Design Report: A Safe and Accessible Glove Doffing Device

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Contents

Abstract

This design report addresses the safety and ergonomic challenges associated with doffing disposable gloves. Focusing on the needs of first-year Engineering Science students and first responders, the team aims to establish a safe and accessible method for removing vinyl gloves. Through a divergent design process utilizing Lotus Blossom and Morph Chart techniques, the team developed and iterated on three primary prototypes: a Hook design, a Glove Slicing mechanism, and a Tape-based design. These prototypes were evaluated against safety, accessibility, and durability requirements via proxy tests measuring contact rates, contaminant splatter, and operational forces. Comparative analysis revealed that the Hook design required excessive force, while the Tape design demonstrated superior performance, achieving a contact rate of 5% and an average doffing time of 8.82 seconds. After a holistic evaluation, the report recommends the final Tape design as the most effective solution for minimizing contamination risks while ensuring ease of use.

Design Report Supplemental Video: `https://youtu.be/_ekc9W8wXEI`

1 Introduction

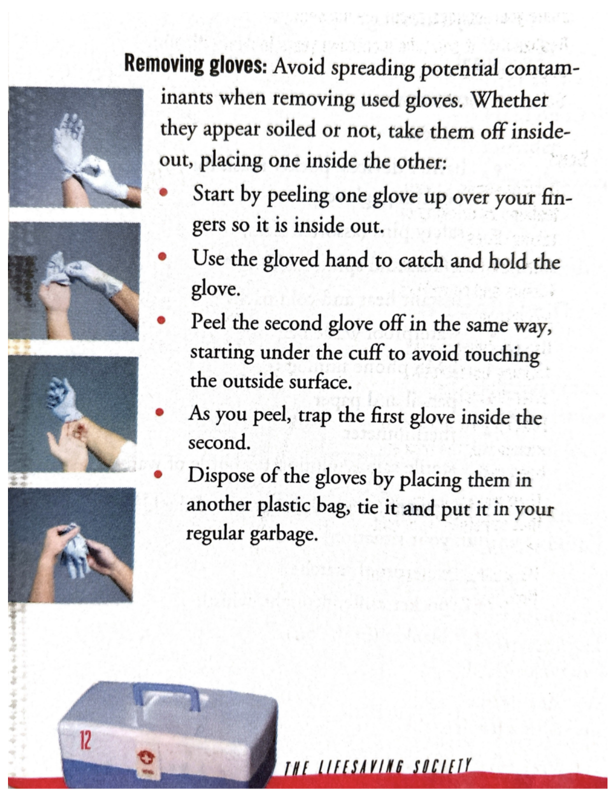
The purpose of this report is to present an evidence and iteration-based design process undertaken to develop a final design recommendation for our Splartz opportunity: doffing (removing) disposable gloves. Firstly, this document will go over the opportunity, the requirements and the Evaluation Criteria that will be used to compare different designs. Following this, the document will go over diverging process, prototypes, and iterations. Finally, this document will end with testing and the final design decision.

2 Framing The Opportunity

Disposable gloves are commonly used by first-year Engineering Science students during laboratory sessions and hands-on design activities such as Praxis Teardown [1] and the CIV Bridge Project. These environments often involve low-level contamination risks that can become a risk to hygiene and safety. Despite frequent glove use, existing doffing methods are often tedious [2] and prone to accidental skin–glove contact [3], making glove removal neither safe nor ergonomic for many users.

2.1 Background

Many Canadian first-aid organizations teach multi-step procedures for safely removing disposable gloves. One example is the Royal Lifesaving Society of Canada, which instructs the **pinch, pull, slide** technique to invert gloves and contain contaminants. Although effective when performed correctly, this method is multi-step, requires coordinated hand motions, and becomes more difficult with prolonged usage [2]. These challenges increase the likelihood of accidental contamination during glove removal [3]. Figure 1 illustrates the Lifesaving Society's recommended procedure, as described in the Canadian First Aid Manual [4].


Removing gloves: Avoid spreading potential contaminants when removing used gloves. Whether they appear soiled or not, take them off inside-out, placing one inside the other:

- Start by peeling one glove up over your fingers so it is inside out.
- Use the gloved hand to catch and hold the glove.
- Peel the second glove off in the same way, starting under the cuff to avoid touching the outside surface.
- As you peel, trap the first glove inside the second.
- Dispose of the gloves by placing them in another plastic bag, tie it and put it in your regular garbage.

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THE LIFESAVING SOCIETY

Figure 1: Royal Lifesaving Society of Canada procedures of doffing gloves [4].

2.2 Definitions

This design report will many times use the verb "doffing" a glove, which means removing the glove from the hand while avoiding contamination [5].

This design report will address Vinyl gloves, as they are the most suitable for the low-risk environments [6] that first-year EngSci students frequently work in. Additionally, Vinyl gloves can be found in UofT labs [7], especially due to latex allergies.

2.3 Stakeholders

Within the broad range of disposable glove users, this opportunity primarily concerns individuals who remove disposable gloves in environments where hygiene and contamination control are desirable. For this design report, the key stakeholders are:

- Engineering Science students, who frequently use disposable gloves in laboratories, Praxis Studio activities [1], and hands-on design work, such as the CIV102 bridge project.
- First-aid responders and lifeguards, where some EngSci students (including two members of our team) volunteer or work (such as UofT's first responders team, UTEFR), and who regularly doff gloves [8] after exposure to bodily fluids or contaminants.
- Laboratory personnel and teaching assistants, who supervise or conduct experiments in UofT labs [7].

These stakeholders share common needs: minimizing accidental contamination during glove removal [3], reducing discomfort [2], and a doffing method that is easy accessible to users with varying levels of training or dexterity.

2.4 Justification

Although the current standard procedure reduces contamination, it is inefficient and unintuitive. A study investigating the patterns of doffing practices adopted by healthcare workers [3] found that 37% contaminated their skin when doffing gloves. A more accessible and simpler method could reduce contamination while improving comfort and reliability. These findings justify the pursuit of improved glove doffing methods, those that make doffing quicker and easier, such as methods that do not require inversion.

2.5 Need Statement

Need: A safe and accessible way to take off disposable gloves.

This need captures the critical challenge faced by first-year EngSci glove users across low-risk projects, laboratory, and emergency settings; reliably removing disposable gloves without **contamination** or **discomfort**. It emphasizes the importance of a design that balances safety and ergonomics, ensuring reliable glove removal for users with varying strength, dexterity, and experience.

3 Requirements and Evaluation Criteria

The Requirements and Evaluation Criteria were derived from the objectives of the Needs (NGO) of the revised Design Brief [Appendix C]. They are organized into three sections corresponding to the Goals of this opportunity: Safety, Accessibility, and Durability. Evaluation criteria requirements are paired with clear, low-fidelity methods and measurement procedures. This ensures objective comparison between each design within the scope of Praxis 1.

3.1 Design for Safety

Df Safety is the primary focus of this splartz, as our stakeholders are individuals who operate in contaminated environments and rely on disposable gloves to keep themselves safe from potentially hazardous materials.

