University of Toronto
Faculty of Applied Science & Engineering
APS112 & APS113
Conceptual Design Specifications (CDS)

Team #	101	Date	26/03/2021

Tutorial Section	TUT0118
Teaching Assistant	Daire Crawford
Communication Instructor	Angelica Radjenovic
Prepared By (Your names and student numbers)	Rayan Sibai - 1008017584 John Hiscock - 1007813001 Tanya Rustogi - 1007828665 Sahana Prabhu - 1007859550 Adelaide Qige Qi - 1007815250 Samantha Ramirez Ruvalcaba - 1007756830

Please check off which components you are submitting for your assignment:

_√_ CDS submitted as a PDF to Quercus with the following components:

_√_ Cover Page
_√_ Executive Summary
_√_ Introduction
_√_ Problem Statement
_√_ Service Environment
_√_ Stakeholders
_√_ Detailed Requirements
_√_ Alternative Designs
_√_ Proposed Conceptual Design
_√_ Measures of Success
_√_ Conclusion
_√_ Reference list
_√_ Appendices

_√_ Attribution table with ALL team members' signatures submitted as a PDF to Quercus. An incomplete or missing attribution table will result in zero on the assignment for the team.

Executive Summary

The client of this project is Dr. Andrey Shukalyuk, Health and Safety advisor for the Faculty of Applied Science and Engineering (FASE) at the University of Toronto (UofT). The client is looking to reduce the waste created by Personal Protective Equipment (PPE) in wet laboratories on the UofT St. George Campus. The client wants a solution that moves toward the overarching goal at UofT to decrease carbon emissions by addressing the waste associated with PPE.

Based on the client statement, a meeting with the client, and a tour of one of the wet laboratories at UofT, the team has decided that the client needs a way to reduce the number of nitrile gloves consumed in laboratories. Nitrile gloves cause the most significant environmental issue because their use is unavoidable for safety reasons, they require replacement throughout a lab session, and users do not always select the appropriate size, leading to wastage of unused gloves. There is an evident gap created by the lack of a proper dispensation and disposal system. For this reason, the team has chosen to scope the project down to strictly the dispensing and disposing processes of nitrile gloves.

To address this problem, the team first defined the service environment of the design. The physical environment considers wet laboratory conditions, such as the temperature, pressure, capacity, biohazard safety level, and disposal systems present. The living environment considers the users and microorganisms present, and the virtual environment considers the electrical and wireless components. The team then considered the stakeholders that will be impacted by, or influence, the design; the FASE teaching team, investors, caretakers, special event staff, and multiple levels of government.

The functions, objectives, and constraints, commonly known together as detailed requirements, were then defined. The team identified two primary functions: the design should ensure that the desired number of gloves are made available, and the design should dispose of gloves based on contamination. In terms of objectives, the team decided that the design should reduce unintended waste, be easy to operate, maintain optimum temperature, it should be scalable, and compatible with various glove types. Finally, the constraints include being able to operate with the five main sizes of gloves, fall within the annual budget of $10,000 CAD, accommodate the dimensions of a glove box, maintain sterilization prior to use, and preserve the structural integrity of the gloves.

With all of the necessary requirements defined, the team moved to idea generation. After thoroughly exploring the design space through structured brainstorming, analogies, and a morphological chart, a list of 50 ideas was generated. Through multi-voting and a graphical decision chart, the team arrived at three alternative designs; LabSpenser, PosterIt, and LabCheck.

From here, the team used the Pugh Method to select one design; LabSpenser, as the proposed conceptual design. To measure the success of this design, the team has planned a series of tests in the preparatory, dispensation, and disposal components of the design. The team will be able to gather a variety of quantitative and qualitative data to determine the efficacy of the proposed design.

Moving forward, the team will partially carry out the four week plan for the measures of success over the course of two weeks, providing an insight on the efficacy of the final design. The results will be summarized and made available in the Final Presentation on April 19, 2022.

1.0 Introduction

The client, Dr. Andrey Shukalyuk, Health and Safety Advisor for the Faculty of Applied Science and Engineering at the University of Toronto (UofT), wants to reduce the amount of wasted Personal Protective Equipment (PPE) in wet laboratories on the St. George Campus. The team outlined the service environment, associated stakeholders, and detailed requirements consisting of the functions, objectives, and constraints of the solution space. Using this information, the design space was explored, generating a list of 50 ideas. The final idea, 'LabSpenser' was chosen by evaluating withthe objectives.

2.0 Problem Statement

The client wants to reduce the carbon emissions and indiscriminate waste associated with PPE. While coats and eyewear are reused multiple times, the same cannot be replicated for gloves [1]. Currently, one laboratory uses roughly 9,000 single-use nitrile gloves each semester (Appendix B), causing the emission of 26g CO_2 equivalents accounting for virgin nitrile production and landfill disposal (Figure 1) [2]. There is an opportunity to reduce the contribution of nitrile gloves to the overall CO_2 emissions at UofT and should be addressed to meet the target of net negative emissions by 2050 (Figure 2) [3].

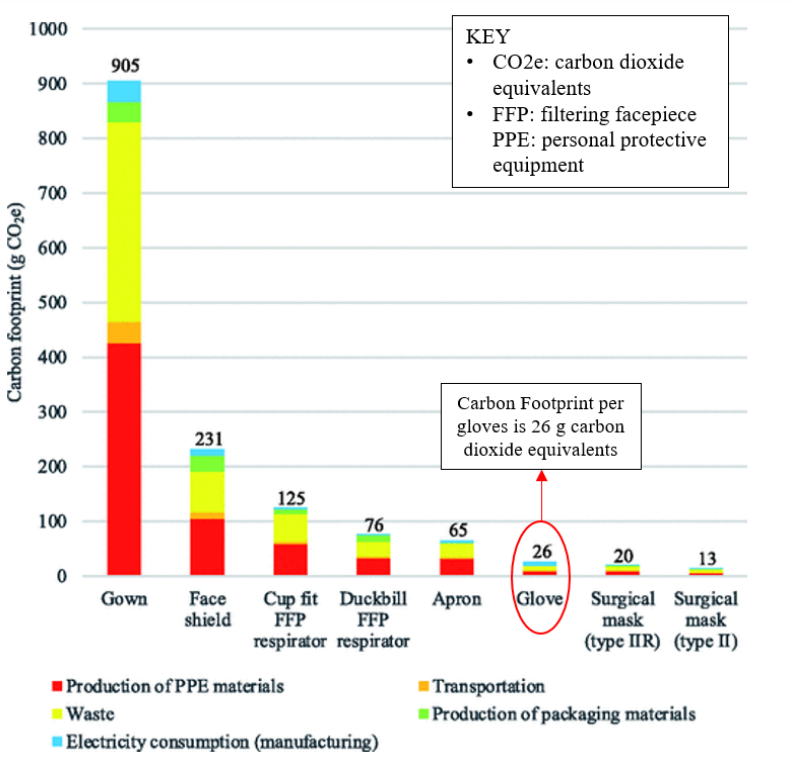

Figure 1: Carbon footprint by different types of PPE [2]

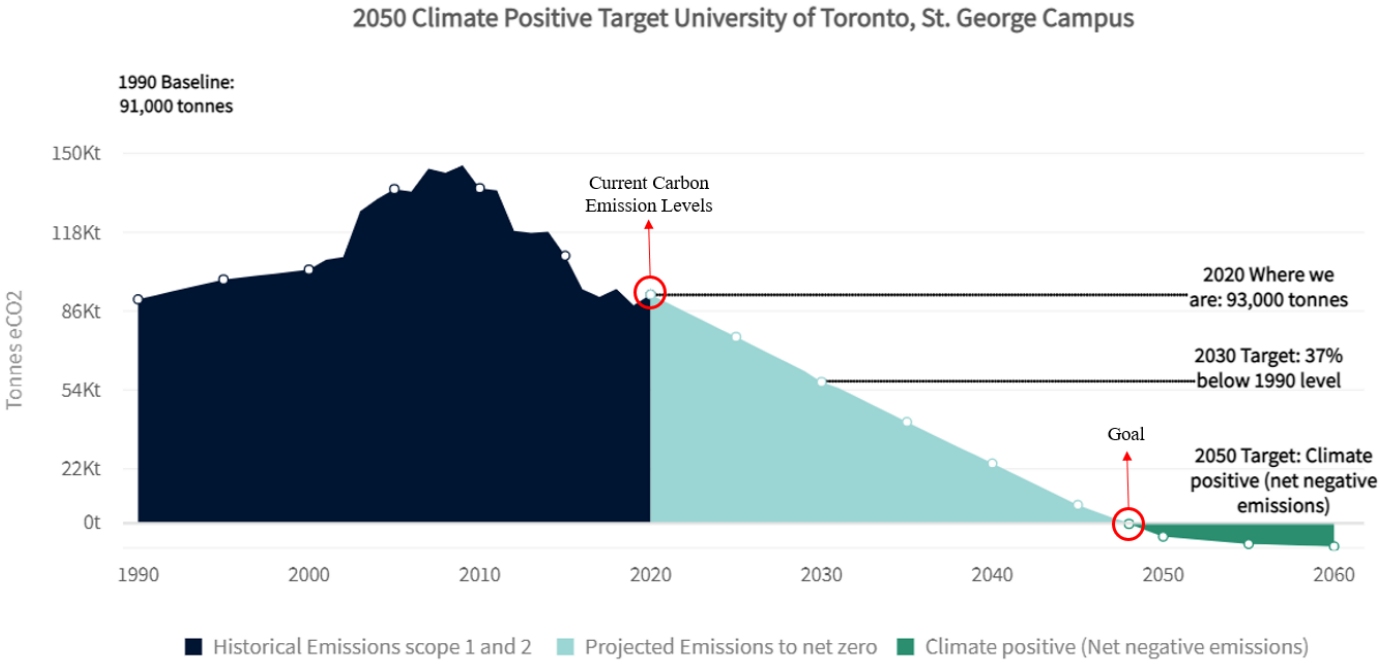

Figure 2: Historical and projected future carbon emissions at the UofT St. George campus [3]

The life span of a glove is reduced by unintended wastage due to user inexperience, limited shelf-life, and the inability to disinfect and reuse gloves [4] (Appendix A). Additionally, the 'Microflex Nitrile Gloves' currently used in the teaching labs are non-decomposable since they are unable to undergo microbial decomposition of the polymer and depend solely on physical factors (heat, stress, light, and moisture) [5]. Although gloves made of alternate materials (e.g. latex) that are derived from natural products have been used in the past, they have caused allergies [6], are not as durable [7], or are too expensive (Appendix A).

The engineering need is a means of reducing wastage of nitrile gloves and the associated 'gap' the design will fill is the lack of a process that prolongs the lifespan of each glove, ultimately minimizing carbon emissions. The scope of this design focuses on the dispensation, and disposal of gloves to reduce unintended wastage, effectively increasing its longevity in biosafety hazard level two laboratories.

3.0 Service Environment

The Service Environment focuses on describing the typical physical, living, and virtual environment elements found in the location in which the design will operate. Below is a table consisting of the typical classrooms in which wet labs are conducted and how these standards impact the design.

Table 1.0: Service environment in which the design will operate and impact

	Standard Variables	
Types of Service Environment	**Variable Name**	**Impact on Design**
Physical Environment	Temperature [8]	Laboratories must have individual temperature controls to accommodate glove storage.
	Laboratory Biohazard Level [9]	UofT labs are containment levels 1 and 2 (Appendix J).
	Room Dimensions	Laboratories must abide by the Canadian National Building Code [10].
	Inward directional Airflow [11]	Level 2 or higher laboratories must have negative pressure (Appendix B).
	Disposal [12]	Separate bins contain radioactive, chemical and bio-hazardous waste. Gloves are disposed of accordingly.
Living Environment	University and High School Students	Inexperience with gloves increases waste (Appendix A). There are roughly 20-35 students per practical (Appendix B).
	Teaching Assistants (TAs) and Professors	TAs and professors are required to use PPE in laboratories [13].
	Microbes and Bacteria	There may be microbes and bacteria present that will impact glove sterility (Appendix B).
Virtual Environment	Electricity	The electricity in the lab can be used to make the design autonomous.
	Internet Connectivity	The design can be implemented via technological platforms.

4.0 Stakeholders

Stakeholders are defined as any person or group of people that will be affected by, or influence, the design, and must be taken into consideration to determine the success of the design. The stakeholders associated with making wet laboratories more environmentally friendly were generated through mind mapping (Appendix C), and are outlined below (Table 2.0).

Table 2.0: Stakeholders for the design to make wet laboratories greener

Stakeholder	Examples	Stakeholder Impact and Influence
UofT FASE Teaching Team	Professors, Teaching Assistants, Safety Course Instructors	The teaching team is responsible for supervising and ensuring the safety of users. Safety courses may need amending depending on the solution, thus leaving a neutral or negative impact.
Investors	Bank of Montreal (BMO) [14]	Invested money may be used to purchase PPE, therefore also funding the solution. There would be a positive impact due to effective fund usage.
Caretakers	UofT Caretaking Team, Environmental Health and Safety (EHS)	The UofT Caretaking Team is responsible for regular waste, EHS disposes of chemical and biological waste (Appendix B). An easier to manage solution will therefore have a positive impact.
Special Event Staff	Tours, Outreach Events	Implementing the solution may require supplemental training on how to adapt tours [15], which is a negative impact.
Governments	Canadian Government, Government of Ontario	Governments have provided developmental funding through the LIFT Project [16]. The laboratories must follow government enforced codes and standards [10]. Governments are positively impacted through the promotion of sustainability.

5.0 Detailed Requirements

The information in this section highlights the requirements for the design and criteria for evaluating success in an effort to fulfill the gap and the client's needs.

5.1 Functions

The functions are what the design must do to ensure that there is less nitrile glove wastage. The functions (Table 3.0) were identified using the black box method (Appendix F and G).

Table 3.0: Functions for the dispensing and disposal of gloves

Aspect	Dispensing	Disposal
Primary Function	**F1**:Ensure dispensation of the exact number of gloves the user needs.	**F2**:Will separate the used gloves based on the contamination.
Secondary Functions	**F1.1**: Takes user input, including the hand size and number of gloves. **F1.2**: Stores different sizes of gloves (Appendix H). **F1.3**: Ensures gloves that are not dispensed remain sterile. **F1.4**: Indicates which gloves to take and makes them available.	**F2.1**: Takes user input about usage (length of time of used, materials handled). **F2.2**: Receives and stores the recyclable and non-recyclable gloves separately. **F2.3**: Will hold up to approximately 22.7 liters [17] (Appendix I) of both waste and recyclable gloves similar to the current sorting system. **F2.4**: Ensures hazardous waste is contained safely without leakage or cross-contamination. **F2.5**: Indicates whether the gloves can be recycled or not.

