appropriate volume level without drawing unwanted attention from others.
HUD (head-up display) contact lens	This HUD contact lens would feature a display along with a microphone that receives data, which would display a visual indicator in Megan's field of view to show when her volume level is too loud. The contact lens can be worn comfortably for extended periods, and its lightweight design ensures minimal interference with Megan's daily routines. With this HUD contact lens, Megan can maintain an appropriate volume level without having to pause or disrupt her activities.
Colour changing wall/projector	Specific walls of Megan's classroom are fixed with a projector on the ceiling. Megan will have a microphone in her ear. When she is loud, the microphone will detect her loud volume and send a signal to the walls to

	slowly change hues into a different colour. When Megan quiets down, they would either resort back to their original colour, or stop changing hues. When Megan is outdoors, there will be projectors fixed to the inside of windows and basketball backboards. When her microphone detects that she is loud, it would send a signal to the projectors inside the school and change the colour of the windows, thus informing Megan of her noise volume.
A digital ruler that displays volume levels	A clear ruler that Megan can put on her desk and carry with her through a fanny pack. The ruler will be transparent and have a digital display system embedded in the middle of the ruler and will do two things. One will have a microchip that will detect the sound level and display one of three colours (red, yellow, green). The colours represent the same concepts as a traffic signal with red being an alert to stop Megan from talking loud, yellow being a warning that her volume is increasing and green reflecting that she is speaking at a reasonable volume. The second thing that can be implemented in this design is that the ruler can vibrate when it is yellow and vibrate multiple times when it is red to alert Megan in settings where she cannot see the ruler directly.
Patch on neck/chest	The patch will work in two steps. The first step is that it can be implemented on either the neck or the chest to allow for detection of movement using an accelerometer. Same process for step one will be on the chest implementation. The second step will have a miniature chemical reaction which will make the patch feel cold upon the detection of the movement in the service area.
A device that blows bubbles when she is loud	A bubble gun like design that will be around the size of a tennis ball which can be easily concealed in most objects or in a fanny pack. Upon the detection of volume, the motor will spin a fan and push bubbles in front of Megan or in her line of sight. The bubbles will be made from a non-toxic, non-scented soap which should be tear free and produce roughly 20 bubbles per spray. The bubbles should be blown only when she is loud.
Artificial mole that beeps and lights up slightly	An adhesive artificial mole that will stick onto the skin, preferably the lower arm for visual access. The mole will consist of a mini LED which will either light up or not light up and will have a small vibrating motor to provide physical feedback. The light and motor are activated when Megan's volume surpasses a certain threshold of volume pre determined from before. The approximate size of the device would be smaller than the eraser part of a mechanical pencil and should match Megan's skin tone.

The next step in the idea selection process was a second round of multivoting to narrow down the ideas into final designs that best met the objectives based on the full descriptions developed. Each member (YP - Yashvi Patel, DA - Danielle Akinlalu, MH - Max Haim, AS - Aaryaman Singh, PK - Paarth Kashyap), was given 5 votes to select designs. See Table 6 below for the results of the second round of multivoting. The top designs resulting from the vote (designs with at least 1 vote and practical to implement) were chosen to move on to the next phase comparing them in terms of how they accomplish the objectives.

Table 6. Results from the second round of multivoting.

Ideas	YP	DA	MH	AS	PK	**Total**
A colour changing & vibrating bracelet	1	1	1	1	1	**5**
Compressive shoe		1	1	1		**3**
Noise Canceling Mask			1		1	**2**
Soft-talker like design TM	1	1				**2**
Glasses that Show Volume Level				1	1	**2**
A digital ruler that displays volume levels	1			1		**2**
A device that blows bubbles when she is loud			1		1	**2**
Electronic mask	1					**1**
Colour projecting band			1			**1**
Implementation on Neck		1				**1**
A headband that tightens when Megan is loud				1		**1**
Finger ring	1					**1**
Patch on neck/chest		1				**1**
Artificial mole that beeps and lights up slightly					1	**1**
Ice pack Clothing						**0**
Colour-changing ring						**0**
A pen that has a small blinking light and vibrates						**0**
Colour changing socks which also compress and decompress to alert her						**0**

HUD (head-up display) contact lens						**0**
Colour changing wall/projector						**0**

The top designs were given rankings for the top two objectives of being discreet and child-friendly. Scores were chosen after a conversation with the team. Table 7 below contains the Top designs and their scores for the objectives in preparation for the creation of a graphical decision matrix.

Table 7: The scores that each finalist idea received for the two top objectives.

	Idea Name	Objective 1: Discreet	Objective 2: Child-Friendly
1	A colour changing & vibrating bracelet	9	10
2	Compressive shoe	10	7
3	Noise Canceling Mask	5	7
4	Soft-talker like design TM	7	5
5	Glasses that Show Volume Level	8	7
6	A digital ruler that displays volume levels	5	6
7	A device that blows bubbles when she is loud	3	8
8	Electronic mask	4	2
9	Colour projecting band	4	6
10	Implementation on Neck	6	7

The ideas and their scores with regards to the top objectives were then plotted onto a graphical decision matrix in Figure 5 below.

Table 8. Justification for scores given.