3.1.1 Minimizing Contact

The device must enable glove removal without direct contact between the user's bare skin and the contaminated glove surface.
Method: Record number of hand–glove contact events during standardized doffing trials.
Requirement: Below the **37%** threshold of contact events documented for standard manual glove doffing [3].
Evaluation Criteria: The lower the percentage of contamination by contact, the better.
Connection to Stakeholders: EngSci students, first aid responders, and laboratory workers will benefit from a minimized risk of contamination by hand to glove contact.

3.1.2 Limit Splatter of Contaminants

The design must reduce the splatter of contaminants from glove to other surfaces
Method: Doffing with colored liquid-soaked glove, record number and distance of droplets [9].
Requirement: Number of droplets between 2 ft and 3 ft is fewer than hand-doffing [9].
Evaluation Criteria: The lesser the amount of droplets, the better.
Connection to Stakeholders: Minimizing splatter protects stakeholders by reducing secondary contamination risk. This maintains safer labs, teaching spaces, and first aid environments.

3.2 Design for Accessibility

Df Accessiblity is imperative to consider, as designs must be efficient and usable for all of our stakeholders, which include people who may have varying mobility levels or physical strength.

3.2.1 Low Operational Force

Users must be able to operate the device with minimal exertion.
Method: Place doffing device on scale, then perform glove doffing. Record the maximum force displayed on the scale.
Requirement: The maximum force required to operate the device must be below 22.2 N [10].
Evaluation Criteria: The lower the maximum force, the better.
Connection to Stakeholders: Ensuring low required force allows all stakeholders to operate the device safely and comfortably, no matter their physical abilities.

3.2.2 Quick Usage

Using the device must be quick and efficient.
Method: Measure time it takes to doff both hands.
Requirement: Average glove doffing time must be lower than 10.9 s [9]
Evaluation Criteria: The lower the doffing time, the better.
Connection to Stakeholders: Faster doffing improves workflow and limits extended exposure to contaminants to stakeholders that often work in time sensitive environments.

3.2.3 Portability

Device characteristics must be sufficient to carry around during on-field usage.
Method: Weigh device using an electronic scale.
Requirement: Device must be under 500 g [11].
Evaluation Criteria: The lighter the device, the better.
Connection to Stakeholders: EngSci students benefit from a lightweight design that can be transported and stored easily. First aid responders and lifeguards often use gloves in dynamic environments, needing easy-to-carry equipment.

3.3 Design for Durability

Although safety and accessibility are our main priorities, Design for Durability is also a crucial feature we must account for, as reduced performance due to durability issues can undermine all of the other Dfxs that have been taken into consideration.

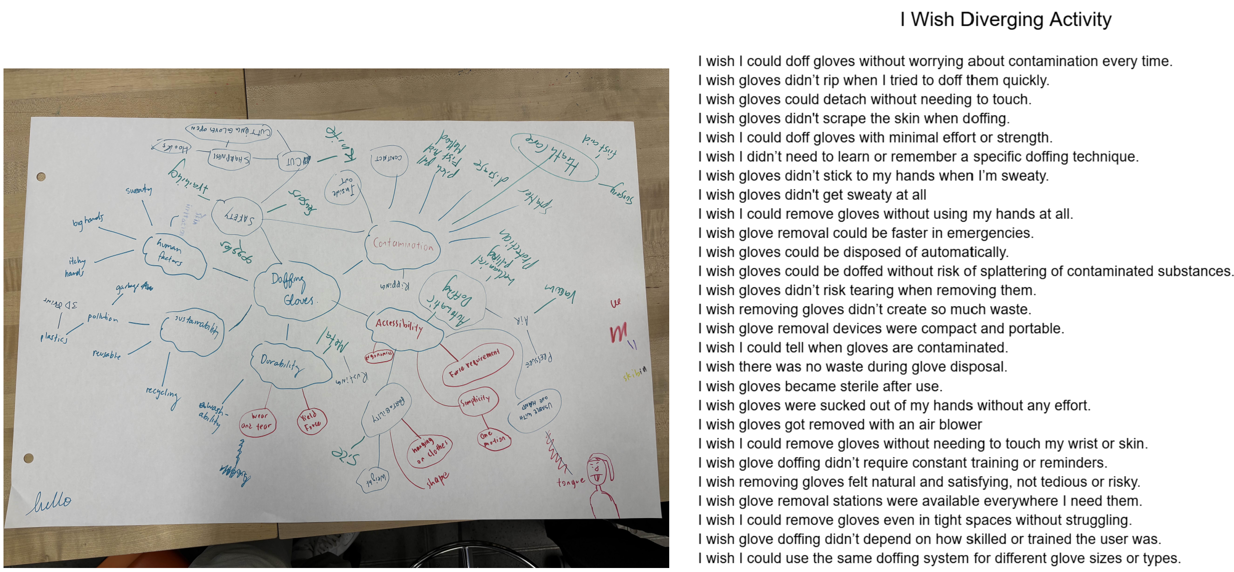
3.3.1 Load Tolerance

Device must be able to withstand loads that are much higher than its typical operational load.
Method: Apply a force three times the operational load determined in evaluation criteria 3.2.1 [12].
Requirement: Device must not break.
Evaluation Criteria: No evaluation criteria needed.
Connection to Stakeholders: A device that withstands many times its operational load ensures that our stakeholders are not left vulnerable due to sudden device failure.

4 Diverging Process

To come up with design ideas, our team utilized three diverging techniques learned during the Praxis 1 studios.

4.1 Utilized Techniques


I Wish Diverging Activity

I wish I could doff gloves without worrying about contamination every time.
I wish gloves didn't rip when I tried to doff them quickly.
I wish gloves could detach without needing to touch.
I wish gloves didn't scrape the skin when doffing.
I wish I could doff gloves with minimal effort or strength.
I wish I didn't need to learn or remember a specific doffing technique.
I wish gloves didn't stick to my hands when I'm sweaty.
I wish gloves didn't get sweaty at all
I wish I could remove gloves without using my hands at all.
I wish glove removal could be faster in emergencies.
I wish gloves could be disposed of automatically.
I wish gloves could be doffed without risk of splattering of contaminated substances.
I wish gloves didn't risk tearing when removing them.
I wish removing gloves didn't create so much waste.
I wish glove removal devices were compact and portable.
I wish I could tell when gloves are contaminated.
I wish there was no waste during glove disposal.
I wish gloves became sterile after use.
I wish gloves were sucked out of my hands without any effort.
I wish gloves got removed with an air blower
I wish I could remove gloves without needing to touch my wrist or skin.
I wish glove doffing didn't require constant training or reminders.
I wish removing gloves felt natural and satisfying, not tedious or risky.
I wish glove removal stations were available everywhere I need them.
I wish I could remove gloves even in tight spaces without struggling.
I wish glove doffing didn't depend on how skilled or trained the user was.
I wish I could use the same doffing system for different glove sizes or types.