5.2 Objectives

The objectives will be used to evaluate the success of a design, and are based on the client's desired outcome of more environmentally friendly laboratories. They are listed (Table 4.0) in decreasing importance (Appendix D) and were generated through application of the How-Why Tree (Appendix E).

Table 4.0: Objectives for the dispensing and disposal of gloves

Objectives	Goals	Metrics
Reduce Unintended Waste	**O1: Should** minimize unintended dispensation and waste of unused gloves.	Accurate number of gloves dispensed.
Easy to Operate	**O2: Should** have a Net Promoter Score more than 75% [18].	Survey score.
Maintains Optimum Temperature	**O3: Should** maintain a cool environment between 50°F to 72°F (no bacterial growth, damage or contamination) [19].	Temperature of storage (°F).
Storage Capacity is Scalable	**O4: Should** be applicable to laboratories of different sizes (bigger labs need more gloves) and respond to changes in demand.	Number of gloves stored.
Compatible	**O5: Should** be applicable to gloves with different uses and sizes according to experimental requirements.	Number of types of gloves stored/recycled (Appendix H).

5.3 Constraints

Constraints are standards and restrictions that the design must meet to be considered a safe and feasible solution for laboratories. The constraints (Table 5.0) are based on limitations set by the client and safety.

Table 5.0: Constraints for the dispensing and disposal of gloves

From client/scope	Constraint	Metric	Targets
Client	**C1.1:Sizes**	Glove sizes.	Must be able to store and dispose of five sizes of gloves (XS, S, M, L, XL) (Appendix B).
	C1.2:Number	Gloves held by the design.	Must be able to store and dispose of a total of 500 gloves (Appendix B).
	C1.3:Budget	Dollars (CAD) .	Must be less than $10,000 annually (Appendix B).
Scope	**C2.1:Dimensions**	Meters.	The design must be able to store and dispose of gloves of dimensions 0.245 x 0.08 x 0.140-0.254 [20].
	C2.2:Preserve Durability	Number of punctures.	Gloves must not fail the pinhole test (Appendix K).
	C2.3:Sterilized	Indicator color (Appendix L).	Gloves must be kept sterile until disposed to the user.

6.0 Alternative Designs

The information in this section highlights our top three designs and the process used to finalize them.

6.1 Idea Generation Process

We began with structured brainstorming (Appendix M.a) where each member contributed ten ideas that they used methods including Analogies to create (Appendix M.c). After eliminating repetitions (Appendix M.b), we chose to use a Morphological Chart (Appendix M.d) to combine aspects of different ideas to ensure all aspects of the scope were covered, resulting in 50 unique ideas (Appendix M.e).

6.2 Alternative Design Selection Process

We started with a feasibility check (Appendix N.a) to either amend or omit non-feasible ideas. Then we voted for the top ten ideas using multi-voting (Appendix N.b). After round one, the six ideas with at least three votes were selected. To select the last four ideas, the next best 13 ideas were voted on. With a list of ten ideas, we constructed a graphical decision chart (Appendix N.c), ranking each idea out of five on the two most important objectives: reduction of unintended waste and ease of operation. This left us with three alternative designs, LabSpenser, PosterIt, and LabCheck.

6.3 Alternative Designs

The alternative designs will feature three main components: preparation, dispensation, and disposal, which are used to achieve the desired functions.

6.3.1 LabSpenser

To ensure that users understand how to acquire and dispose of gloves, they must watch mandatory interactive videos, containing questions that must be correctly answered to complete the module (Figure 3). To ensure that the user knows their glove size prior to entering the lab, they will be informed on how to properly measure their hand, prompted to input measurements, and given their size as output. To prevent multi-dispensing, the final design has two main characteristics: interfolding gloves using the interleaving method [21] and altering the dispensation opening with an external bracket (Figure 3). Regarding disposal, the lab will be sectioned according to the nature of the chemicals being handled in each experiment (Appendix P). This will make it easier to separate gloves according to contamination. Each section's gloves will be disposed of in a bin with the section's number. Table 6.0 below highlights how the design meets the objectives.

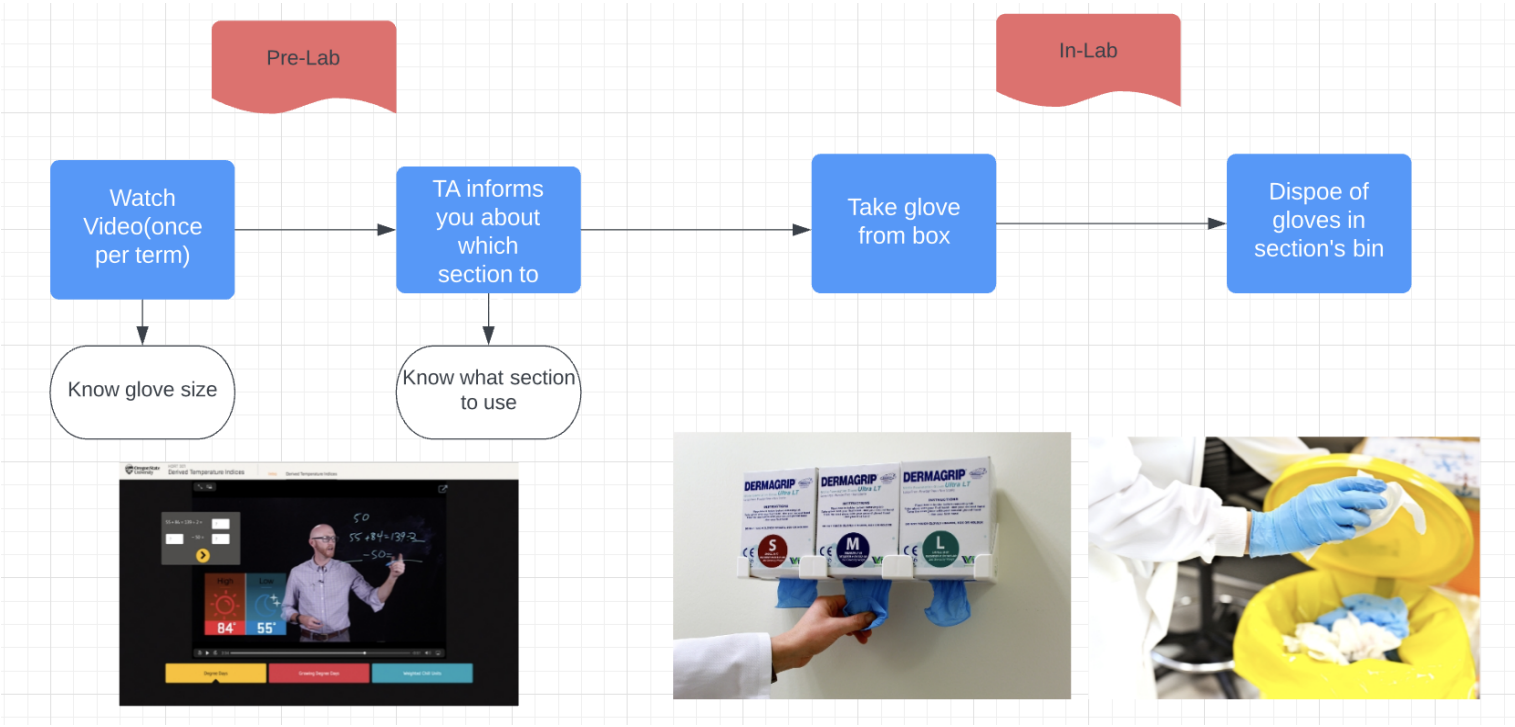

Figure 3: Flowchart for LabSpenser [22][23][24]

Table 6.0: Objectives Analysis of Interactive Video & Online Questionnaire

Objective	How Design Meets Objective
O1	- Only one glove comes out of the box - Recyclable and non-recyclable gloves are separated
O2	- Questions are in video, user only has to provide an answer - As easy as a pulling tissue from a tissue box - Bin easily identifiable
O3	- Same as current system, gloves kept at same temperature as lab
O4	- If more gloves are needed, more glove boxes can be implemented
O5	- Boxes available for any sizes

6.3.2 PosterIt

To prevent glove wastage by minimizing size uncertainty, posters outlining a step by step process to use the glove dispensing machine, the impact made by the users' decisions, and a graphic that allows users to measure their hand size (Figure 4) will be placed in the laboratory. An external filter will be placed on the glove dispenser to prevent multi-dispensing. Inspired by Inspocare's Glovesafe system [25], the design will consist of a rectangular case to hold gloves, with a semi-circular lip underneath to catch any gloves that may be dispensed unintentionally, preventing droppage, and ultimately wastage. With regards to glove disposal, the surrounding posters will inform students that they must first speak to the TA prior to glove disposal, ensuring proper disposal bin identification. Table 7.0 outlines how the design meets the objectives.

Figure 4: Example Posters [25]

Table 7.0: Objectives Analysis of Informative Posters and Authority's Assistance

Objective	How Design Meets Objective
O1	- System allows one glove to be pulled at a time
O2	- Easily understandable language
O3	- Temperature remains the same
O4	- Number of boxes adaptable
O5	- Design does not work for varying box sizes

6.3.3 LabCheck

On a weekly basis, users must complete a form, similar to UCheck, containing questions about the dispensing system, disposal system, and a section requiring hand measurements, that will result in a green checkmark along with the user's glove size, allowing them to enter the lab. To prevent users from memorizing the questions or answers, a sample of questions will be provided at random from a question bank. In terms of the dispensation component, the gloves will be placed in boxes with circular holes (Figure 5), promoting the dispensation of one glove at a time. When the number of gloves lower to half capacity, part of the box will be removable, making the gloves more readily accessible. With regards to disposal, there will be a QR code on each lab bench, sending users to a questionnaire that prompts users for the chemicals that were handled, and the duration of glove use, then providing the user with the correct disposal location. Table 8.0 outlines how the design meets the objectives.

Figure 5: Flowchart for LabCheck [26][27]

Table 8.0: Objectives Analysis of LabCheck

Objective	How Design Meets Objective
O1	- Only one glove dispensed at a time
O2	- The questionnaires are easy and straightforward - The disposal is similar to the current state
O3	- The gloves remain at the same temperature as the current state
O4	- More boxes can easily be created as required - No limit on questionnaire input
O5	- Different boxes available for different sizes and types

7.0 Proposed Conceptual Design

LabSpenser was chosen over others using the Pugh Method by evaluating the relative success of each design against the five objectives (Appendix O).

This design best addresses unintended wastage at the dispensation stage by altering student behavior to reduce human error and by changing the dispensation mechanism to avoid multi-dispensing. This is achieved through interactive videos that use active learning [28] to ensure that students understand how to correctly collect and dispose of gloves.

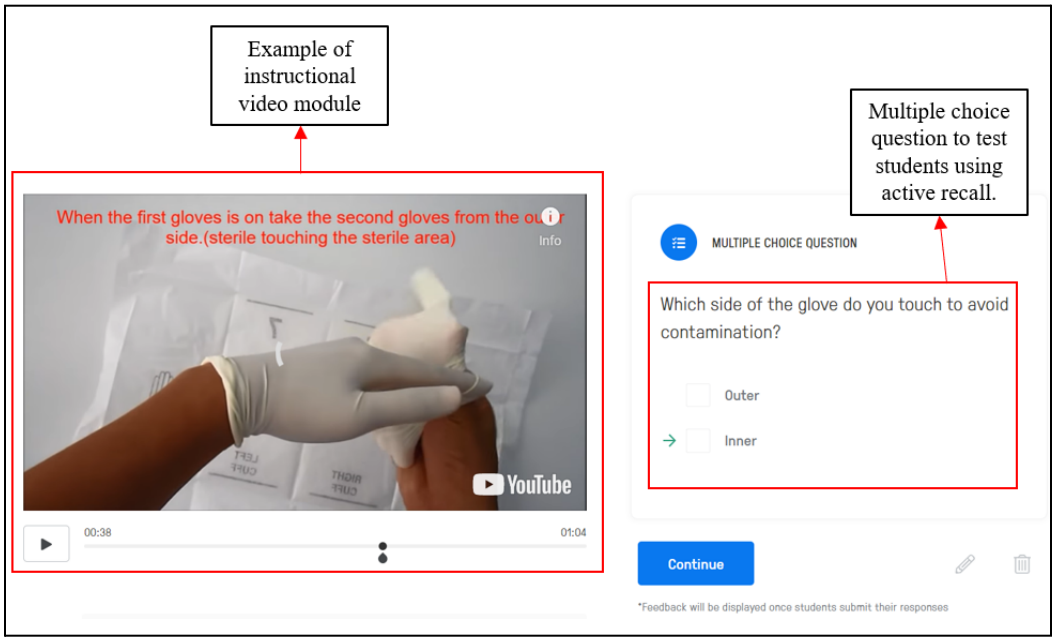

Figure 6: Interactive Video Module [29]

Additionally, the interleaving method of folding increases the lifespan of gloves by 10% and reduces multi-dispensing and spillage by 100% according to tests conducted by Polyco Healthline [30]. To make this an economically feasible solution, we recommend using the existing glove box with a retrofit bracket that can be added on top, exposing the cuff only (Figure 7). This will drastically reduce multi-dispensing caused by students pulling multiple gloves, as less area is exposed.