	Idea Name	Objective 1: Discreet	Objective 2: Child-Friendly
1	A colour changing & vibrating bracelet	The bracelet replaces something that she regularly wears on her wrist. No	Children love wearing bracelets on a regular basis and know how to safely

		noticeable difference to the user. Score: 9	operate them. Score: 10
2	Compressive shoe	Fully contained in a shoe. Fully hidden and non visible. Score: 10	Children can be very selective about their shoes, and grow out of them often. Score: 7
3	Noise Canceling Mask	Very few kids wear masks at school. Visible to everyone, however, marks have been normalised by Covid. Score: 5	Will be designed to be comfortable to wear, however the users may complain about fit or size. Score: 7
4	Soft-talker like design TM	Wears on the wrist hidden from other students, however it is large. Score: 7	Designed for adults. Children were not the target audience when it was designed. Score: 5
5	Glasses that Show Volume Level	Many children wear glasses to see. Glasses can look cool and help fit in. Score: 8	Makes the user look cool, however children do not necessarily find glasses comfortable. Score: 7
6	A digital ruler that displays volume levels	Vibrates when in a fanny pack, concealing the majority of its noise, however the fanny pack is large, and when on desk, it lights up creating a potential disturbance. Score: 5	If handled incorrectly, it could easily break and exposed electronic components can be dangerous for children in a classroom. Score: 6
7	A device that blows bubbles when she is loud	While the machine is hidden, the bubbles exiting the machine are visible to others creating a visible distraction. Score: 3	Children love seeing bubbles and popping them, however the effect can easily wear out over time. Score: 8
8	Electronic mask	Very visible, different and abstract. Score: 4	Not good for children. Can silence them at the wrong times and frustrated users.

			Score: 2
9	Colour projecting band	Will require large equipment to project a good colour against the arm. Machinery will be strongly visible. Score: 4	Lights will look amazing and be loved by users. Many children wear bracelets today, however it may be too heavy to wear on a regular basis. Score: 6
10	Implementation on Neck	Under shirt, fully hidden, however could be uncomfortable as it is in direct contact with skin. Score: 6	Very simple to use. Hardest part is setting it up correctly onto the neck. Passive effort required. Score: 7

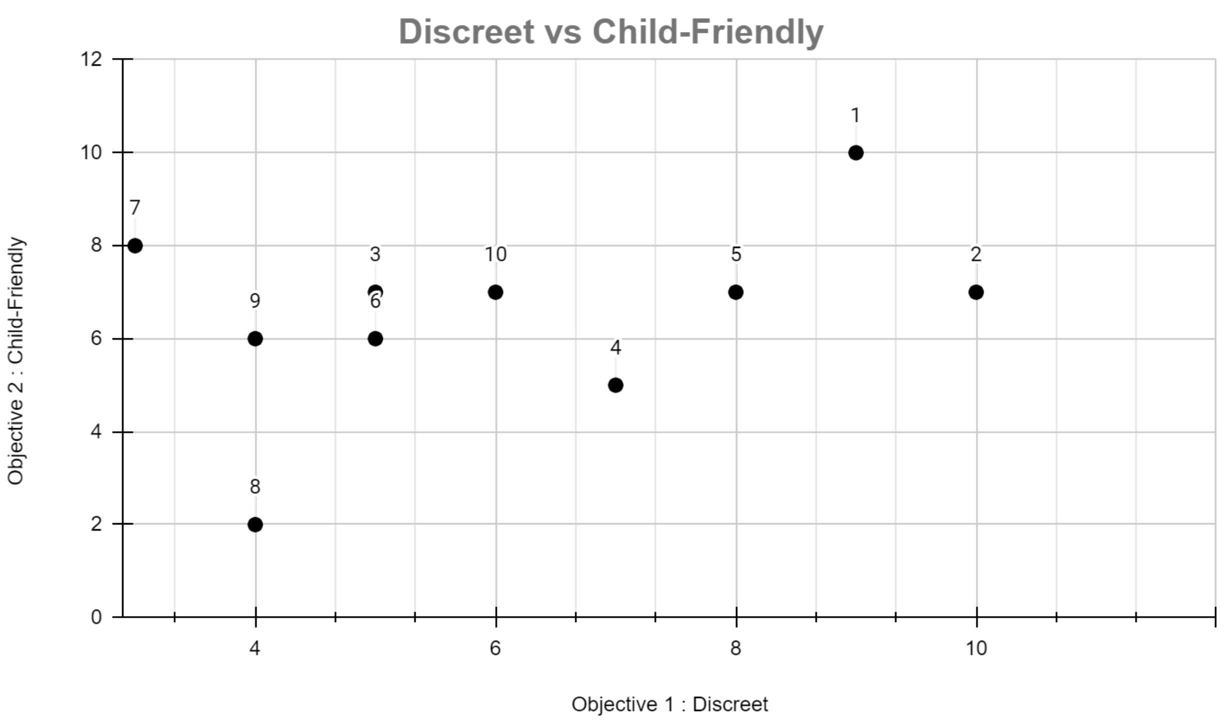


Figure 6: A graphical representation of how the various ideas met the main objectives. Note that the numbers on the points plotted correspond to the ideas in Table 8 above.

Based on the graphical decision chart, the ideas that best suited the objectives were the Colour Changing & Vibrating Bracelet, the Compressive Shoe, and the Glasses that Show Volume Level.

The top three ideas were fully developed by individual group members and presented as seen in section 6.3 of this document and Table 9 below.. To decide on the best design, the ideas were placed on a Pugh chart to measure how well they meet the prescribed objectives in comparison to an existing solution of a Soft-Talker described in Appendix L.

Table 9: The Pugh chart used to compare the final three designs and how well they achieve the functions against an existing Soft-Talker. Please note that the scale ranges from -2 to 2.