(a) Lotus Blossom Chart **(b)** I Wish Activity

Figure 2: The Lotus Blossom and I Wish Diverging Activities

In order to generate a broad range of possible design ideas with as little bias as possible, our team used three key systematic diverging techniques: the Lotus Blossom technique, a Morph Chart, and "I Wish" statements. These three tools combined allowed us to become less cognitively anchored to biases such as the existing hook reference design.

During the start of our diverging, we utilized the Lotus Blossom and "I Wish" statements (Figure 2) to come up with ideas for individual aspects of the problem, such as safety, durability, or ergonomics. By shrinking the scope of the problem space, we limited the implicit desire of wanting to satisfy all the requirements simultaneously. By reducing complexity in this way, we were ultimately able to grow our design space, allowing us to noticeably develop more creative ideas with reduced confirmation and anchoring bias. Specifically, this deconstruction prevented the team from fixating on our initial anchor (the Slicing design) by forcing the generation of solutions for isolated sub-functions rather than whole doffing devices. Although these two diverging techniques did not directly result in any prototypes, they were crucial as a form of abstraction before the Morph Chart.

4.2 Morph Chart

Following the Lotus Blossom and "I Wish" statements, we utilized a Morph Chart figure 3 to organize ideas we came up with into rudimentary aspects. This included device mounting, doffing mechanisms, and glove disposal mechanisms. By breaking down each specific functions, we were able to mix and combine different aspects to synthesize new prototype designs 4, 5, and 6, which were not initially intuitive or self-evident. Furthermore, the focus required to populate the 'doffing' column sparked the inception of the tape design, as we were compelled to simplify the doffing mechanism into a minimum, elementary action. The morph chart in its entirety allowed a focused and reduced design space to help us remove constraints and generate ideas.

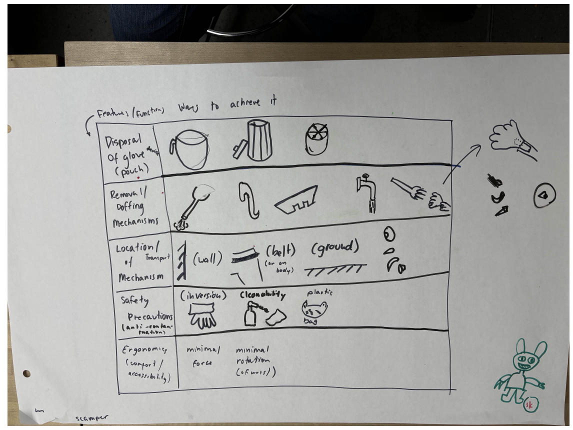


Figure 3: Picture of our Morph Chart

5 Prototypes

The following section outlines all five of our initial prototypes.

5.1 Hook Design

This design was heavily influenced by an existing hook-style reference design [13], which uses a fixed hook inserted between the glove and hand as leverage to slide the glove off of the hand. We adapted this concept by scaling the hook down and redesigning the mounting system to fit securely on a belt, improving portability. This design preserves the simple and intuitive nature of a hook design, while increasing its usability for EngSci students who work in dynamic environments.

Figure 4: 3rd iteration of hook design based upon the reference design [13]

5.2 Glove Slicing Design

Instead of doffing the glove, an alternative solution is to simply cut the glove open using a shielded blade. We speculated that this would result in less splatter of the contaminants on the glove, which was confirmed by our testing [Appendix A]. Additionally, the design figure 5 is light and is attached to your belt (see 6.1) which allows for increased portability. One concern for this design, however, is that an exposed blade may be hazardous for anyone working in a contaminated environment. Since any sort of cut or open wound could be incredibly vulnerable to pathogens and bacteria [15], this design needs a specific requirement that the blade must be impossible to reach with any size hand.

Figure 5: 4th iteration of glove slicing design

5.3 Tape Design

This is our simplest design concept, involving a small piece of tape or a pull-tab adhered to the inner wrist cuff of the glove. The design adds a physical feature that users can easily grasp, allowing them to peel the glove off in a controlled motion. This design imitates the standard doffing procedure [3], but the addition of the tab reduces the need for sliding fingers under the cuff, minimizing risks and maximizing ergonomics. Early testing showed that this design inverted the glove during removal, which contained the contaminants inside of the glove. However, testing also demonstrated that an external glove tab (see Figure 6) may become contaminated during the usage of gloves. In order to avoid exposing the user to contaminated surfaces, the tab must be tucked under the cuff of the glove before doffing.

Figure 6: The final tape doffing design

5.4 Air Blower Design

In this design concept, the device directs a controlled burst of air into the glove, inflating it slightly to loosen the cuff and make removal easier. While the concept is viable in theory, early testing with a bike pump showed that moderately pressured air was not enough to overcome the friction between the hand and the glove, especially when there was moisture on the hands. Furthermore, this design does not meet the portability evaluation criteria, as most air blowers are either large, heavy or require air tanks to operate. Therefore, the air-blower concept was excluded from further development due to limited effectiveness and portability.

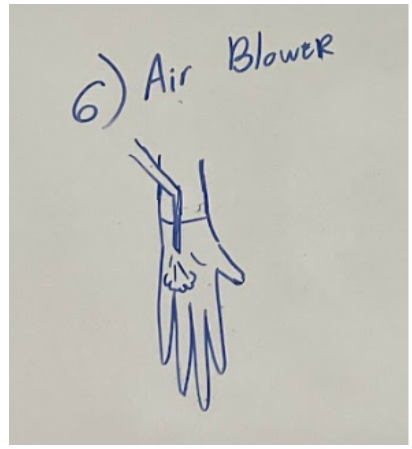


Figure 7: Sketch of air blower prototype

5.5 Water Pump Design

Similar to the air-blower concept, this design involves pumping water into the glove through a nozzle positioned at the wrist. The tap nozzle fills the glove with water, and as the glove fills up, the weight and flow of the water help push the glove off and fall into the sink. Although this worked as intended when prototype testing with a tap in the Engineering Science common room kitchen, this design also exhibited similar problems to the Air Blower design. Any design involving pumping water would require heavy setup, which means that this would not meet the portability requirement. Furthermore, pumping water into the glove may cause a variety of different complications, such as increasing and more unpredictable splatter (which happened with our prototype), or water reacting with substances on the glove. Therefore, the Water Pump concept was also excluded from further development.

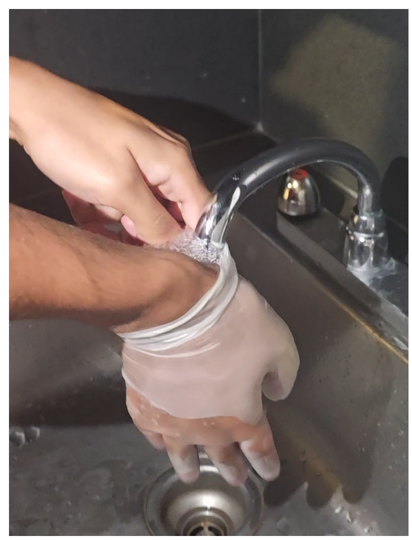


Figure 8: Testing of the water glove doffing design concept

6 Design Iterations

This section outlines all of our design iterations for the Hook and Glove Slicing designs. Note that the design decisions and iterations for the tape design are discussed in the recommended design section.