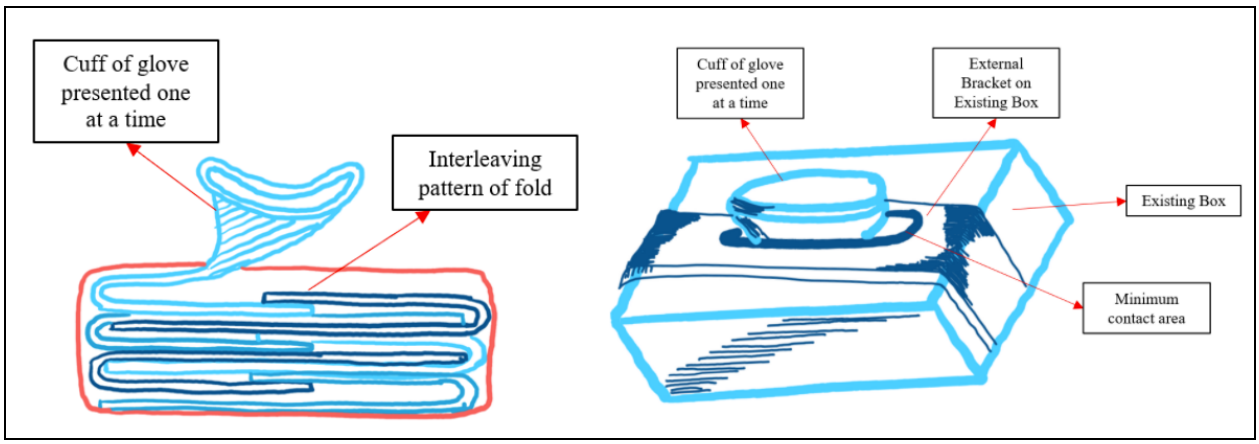

Figure 7: Glove Dispenser Case

Additionally the disposal system reduces the carbon footprint of the gloves by ensuring they are separated according to their type of contamination [31] (Appendix P), allowing for appropriate recycling. Waste separation has been proven to be fundamental for sustainability [32].

8.0 Measures of Success

To ensure that the LabSpenser is the most effective solution for reducing waste in laboratories, we have laid out the following four week series of tests.

8.1 Preparation (Week 1)

- The learning module will be made available to a sample of volunteers.
    - Following the completion of the module, volunteers will take a short test to determine how much they have learned.
        - The individual scores will be averaged to represent efficacy. The team has determined that an average score of 80% would be desirable.
    - Volunteers will then be asked to score the video out of five on overall enjoyability and preparatory experience.
        - These scores will be used to ensure that the learning module is a positive experience.

8.2 Dispensation (Weeks 2 and 3)

- The Pinhole Test (Appendix K) and the Spore Test (Appendix L) will be performed on untouched gloves to determine initial sterility and structural integrity conditions. After washing hands, putting on a mask, and wearing gloves, we will prepare 10 LabSpenser boxes.
    - The time required to prepare each box of gloves will be recorded, then averaged.
        - Calculations will follow to determine the amount of time required to meet the demands of a single laboratory (Appendix B).
    - For both systems, we will pull each glove out of the box, one by one, recording the number of system malfunctions, including but not limited to entanglements or jams.

        - The results for each system will be compared to quantitatively determine the impact of the LabSpenser.
        - The Pinhole Test and Spore Test will be used on five gloves per test to determine if a change in initial conditions has occurred.

8.3 Disposal (Week 4)

- Three different sized laboratories on the UofT St. George campus will be investigated.
    - For one day per lab, we will monitor the number of gloves used and their disposal. We will then implement the sectioned lab system, as required by the LabSpenser.
        - For both states of each laboratory, the total number of gloves and the number of correctly disposed gloves will be recorded to give a reference point for the current state of glove disposal.

9.0 Conclusion

After scoping the problem to the dispensation and disposal of nitrile gloves, we defined the functions, objectives and constraints that were relevant to the service environment. These detailed requirements were used to generate and evaluate solutions using a multitude of methods, ensuring that the gap and need were sufficiently addressed. The measures of success will be used to assess the design's ability to meet our objectives and will be used to identify any necessary amendments to the proposed design. Following the completion of tests, the results will be presented during the Final Presentation, on April 19, 2022.

Reference List

[1] P. H. A. of Canada, “Canadian Biosafety Handbook, Second Edition,” Canada.ca, 09-Mar-2021. [Online]. Available: https://www.canada.ca/en/public-health/services/canadian-biosafetystandards-guidelines/handbook-second-edition/chapter-6-10.html#ch9. [Accessed: 01-Feb-2022].

[2] C. Rizan, M. Reed, and M. F. Bhutta, “Environmental impact of personal protective equipment distributed for use by health and social care services in England in the first six months of the COVID-19 pandemic,” *Sage journals*, 16-Mar-2021. [Online]. Available: https://journals.sagepub.com/doi/full/10.1177/01410768211001583. [Accessed: 10-Feb-2022].

[3] “The University of Toronto ST.GEORGE campus will become climate positive by 2050.,” *Climate Positive Campus*. [Online]. Available: https://climatepositive.utoronto.ca/. [Accessed: 12-Feb-2022].

[4]P. H. A. of Canada, “Government of Canada,” *Canada.ca*, 09-Mar-2021. [Online]. Available: https://www.canada.ca/en/public-health/services/canadian-biosafety-standards-guidelines/handbook-second-edition/chapter-6-10.html#ch9. [Accessed: 12-Feb-2022].

[5] “Biodegradable nitrile glove,” *Biodegradable Nitrile Glove*. [Online]. Available: https://info.showagloves.com/biodegradable-nitrile-glove#:~:text=Regular%20nitrile%20gloves%20cannot%20attract,NEW%20SHOWA%206110PF%20biodegradable%20glove. [Accessed: 11-Feb-2022].

[6] E. Nucera, A. Aruanno, A. Rizzi, and M. Centrone, “Latex allergy: Current status and future perspectives,” *Journal of asthma and allergy*, 28-Sep-2020. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7532063/. [Accessed: 14-Feb-2022].

[7] R. G. Chadwick, “Comparison of nitrile and latex examination gloves,” *Nature News*, 12-Jun-2004. [Online]. Available: https://www.nature.com/articles/4811350. [Accessed: 14-Feb-2022].

[8] “Safe work practices.” [Online]. Available: https://ehs.utoronto.ca/wp-content/uploads/2020/10/Safe-Work-Practices-Centrifuge-Use.pdf. [Accessed: 17-Feb-2022].

[9] “Biosafety,” *Environmental Health & Safety*. [Online]. Available: https://www.utsc.utoronto.ca/ehs/biosafety. [Accessed: 17-Feb-2022].

[10] E. and S. D. Canada, “Government of Canada,” *Laboratory inspection guide - Canada.ca*, 25-May-2021. [Online]. Available: https://www.canada.ca/en/employment-social-development/services/health-safety/reports/laboratory-inspection.html#h4.1. [Accessed: 17-Feb-2022].

[11] “Lab safety design standard - environmental health & safety.” [Online]. Available: https://ehs.utoronto.ca/wp-content/uploads/2018/12/Lab-Safety-Design-Standard-December_2018.pdf. [Accessed: 16-Feb-2022].

[12] “Health & Safety Information,” *Department of Cell & Systems Biology*, 09-Feb-2022. [Online]. Available: https://csb.utoronto.ca/health-safety-information/#disposal. [Accessed: 07-Feb-2022].

[13] “Hand protection gloves - environmental health & safety.” [Online]. Available: https://ehs.utoronto.ca/wp-content/uploads/2015/10/Hand-Protection-Gloves.pdf. [Accessed: 12-Feb-2022].

[14] “BMO donates $5 million to University of Toronto to launch first of its kind program integrating artificial intelligence and humanities,” BMO Donates $5 Million to University of Toronto to Launch First of Its Kind Program Integrating Artificial Intelligence and Humanities - Oct 7, 2019. [Online]. Available: https://newsroom.bmo.com/2019-10-07-BMO-Donates-5-Million-to-University-of-Toronto-to-Launch-First-of-Its-Kind-Program-Integrating-Artificial-Intelligence-and-Humanities. [Accessed: 17-Feb-2022].

[15] “Guidelines for laboratory tours,” *Environmental Health & Safety*, 17-Jan-2021. [Online]. Available: https://ehs.utoronto.ca/guidelines-lab-tours/. [Accessed: 08-Feb-2022].

[16] “U of T's revitalized labs bring new possibilities for Research,” *University of Toronto News*. [Online]. Available: https://www.utoronto.ca/news/u-t-s-revitalized-labs-bring-new-possibilities-research. [Accessed: 09-Feb-2022].

[17] “Plastic pail - 5 gallon, yellow S-7914Y,” *Plastic Pail - 5 Gallon, Yellow*. [Online]. Available: https://www.uline.ca/Product/Detail/S-7914Y/Pails/Plastic-Pail-5-Gallon-Yellow. [Accessed: 17-Feb-2022].

[18] Melanie Predolich,“DISPOSABLE GLOVE STORAGE AND PREVENTING DEGRADATION”, Jul 07, 2020, Available:https://www.yourglovesource.com/blogs/glove-knowledgebase/disposable-glove-storage-and-preventing-degradation, [Accessed: 17-Feb-2022].

[19] Kasia Perzynska, “5 Customer Satisfaction Metrics You Need To Track”, November 19, 2021, https://survicate.com/customer-satisfaction/metrics/ [Accessed: 17-Feb-2022].

[20] A. Ltd., “MICROFLEX® Supreno® se su-690 - Sturdy protection for demanding jobs,” *Ansell*. [Online]. Available: https://www.ansell.com/ca/en/products/microflex-supreno-se-su-690. [Accessed: 09-Feb-2022].

[21] *Espacenet*, 13-Mar-2012. [Online]. Available: https://worldwide.espacenet.com/publicationDetails/biblio?FT=D&date=20120313&DB=EPODOC&CC=US&NR=8132692B2. [Accessed: 25-Mar-2022].

[22] “What's allowed in medical waste containers?,” *Clean*, 30-Jun-2020. [Online]. Available: https://usbioclean.com/whats-allowed-medical-waste-containers/. [Accessed: 25-Mar-2022].

[23] S. M. P. media G. H., “Nitrile protective gloves manual® SLN 319,” *berner*, 17-Apr-2020. [Online]. Available: https://www.berner-safety.de/protective_gloves_with_safedon_system_manual_sln_319_en_1834.html. [Accessed: 25-Mar-2022].

[24] C. Rademacher, “ Should You Consider an Interactive Video Lesson?,” *Ecampus Course Development and training*, 01-Dec-2017. [Online]. Available: https://blogs.oregonstate.edu/inspire/2017/12/01/consider-interactive-video-lesson/. [Accessed: 25-Mar-2022].

[25]S. K.-L. Uoftlibraries, R. Rajeev, J. Li, and G. Zhang, “Application of COVID-19 single-use shredded nitrile gloves in structural concrete: Case study from Australia,” *my.access - University of Toronto Libraries*. [Online]. Available: https://www-sciencedirect-com.myaccess.library.utoronto.ca/science/article/pii/S0048969721065013. [Accessed: 25-Mar-2022].

[26]“Halyard introduces eco pull dispenser system,” *OR Today*, 16-Aug-2018. [Online]. Available: https://ortoday.com/halyard-introduces-eco-pull-dispenser-system/. [Accessed: 25-Mar-2022].

[27]K. Gautam, “New Horizons for Medical Waste Treatment Technology,” *Omnia Health Insights*, 10-Jan-2020. [Online]. Available: https://insights.omnia-health.com/hospital-management/new-horizons-medical-waste-treatment-technology. [Accessed: 25-Mar-2022].

[28] Toufaily, E. ; Z. T. ; L. D. Uoftlibraries, “University of Toronto Libraries - What do learners value in online education? An emerging market perspective,” *my.access - University of Toronto Libraries*. [Online]. Available: https://web-p-ebscohost-com.myaccess.library.utoronto.ca/ehost/pdfviewer/pdfviewer?vid=0&sid=08774da6-2715-446a-b040-cc93610b1d5d%40redis. [Accessed: 25-Mar-2022].

[29] “Make any video your lesson,” *Edpuzzle*. [Online]. Available: https://edpuzzle.com/. [Accessed: 25-Mar-2022].

[30] “Improved glove dispensing redesign cuts risk of HCAIs,” Cleanroom Technology, 07-Nov-2017.[Online]. Available:https://www.cleanroomtechnology.com/news/article_page/Improved_glove_dispensing_redesign_cuts_risk_of_HCAIs/135392. [Accessed: 25-Mar-2022].

[31] “General requirements,” *Environmental Health & Safety*, 28-Jun-2021. [Online]. Available: https://ehs.utoronto.ca/laboratory-hazardous-waste-management-and-disposal-manual/general-requirements/. [Accessed: 25-Mar-2022].

[32] R. Maletz, “Success factors for the implementation of Separate Collection Systems,” *The Handbook of Environmental Chemistry*, vol. 63, pp. 297–313, Jul. 2017. [Online]. Available: .https://doi.org/10.1007/698_2017_51 [Accessed: 25-Mar-2022].

[33] M. Predolich, “What manufacturers do to test the quality of disposable gloves,” *Your Glove Source*, 05-Sep-2017. [Online]. Available: https://www.yourglovesource.com/blogs/glove-knowledgebase/what-manufacturers-do-to-test-the-quality-of-disposable-gloves. [Accessed: 15-Feb-2022].

[34] G. Nambiar, “Sowingo app: Infection Control Recorder,” *gowrinambiar.com*, 2019. [Online]. Available: https://gowrinambiar.com/infection-control-machine-testing.html. [Accessed: 06-Mar-2022].

Appendix A - Meeting with Client (09/02/2022)

Screenshots from Meeting 1 notes

Scoping - What types of PPE (lab coats, goggles, gloves, masks, etc.) are we addressing in this project? Which types have the worst environmental impact here at U of T?

- Gloves → most wasteful → grab the wrong size and throw, when students are in a rush they pull out too many → can't put back into the box → TA can't be there in front of each box on every row to monitor → must be intuitive so students can easily understand what to do and how etc.
- Labcoats → reusable but washed monthly → cotton → students don't bring their own
- Glasses/Goggles → reusable and sanitized using alcohol

Scoping - What aspects of the PPE do we focus on? Material, shipping, sanitizing, disposal, etc.

- How can we minimize the amount we use?
- We cant change material → rubber is expensive, some people are allergic to latex
- Nitrile is usually not known to cause any allergy
- Look at the thickness of the gloves → dont break or crack → so dont need to change often can be worn for 3 hours
- Class is typically 3-4 hours → students wear gloves as soon as they enter but there is a requirement for students to remove gloves, wash hands and re-wear. When students go out to use the washroom, fill water etc it must be removed, hands washed and then return.
- Different disciplines use the same labs and each type, of course, needs different delivery styles → must be applicable to other spaces

Scoping - Which labs are we going to be working with, how do the considerations differ between disciplines?