Objectives	Datum	Weight	Design Solution #1 (Colour changing/vibrating Bracelet)	Design Solution #2 (Compressive Shoe)	Design Solution #3 (Glasses that show Volume Level)
Discreet	Soft-Talker device	5	1 **Justification**: The bracelet will be designed to include Megan's interests. The design will not include the box that the Soft-Talker has, which makes the bracelet more discreet.	2 **Justification**: The compressive shoe is not noticeable to peers at all and compared to a smart watch it will be more discreet as it is a part of her daily wear.	-1 **Justification**: Glasses are fairly visible and can catch attention of peers in comparison to a bracelet/watch-type design. It will not be too visible and normal to peers.
Child-Friendly	Soft-Talker device	4	1 **Justification**: The bracelet will have components like beads and colour that will make the design more enticing and fun for Megan.	-1 **Justification**: The shoe compresses which can make Megan a bit uncomfortable so it is not child-friendly.	0 **Justification**: The glasses are not more or less child-friendly than the existing solution since they can be uncomfortable to wear.
Durable	Soft-Talker device	3	1 **Justification**: The new design will not have a box attached to it like the Soft-Talker that can compromise the durability of the design.	2 **Justification**: A shoe is more rugged and this has more wear and tear capacity and is easy to make waterproof.	-1 **Justification**: Glasses are easy to break in a school environment so therefore they are not more durable than the Soft-Talker.
Lightweight	Soft-Talker device	2	1 **Justification**:	-2 **Justification**:	2 **Justification:** The

			The design will not have the extra amplifier box that is connected to the Soft-Talker, hence it will be more lightweight.	A shoe is heavier than a bracelet and with technology inside they will become much more heavier.	design will be lightweight so it can be easily worn on her face in comparison to the Soft-Talker design.
Water Resistant	Soft-Talker device	1	1 **Justification**: The design will have a water resistant aspect that is not existent in soft- talker.	2 **Justification**: The design will be easy to make waterproof as there are pre-existing waterproof shoes.	-1 **Justification**: The design will be hard to make waterproof as it involves technology inside of the glasses.
Total			15	10	-5

Based on the results from the Pugh chart comparison, it was clear that the colour changing and vibrating wristband was the solution that best met the prescribed functions and objectives.

Appendix K: Foot Compression Shoe

Overall Functionality of Design:
The shoe will remain normally fitted until the microphone detects a volume exceeding the set threshold, where it sends a signal down to the shoe. Another microphone is contained in the shoe to compare Megan's noise level to the surroundings. If the surroundings are measured as less than 60 decibels (conversation level), the motor tightens the velcro straps. This tightens the shoe and physically informs Megan of her volume. When Megan quiets down, the velcro is released and the shoe is loosened to its normal state.

Parts:

1. Any velcro based shoe - Design is independent of shoe size. Relies on velcro count of shoes.
2. Microphone behind the heel
3. Motor and shaft fixed to the shoe
4. Neck microphone connecting neck to the shoe.

Design:

1. Neck microphone attached to neck with a wire running down the users shirt and pant leg.
    a. When it detects an unwarranted loud volume, it sends a signal down to the shoe.
2. Loops (smooth part of velcro, not fixed to the shoe) is disconnected from the shoe
    a. Loops are attached to a cylindrical rod of 3mm in diameter and two thirds the length of the shoe.
3. Rod is attached back to the shoe using a journal bearing support style attachment
    a. This allows the rod to rotate but restricts movement
4. Motor is fixed to one end of the rod
    a. When turned on, rod rotates and tightens the velcro which tightnes the shoe
        i. This informs the user that they are loud

Weight Breakdown:

The motor mass breakdown is described in Table 9.

Table 10. Breakdown of weights for the compressive shoe

Item	**Mass (in g)**
Shoe	680 [35]
Motor and Shaft	20 [49]
AAA Battery	12 [50]
Ceramic coating and Miscellaneous	10 [44]

Calculations:

<u>Mass of compressive shoe:</u> 722.7 g

<u>Mass of original shoe:</u> 680 g

<u>Additional mass from compressive shoe:</u> 42.7 g

<u>Additional mass as a percentage:</u> 6.28%

These calculations show that the compressive shoe is only 6.28% heavier than shoes which are regularly worn.

Notes on materials chosen:

The shoe is a standard shoe which is modified to implement the design. This was done to ensure that Megan has a comfortable shoe to her liking. The specific motor and shaft was chosen since it is small enough to fit on the side of the shoe while remaining hidden and unnoticeable to the eye. The small radius of the shaft ensures that the rate of compression is comfortable to Megan. The AAA battery was chosen since it is commonly used in small electronic devices and is small enough to remain well hidden from the surroundings. The ceramic coating was chosen since it is a simple standard method to waterproof items and objects.

Appendix L: Alternate Designs Dimensions

Heads-Up Glasses: [51]

Frame:

1. Length: 100 mm
2. Width: 5 mm
3. Width space: 125 mm

Casing:

1. Length: 30 mm
2. width: 12 mm

Foot Compression Shoe:

Shoe:

1. Length: 15 cm
2. width: 5 cm

Mechanism:

1. Length: 8 cm

Alerting Bracelet: [52]

Band:

1. Length: 221 mm
2. Width: 20 mm

Casing:

1. Length: 35 mm
2. Width: 5 mm
3. Height: 30 mm

Appendix M: Alternate Designs Images

Heads-Up-Glasses:

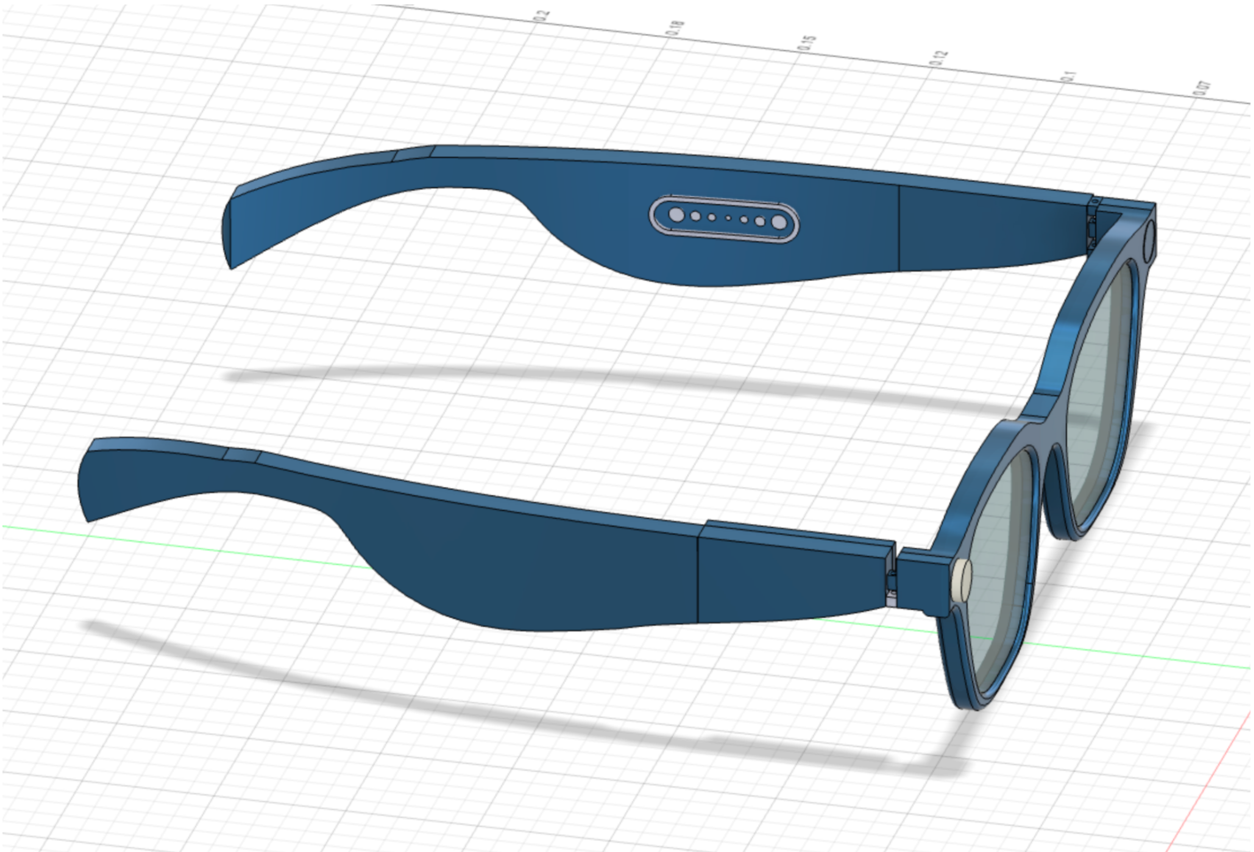


Figure 7: A schematic of the heads-up-glasses.

Alerting Bracelet:

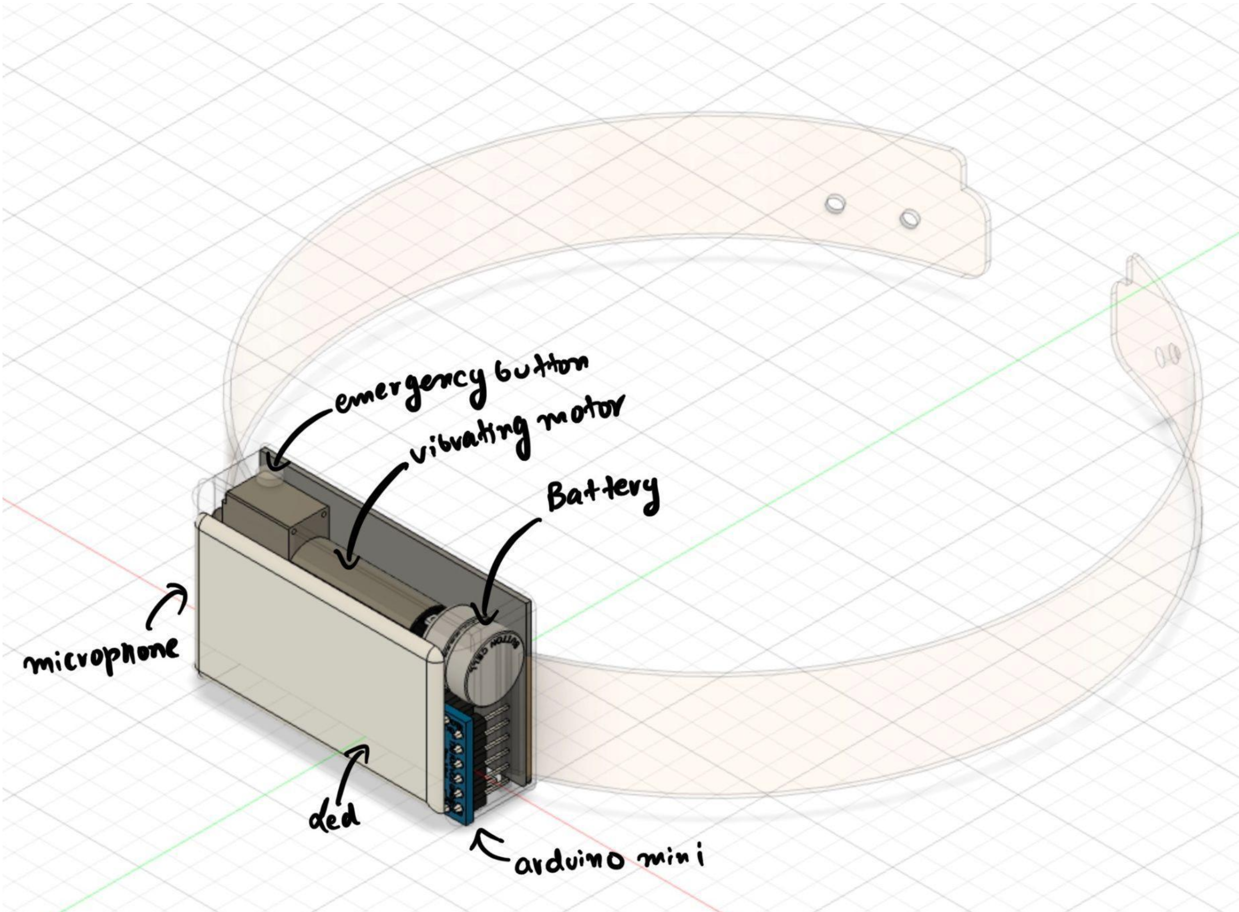


Figure 8: A schematic of the internal components of the alerting bracelet.

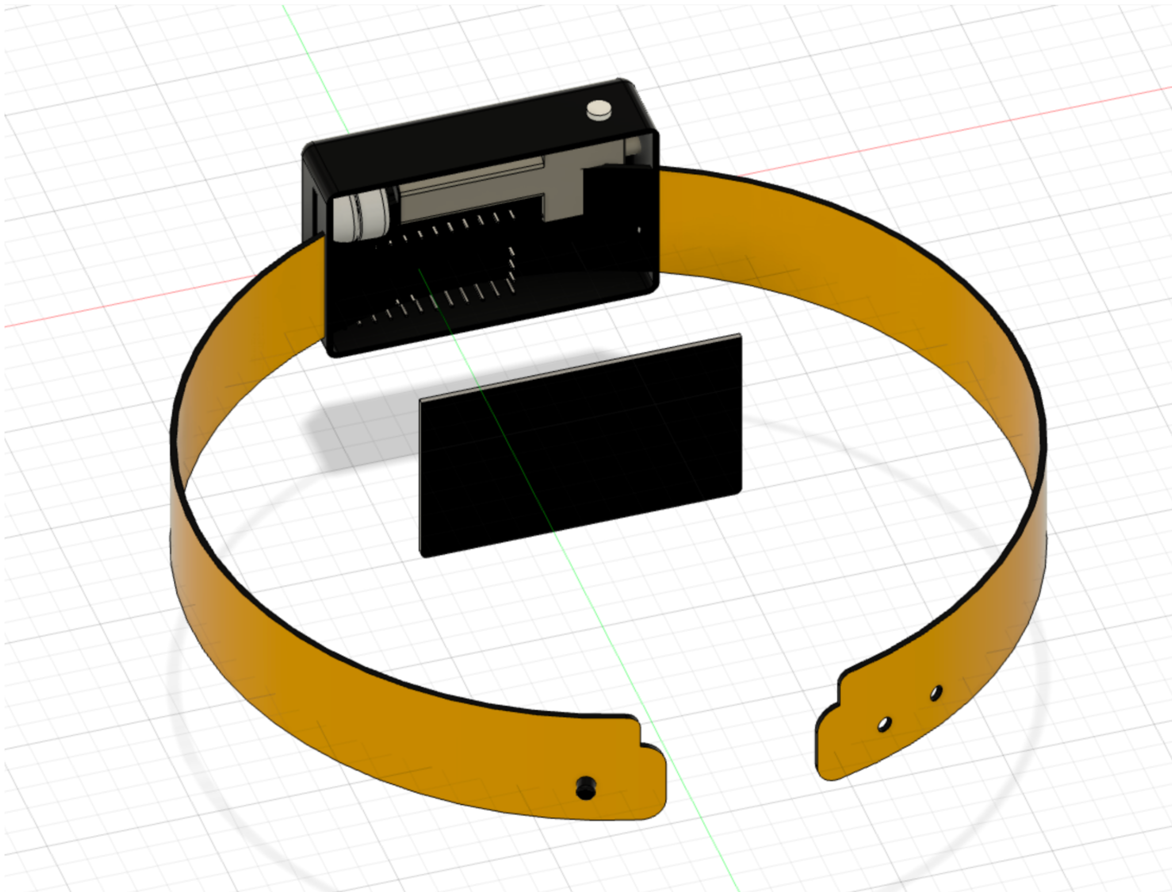


Figure 9: A view of the internal components of the bracelet from the back of the module.