6.1 Justifying Mount Belt usage

Many of our hook and glove splicing designs include belt mounts. Belts allow for our prototypes to be significantly lighter and allow for doffing in mobile environments due to not needing a stationary mount. Additionally, using a body mount like a belt acts as the anchor, allowing the user to use their arm as leverage to doff the glove. Finally, the belt mount allows the portability requirement to be met.

To address the constraint that not all Engineering Science students wear belts, the mounting mechanism can be removed from the person and mounted to stationary objects, such as a desk edge or wall rail, effectively converting it into a stationary unit when workspace permits.

However, the body-mounted design offers distinct advantages for some of our other stakeholders: first responders. Unlike most students, these stakeholders operate in dynamic environments where a stationary table is rarely available, and as part of their uniforms, many emergency personnel regularly wear duty belts [14]. This aligns with the portability requirement derived for dynamic environments, ensuring the solution is scalable beyond the laboratory setting.

6.2 Hook - First Iteration

Figure 9 shows our first hook design. It was essentially the reference design [13], but modified to fit within the dimensions of our 3D printer.

Figure 9: 1st iteration of hook design

6.3 Hook - Iteration 2

Figure 10 shows our second hook design. It was a 60% scaled-down version of the reference design [13] to cater towards our portability evaluation criteria. Additionally, it was mounted on top of the belt hoops, also for reasons of portability.

Figure 10: 2nd iteration of hook design

6.4 Hook - Iteration 3

Figure 11 shows our final hook design. The width of the hook was increased to decrease the stress the hook experiences during doffing. During testing, however, iterations 2 and 3, which focused on portability and lowering the required force, failed the 3× load requirement and were significantly outperformed by Iteration 1 in both doffing time and contact rates [Appendix A]. Therefore, the hook iteration that will be compared to the other designs is Iteration 1, making a tradeoff of slightly less accessibility and portability for more safety, efficiency, and durability.

Figure 11: 3rd iteration of hook design

6.5 Glove Slicing - Iteration 1

Figure 12 shows our first glove slicing design with dual blades. There was an attempt to shield the hand from cutting by making the depth of the device larger, but the blades are very exposed.

Figure 12: 1st iteration of glove slicing design

6.6 Glove Slicing - Iteration 2

The second iteration (Figure 15) switches to one blade in an attempt to shield the blade's outer contact. Additionally, the doors to replace the blades are moved belt-side to prevent accidental opening during operation.

Figure 13: 2nd iteration of glove slicing design

6.7 Glove Slicing - Iteration 3

The third iteration (Figure 14) reduces the width of the cutting slit to protect users with smaller fingers. From testing, accidental injury from the blade is now impossible due to the width of the slit. The cutting door was kept from iteration 2.

Figure 14: 3rd iteration of glove slicing design

6.8 Glove Slicing - Final Iteration

The fourth and final iteration (Figure 15) re-adds the second blade after it was found that the first 2-bladed design from iteration 1 significantly outperformed iterations 2 and 3 in cutting time. The blade-swapping door from iteration 2 and the thinner cutting slip from iteration 3 were kept. Additionally, the depth of the cutter was halved to decrease doffing time. From testing [Appendix A], the final iteration outperformed the previous iterations in all metrics (doffing time, weight, splatter, and doffing force).

Figure 15: Final iteration of glove slicing design

7 Testing and Comparing Designs

To converge toward a final recommendation, we conducted a series of low-fidelity proxy tests to evaluate each prototype against the requirements and evaluation criteria outlined in

Section 3. The goal of these tests was not to obtain precise engineering measurements, but to generate comparative evidence that could distinguish the performance characteristics of each concept.

7.1 Proxy Tests

Each prototype was tested using simple, repeatable procedures designed to approximate the criteria introduced in our Requirements. The following proxy tests were performed:

- **Contact contamination:** Gloves were covered in dye diluted with water and doffed. After doffing, the tester's hand was inspected for any visible stains. The number of contacts were recorded over 20 trials, and was converted into a contact rate.
- **Splatter tests:** Gloves were covered in dye diluted with water and doffed with a white poster paper laid out in front of tester. Two boxes were made at the 2ft and 3ft location to simulate bins. Splatter droplets at each location were counted after each trial, and averaged.
- **Operational force:** While doffing, the downward force applied on the device was measured using a kitchen scale. The maximum value in grams was record, then converted into Newtons to find $F_{\max}$.
- **Time to doff:** The time required to remove the gloves from both hands was measured with a phone timer and averaged over 5 trials.
- **Portability:** Mass of each device was measured with a kitchen scale.
- **3× load:** Each device was loaded with continuously increasing force until reaching three times its measured operational load. Devices were visually inspected for deformation or failure.

Using the test results, the measurement matrix of our 3 remaining designs is shown in Figure 16.

Measurement Matrix Against Key Evaluation Criteria

Design	Tape	Slicer	Hook	Requirement
Contact (%)	5	10	25	37
Splatter 2ft (# of drops)	3.2	2.4	28	26.5
Splatter 3ft (# of drops)	0	0	2.6	6.6
Fmax (N)	15.21	17.78	51.47	22.2
Time to doff (s)	8.82	9.46	28.46	10.9
Mass (g)	0.5	22	75	500
Failure at 3x Load?	No	No	No	No

Figure 16: Measurement Matrix for key evaluation criterion for the remaining designs. Requirements are shaded in yellow, best performance in each metric is shaded with green, and performances that do not meet the requirements are shaded in red.

7.2 Interpreting the Data

While proxy tests were low-fidelity, they produced clear performance trends:
Strengths of the data: The tests directly reflect the evaluation criteria defined earlier, facilitating comparison between designs. Because all prototypes were evaluated under identical procedures, relative performance differences are meaningful even if absolute precision is limited.

Limitations of the data: Sample sizes were small, so randomness might have affected some results.

For the splatter test, instead of the two bin setup used in the original experiment [9], we adapted the experiment and drew equivalent areas on paper on the ground. Amount of drops of contaminant were compared to the added amount on top and on the side of the bins from the experiment.

Despite these limitations, the data sufficiently supports comparative decision-making in the scope of a Praxis 1 Design Report.

7.3 Comparing Designs

In order to converge, we constructed the following Pugh charts based on our testing metrics.

The first Pugh Chart was the Tape and Slicer concepts against the Hook design, as shown in Figure 17. By using the Hook design as a reference, it is made very clear that both the Tape and Slicer designs are superior from it in every single metric (see Measurement Matrix).

Pugh Chart compared with Hook

Design	Tape	Slicer	Hook
Contact	better	better	same
Splatter 2ft	better	better	same
Splatter 3ft	better	better	same
Fmax	better	better	same
Time to doff	better	better	same
Mass	better	better	same

Figure 17: Pugh chart of Tape and Slicer compared with hook. Metrics with better performance is shaded in green.