- Eng Sci and Chemical Engineering → wet labs → disposable gloves and "tubes"
- Especially first year teaching courses → no experience
- Night classes → tired, want to leave early, hurry to finish work and leave
- Biomed minor → first time in lab → no experience

Gap - What are the current problems faced by the PPE? PPE is unsustainable cuz of the way they are made or used

- Lab coats → cotton is preferred but expensive → cotton and polyester mix is slightly cheaper → occasionally use disposable single use lab coats because they are cheap but used for one time events → outreach programs → laws → minors from highschool who come to see engineering as a prospective course, their safety is priority and taking inexperience into account highest degree of PPE must be used
- Cost is very important factor
- **Can the cost of washing, soap and bleach depending on frequency of washing be offset by buying biodegradable lab coats that don't need wash but can be disposed?**

Scoping → long term increase of sustainability → a solution that is relevant to not just the status quo but also for a post covid scenario

- Take into consideration and suggest how the solution will be adaptable to a time without covid → ability to share items etc.

Past Solutions and potential features of the new ideal solution

- Behavioural change of students → work on their wasteful habits → a system to change their mindset and behaviour to instill the need to reduce wastage without affecting the iterative learning process (make mistakes, address failures and learn) while ensuring they are careful and cognizant of the safety hazard
- Think about optimization and how to maximize what we have
- Office of sustainability at UofT → remove napkins at handwash station → solution was to put a fabric cloth towel that is a roll (etsy reusable paper towels) → not a great solution → lab works from 9-9 → towel will always be wet and can lead to more contamination → solution needs to be student proof → even if some student isnt careful to wash their hands it shouldn't affect the next person.
- by protocol students that use the biosafety cabinet (protects both users and the biomaterials from contaminants) → everything must be sprayed with alcohol and wiped down with napkins → using fibre cloth could work but need to ensure students don't leave it around and mould forms on top of the ethanol in the cloth → previously tried to change to cheaper napkins that are made from recycled material → problems: has a lot of

- by protocol students that use the biosafety cabinet (protects both users and the biomaterials from contaminants) → everything must be sprayed with alcohol and wiped down with napkins → using fibre cloth could work but need to ensure students don't leave it around and mould forms on top of the ethanol in the cloth → previously tried to change to cheaper napkins that are made from recycled material → problems: has a lot of fibres that increased the amount of work given that these fibre deposits needed more napkins to clean them.

Appendix B - Laboratory Tour Notes (16/02/2022)

Calculation of the number of gloves = 3 sizes * 3 cases * 10 box/case * 100 gloves/box = 9000 gloves per semester.

The screenshots show the notes were taken when visiting the Teaching Labs and Design Studios:

- 210 lab coats per semester (320 dollars) per semester
- Gloves - 5 sizes (XS, S, M, L, XL) - chemical engineering - solvents absorbed through the gloves — double gloves (medium + large)
- Fume hood - 2-3 pairs of gloves at a minimum
- 3 cases of each size (10 boxes per case) - 100 gloves per box
- Least consumed is extra large and extra small
- No way to decide what size their hands are for the first time — safety perspective we need them to fit perfectly (too small causes it to stretch and tear, too but might allow chemicals to enter)
- Work with acids and bacteria
- Safety training before lab — regular garbage for non-toxic
- Green bin for toxic
- Yellow for biomaterials
- Every Friday staff from environmental health and safety collects them
- Burial of chemicals
- Chemical waste collection
- Cyline when working with biological specimen need special gloves (Chemical resistant gloves) - only TAs not a student
- Micropipettes
- Use gloves in dry labs even to handle microscopes
- Cloth without fibres
- Cleaning glassware is extremely tedious and not perfect
- Teaching lab environment — too many students, lack of experience, not cost-efficient
- 20-35 students in the BME lab sessions
- 2/3 times a month before covid for high school
- Glass pastor aspirator
- Material that can't promote microbial growth
- Same experiment each semester
- Need to satisfy round of funding
- Eng Sci Biomed + chem
- Students are not part of the cleanup process, not enough time between labs — more time between labs is helpful to clean up
- Sometimes TAs help
- Budget allocated to each lab → CAD 100,000 and about 25-30% allocated to purchasing PPE and single-use safety products.

Appendix C - Mind Mapping for Stakeholders

The stakeholders of this project were generated through brainstorming and mind mapping. An excerpt from an Engineering Notebook is shown below to demonstrate this map.

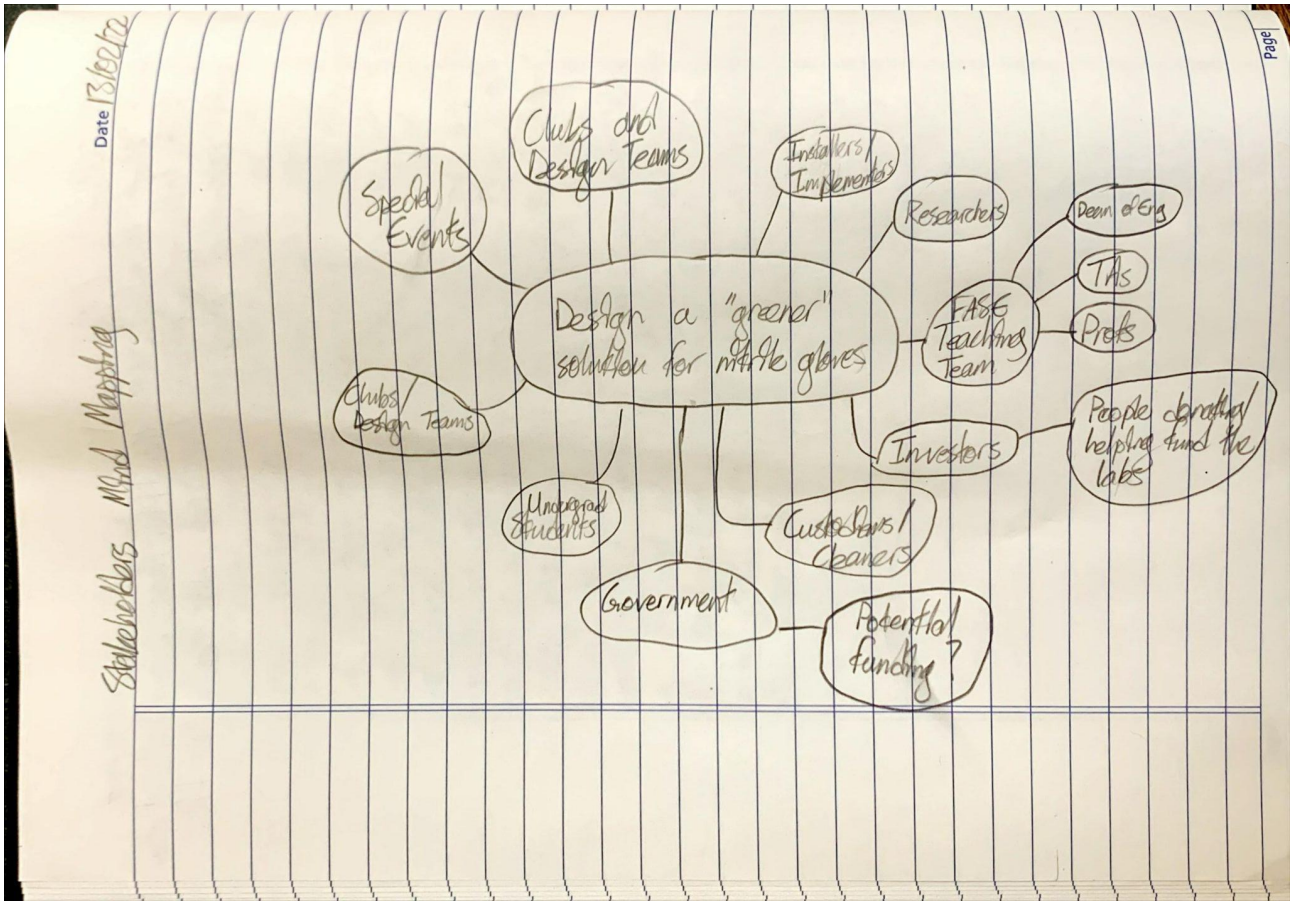

Figure 8: Mind Mapping Chart for identifying the Stakeholders that influence or are impacted by the design for making wet laboratories greener.

Appendix D - Pairwise Comparison Table for the Objectives

The importance of each objective is determined through pairwise comparison. The importance of different objectives was ranked from high to low after the application of pairwise comparison.

Table 9.0: Pairwise Comparison Table

	Reduce unintended waste	Compatible	Easy to Operate	Storage capacity is scalable	Maintain optimum temperature	Total
Reduce Unintended Waste	--	1	1	1	1	4
Compatible	0	--	0	0	0	0
Easy to Operate	0	1	--	1	1	3
Storage Capacity is Scalable	0	1	0	--	0	1
Maintain optimum temperature	0	1	0	1	--	2

Appendix E - How-Why Tree for the Objectives

The How-Why Tree is a brainstorming technique used for generating more related and useful objectives for the design. The sequence of the How-Why Tree is from describing Why, at the top, to How, at the bottom. The results of this technique as applied to the scope for the design are shown in Table 4.

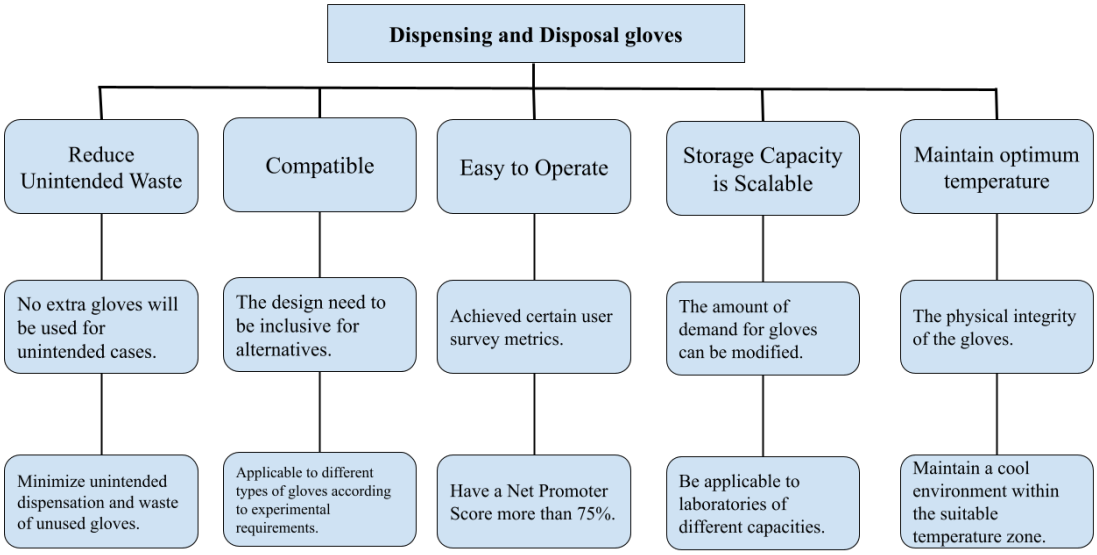

Figure 9: How-Why Table for objectives

Appendix F - Black Box Method: Ensuring that the Exact Number of Gloves is Dispensed

The black box method is used to test the internal workings of the design by analyzing the input and output, it helps to examine the functions of the design. This is the black box method for primary functions.

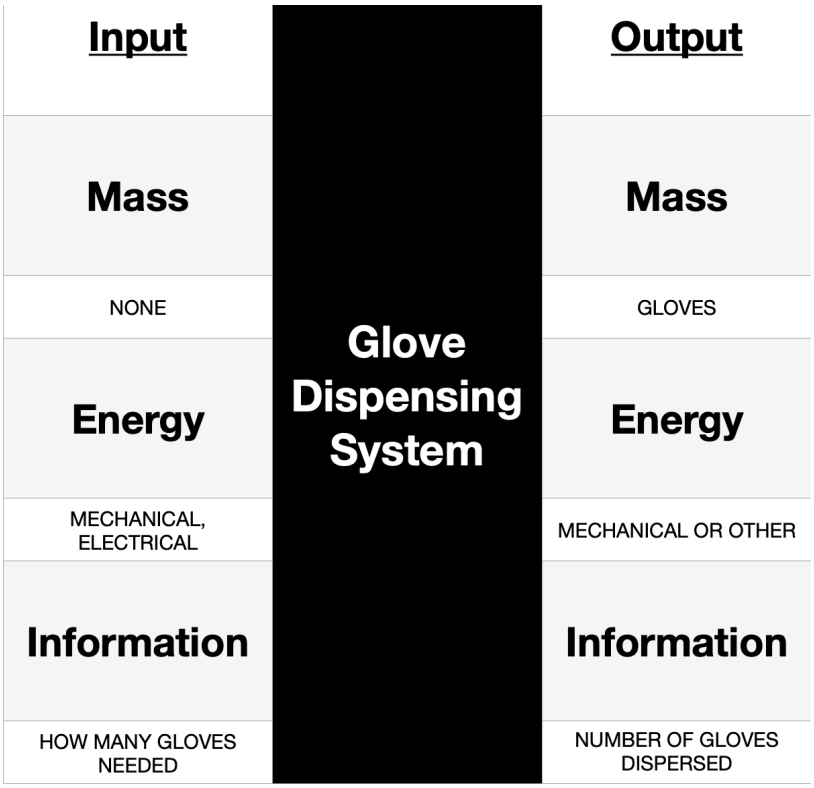

Figure 10: Black box method to highlight the mass, energy, and information input and output for F1.0, to create the primary functions

Appendix G - Black Box Method: Separating Used Gloves Based on Contamination

The black box method is used to test the internal workings of the design by analyzing the input and output, it helps to examine the functions of the design. This is the black box method for secondary functions.