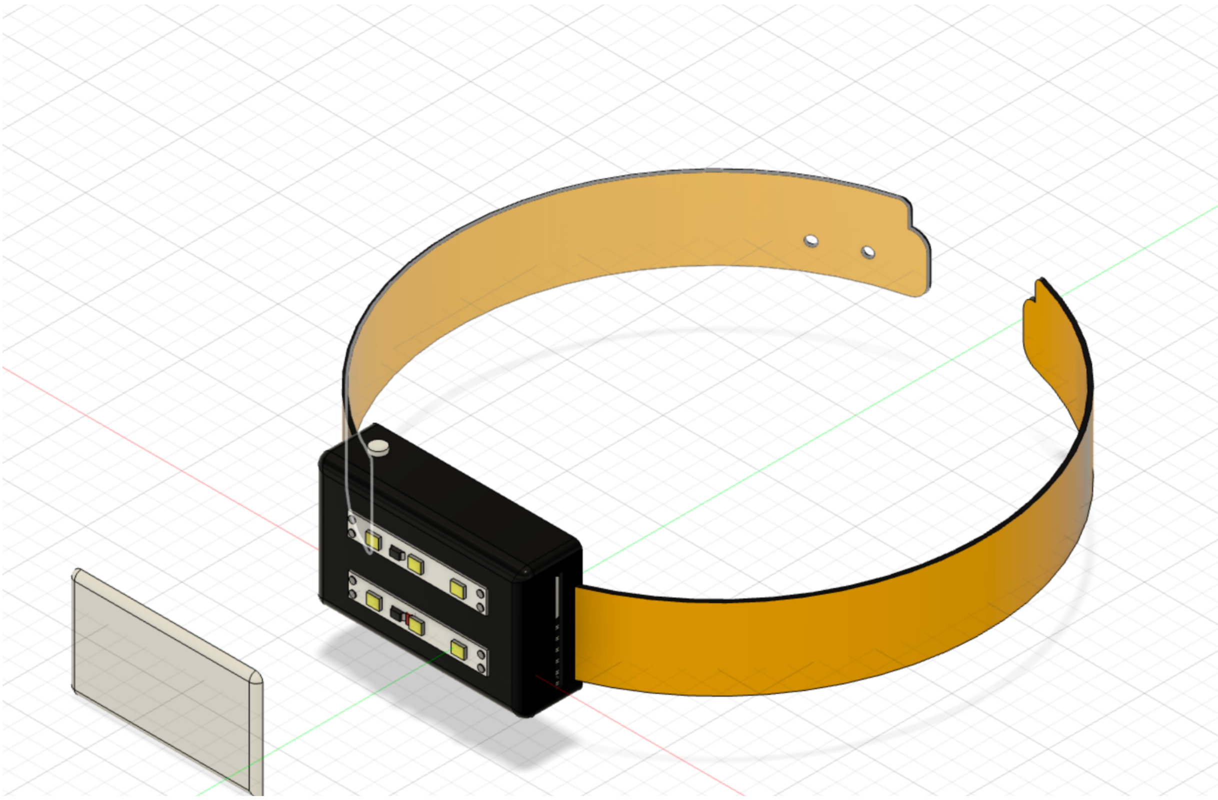


Figure 10: The arduino board and sensors housed in the technological centre of the bracelet.

Appendix N: Datum for Pugh Chart

Soft-talker design is made for people with a permanent hearing disability who have problems monitoring their volume levels (see figure 8). The design uses a microphone to detect volume and amplify the volume. Depending on the volume frequency if there is an increase the bracelet sends a vibratory signal to the user.

The specifics of this design includes:

- The device can be placed around the neck as a pendant or in breast pocket to detect volume levels of the user.
- If the pre-set level is exceeded the motor on the wrist watch turns on and causes a vibratory signal to be released to the user.
- The vibrations of the bracelet decrease as the user approaches the pre-set volume level.

Below is a figure of the design [53]:

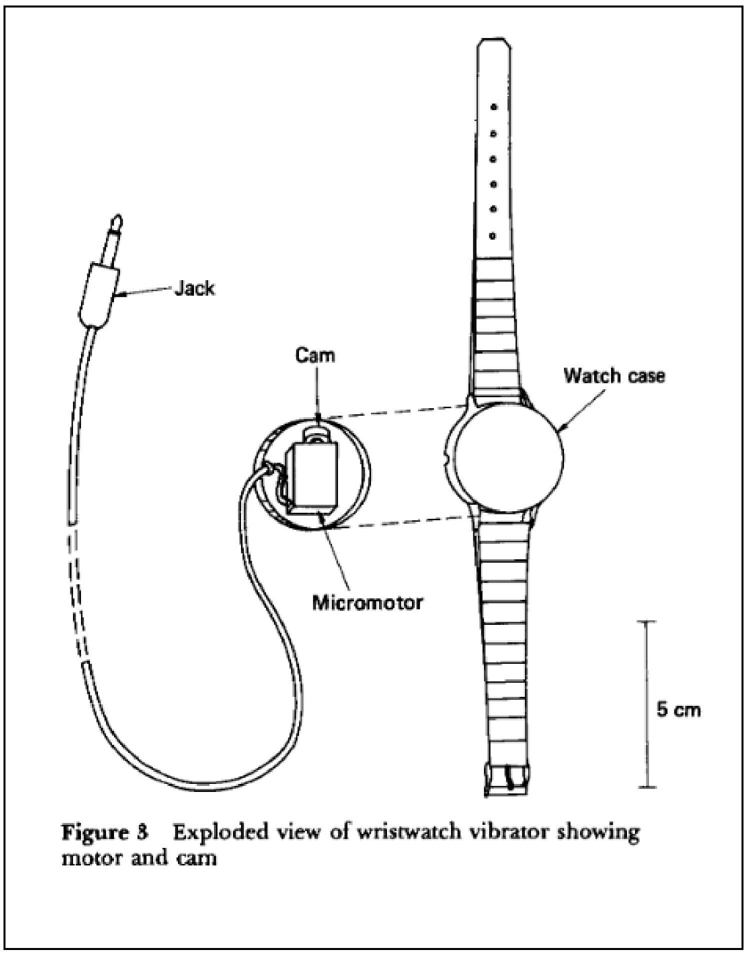


Figure 11: Soft-Talker schematic.

Appendix O: Design Calculations

Table 11. A list of calculations that provide specifications on the design's functions and aesthetics.