With the Hook design rendered the worst of the designs, the converging process shifted to the relative advantages of the remaining concepts: Tape and Slicer. To do this, we developed a second Pugh chart with the Tape design as the reference. It is shown in Figure 18 how the tape design outperforms the slicer design, being better in four out of six categories. However, claiming the tape design is the design of choice cannot be done after purely examining the Pugh chart. Thus, a holistic evaluation has to be made.

Pugh Chart compared with Tape

Design	Tape	Slicer	Hook
Contact	same	worse	worse
Splatter 2ft	same	better	worse
Splatter 3ft	same	same	worse
Fmax	same	worse	worse
Time to doff	same	worse	worse
Mass	same	worse	worse

Figure 18: Pugh chart of Tape and Slicer compared with hook. Metrics with better performance is shaded in green, worse performance in red, and same performance in yellow.

7.4 Holistic Evaluation

To make a more informed decision, we surveyed 10 first-year EngSci students to compare our stakeholder's preference between the Slicer and Tape designs [Appendix B]. 7 students preferred the Tape, one student had no answer and 2 preferred the Slicer.

To further examine the Tape design in a broader scope, we can evaluate the scope of stakeholders it applies to (since we want it to impact as many as we can). While the Hook and Slicer designs must be mounted on either a belt or a different rigid body, the Tape can be used anywhere without the need of mounts, since it is attached directly onto the glove. Therefore, the tape design has the potential to benefit more of our stakeholders.

Steelmanning + Counterclaim: The Glove Slicing design meets all the requirements, does as well as the Tape in the safety evaluation criteria, has the blade isolated from reach, and performs better than both the Hook reference design and the standard hand-doffing procedure in the evaluation criteria. While reasonable to say that the Glove Slicing mechanism may be the design of choice, this interpretation does not hold when examined more holistically. While the Slicer matches the Tape design in safety evaluations, it introduces additional risks through its blade mechanism, greater force requirement, more weight, and more complexity. The Tape Design's better performance in most evaluation criteria, coupled with the results from the Appendix B survey and the belt limitation for the slicing design indicate that the Tape is the design that fits out stakeholder needs the most.

8 Final Design Recommendation - The Tape Design

Ultimately, the factors discussed in the Holistic Evaluation make the Tape design the safest, most accessible, and stakeholder-aligned design.

8.1 Design Decision 1

Our first design decision for testing the tape design uses clear scotch tape as the tab. The tab is one continuous 18cm piece folded onto the glove and itself so that 9cm sticks out beyond the edge of the glove. The 9 cm tab satisfies the recommendation that a tab should be large enough to grip between the thumb and the knuckle [16].

Figure 19: The first tape doffing design

8.2 Design Decision 2

From testing the first design iteration (Figure 18), it was found that it could be hard to locate the tab quickly during testing, especially for the tucked-in tab, as both the vinyl glove and the tape tab were transparent. To solve this, bright green 3M 401+ high-performance paint-bleed-resistant masking tape [17] was used to make the tab visible, while also resisting damage from moisture, speculating it would make doffing more efficient. Testing proved our speculation right, as we found from testing that dual hand doffing time with green tape was on average 1.31 seconds faster than with clear tape [Appendix A]. Contact and max force had small changes, which can be attributed to randomness, considering the small sample size. The second iteration can be seen in Figure 20.

Figure 20: The Second tape doffing design

8.3 Design Decision 3

For the final iteration (Figure 21), we used the same 18cm strip setup as iteration 1 and the green 3M 401+ high-performance paint-bleed-resistant masking tape [17], but we placed the tape parallel to the thumb. Through experimental testing, where we varied the placement of the tape, it was found that 8 out of 10 users [Appendix B] felt the least discomfort when the tape was positioned on the thumb area, in addition to having the fastest doffing time and lowest max force.

Figure 21: The Final tape doffing design

9 Conclusion

This design report sought to address the lack of safe and accessible methods for doffing disposable gloves, a challenge prevalent among Engineering Science students and first responders. Through a structured diverging process utilizing Lotus Blossom, "I Wish," and the Morph Chart techniques, the team moved beyond our cognitive biases to develop three distinct prototypes: the Hook, the Glove Slicing mechanism, and the Tape design.

Subsequently, the team performed proxy tests which revealed disparities between the three designs. The Hook design was deemed unsuitable as its operational force of 51.47 N and its performance in other metrics compared against other designs were poor. While the slicing method performed well and met all metrics, after a holistic evaluation, it was determined that the tape design was the more desired option.

This solution demonstrated superior performance across all critical metrics, achieving a minimized contact rate of 5%, an average doffing time of 8.82 seconds, and a negligible mass of 0.5 g. Furthermore, user feedback from Engineering Science students heavily favored this design (70% preference) due to its comfort and similarity to standard doffing procedures.

The tape design requires no external mounting, offering the most compatibility for our stakeholders (in both stationary and dynamic environments). This design report demonstrated how an intuitive, low complexity solution that mimics and optimizes the standard glove doffing procedure can outperform more intricate and sophisticated alternatives. By providing this final recommendation, the team delivers a solution to the opportunity that can integrate into the daily lives of students and first responders, ensuring that their safety is not compromised.

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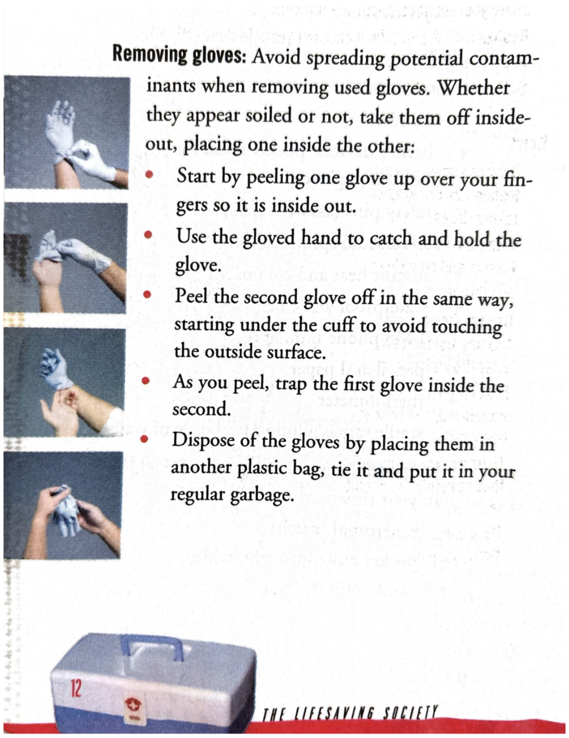
10.2 Source Extracts

10.2.1 ESC101 Studio [1]

This extract depicts first-year EngSci student using vinyl disposable gloves during Praxis Teardown

10.2.2 Canadian First Aid Manual [4]

This extract depicts the Lifesaving Society's method used to remove gloves.