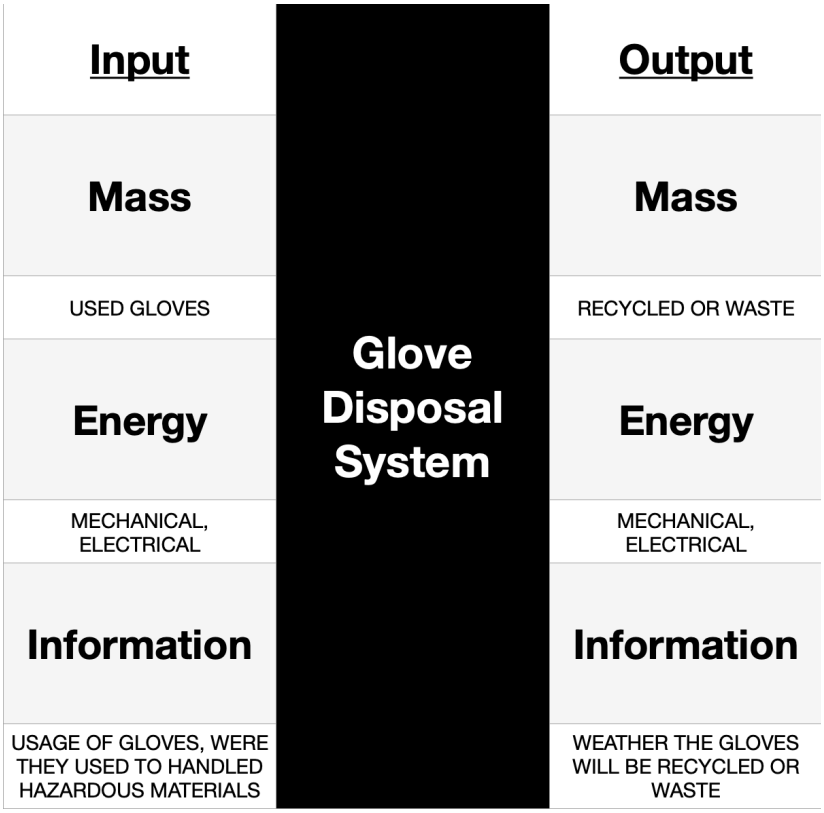

Figure 11: Black box method to highlight the mass, energy, and information input and output for F2.0, to create the secondary functions

Appendix H - Gloves Currently Used by Client

The box of 100 gloves that is used by the client is shown in size medium, one of five sizes.

Figure 12: Image of Microflex Supreno SE box of gloves (100 gloves) used by the client

Appendix I - Biohazardous Waste Disposal Bins

The bins/wastage technique currently used by the lab to dispose of gloves and other chemical waste.

Figure 13: Image of waste bins in client's lab

Appendix J - Service Environment

Pictures of the lab and the service environment that the design and the client are working in.

Figure 14: Image of the wet laboratory

Appendix K - Pinhole Test

There are many tests that manufacturers use to check the quality of the gloves. One of these tests is the pinhole test, the pinhole test is to check the quality of the gloves. This is done by filling each glove with 1000 mL of room water temperature and hanging it for 2 minutes. If no water escapes the glove, it passes the test. If water starts dripping out from the glove, the glove does not pass the test [33].

Appendix L - Spore Test

A biological indicator in a small test tube is placed into the machinery. The machinery is used (dispenses the glove) and the indicator is checked. If the indicator stays purple indicating that the indicator has not been contaminated, the machine passes the sterilization test. If the indicator turns color, the indicator has been contaminated and the machine does not pass the sterilization test [34].

Appendix M - Idea Generation Method

The appendix will show and explain the methods involved in our idea generation process.

a. Separate brainstorming (each team member generated 10 ideas)

- Sahana:

1. **(TA gives one glove + monitors disposal)** Ensure a TA is present in each lab to monitor students and guide them to ensure they only take 1 glove of the right size and dispose of it in the correct bin such that wastage is reduced and recycling is increased.

2. **(measurement chart for glove size + app to decide disposal)** Install a 'Glove Use Introductory Toolbox' on each table in the lab (1 shared by 6 students) that contains a glove measurement chart that students can place their hands on and find out their right size to prevent disposal of many gloves while trying to find the right fit. Finding the right fit will also reduce the chances of tearing. It will also contain a bar code that will lead to an app where the student can select the experiment to be conducted from a pre-existing library and get instructions on which bin to dispose of the glove depending on the toxicity/nature of chemicals handled.

3. **(Training module + measuring tape for size)** During the lab safety training module undergone by all undergraduate students who will enter the teaching lab add a section specifically on reducing waste in the laboratory. Give students a measuring tape to measure palm size and use a chart like the one below to assess their glove size. Include a module that teaches students the different types of disposal according to the nature of chemical handling.

4. **(Questionnaire for size + ucheck type app)**Make students undergo a questionnaire test that will assess if students know their glove size and the correct method of disposal (e.g. questions on match chemical to the ability to recycle etc.). If the student does not pass the test they may not enter the lab. (Similar to how we fill out UCheck to enter campus).

5. **(Intro lab session + only one bin on each table)**Include an introductory lab at the beginning of each semester where the palm-size of students is measured. Assign students to a spot in the lab for the semester. Ensure that the TA/lab assistant places exactly one pair of gloves on each person's table according to their palm-size record. Depending on the type of experiment to be conducted (uses toxic chemicals, biomaterials, etc.) have only 1 corresponding type of bin in the lab so no wrong disposal is possible.

6. **(increase time between labs + TA distribute/dispose)**Increase the time between consecutive lab tutorials to at least 1 hour. Assign this time to the TA/lab assistant to individually measure and distribute gloves to students. Any additional gloves must be taken from the TA/lab assistant (none will be placed on the table directly). At the end of the lab, gloves will be placed on the table and the TA/lab assistant will collect and appropriately dispose of the gloves.

7. **(Kimberly-Clark ppe recycling)**Switch to Kimberly-Clark PPE that has dispensers that dispense a single glove at a time and collect nitrile gloves that are not contaminated with blood or biohazardous material to be recycled into outdoor furniture and other products. (https://www.fishersci.ca/ca/en/selection-guides/safety/kimberly-clark-professional-rightcycle.html)

8. **(Eco pull dispenser + instruction manual on bin)**Install a "Eco Pull dispenser system" by Hallyard Health that ensures only 1 glove is dispensed. It reduces wastage by multiple gloves being pulled out by about 50%. Install instruction manuals on each desk on the disposal of gloves depending on the nature of chemicals handled.

9. **(SafeDon dispenser + 3 bins on each table)**Install SafeDon glove dispensation system that uses an interleaving fold to dispense gloves one at a time. The box is also designed such that to pull out a glove the individual only needs to touch the exterior cuff reducing chances of contamination of other stored gloves. Install 3 separate recycling bins in every table to make disposal and recycling more convenient for students. (https://www.cleanroomtechnology.com/news/article_page/Improved_glove_dispensing_redesign_cuts_risk_of_HCAIs/135392)

10. **(GloveSafe dispenser + structural concrete mix)**Install the Inspacare GloveSafe dispenser that reduces unintended wastage of gloves. It ensures that the gloves are pulled using a "pincer grasp" and pass through a filter that only lets one glove pass through. It also has a "half-cylindrical safety ledge" that reduces the chance of excess gloves falling to the floor. Placing a chart that identifies contaminants and guides appropriate disposal will ensure that gloves that are not heavily contaminated can be separated. They can then be shredded and used in structural concrete.(https://inspacare.com/#our-solution) (https://www-sciencedirect-com.myaccess.library.utoronto.ca/science/article/pii/S0048969721065013)

- John:
    1. As part of the safety courses that students are required to take before entering the lab, implement a section that includes glove sizing and disposal information. Much like how students are required to pass the safety course to gain lab access, they must also pass the glove information section. Some courses may include a section on gloves, and in this case, the solution may be to improve the existing section of the course.
    2. Create informational posters and post them around the labs or campus. These posters will highlight the environmental issues as well as UofT's goals in correcting the issue. The posters can be placed on doors to the laboratories, or even above the disposal bins to highlight the concerns. Students will be reminded of the impact of their actions during the dispensing and disposing of gloves.
    3. Implement a short questionnaire either before or after glove use. This questionnaire will ask the user what chemicals they will be handling, and will then provide them with the correct disposal option. This questionnaire could either be digital (website accessed via QR code, or something to that effect) or a hard copy.

4. Avoid using gloves in simpler labs that may not even require gloves. On a case by case basis, the TA may have the authority to decide if gloves are even required at all in a given lab experiment. For students in earlier years, or visiting high school students, some of the experiments they perform do not use any chemicals that are harmful to the skin. Under current protocols, the participants are still required to wear gloves. This may not be necessary.
5. Implement a system that scans the user's hand to select the appropriate glove size for the user. The scanning system should also scan the gloves for hazardous materials, and then select the correct disposal bin accordingly.
6. Create a consistent schedule that requires students to update their lab safety knowledge. This could be something along the lines of once every six weeks, and would only be a short test, ensuring that students maintain their lab safety knowledge. This test would have a section about the environmental impacts of PPE, including nitrile gloves, and how to properly select and dispose of the gloves.
7. Create a system that only makes one glove available to the user at any given time. This would be along the lines of a section attached to the box of gloves that can hold at most one glove. Essentially, this would be the reverse of a mailbox. In a mailbox, users open the compartment, which is empty, place the mail in the compartment, then close the compartment. The next user who opens the compartment will not have access to the previous user's mail. To dispose, a forwards mailbox system could be implemented, preventing users from coming in contact with contaminated gloves.
8. Create a specialized bacteria solution that is tailored specifically to break down nitrile gloves at a faster paste. The decomposed solution can then be disposed of accordingly by EHS.
9. In lab protocols that do not use dangerous chemicals, there is the possibility that students may be able to keep the gloves and use them for multiple sessions, providing there is no damage done to the gloves. This is also under the assumption that contamination of the gloves is not an issue.
10. Create a system with a large horizontal elastic sheet, where users are able to place their hand on the sheet, just enough to make an indent, leaving a temporary outline of their hand size. A machine could then read this and recommend an appropriate glove based on the user's hand size.

- Samantha:
    1. Invest in a cleaning machine/structure that is able to disinfect gloves so that each glove has a lifespan of three uses before disposal.

    2. Conduct a mandatory seminar in which students are taught how to maintain a pair of gloves during a lab by being careful with them, thus, maximizing their longevity.

    3. Implement rules stating the maximum number of gloves allowed for use in a certain period of time by each student. Penalties such as fines will act as consequences.

4. Create a hand measurer similar to those found in shoe stores for feet. Measure the maximum and minimum length, height and width each glove can expand to and label it on the hand measurer. Correlate the size S, M or L (found by measuring the max and min size for each glove size) and label it on the hand measurer. Students will be able to know exactly what size their glove needs to be.

5. Create a biodegradable alternative glove for the ones already in use. This ensures that despite the volume of waste provided by dispensation of gloves, the waste will remain green or sustainable.

6. Invest in the research project that supports the idea of transforming plastic waste such as nitrile gloves into fossil fuels. This can be implemented school wide or scaled down for glove disposal only.

7. Create a system in which labs are conducted in groups when possible and only one person (or the minimum number of people required) wear gloves in order to reduce usage.

8. Increase measures of protocols regarding how much research must be conducted before conducting a lab. If more research is made by students before conducting a lab, the likelihood of committing small mistakes will decrease. Thus, experiments will be conducted less times as a means to increase accuracy or decrease uncertainties due to small errors.

9. Introduce a seminar that must be attended by students before entering a lab. The seminar should explain the importance of sustainability and how their actions in the lab can adversely affect achieving a more sustainable lab.

10. Introduce voluntary positions where volunteers are stationed in the labs to make sure students are disposing of their gloves correctly (in the right bins). This will ensure that disposal of gloves is done correctly enough that it can be coupled with one of the above ideas, for example, washing gloves.

- Tanya:
    1. Have a new personnel waiting at the door to dispense and give a glove to each student depending on the lab that is going to be performed that day to make sure that none of the gloves go to waste. The same personnel then disposes of the gloves at the end in the correct waste bin depending on the chemicals used for the lab.
    2. Online videos to watch and tests/quizzes as well as an in person training and testing to be done before labs begin where the student learns correct disposal and their gloves size as well as correct dispensing of gloves to make sure only one glove dispenses. (similar to myhal training)
    3. Students place their hand into a device that scans their hand to find the perfect glove for them and dispenses one glove into a compartment from where it can be picked up. At the

end of the lab, the students place their dirty glove in another machine which detects the chemicals used and sorts the glove into the correct waste bin.
4. Students have to download an app that scans their hand and tells them the correct size of their glove, reducing glove waste due to not knowing the correct size. After the lab, students select the lab they completed from a list of options and the app tells them what kind of waste the glove should be thrown into.
5. A certain amount of students' grades is set to correct removal and disposal for each lab giving them an incentive to practice correct disposal and removal.
6. Perform a lab with less toxic material which causes students not to need the use of gloves.
7. A machine which dispenses the gloves to the student upon selection of size similar to a vending machine and then the student disposes the gloves into the correct waste bin.
8. Posters up on the walls and tables of the lab to remind students of correct dispensing and disposal of gloves.
9. Placing gloves on the students tables before they enter the lab and telling them which waste bin the gloves should be disposed into.

- Rayan:
    1. Split the lab into different sections (e.g. a section for handling chemicals) and dispose of all gloves from the section into one bin.
    2. Create a machine where you input the number of gloves you need and size, or the usage of gloves and how it should be disposed
    3. Educational posters on how to use and prolong the lifespan of the gloves and where to dispose of them
    4. Students sign up beforehand and gloves size they need and the ta will have the gloves ready for the students
    5. Assign a different student each lab to be responsible to give out and dispose of gloves
    6. Use a credit system, a student can only use X gloves per semester/year.
    7. Use different glove colors when handling different things, e.g. red gloves for when handling chemicals. Each color also will have a same colored bin so it is easier for the students to dispose of the gloves.
    8. TA will do a quick demonstration at the beginning of the lab, how to dispose of gloves, sizes, what gloves to use, etc.
    9. Create a course on or add to existing safety courses, glove usage, how to dispose of them, this way students can learn before the labs and it becomes easy for them to do while they are in the lab.

- Adelaide:
    1. A gloves dispensing machine which can detect the size of users' hands by putting hands on the screen and scanning the rough contour of hand. Then it is able to dispense appropriate sizes of gloves for users and reduce the unintended waste of gloves.
    2. For the lab course syllabus, add an introduction of glove usage within the lab time. E.g. It is not allowed to attach two gloves for one user in one time. The used gloves should be thrown in the particular recycled garbage and so on.