Element	Equation	Calculation	Justification
Power (W) [54]	$P = VI$ P = *Power* V = *Voltage of Arduino* I = *Current of Arduino*	$P = (5V)(50 * 10^{-3}A)$ $= 0.25\ W$	The power of the device can be calculated using the capacities of the Arduino [55]. The power will be used to calculate energy consumption.
Energy consumption (kWh) [56]	$E = P * \frac{t}{1000}$ E = *Energy* P = *Power* t = *Time (Battery Life)*	$115 * 10^{-3}Ah = 0.25\ W * \frac{t}{1000}$ $t = 460\ hours$	The energy consumption can be used to find time, which is necessary to know to determine how often the battery [57] in the bracelet should be replaced to maintain durability [57].
Sound Intensity (W/m^2) [58]	$I = \frac{(\Delta pmax)^2}{2\rho v}$ I = *Sound Intensity* $\Delta pmax$ = *Change in Pressure or Amplitude* ρ = *Density of material sound is travelling through* [59] v = *Speed of observed sound* [60]	$Io = \frac{(0.2\ Pa)^2}{2(1.293\ kg-m^3)(343\ m/s)}$ $= 4.509593 * 10^{-5}\ W/$ $I = \frac{(0.0632456\ Pa)^2}{2(1.293\ kg-m^3)(343\ m/s)}$ $= 4.509599 * 10^{-6}\ W/$	The sound intensity of both Megan and her surrounding environment must be calculated and compared by the device. A sample calculation was done with the maximum permitted volume level, but will really be calculated with any volume level Megan creates. Megan's sound intensity relative to her environment will provide information on how loud Megan is being, which can
Sound Intensity Level (dB) [61]	$\beta = 10\ log10\ (\frac{I}{Io})$ β = *Sound intensity level* I = *Sound intensity (Megan)* Io = *Reference intensity (Surrounding)*	$\beta = 9.99\ dB$	

			be implemented in the prototype.
Wristband Length (cm) [62].	*Wristband Length = Wrist Circumference + (Overlap * Lug Width)*	$Wlength = 12.6cm + (2.5 * 3.8)cm = 22.1\ cm$	The overlap is the amount of extending after the wristband has been fastened. The lug width is the distance between lugs on the small box where the wristband will be attached [63]. The wrist circumference has been estimated using the average children's sizing and the teammate who will be wearing the prototype.
Mass of Wristband (g)	*Wm = length * width * height * silicone density*	$Wm = (22.1cm)(0.3cm)(2cm)(1.24\ g/cc) = 16.4424\ g$	The mass of the wristband must be calculated using the wristband length, bracelet dimensions, and silicone density [64]. The mass of the wristband will be used to calculate the total weight.
Mass of Casing (g)	*Cm = length * polycarbonate density*	$Cm = (0.45\ cm)(1.2\ g/cc) = 0.54\ g$	The mass of the casing must be calculated using details on dimensions and materials [65]. The mass of the casing will be used to calculate the total weight.
Total Mass of design (g)	Total Weight = $W_m + C_m + A_m + B_m + 3L_m$	$Total\ Mass = 16.4424g + 0.54g + 13g + 2.3g + 0.31g$	The weight of all components, excluding wiring, of

	W_m = *Mass of wristband* C_m = *Mass of casing* A_m = *Mass of Arduino* [55] B_m = *Mass of LR44 Battery* [66] L_m = *Mass of light* [67]	$= 32.5924\ g$	the design should be calculated to ensure the lightweight objective is achieved.
Hours to School day conversion	h = *total hours* d = *school days* n = *hours per day* [68]	$d = \frac{h}{n}$ $= \frac{460}{6}$ $= 76.6\ days$	Based on 6 hours of use of the wristband per day, and a battery life expectancy of 460 hours, the battery should last at least 76 days before needing replacement.

Appendix P: Measure of Success Procedures

Table 12. Procedures to test design functions.

Speech Recognition	
6. Record the intended speaker and ensure their voice has been stored in the bracelet's database. 7. Set up the bracelet in a quiet environment without any external noise that might interfere with speech recognition. 8. Prompt the intended speaker to talk in a clear voice for a few minutes. 9. Observe if the bracelet is functioning according to the speaker's voice and record the results. 10. Set up the bracelet in a non-controlled environment to observe speech recognition with external interferences. 11. Observe if the bracelet is functioning according to the speaker's voice and record the results. 12. Repeat the testing in a quiet environment and in a differing non-controlled environment (ex. classroom, outside, hallways).	Testing the bracelet's ability to sync to a chosen person's voice ensures that the design can identify and detect Megan's voice from her surroundings.
Lighting	

1. Download a sound level meter app (ex. NIOSH or Decibel X).
2. Set up the bracelet in a quiet environment without any external noise that might interfere with the microphone.
3. Create a noise, observe, and document if the device vibrates in the following condition:
    a. Under 60 dB.
    b. Between 60 dB and 70 dB (inclusive).
    c. Greater than 70 dB.
4. Repeat the test in different environments of ranging noise levels, for example, a classroom, common area, cafeteria, etc.
5. Analyze the results to determine if the device's lighting features work as intended during each stage of volume.
	This will verify that each colour will light up according to Megan's voice range, which will aid Megan in regulating her volume.

Vibration	

1. Download a sound level meter app (ex. NIOSH or Decibel X).
2. Set up the bracelet in a quiet environment without any external noise that might interfere with the microphone.
3. Create a noise, observe, and document if the device vibrates in the following condition:
    a. Under 60 dB.
    b. Between 60 dB and 70 dB (inclusive).
    c. Greater than 70 dB.
4. Repeat the test in different environments of ranging noise levels, for
	This guarantees that Megan will always be notified when she is too loud. This must work both indoors and outdoors, especially in

example, a classroom, common area, cafeteria, etc. 5. Analyze the results to determine if the device's vibration features only work when the speaker's volume level passes the threshold of 70 dB.	situations where Megan cannot constantly look at her wrist.

Table 13. Procedures to test the design's durability and water resistance.

Drop Test	

1. Ensure the bracelet is fully charged and functional.
2. Drop the bracelet according to the following conditions to simulate real-life drop scenarios
    a. Dropping while walking or running
    b. Knocked off wrist due to collision
    c. Dropped from hands
    d. Falling from a shelf
3. Perform the drop test from progressively increasing heights and/or speeds.
4. Document results and visible damage after each drop.
5. Analyze the bracelet by comparing its conditions and functionality before and after the test.
6. Repeat the test and document the final results.
	This test ensures the bracelet will function as intended because its durability will not be compromised if the design should fall.