Removing gloves: Avoid spreading potential contaminants when removing used gloves. Whether they appear soiled or not, take them off inside-out, placing one inside the other:

- Start by peeling one glove up over your fingers so it is inside out.
- Use the gloved hand to catch and hold the glove.
- Peel the second glove off in the same way, starting under the cuff to avoid touching the outside surface.
- As you peel, trap the first glove inside the second.
- Dispose of the gloves by placing them in another plastic bag, tie it and put it in your regular garbage.

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10.2.3 UTEFR [8]

This extract depicts two UTEFR members rescue breaths to a manikin, one of them wearing gloves.

11 Appendix

11.1 Appendix A: Data From Testing

11.1.1 Measurement Matrices Between Iterations

Measurement Matrix Of Hook Iterations

Iteration	1	2	3	Requirement
Contact (%)	25	35	30	37
Fmax (N)	51.47	26.79	32.58	22.2
Time to doff (s)	28.46	43.22	39.83	10.9
Mass (g)	75	33	42	500
Failure at 3x Load?	No	Yes	Yes	No

Measurement Matrix Of Slicer Iterations

Iteration	1	2	3	4	Requirement
Contact (%)	15	20	15	10	37
Fmax (N)	25.59	34.55	30.23	17.78	22.2
Time to doff (s)	10.34	16.29	14.7	9.46	10.9
Mass (g)	27	28	29	22	500
Failure at 3x Load?	No	No	No	No	No

Measurement Matrix Of Tape Iterations

Iteration	1	2	3	Requirement
Contact (%)	10	5	5	37
Fmax (N)	16.78	17.02	15.21	22.2
Time to doff (s)	10.74	9.43	8.82	10.9
Mass (g)	0.5	0.5	0.5	500
Failure at 3x Load?	No	No	No	No

11.1.2 Testing With 3 Remaining Designs

Contact Rate Test

Design	Tape	Slicer	Hook	Requirement
contact(#)	1	2	5	7.4
contact(%) 20 trials	5%	10%	25%	37%

Portability Test

Design	Tape	Hook	Slicer	Requirement
Mass(g)	0.5	75	22	500

Operational Load Test

Design	Tape	Slicer	Hook	Requirement
Fmax(N)	15.21	17.78	51.47	22.2
Failure at 3x Load?	No	No	No	No

Operational Load Test

Design	Tape	Slicer	Hook	Requirement
Fmax(N)	15.21	17.78	51.47	22.2
Failure at 3x Load?	No	No	No	No

			Splatter Test				
trial #	1	2	3	4	5	AVERAGE	Requirement
Tape splatter @ 2ft	4	2	4	3	3	3.2	26.5
Tape splatter@ 3ft	0	0	0	0	0	0	6.6
Slicer splatter @ 2ft	2	4	3	1	2	2.4	26.5
Slicer splatter@ 3ft	0	0	0	0	0	0	6.6
Hook splatter @2ft	28	30	30	25	27	28	26.5
Hook splatter @3ft	3	1	3	4	2	2.6	6.6

11.2 Appendix B: Student Survey

Engineering Science student surveys		
Name	Choice	Choice
Student 1	Tape	Palm
Student 2	Tape	Thumb
Student 3	Tape	Thumb
Student 4	Slicer	Thumb
Student 5	Tape	Thumb
Student 6	Tape	Palm
Student 7	Tape	THumb
Student 8	Tape	Thumb
Student 9	No decision	Thumb
Student 10	Tape	Thumb

Figure 22: 10 Uoft Engineering Science students were given the 3 designs(Tape, Slicer, Hook) and asked which was the most comfortable to doff, along with which tape placement(tape on palm or thumb) is the most comfortable. The survey results are shown in this table. Student 9 claimed that she could not make a decision between tape and slicer.

11.3 Appendix C: Design Brief

Doffing Disposable Gloves
A Design Brief

Anonymous Authors

Oct 11th, 2025

1783 words

Contents

1 Introduction

This design brief outlines the ergonomic issues associated with doffing (removing) disposable one-time-use gloves safely. It provides a set of engineering Needs, Goals, and Objectives (NGOs) for a design solution with a focus on safety and accessibility. Using disposable gloves is a universal experience for members of the 2T9 Engineering Science (EngSci) Community, whether for extracurricular or in-class activities. Unfortunately, current strategies for removing such gloves without contamination often result in pinching or discomfort for the user. Therefore, this design brief aims to provide a set of NGOs to inform and inspire safe and usability-focused designs that can be used by the 2T9 Engineering Science community to doff disposable gloves desirably.

1.1 Definitions

Figure 1: Examples of "disposable gloves"

Definitions

The gloves that are addressed by this design brief have the following characteristics:

1. They satisfy ISO 25518:2021 [1], "Single-use rubber gloves for general applications".
2. They are stretchy and conform to your hand and are commonly made of Nitrile, Latex, Vinyl, or Polychloroprene [2].
3. The gloves can be "Textured", "non-Textured", "Powdered", or "Powder-Free" [1].
4. They have a cuff terminated by either a smooth or rolled rim.

1.2 Stakeholders

Disposable gloves are used by a diverse set of users in their daily activities. Each stakeholder has different interests and levels of influence in framing the space of this opportunity.

The **primary stakeholders** in this opportunity are UofT students who may use disposable gloves in laboratory settings. Many first-year EngSci students also used disposable gloves for Studio 2 (Teardown), making glove doffing a firsthand experience. Beyond academic situations, glove usage also comes from personal interests (such as first aid), extracurriculars, and employment (such as lifeguarding), in which all students participate. The original design brief team includes a member of the UofT First Responders team, UTEFR. Figure 2 depicts members of UTEFR in training action.

Figure 2: UTEFR member (left) delivering rescue breaths to a manikin, while another (right) holds it wearing gloves.

Beyond these groups are **secondary stakeholders**, those who may not use gloves regularly. This includes, but is not limited to, UofT staff (professors and administration) and the remaining EngSci students who do not fall into the above categories. These stakeholders **indirectly** benefit from the improved hygiene and waste management that correct doffing provides, so it is important to keep them satisfied.

The broad range of stakeholders shows that glove removal is **not isolated** to one environment, making it a legitimate opportunity to explore in the context of engineering design.

1.3 Background

Figure 3 depicts a poster explaining a six-step method for safely doffing a pair of gloves. This method involves a **pinch, pull, slide technique**. The end result consists of two inverted gloves (the non-contaminated side on the outside). This is the current, standard method used for doffing gloves and is taught within many first aid courses in Canada. This standard is defined by The Royal Lifesaving Society [3], making this standard credible and appealing to stakeholders' **ethos**.

This technique is uncomfortable and cumbersome. These challenges are compounded during repeated use. Prolonged glove wear causes heat and moisture buildup, increasing friction and adhesion between the glove and hand.

Figure 3: Six-step poster on how to safely remove gloves (Watson Gloves, 2020).