3. The storage of gloves should keep an appropriate environment. Should keep the humidity good for gloves storage and will not lead to the damage of gloves. The sizes and categories are classified well in the storage.
4. Post up some gloves using instructions on the wall in the laboratories. In the instruction, include appropriate gloves dispensing way and mention how to correctly get the correct size through eyewalling or some approachable measurements.
5. Initiate some green lab or PPE lectures within the university. In the lectures, talk about serious plastic glove usage within the lab and let students reduce the unintended gloves waste within the lab.
6. Generate a machine which can record the number of gloves approached by each student. The recording through face id, fingerprint or utorid. Limit the amount of gloves for a student to approach in one day or in a time period.
7. Have a scoring mechanism. The glove usage, dispension and so on will be recorded by adding or minusing scores through some ways. The score can be one component of GPA (participation part) or the highest score can have a bonus and lowest has a penalty.
8. At the beginning of the semester, teach students how to measure their hand sizes and tell them which size of gloves is appropriate. Let them use the appropriate glove size within the following time.
9. Separate brainstorming (each team member generated 10 ideas)

b. Removing duplicated ideas (the red words shows the similar ideas with previous)

- Sahana:
    1. **(TA gives one glove + monitors disposal)** Ensure a TA is present in each lab to monitor students and guide them to ensure they only take 1 glove of the right size and dispose of it in the correct bin such that wastage is reduced and recycling is increased.

    2. **(measurement chart for glove size + app to decide disposal)** Install a ‘Glove Use Introductory Toolbox’ on each table in the lab (1 shared by 6 students) that contains a glove measurement chart that students can place their hands on and find out their right size to prevent disposal of many gloves while trying to find the right fit. Finding the right fit will also reduce the chances of tearing. It will also contain a bar code that will lead to an app where the student can select the experiment to be conducted from a pre-existing library and get instructions on which bin to dispose of the glove depending on the toxicity/nature of chemicals handled.

    3. **(Training module + measuring tape for size)** During the lab safety training module undergone by all undergraduate students who will enter the teaching lab add a section specifically on reducing waste in the laboratory. Give students a measuring tape to measure palm size and use a chart like the one below to assess their glove size. Include a module that teaches students the different types of disposal according to the nature of chemical handling.

    4. **(Questionnaire for size + ucheck type app)**Make students undergo a questionnaire test that will assess if students know their glove size and the correct method of disposal (e.g.

questions on match chemical to the ability to recycle etc.). If the student does not pass the test they may not enter the lab. (Similar to how we fill out UCheck to enter campus).

5. **(Intro lab session + only one bin on each table)**Include an introductory lab at the beginning of each semester where the palm-size of students is measured. Assign students to a spot in the lab for the semester. Ensure that the TA/lab assistant places exactly one pair of gloves on each person's table according to their palm-size record. Depending on the type of experiment to be conducted (uses toxic chemicals, biomaterials, etc.) have only 1 corresponding type of bin in the lab so no wrong disposal is possible.

6. **(increase time between labs + TA distribute/dispose)**Increase the time between consecutive lab tutorials to at least 1 hour. Assign this time to the TA/lab assistant to individually measure and distribute gloves to students. Any additional gloves must be taken from the TA/lab assistant (none will be placed on the table directly). At the end of the lab, gloves will be placed on the table and the TA/lab assistant will collect and appropriately dispose of the gloves.

7. **(Kimberly-Clark ppe recycling)**Switch to Kimberly-Clark PPE that has dispensers that dispense a single glove at a time and collect nitrile gloves that are not contaminated with blood or biohazardous material to be recycled into outdoor furniture and other products. (https://www.fishersci.ca/ca/en/selection-guides/safety/kimberly-clark-professional-rightcycle.html)

8. **(Eco pull dispenser + instruction manual on bin)**Install a "Eco Pull dispenser system" by Hallyard Health that ensures only 1 glove is dispensed. It reduces wastage by multiple gloves being pulled out by about 50%. Install instruction manuals on each desk on the disposal of gloves depending on the nature of chemicals handled. (https://www.mcknights.com/news/products/new-glove-dispenser-controls-waste)

9. **(SafeDon dispenser + 3 bins on each table)**Install SafeDon glove dispensation system that uses an interleaving fold to dispense gloves one at a time. The box is also designed such that to pull out a glove the individual only needs to touch the exterior cuff reducing chances of contamination of other stored gloves. Install 3 separate recycling bins in every table to make disposal and recycling more convenient for students.

10. **(GloveSafe dispenser + structural concrete mix)** Install the Inspacare GloveSafe dispenser that reduces unintended wastage of gloves. It ensures that the gloves are pulled using a "pincer grasp" and pass through a filter that only lets one glove pass through. It also has a "half-cylindrical safety ledge" that reduces the chance of excess gloves falling to the floor. Placing a chart that identifies contaminants and guides appropriate disposal will ensure that gloves that are not heavily contaminated can be separated. They can then be shredded and used in structural concrete.(https://inspacare.com/#our-solution)

- John:

1. As part of the safety courses that students are required to take before entering the lab, implement a section that includes glove sizing and disposal information. Much like how students are required to pass the safety course to gain lab access, they must also pass the glove information section. Some courses may include a section on gloves, and in this case, the solution may be to improve the existing section of the course. (same as 1.3)
2. Create informational posters and post them around the labs or campus. These posters will highlight the environmental issues as well as UofT's goals in correcting the issue. The posters can be placed on doors to the laboratories, or even above the disposal bins to highlight the concerns. Students will be reminded of the impact of their actions during the dispensing and disposing of gloves.
3. Implement a short questionnaire either before or after glove use. This questionnaire will ask the user what chemicals they will be handling, and will then provide them with the correct disposal option. This questionnaire could either be digital (website accessed via QR code, or something to that effect) or a hard copy. (same as 1.4)
4. Avoid using gloves in simpler labs that may not even require gloves. On a case by case basis, the TA may have the authority to decide if gloves are even required at all in a given lab experiment. For students in earlier years, or visiting high school students, some of the experiments they perform do not use any chemicals that are harmful to the skin. Under current protocols, the participants are still required to wear gloves. This may not be necessary.
5. Implement a system that scans the user's hand to select the appropriate glove size for the user. The scanning system should also scan the gloves for hazardous materials, and then select the correct disposal bin accordingly.
6. Create a consistent schedule that requires students to update their lab safety knowledge. This could be something along the lines of once every six weeks, and would only be a short test, ensuring that students maintain their lab safety knowledge. This test would have a section about the environmental impacts of PPE, including nitrile gloves, and how to properly select and dispose of the gloves.
7. Create a system that only makes one glove available to the user at any given time. This would be along the lines of a section attached to the box of gloves that can hold at most one glove. Essentially, this would be the reverse of a mailbox. In a mailbox, users open the compartment, which is empty, place the mail in the compartment, then close the compartment. The next user who opens the compartment will not have access to the previous user's mail. To dispose, a forwards mailbox system could be implemented, preventing users from coming in contact with contaminated gloves.
8. Create a specialized bacteria solution that is tailored specifically to break down nitrile gloves at a faster paste. The decomposed solution can then be disposed of accordingly by EHS.
9. In lab protocols that do not use dangerous chemicals, there is the possibility that students may be able to keep the gloves and use them for multiple sessions, providing there is no damage done to the gloves. This is also under the assumption that contamination of the gloves is not an issue.
10. Create a system with a large horizontal elastic sheet, where users are able to place their hand on the sheet, just enough to make an indent, leaving a temporary outline of their

hand size. A machine could then read this and recommend an appropriate glove based on the user's hand size.

- Samantha:
    1. Invest in a cleaning machine/structure that is able to disinfect gloves so that each glove has a lifespan of three uses before disposal.

    2. Conduct a mandatory seminar in which students are taught how to maintain a pair of gloves during a lab by being careful with them, thus, maximizing their longevity. (similar to 2.1/1.3)

    3. Implement rules stating the maximum number of gloves allowed for use in a certain period of time by each student. Penalties such as fines will act as consequences.

    4. Create a hand measurer similar to those found in shoe stores for feet. Measure the maximum and minimum length, height and width each glove can expand to and label it on the hand measurer. Correlate the size S, M or L (found by measuring the max and min size for each glove size) and label it on the hand measurer. Students will be able to know exactly what size their glove needs to be.

    5. Create a biodegradable alternative glove for the ones already in use. This ensures that despite the volume of waste provided by dispensation of gloves, the waste will remain green or sustainable. (similar to 1.7)

    6. Invest in the research project that supports the idea of transforming plastic waste such as nitrile gloves into fossil fuels. This can be implemented school wide or scaled down for glove disposal only.

    7. Create a system in which labs are conducted in groups when possible and only one person (or the minimum number of people required) wear gloves in order to reduce usage.

    8. Increase measures of protocols regarding how much research must be conducted before conducting a lab. If more research is made by students before conducting a lab, the likelihood of committing small mistakes will decrease. Thus, experiments will be conducted less times as a means to increase accuracy or decrease uncertainties due to small errors.

    9. Introduce a seminar that must be attended by students before entering a lab. The seminar should explain the importance of sustainability and how their actions in the lab can adversely affect achieving a more sustainable lab. (similar to 3.2, 2.1)

    10. Introduce voluntary positions where volunteers are stationed in the labs to make sure students are disposing of their gloves correctly (in the right bins). This will ensure that

disposal of gloves is done correctly enough that it can be coupled with one of the above ideas, for example, washing gloves. (similar to 1.1)

- Tanya:
    1. Have a new personnel waiting at the door to dispense and give a glove to each student depending on the lab that is going to be performed that day to make sure that none of the gloves go to waste. The same personnel then disposes of the gloves at the end in the correct waste bin depending on the chemicals used for the lab. (similar to 1.1)
    2. Online videos to watch and tests/quizzes as well as an in person training and testing to be done before labs begin where the student learns correct disposal and their gloves size as well as correct dispensing of gloves to make sure only one glove dispenses. (similar to myhal training) (similar to 2.1)
    3. Students place their hand into a device that scans their hand to find the perfect glove for them and dispenses one glove into a compartment from where it can be picked up. At the end of the lab, the students place their dirty glove in another machine which detects the chemicals used and sorts the glove into the correct waste bin. (similar to 2.5)
    4. Students have to download an app that scans their hand and tells them the correct size of their glove, reducing glove waste due to not knowing the correct size. After the lab, students select the lab they completed from a list of options and the app tells them what kind of waste the glove should be thrown into. (similar to 2.5)
    5. A certain amount of students' grades is set to correct removal and disposal for each lab giving them an incentive to practice correct disposal and removal.
    6. Perform a lab with less toxic material which causes students not to need the use of gloves. (similar to 2.4)
    7. A machine which dispenses the gloves to the student upon selection of size similar to a vending machine and then the student disposes the gloves into the correct waste bin.
    8. Posters up on the walls and tables of the lab to remind students of correct dispensing and disposal of gloves. (similar to 2.2)
    9. Placing gloves on the students tables before they enter the lab and telling them which waste bin the gloves should be disposed into. (similar to 1.6)

- Rayan:
    1. Split the lab into different sections (e.g. a section for handling chemicals) and dispose of all gloves from the section into one bin.
    2. Create a machine where you input the number of gloves you need and size, or the usage of gloves and how it should be disposed (similar 2.7)
    3. Educational posters on how to use and prolong the lifespan of the gloves and where to dispose of them(same as 2.2)
    4. Students sign up beforehand and gloves size they need and the ta will have the gloves ready for the students (similar 1.4/1.5/1.6)
    5. Assign a different student to each lab to be responsible to give out and dispose of gloves (same as 3.10).
    6. Use a credit system, a student can only use X gloves per semester/year. (similar to 3.3)

7. Use different glove colors when handling different things, e.g. red gloves for when handling chemicals. Each color also will have a same colored bin so it is easier for the students to dispose of the gloves.
8. TA will do a quick demonstration at the beginning of the lab, how to dispose of gloves, sizes, what gloves to use, etc.(same 1.3/1.5)
9. Create a course on or add to existing safety courses, glove usage, how to dispose of them, this way students can learn before the labs and it becomes easy for them to do while they are in the lab.(same as 1.3)

- Adelaide:
    1. A gloves dispensing machine which can detect the size of users' hands by putting hands on the screen and scanning the rough contour of hand. Then it is able to dispense appropriate sizes of gloves for users and reduce the unintended waste of gloves. (similar to 2.5)
    2. For the lab course syllabus, add an introduction of glove usage within the lab time. E.g. It is not allowed to attach two gloves for one user in one time. The used gloves should be thrown in the particular recycled garbage and so on. (similar to 2.1)
    3. The storage of gloves should keep an appropriate environment. Should keep the humidity good for gloves storage and will not lead to the damage of gloves. The sizes and categories are classified well in the storage.
    4. Post up some gloves using instructions on the wall in the laboratories. In the instruction, include appropriate gloves dispensing way and mention how to correctly get the correct size through eyewalling or some approachable measurements. (similar to 2.2)
    5. Initiate some green lab or PPE lectures within the university. In the lectures, talk about serious plastic glove usage within the lab and let students reduce the unintended gloves waste within the lab.
    6. Generate a machine which can record the number of gloves approached by each student. The recording through face id, fingerprint or utorid. Limit the amount of gloves for a student to approach in one day or in a time period.
    7. Have a scoring mechanism. The glove usage, dispension and so on will be recorded by adding or minusing scores through some ways. The score can be one component of GPA (participation part) or the highest score can have a bonus and lowest has a penalty. (similar to 4.5)
    8. At the beginning of the semester, teach students how to measure their hand sizes and tell them which size of gloves is appropriate. Let them use the appropriate glove size within the following time. (similar to 1.2??)

c. Analogy Method

The process of idea generation by analogies to other ideas.

- Switch to Kimberly-Clark PPE that has dispensers that dispense a single glove at a time and collect nitrile gloves that are not contaminated with blood or biohazardous material to be recycled into outdoor furniture and other products.
    - The Rightcycle Program by Kimberly-Clark PPE Professional which turns used PPE into new goods for recycling.