Water Resistance	
1. Prepare litmus paper by cutting it into small, uniform squares. 2. Prepare a bowl of water large enough to fully submerge the bracelet. 3. Before proceeding onwards, ensure the bracelet is fully charged and functional. 4. Submerge the bracelet into the bowl of water for 30 seconds. 5. Remove the bracelet. 6. Place a piece of litmus paper on different parts of the bracelet inside the box holding the internal components. 7. Observe the colour change of the litmus paper. A change in colour means the water penetrated the box and the design is not water-resistant. If the litmus paper is the same colour, the box is water resistant. 8. Analyze the bracelet by comparing its conditions and functionality before and after the test. 9. Repeat the test and document the results.	This test ensures the bracelet will function as intended by effectively protecting the inner components in situations where it might get wet– like washing hands or under the rain.
Battery Life	
1. Place a new battery inside the bracelet to ensure it is fully charged.	The device

2. Begin timing the battery life with a stopwatch. 3. Use the smartwatch as normal in everyday conditions. 4. Monitor the behaviour of the bracelet and record any fluctuations or errors and the times they occurred. 5. Stop timing when the bracelet shuts off or is malfunctioning. 6. Repeat the test and document the results. 7. Analyze the final results to determine the mean time to failure and consider another powering method if the battery is not performing to a high enough standard.	does not have a charging system so the battery must power the device for a long duration.

Table 14. Procedures to test discreetness.

Noticeability Test	

5. Have a user wear the bracelet for a week.
6. Have another member document how often people look at the bracelet and the reasoning. For example:
    a. Is the vibration too loud?
    b. Is the colour of the bracelet conspicuous?
    c. Are the changing lights too bright?
7. Repeat the test in differing social situations (ex. classrooms, social outings, etc.)
8. Evaluate the level of discreetness by the frequency of people's reactions to the bracelet.
	Testing discreetness ensures the design will integrate into Megan's school environment and reduce distractions to her peers.

Table 15. Procedures to test child-friendliness

Band Test	

1. In a closed environment put the available bands on a table and allow Megan to choose a band that she likes.
    a. Check for what kind of band she chooses.
    b. Check for how much she likes the variety of bands.
2. Next allow her to change the band and see how simple it is for her to put on. She can also put the bracelet on.
    a. Use a timer to better get an idea of how long she takes to put on the device and take it off.
    b. Check if she requires any assistance.
3. Check if she is uncomfortable with the band.
    a. Timer on how long she leaves the bracelet without fidgeting with it or trying to remove it.
	This test will show the team if we can create a solution that is tailored to Megan's interests by allowing her to choose her favourite band and observing her behaviours to it.

Observation Stage	
1. Allow Megan to wear the device to school and observe the usage of the device. a. How do her peers react? Check for unusual reactions or any extra attention from the device. b. If she is able to wear the device the whole day without any discomfort? c. The device informs her in a harm-free manner, when it lights up and vibrates it does not scare her or catch her off guard. d. How often the device actually does its job and if it helps Megan quiet down. i. Measure how much time it takes for Megan to quiet down after she gets an alert.	This stage occurs before fully implementing the device in Megan's everyday life. Megan's usage of the device will be observed to ensure the device's usage is intuitive.

Appendix Q: Attribution Table

Engineering Strategies and Practice APS 111-112	**Attribution Table**

Tutorial #:	0115	Team #:	071
Assignment:	Conceptual Design Specifics	Date:	March 26, 2023

The Attribution Table is a major resource used by your TA in determining whether there was equal contribution to the team assignment. If your TA determines that there was significant under contribution, then they may apply an individual penalty to the under contributing team members' grade. As a future professional engineer you should NOT sign any document you have not read and do not agree with.

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Section	Student Names				
	Yashvi	Aaryaman	Danielle	Paarth	Max
Executive Summary Modification	ET,FP	ET, FP	WD, FP	FP	ET, FP
Introduction Modification	ET,FP	FP	WD, FP	ET, FP	FP, ET
Problem Statement Modification	FP,WD,ET	ET, FP	MR, FP	ET, FP	ET

Service Environment	MR,ET,FP	WD, MR, ET, FP, RS1	ET, FP	ET, FP	MR, ET
Stakeholders Modification	ET,FP	FP	FP	ET, FP, WD	ET, FP
Detailed Requirements - Intro Modification	ET,FP	ET, FP	WD, FP	ET, FP, WD	ET
Function Modification	ET,FP	ET, FP	ET, FP	ET, FP, WD	ET
Objectives Modification	MR,ET,FP	ET, FP	ET, FP	ET, FP	ET, FP
Constraints Modification	ET,FP	WD, ET, FP, RS2	MR, RS2	ET, FP	ET
Alternative Designs	ET,FP	ET, FP, OR1	ET, FP	ET, FP, WD	WD, MR, ET
Proposed Conceptual Designs	WD,MR,ET,FP	ET, FP	ET, FP	ET, FP	ET, MR, FP
Measures of Success	ET,FP	ET, FP	RS3, WD, ET, FP	ET, FP	MR, ET, FP
Conclusion	ET,FP,WD	FP	ET, FP	ET	ET, MR

Fill in abbreviations for roles for each of the required content elements using the abbreviations found on the next page. You do not have to fill in every cell.

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RS2: Laws and regulations in Ontario

RS3: Measures of Success Calculations

If you put OR (other) please add a number identifier such as OR1, OR2, etc. Explain the role below:

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