1.4 Justification

Although the current standard reduces contamination, it is inefficient and unintuitive. A study investigating the patterns of doffing practices adopted by healthcare workers [4] found that 21% of workers doff their gloves incorrectly. About **91% of errors were avoidable** (44% incaution, 47% non-inversion), showing that even trained users struggle. A more accessible method could reduce contamination while improving comfort and reliability. These findings justify the pursuit of improved glove doffing methods, those that make doffing quicker and easier, such as methods that do not require inversion.

2 Reference Designs

There are few existing reference designs related to doffing gloves. The few reference designs can broadly be divided into two main categories: **hooks** and **air machines**. Each has advantages and disadvantages, and a good design should incorporate characteristics from **both**. Most reference designs keep the contaminated side of the glove exposed, rather than turning it **inside out**. Each of these reference designs is useful for **framing** different **goals** and **objectives**.

2.1 Hook Designs

Although designs that **solely** rely on hooks are efficient in taking the gloves off, working in an analog way as the fingers in the procedure for doffing the second glove, they can cause the cuffs of the gloves to scrape and similarly create discomfort on the skin, especially when the hand is sweaty.

Most existing hook designs consist of simple static-mounted hooks (Figure 4), which are **not portable** and therefore impractical in dynamic environments. This can be a problem for people who must change gloves quickly in the field, such as UofT students in UTEFR.

The only portable design (Figure 5) is **unusable for anyone wearing two gloves**, as it requires one non-contaminated hand to use. Additionally, its geometry places the user's hand near the contaminated glove surface, **facilitating contamination** from contact and splatter.

Figure 4. Fixed hook reference design [5]

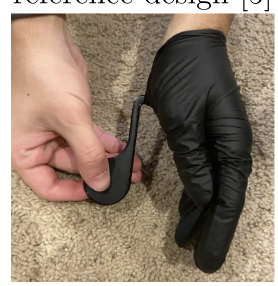


Figure 5. Portable hook reference design [6]

2.2 Air-Powered Designs

Most air-powered reference designs use **vacuum** chambers for doffing gloves. Vacuum systems are **non-portable**, can cause hand **injuries** from pressure, and **often fail** to remove gloves fully when **moist**. Vacuum machines would also require **subsequent cleanings** after doffing the contaminated gloves, which should be avoided in a solution for this opportunity.

One reference design (Figure 7) utilizes air ventilation to facilitate glove doffing. Although the stated reference design only works for **single-size gloves** (the design should work for multiple glove sizes) of a **different material**, the air ventilation idea could be implemented in a design for this opportunity.

If a design were to be considered an air machine, the designer should be **careful** to keep the vacuum or air dispenser from **splattering** the substances found on the glove. Additionally, the machine should be designed to be **easy to clean** without the risk of compromising its functionality or safety.

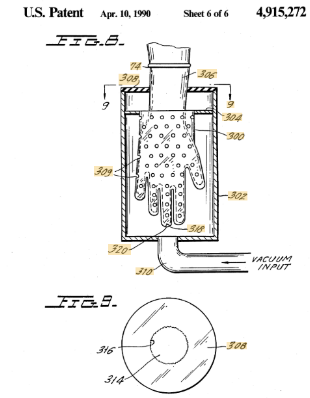


Figure 6. Vacuum reference design [7]

Figure 7. Air dispenser reference design [8]

3 Need, Goals, Objectives

The reference designs above do not fully satisfy all the requirements that define an excellent solution to this opportunity. The following section establishes a structured set of Needs, Goals, and Objectives that address these shortcomings to guide the development of an improved design.

3.1 Need

Need: A safe and accessible way to take off disposable gloves.

This need captures the critical challenge faced by glove users across medical, laboratory, and emergency settings; reliably removing disposable gloves without **contamination** or **discomfort**. It emphasizes the importance of a design that balances safety and ergonomics, ensuring reliable glove removal for users with varying strength, dexterity, and experience.

3.2 Design for Safety

Goal 1: Ensure the glove-doffing process prevents contamination and injury to the user and the surrounding environment.

Following IEC 62366-1 [9], safety in glove doffing requires preventing contamination from skin contact or splatter. The objectives below define measurable safety criteria.

Table 1: Goal 1 — Safety criteria and acceptance thresholds.

Objective	**Criterion**	**Metric**	**Threshold**
1.1 Contact	No direct contact between bare skin and the outer glove surface during removal.	Compare standard vs. device-assisted doffing across 100 trials; count any skin to glove exterior contact events.	$\leq$ 3% of trials with any contact.
1.2 Splat-ter	No splatter of glove substances to surroundings.	Glove coated with fluorescent solution; collect bins at 2 and 3 ft and quantify under UV light.	Better results than regular doffing [10] across 50 trials.

[a] Healthcare workers show ~21% incorrect doffing; most are avoidable errors [4]. The 3% target sets a significantly safer bar for this device.

Further description and Justification.

1. **1.1 Contact:** Define a contact event as any bare-skin touch of the glove exterior during removal. Even small contact between the glove and hands can cause contamination in a sterile environment.
2. **1.2 Splatter:** Controlling substance splatter matters; stretching and releasing gloves can fling contaminants into the environment, which is unacceptable in sterile settings. Same metric and method used in research found [10].

3.3 Design for Accessibility

Goal 2: Provide an easily accessible and ergonomically comfortable method operable by users with varying strength, dexterity, and mobility.

According to the 2010 ADA Standards for Accessible Design [11], accessibility requires that all users can operate a device safely and comfortably regardless of strength, dexterity, and mobility. The following objectives define how ease of use and universal accessibility are measured and verified through standardized testing and usability evaluations.

Table 2: Goal 2 — Accessibility criteria and acceptance thresholds.

Objective	Criterion	Metric	Threshold
2.1 Force	Avoid excessive force causing discomfort.	Measure peak $F_{\max}$ for five hand sizes with a force sensor aligned to the device's pull path (3 trials per size).	$F_{\max} \leq 22.2\,\mathrm{N}\,(5\,\mathrm{lb})$ ADA Standard [11] for all trials.
2.2 One-hand operation	Operable with one hand without pinching/twisting (ADA Standard [11])	Time 30 or more trials of single-handed use by representative users. time = t	Pass if $t_{avg} < 5$ and all trials $t < 7\,\mathrm{s}$.
2.3 Size & materials	Works across sizes and common glove materials.	Test four materials (latex, nitrile, vinyl, polychloroprene) × five ISO sizes; repeat important Goal 1 and 2 tests.	All combinations meet Safety (Goal 1) and Force (Objective 2.1) thresholds.
2.4 Portability	Light and usable in the field.	Weight of the device.	500g is the ergonomic limit for precision tools attached to a belt[12].

Further Description and Justification:

1. **2.1 Force:** The mechanism should respond to light force to prevent cumulative strain on wrists and arms, ensuring accessbility for users with reduced strength or dexterity.
2. **2.2 One Hand Operation:** The device should enable smooth, low-effort operation to minimize strain and ensure comfort during repeated use.
3. **2.3 Size & Materials:** Testing all material and hand sizes ensures broad applicability in varied environments such as laboratories, hospitals, and kitchens.
4. **2.4 Portability:** For a design to be usable and effective in the field, it must not weight much so it can be carried and moved around easily.