- Install an “EcoPull dispenser system” by Halyard Health that ensures only 1 glove is dispensed.
    - SafeDon dispenses gloves
- Install SafeDon glove dispensation system that uses an interleaving fold to dispense gloves one at a time.
    - The unique patented design of the Inspacare GloveSafe

d. Morphological Chart

Table 10.0: Morphological Chart

Measuring Glove Size	**Dispensing the glove**	**Disposing of the glove**
Measurement chart	TA giving gloves to each students	Through app
Measuring tape	Questionnaire	Training module
Questionnaire	Lab training	Only one bin
Lab training	Eco pull dispenser	TA disposes
Scanning device	Safedon dispenser	Instruction manual on each desk
machine indent handprint glove size	Glovesafe dispenser	Kimberly-Clark PPE recycling
	Machine dispenser/ reverse mailbox	Different bins
	vending machine disposal	Structural concrete
		Scanning device
		weekly tests/ ucheck
		bacteria solution
		machine to disinfect and reuse gloves
		volunteer system
		different colored gloves for different chemicals

e. Final 50 ideas

1. Increase the time between consecutive lab tutorials to at least 1 hour. Assign this time to the TA/lab assistant to individually measure and distribute gloves to students. Any additional gloves must be taken from the TA/lab assistant (none will be placed on the

table directly). At the end of the lab, gloves will be placed on the table and the TA/lab assistant will collect and appropriately dispose of the gloves.

2. Create informational posters and post them around the labs or campus. These posters will highlight the environmental issues as well as UofT's goals in correcting the issue. The posters can be placed on doors to the laboratories, or even above the disposal bins to highlight the concerns. Students will be reminded of the impact of their actions during the dispensing and disposing of gloves.
3. Avoid using gloves in simpler labs that may not even require gloves. On a case by case basis, the TA may have the authority to decide if gloves are even required at all in a given lab experiment. For students in earlier years, or visiting high school students, some of the experiments they perform do not use any chemicals that are harmful to the skin. Under current protocols, the participants are still required to wear gloves. This may not be necessary.
4. A short test that will be repeated periodically ensuring students maintain their lab and safety knowledge up to date.
5. Create a specialized bacteria solution that is tailored specifically to break down nitrile gloves at a faster paste. The decomposed solution can then be disposed of accordingly by EHS.
6. Using the same glove multiple times, if possible. The gloves are able to be reused if the usage of gloves is fine and do not cause damage to the gloves. Or users just take off the gloves for a while and then come back. The gloves should be able to be reused.
7. Create a system in which labs are conducted in groups when possible and only one person (or the minimum number of people required) wear gloves in order to reduce usage.
8. Having group labs instead of individual labs where only one person has to actually perform the lab, the rest of the group is responsible for set-up, dispensing and disposal/clean-up.
9. A certain amount of students' grades is set to correct removal and disposal for each lab giving them an incentive to practice correct disposal and removal.
10. Giving students more time to complete labs to ensure that they have enough time to use and dispose of the gloves. Once students have enough time, they will be patient with the gloves disposal process and then the completion of gloves disposal will be better.
11. Invest in the research project that supports the idea of transforming plastic waste such as nitrile gloves into fossil fuels. This can be implemented school-wide or scaled down for glove disposal only.
12. A device/process/solution that can change the size of gloves in the case that a student chose to use the wrong glove size. If the student chooses the gloves with wrong sizes, the device will be able to modify the size of the gloves. The device will be able to pump out the extra air in the gloves and make the gloves to an appropriate size.
13. Ensure a TA is present in each lab to monitor students and guide them to ensure they only take 1 glove of the right size and dispose of it in the correct bin such that wastage is reduced and recycling is increased.
14. Install a 'Glove Use Introductory Toolbox' on each table in the lab (1 shared by 6 students) that contains a glove measurement chart that students can place their hands on and find out their right size to prevent disposal of many gloves while trying to find the

right fit. Finding the right fit will also reduce the chances of tearing. It will also contain a bar code that will lead to an app where the student can select the experiment to be conducted from a pre-existing library and get instructions on which bin to dispose of the glove depending on the toxicity/nature of chemicals handled.

15. During the lab safety training module undergone by all undergraduate students who will enter the teaching lab add a section specifically on reducing waste in the laboratory. Give students a measuring tape to measure palm size and use a chart like the one below to assess their glove size. Include a module that teaches students the different types of disposal according to the nature of chemical handling.
16. Make students undergo a questionnaire test that will assess if students know their glove size and the correct method of disposal (e.g. questions on match chemical to the ability to recycle etc.). If the student does not pass the test they may not enter the lab. (Similar to how we fill out UCheck to enter campus).
17. Include an introductory lab at the beginning of each semester where the palm-size of students is measured. Assign students to a spot in the lab for the semester. Ensure that the TA/lab assistant places exactly one pair of gloves on each person's table according to their palm-size record. Depending on the type of experiment to be conducted (uses toxic chemicals, biomaterials, etc.) have only 1 corresponding type of bin in the lab so no wrong disposal is possible.
18. Switch to Kimberly-Clark PPE that has dispensers that dispense a single glove at a time and collect nitrile gloves that are not contaminated with blood or biohazardous material to be recycled into outdoor furniture and other products.
19. Install a "Eco Pull dispenser system" by Halyard Health that ensures only 1 glove is dispensed. It reduces wastage by multiple gloves being pulled out by about 50%. Install instruction manuals on each desk on the disposal of gloves depending on the nature of chemicals handled.
20. Install SafeDon glove dispensation system that uses an interleaving fold to dispense gloves one at a time. The box is also designed such that to pull out a glove the individual only needs to touch the exterior cuff reducing chances of contamination of other stored gloves. Install 3 separate recycling bins in every table to make disposal and recycling more convenient for students.
21. Install the Inspacare GloveSafe dispenser that reduces unintended wastage of gloves. It ensures that the gloves are pulled using a "pincer grasp" and pass through a filter that only lets one glove pass through. It also has a "half-cylindrical safety ledge" that reduces the chance of excess gloves falling to the floor. Placing a chart that identifies contaminants and guides appropriate disposal will ensure that gloves that are not heavily contaminated can be separated. They can then be shredded and used in structural concrete.
22. Implement a system that scans the user's hand to select the appropriate glove size for the user. The scanning system should also scan the gloves for hazardous materials, and then select the correct disposal bin accordingly.
23. Create a system that only makes one glove available to the user at any given time. This would be along the lines of a section attached to the box of gloves that can hold at most one glove. Essentially, this would be the reverse of a mailbox. In a mailbox, users open

the compartment, which is empty, place the mail in the compartment, then close the compartment. The next user who opens the compartment will not have access to the previous user's mail. To dispose, a forwards mailbox system could be implemented, preventing users from coming in contact with contaminated gloves.

24. A machine that uses a user's temporary hand-dent to recommend a glove size
25. A cleaning machine that is able to disinfect gloves to increase its usage. We would like to produce a cleaning machine which is able to clean the used gloves. The used gloves will be collected in a bin and the cleaning machine will clean the gloves. The cleaned gloves will be able to be reused for the future experiment.
26. Create a hand measurer similar to those found in shoe stores for feet. Measure the maximum and minimum length, height and width each glove can expand to and label it on the hand measurer. Correlate the size S, M or L (found by measuring the max and min size for each glove size) and label it on the hand measurer. Students will be able to know exactly what size their glove needs to be.
27. Introduce voluntary positions where volunteers are stationed in the labs to make sure students are disposing of their gloves correctly (in the right bins). This will ensure that disposal of gloves is done correctly enough that it can be coupled with one of the above ideas, for example, washing gloves.
28. A QR code similar to the uncheck website we already have at UofT will be created where students are required to answer some questions regarding the labs they will be conducting. A system will be used where the bottom of the box pushes upwards to reduce glove waste. Gloves will be disposed of via the help of a TA.
29. A machine which dispenses the gloves to the student upon selection of size similar to a vending machine and then the student disposes the gloves into the correct waste bin.
30. Split the lab into different sections (e.g. a section for handling chemicals) and dispose of all gloves from the section into one bin.
31. Add stickers to gloves when handling different things, e.g. red sticker gloves for when handling chemicals. Each sticker color also will have a same colored bin so it is easier for the students to dispose of the gloves.
32. TA gives each student a glove of their predetermined size, then the TA takes the glove after the lab has been completed, and breaks it down using a bacteria solution.
33. TA gives each student a glove of their predetermined size and students use an app to know the correct disposal depending on the chemicals used
34. Students have to download an app that scans their hand and tells them the correct size of their glove, reducing glove waste due to not knowing the correct size. After the lab, students select the lab they completed from a list of options and the app tells them what kind of waste the glove should be thrown into.
35. Switch to Kimberly-Clark PPE that has dispensers that dispense a single glove at a time and collect nitrile gloves that are not contaminated with blood or biohazardous material to be recycled into outdoor furniture and other products.
36. Students use a scanning mechanism, similar to a fingerprint scanner, to find their glove size which is then dispensed to them using the same machine and disposed of the gloves in one of 3 bins.

37. Use a measuring tape to find out the size of the glove required. Then, students use an Eco Pull dispenser to dispense the glove and then it is disposed of at the end by having only one bin available for all of the students in the lab.
38. Students are given lab training to learn the importance of not wasting gloves, measure their size and learn how to pull only one glove out. Then the disposal is done through a questionnaire provided by UofT.
39. Students have to maintain their glove usage knowledge by completing an assessment before every lab to make sure they know their glove size, and how to dispense and dispose of gloves. Gloves will be disposed of via the TA's help.
40. The safedon dispenser is installed for students to take only one glove and there is an instruction manual on each desk guiding students on how to dispose of the glove.
41. Create an interactive video that is mandatory for students to watch. Throughout the video, students will be asked questions that will show that they understand what is being taught. After the video, students will use a dispensation system similar to the Safedon system that already exists. To dispose, the lab will be split into different sections with bins in each section.
42. Students must be in charge of assigning one person to be in charge of dispensing the gloves for everyone. In order to dispose of the gloves, the same person will go around and collect the used gloves from the other students whilst making sure that they dispose of them in their respective bins.
43. Introduce a seminar that must be attended by students before entering a lab. The seminar should explain the importance of sustainability and how their actions in the lab can adversely affect achieving a more sustainable lab. This will make sure that students dispense and dispose of their gloves responsibly and correctly.
44. Students team up together and conduct labs in groups. One person in each lab group will be responsible for making sure their team dispenses the right amount of gloves and that all of the gloves used by their team members are disposed of in the right bins.
45. Have a new personnel waiting at the door to dispense and give a glove to each student depending on the lab that is going to be performed that day to make sure that none of the gloves go to waste. The same personnel then disposes of the gloves at the end in the correct waste bin depending on the chemicals used for the lab.
46. Students place their hand into a device that scans their hand to find the perfect glove for them and dispenses one glove into a compartment from where it can be picked up. At the end of the lab, the students place their dirty glove in another machine which detects the chemicals used and sorts the glove into the correct waste bin.
47. Collect the nitrile gloves. Invest in an extruder to break the gloves down into plastic granules. They can then be shredded and used in structural concrete. Use this to make new plastic products rather than using virgin plastic.
48. Initiate some green lab or PPE lectures within the university. In the lectures, talk about serious plastic glove usage within the lab and let students reduce the unintended gloves waste within the lab. This will be given in the form of a lecture at the beginning of the semester. Then, to dispose, students will participate in a closing lecture where they will learn where the different bins are.

49. Every lab protocol that is made available to students before a given lab must contain a section on how to correctly use and dispose of nitrile gloves. This will be given in a poster and will also be hung up around the laboratory.
50. Students must manually enter their size, which has already been determined from measuring their hand to a system that dispenses one glove into a compartment from where it can be picked up. The glove can then be returned to the system after use and it will be disposed of appropriately.

Appendix N - Idea Selection Method

a. Feasibility check

Feasibility check is the idea selection process which removes the unfeasible ideas. The ideas highlighted in yellow are the removed ideas.

1. Increase the time between consecutive lab tutorials to at least 1 hour. Assign this time to the TA/lab assistant to individually measure and distribute gloves to students. Any additional gloves must be taken from the TA/lab assistant (none will be placed on the table directly). At the end of the lab, gloves will be placed on the table and the TA/lab assistant will collect and appropriately dispose of the gloves.
2. Create informational posters and post them around the labs or campus. These posters will highlight the environmental issues as well as UofT's goals in correcting the issue. The posters can be placed on doors to the laboratories, or even above the disposal bins to highlight the concerns. Students will be reminded of the impact of their actions during the dispensing and disposing of gloves.
3. Avoid using gloves in simpler labs that may not even require gloves. On a case by case basis, the TA may have the authority to decide if gloves are even required at all in a given lab experiment. For students in earlier years, or visiting high school students, some of the experiments they perform do not use any chemicals that are harmful to the skin. Under current protocols, the participants are still required to wear gloves. This may not be necessary.
4. A short test that will be repeated periodically ensuring students maintain their lab and safety knowledge up to date.
5. Create a specialized bacteria solution that is tailored specifically to break down nitrile gloves at a faster paste. The decomposed solution can then be disposed of accordingly by EHS.
6. Using the same glove multiple times, if possible. The gloves are able to be reused if the usage of gloves is fine and do not cause damage to the gloves. Or users just take off the gloves for a while and then come back. The gloves should be able to be reused.
7. Create a system in which labs are conducted in groups when possible and only one person (or the minimum number of people required) wear gloves in order to reduce usage.
8. Having group labs instead of individual labs where only one person has to actually perform the lab, the rest of the group is responsible for set-up, dispensing and disposal/clean-up.
9. A certain amount of students' grades is set to correct removal and disposal for each lab giving them an incentive to practice correct disposal and removal.
10. Giving students more time to complete labs to ensure that they have enough time to use and dispose of the gloves. Once students have enough time, they will be patient with the gloves disposal process and then the completion of gloves disposal will be better.
11. Invest in1 the research project that supports the idea of transforming plastic waste such as nitrile gloves into fossil fuels. This can be implemented school-wide or scaled down for glove disposal only.
12. A device/process/solution that can change the size of gloves in the case that a student chose to use the wrong glove size. If the student chooses the gloves with wrong sizes, the

device will be able to modify the size of the gloves. The device will be able to pump out the extra air in the gloves and make the gloves to an appropriate size.

13. Ensure a TA is present in each lab to monitor students and guide them to ensure they only take 1 glove of the right size and dispose of it in the correct bin such that wastage is reduced and recycling is increased.
14. Install a 'Glove Use Introductory Toolbox' on each table in the lab (1 shared by 6 students) that contains a glove measurement chart that students can place their hands on and find out their right size to prevent disposal of many gloves while trying to find the right fit. Finding the right fit will also reduce the chances of tearing. It will also contain a bar code that will lead to an app where the student can select the experiment to be conducted from a pre-existing library and get instructions on which bin to dispose of the glove depending on the toxicity/nature of chemicals handled.
15. During the lab safety training module undergone by all undergraduate students who will enter the teaching lab add a section specifically on reducing waste in the laboratory. Give students a measuring tape to measure palm size and use a chart like the one below to assess their glove size. Include a module that teaches students the different types of disposal according to the nature of chemical handling.
16. Make students undergo a questionnaire test that will assess if students know their glove size and the correct method of disposal (e.g. questions on match chemical to the ability to recycle etc.). If the student does not pass the test they may not enter the lab. (Similar to how we fill out UCheck to enter campus).
17. Include an introductory lab at the beginning of each semester where the palm-size of students is measured. Assign students to a spot in the lab for the semester. Ensure that the TA/lab assistant places exactly one pair of gloves on each person's table according to their palm-size record. Depending on the type of experiment to be conducted (uses toxic chemicals, biomaterials, etc.) have only 1 corresponding type of bin in the lab so no wrong disposal is possible.
18. Switch to Kimberly-Clark PPE that has dispensers that dispense a single glove at a time and collect nitrile gloves that are not contaminated with blood or biohazardous material to be recycled into outdoor furniture and other products.
19. Install a "Eco Pull dispenser system" by Halyard Health that ensures only 1 glove is dispensed. It reduces wastage by multiple gloves being pulled out by about 50%. Install instruction manuals on each desk on the disposal of gloves depending on the nature of chemicals handled.
20. Install SafeDon glove dispensation system that uses an interleaving fold to dispense gloves one at a time. The box is also designed such that to pull out a glove the individual only needs to touch the exterior cuff reducing chances of contamination of other stored gloves. Install 3 separate recycling bins in every table to make disposal and recycling more convenient for students.
21. Install the Inspacare GloveSafe dispenser that reduces unintended wastage of gloves. It ensures that the gloves are pulled using a "pincer grasp" and pass through a filter that only lets one glove pass through. It also has a "half-cylindrical safety ledge" that reduces the chance of excess gloves falling to the floor. Placing a chart that identifies contaminants and guides appropriate disposal will ensure that gloves that are not heavily

contaminated can be separated. They can then be shredded and used in structural concrete.

22. Implement a system that scans the user's hand to select the appropriate glove size for the user. The scanning system should also scan the gloves for hazardous materials, and then select the correct disposal bin accordingly.
23. Create a system that only makes one glove available to the user at any given time. This would be along the lines of a section attached to the box of gloves that can hold at most one glove. Essentially, this would be the reverse of a mailbox. In a mailbox, users open the compartment, which is empty, place the mail in the compartment, then close the compartment. The next user who opens the compartment will not have access to the previous user's mail. To dispose, a forwards mailbox system could be implemented, preventing users from coming in contact with contaminated gloves.
24. A machine that uses a user's temporary hand-dent to recommend a glove size
25. A cleaning machine that is able to disinfect gloves to increase its usage. We would like to produce a cleaning machine which is able to clean the used gloves. The used gloves will be collected in a bin and the cleaning machine will clean the gloves. The cleaned gloves will be able to be reused for the future experiment.
26. Create a hand measurer similar to those found in shoe stores for feet. Measure the maximum and minimum length, height and width each glove can expand to and label it on the hand measurer. Correlate the size S, M or L (found by measuring the max and min size for each glove size) and label it on the hand measurer. Students will be able to know exactly what size their glove needs to be.
27. Introduce voluntary positions where volunteers are stationed in the labs to make sure students are disposing of their gloves correctly (in the right bins). This will ensure that disposal of gloves is done correctly enough that it can be coupled with one of the above ideas, for example, washing gloves.
28. A QR code similar to the uncheck website we already have at UofT will be created where students are required to answer some questions regarding the labs they will be conducting. A system will be used where the bottom of the box pushes upwards to reduce glove waste. Gloves will be disposed of via the help of a TA.
29. A machine which dispenses the gloves to the student upon selection of size similar to a vending machine and then the student disposes the gloves into the correct waste bin.
30. Split the lab into different sections (e.g. a section for handling chemicals) and dispose of all gloves from the section into one bin.
31. Add stickers to gloves when handling different things, e.g. red sticker gloves for when handling chemicals. Each sticker color also will have a same colored bin so it is easier for the students to dispose of the gloves.
32. TA gives each student a glove of their predetermined size, then the TA takes the glove after the lab has been completed, and breaks it down using a bacteria solution.
33. TA gives each student a glove of their predetermined size and students use an app to know the correct disposal depending on the chemicals used
34. Students have to download an app that scans their hand and tells them the correct size of their glove, reducing glove waste due to not knowing the correct size. After the lab,

students select the lab they completed from a list of options and the app tells them what kind of waste the glove should be thrown into.

35. Switch to Kimberly-Clark PPE that has dispensers that dispense a single glove at a time and collect nitrile gloves that are not contaminated with blood or biohazardous material to be recycled into outdoor furniture and other products.
36. Students use a scanning mechanism, similar to a fingerprint scanner, to find their glove size which is then dispensed to them using the same machine and disposed of the gloves in one of 3 bins.
37. Use a measuring tape to find out the size of the glove required. Then, students use an Eco Pull dispenser to dispense the glove and then it is disposed of at the end by having only one bin available for all of the students in the lab.
38. Students are given lab training to learn the importance of not wasting gloves, measure their size and learn how to pull only one glove out. Then the disposal is done through a questionnaire provided by UofT.
39. Students have to maintain their glove usage knowledge by completing an assessment before every lab to make sure they know their glove size, and how to dispense and dispose of gloves. Gloves will be disposed of via the TA's help.
40. The safedon dispenser is installed for students to take only one glove and there is an instruction manual on each desk guiding students on how to dispose of the glove.
41. Create an interactive video that is mandatory for students to watch. Throughout the video, students will be asked questions that will show that they understand what is being taught. After the video, students will use a dispensation system similar to the safe don system that already exists. To dispose, the lab will be split into different sections with bins in each section.
42. Students must be in charge of assigning one person to be in charge of dispensing the gloves for everyone. In order to dispose of the gloves, the same person will go around and collect the used gloves from the other students whilst making sure that they dispose of them in their respective bins.
43. Introduce a seminar that must be attended by students before entering a lab. The seminar should explain the importance of sustainability and how their actions in the lab can adversely affect achieving a more sustainable lab. This will make sure that students dispense and dispose of their gloves responsibly and correctly.
44. Students team up together and conduct labs in groups. One person in each lab group will be responsible for making sure their team dispenses the right amount of gloves and that all of the gloves used by their team members are disposed of in the right bins.
45. Have a new personnel waiting at the door to dispense and give a glove to each student depending on the lab that is going to be performed that day to make sure that none of the gloves go to waste. The same personnel then disposes of the gloves at the end in the correct waste bin depending on the chemicals used for the lab.
46. Students place their hand into a device that scans their hand to find the perfect glove for them and dispenses one glove into a compartment from where it can be picked up. At the end of the lab, the students place their dirty glove in another machine which detects the chemicals used and sorts the glove into the correct waste bin.

47. Collect the nitrile gloves. Invest in an extruder to break the gloves down into plastic granules. They can then be shredded and used in structural concrete. Use this to make new plastic products rather than using virgin plastic.
48. Initiate some green lab or PPE lectures within the university. In the lectures, talk about serious plastic glove usage within the lab and let students reduce the unintended gloves waste within the lab. This will be given in the form of a lecture at the beginning of the semester. Then, to dispose, students will participate in a closing lecture where they will learn where the different bins are.
49. Every lab protocol that is made available to students before a given lab must contain a section on how to correctly use and dispose of nitrile gloves. This will be given in a poster and will also be hung up around the laboratory.
50. Students must manually enter their size, which has already been determined from measuring their hand to a system that dispenses one glove into a compartment from where it can be picked up. The glove can then be returned to the system after use and it will be disposed of appropriately.

b. Multi voting

Multi voting is the process in which each number selects their favorite ideas and collects the votes for each idea. Ideas with higher votes will get into next round multi voting. The last 10 ideas are the final 10 ideas.

ROUND 1

Table 11.0: Round 1 of Multivoting Table

Tanya	**John**	**Rayan**	**Samantha**	**Adelaide**	**Sahana**
7	5	7	1	7	4
8	16	9	4	12	5
15	17	21	7	14	14
17	18	23	8	21	17
29	28	27	13	24	21
31	29	28	23	28	29
37	39	29	24	30	33
41	41	35	29	36	35
44	49	41	30	37	44
49	50	50	47	46	47

#1(number of ideas) - 1(amount of votes)

#4 - 2

#5 - 2

#7 - 4

#8 - 1
#9 - 1
#12 - 1
#13 - 1
#14 - 2
#15 - 1
#16 - 1
#17 - 3
#18 - 1
#21- 3
#23- 2
#24- 2
#27-1
#28- 3
#29- 5
#30 - 2
#31 - 2
#33 - 1
#35 - 2
#36 - 1
#37 - 2
#39 - 1
#41 - 3
#44 - 2
#46 - 1
#47 - 2
#49 - 2
#50 - 2

ROUND 2

Table 12.0: Round 2 of Multivoting Table

Tanya	**John**	**Rayan**	**Samantha**	**Adelaide**	**Sahana**
4	23	23	4	14	4
30	35	30	23	24	14
37	37	37	24	37	44
44	50	50	47	47	47

#4(number of ideas) - 3(amount of votes)
#14 - 2
#23 - 3
#24 - 2
#30 - 2

#35 - 1
#37 - 4
#44 - 2
#47 - 3
#50 - 2

c. Graphical Analysis Chart

The graphical analysis chart worked by first selecting two of the most significant objectives which are noticeable. Then, evaluate how well the ten final ideas accomplished each objective by rating from 1 to 5. The result was that idea 41, 28 and 21 were the winner and became our final alternative design solutions.

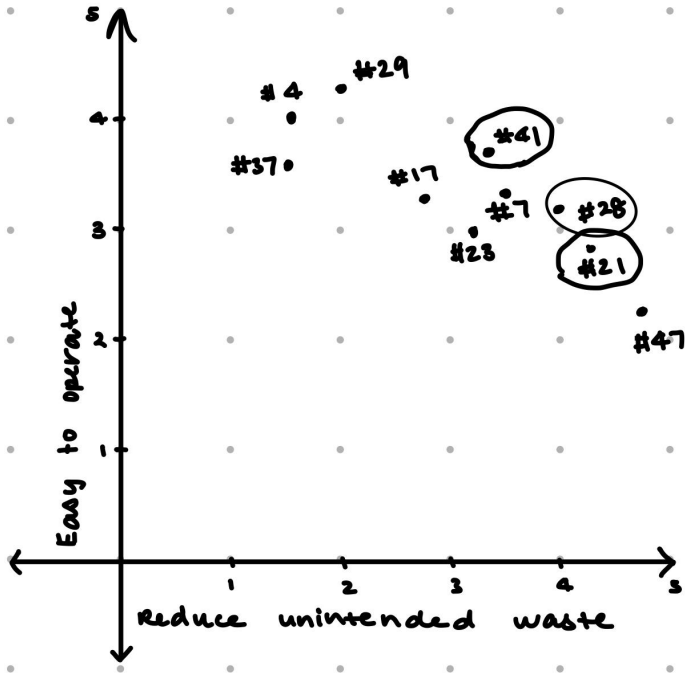

Figure 15: Graphical Analysis chart

Appendix O - Pugh Chart

Table 13.0: Final Pugh Chart

Objectives	**Datum**	**Idea 1#**	**Justification**	**Idea 2#**	**Justification**	**Idea 3#**	**Justification**
Reduce Unintended Waste	s	3	Given that the seminar videos are interactive and mandatory, students must go through the modules and become familiar with the appropriate use and disposal of gloves. Since the majority of unintended waste was due to the inexperience of students (don't know their glove size so try many before they find the perfect fit, don't know how to separate and dispose of appropriately). The dispensation of gloves uses a mechanism of folding that ensures only one glove is dispensed at a time to reduce the chances of multiple gloves being dispensed at the same time. Dividing the class into sections and TA instruction on	2	While the informational charts will help bring awareness amongst students, there is no means of ensuring that students will read and understand them, thus reducing its efficacy slightly. The glove dispensation method contains a component that catches any gloves when they are unintentionally removed. TA assisted disposal will ensure that there is no confusion and that students separate the waste correctly.	2	LabCheck will ensure that students know how to dispose of waste appropriately. Given that this is done every time the student enters the laboratory, it will test their knowledge using concepts of spaced repetition and ensure that the information is understood and applied. The glove dispenser reduces the chance of multiple dispensations by about 50%, so although it is not perfect waste is reduced.

			disposal reduces the chance of confusion and incorrect disposal.				
Easy to Operate	s	-1	Given that the gloves must be removed from their original packaging and refolded by a TA. This is time-consuming and tedious.	-1	Given that the TA must individually check and tell each student where to dispose of their used gloves it is a lot harder and more time-consuming.	-1	LabCheck requires students to fill out a form every time they enter the laboratory which increases the preparation time for the laboratory and reduces the ease of entering it.
Maintains Optimum Temperatur e	s	0	Although there is an exterior bracket that must be added to the existing glove box, it will not change the environment in which the gloves are stored directly. So temperature remains constant.	0	Although there is an exterior casing that must be added to the existing glove box, it will not change the environment in which the gloves are stored directly. So temperature remains constant.	0	Although there is an exterior component that must be added to the existing glove box, it will not change the environment in which the gloves are stored directly. So temperature remains constant.
Storage Capacity is Scalable	s	0	All are equally scalable to the current design. It neither improves nor worsens the situation.	0	All are equally scalable to the current design. It neither improves nor worsens the situation.	0	All are equally scalable to the current design. It neither improves nor worsens the situation.
Compatible	s	1	For the LabSpencer, the user is able to work on different sizes of gloves. It is practical to dispense gloves of different sizes and different	-1	The dispensation part of the design is the glove dispensing machine. For the machine, it is hard to change the box size which contains the gloves. Therefore, the design is hard to	1	LabCheck design is able to apply to different sizes of gloves. The boxes containing gloves can be changed feasibly which will contain different sizes and materials of gloves.

			materials with labels to distinguish.		apply on variable gloves.		
TOTAL		3		0		2	

Appendix P - Types of Contamination

Figure 16: Waste bucket list at University of Toronto