3.4 Design for Durability

Goal 3: Ensure long-term reliability and performance after repeated and realistic use.
While safety and accessibility are primary needs, durability is equally vital. A design that wears out quickly loses those benefits. As defined in ISO 13823:2008 [13], the limit state occurs when a mechanism can no longer function due to degradation from repeated use,

loading, or cleaning. The following objectives outline these limits in three ways.

Table 3: Goal 3 — Durability criteria and acceptance thresholds.

Objective	Criterion	Metric	Threshold
3.1 Life-Cycle	Maintain performance across all previous objectives with repeated use.	Run > 1000 [14] removal cycles; record success rate.	Success rate does not drop by more than one standard deviation.
3.2 Load Tolerance	Resist structural failure under standard operational load.	Increase force with e-gauge until failure; record yield force.	Failure $\geq 3 \times$ operational load ($\approx 66.6\,\mathrm{N}$).
3.3 Cleanability	Remain functional after cleaning.	Perform 6 [15] detergent cleaning cycles; repeat key Safety/Accessibility tests.	Performance within one standard deviation of the pre-clean baseline.

Further Description and Justification:

1. **3.1 Life-Cycle:** Maintaining consistent performance throughout these trials demonstrates that the design resists mechanical wear and degradation over time, ensuring long-term reliability in regular use.
2. **3.2 Load Tolerance:** Design must demonstrate that it can endure repeated glove-removal cycles without degradation.
3. **3.3 Cleanability:** The design must maintain consistent functionality and structural integrity throughout. This ensures that repeated sanitation for use sterile environments does not cause degradation, wear, or measurable loss of performance.

4 Conclusion

In conclusion, this design brief has explained the opportunity of doffing disposable gloves, reviewed the strengths and drawbacks of some reference designs, and created a framework of Needs, Goals, and Objectives to guide and inform the development of a safe and accessible glove doffing device to be used by the 2T9 Engineering Science community. Prospective Praxis design teams are encouraged to build upon or modify these objectives through experimental validation and testing within realistic field environments. Finally, the creation of a successful disposable glove doffing design will not only improve glove doffing for Engineering Science students but may also contribute to safer practices in lab environments, emergency response, and other glove-dependent professions.

5 Appendix

5.1 Wet and Dry Glove Doffing Experiment

5.1.1 Purpose

To experimentally determine the time it takes to doff gloves using the standard defined by The Royal Lifesaving Society [3] in the 1.3 Background section.

5.1.2 Procedure:

Two hands of similar sizes, width $81mm$ and length $184mm$ (measuring defined by ISO 25518:2021 [1]) were used for this experiment. For the dry experiment, both hands were gloved, and the doffing time was recorded using a time app on an iPhone 16. For the wet experiment, the hands were coated with a total of approximately $5ml$ of water, where the hands were rubbed together, such that a thin layer of moisture coated the hands. The gloves were then similarly doffed and timed as the dry experiment. Medium sized nitrile gloves were used for this experiment.

5.1.3 Data

The following table contains the data collected for the 10 total wet and dry glove doffing trials in seconds.

Dry Glove	**Wet Glove**
8.38	10.35
7.47	8.98
8.25	11.31
7.45	8.52
8.21	9.53

Average Dry Glove Time: 7.95s Average Wet Glove Time: 9.74s

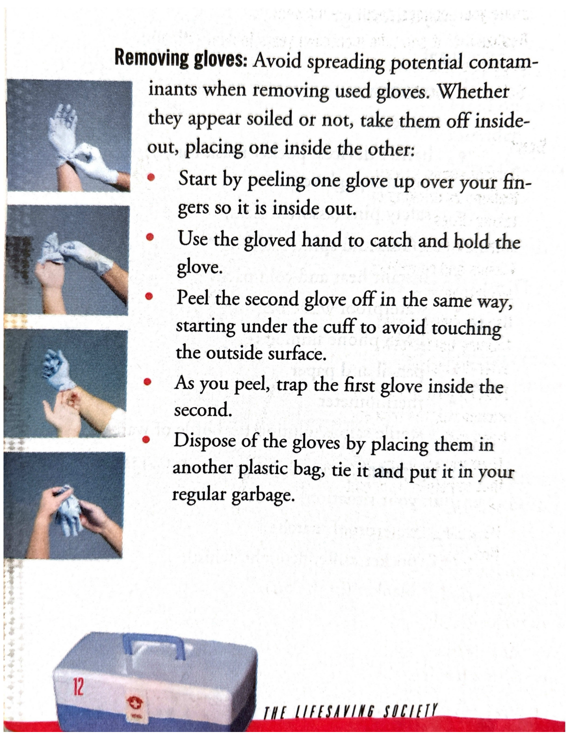
5.1.4 Analysis:

From our experiment, it was found that doffing wet gloves on average takes longer than doffing dry gloves, with respective times of 9.74s and 7.95s. The results found here are used to inform objective 2.2.

5.2 Source Extracts

5.2.1 Canadian First Aid Manual [3]

This extract depicts the Lifesaving Society's method used to remove gloves.



Removing gloves: Avoid spreading potential contaminants when removing used gloves. Whether they appear soiled or not, take them off inside-out, placing one inside the other:

- Start by peeling one glove up over your fingers so it is inside out.
- Use the gloved hand to catch and hold the glove.
- Peel the second glove off in the same way, starting under the cuff to avoid touching the outside surface.
- As you peel, trap the first glove inside the second.
- Dispose of the gloves by placing them in another plastic bag, tie it and put it in your regular garbage.

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5.2.2 Knife Sharpness Chart [10]

This extract depicts the sharpness chart used for source 10.

CLASSIFICATION OF SHARPNESS

Description	edge apex thickness		
	Micron	BESS	REST
Dull The edge reflects visible light.	> 1	> 500	> 5N
Working edge Fingernail test positive. Slices print paper and newspaper.	0.6-0.8	300-400	3-4N
Sharp E.g. quality cutlery out of the box. Slices a sales docket.	~ 0.5	250-300	2-3N
Very sharp E.g. utility knife blade (new). The edge doesn't reflect visible light.	0.3-0.4	150-200	1.4-1.8N
Shaving sharp (see all gradations below) Whittles soft wood.	0.3	160	1.5N
Wickedly sharp Edges less than thickness of a human hair cuticle of 0.3 micron; shaves against the skin.	< 0.3	< 150	
Nuts sharp Filleting/shaving print paper.	0.2-0.3	100-150	
Scary sharp Cuts cigarette rolling paper vertically. Hair violin sign.	0.2	100-110	< 1N
Crazy sharp	< 0.2	< 90	
Insane sharp Cuts a free hanging hair.	0.1-0.15	50-80	0.5-0.6N
Razor sharp Sharpness of the DE shaving razor Gillette. Splits hair.	<= 0.1	<= 50	0.3-0.4N
Sharper than razor Sharpness of the DE shaving razor Feather. Whittles hair. Cuts cigarette rolling paper horizontally.	~ 0.05	<= 30	<= 0.2N

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