Final Design Report

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MagClean: a magnet-powered whiteboard cleaning solution

Prepared for:
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1. Executive Summary

Design Problem and Context
In Northwestern's Design Thinking and Communication (DTC) classrooms, whiteboards are a central tool for instruction, but they are rarely cleaned thoroughly. Instructors often rely on small, inefficient erasers that leave behind ghosting (See Figure 1), smudging, and marker residue, especially on large boards used throughout the day, which lead to decreased legibility, wasted instructional time, and general frustration. DTC instructor Barbara Egel identified this issue and asked for a better solution: a classroom-scale whiteboard cleaner that is affordable, effective, and easy to use.



Figure 1: Ghosting on whiteboard

Team and Project Overview
To address this challenge, Team 32-1—Simon Kaminer, Paul Akpalu, Dominic Belyaev, and Diego Niiler—developed the MagClean Eraser. Over the course of a 10-week DTC design cycle, the team synthesized insights from multiple mockups into a functional final design that supports fast, ergonomic cleaning of large whiteboard surfaces. The result is a non-electric, low-cost tool optimized for daily classroom use.

Design Description and Key Features
The final MagClean Eraser prototype includes several key features designed to improve whiteboard cleaning speed, coverage, and ease of use:

- Telescoping Aluminum Pole (1.5–3 ft):
  Allows users of varying heights to reach high or wide board areas without needing a step

stool. This enhances accessibility and supports full-board cleaning in under a minute.

- Hinge Joint:
  Connects the pole to the eraser head, enabling fluid motion across multiple angles making strokes easier and more ergonomic.

- Dual-Surface Cleaning Pad:
  The erasing head features a central dry-erase eraser section surrounded by a border of microfiber cloth. This layout allows users to clean dry-erase marker residue with the center and simultaneously address ghosting and streaks using the microfiber border when lightly sprayed with solution.

- Magnetic Reinforcement:
  Neodymium magnets embedded behind the cleaning pad apply additional pressure between the eraser and board surface, making erasing more effective with less physical effort.

- Off-the-Shelf Materials:
  All components were selected for durability, affordability, and ease of sourcing. The design can be replicated or repaired using commonly available parts.

Outcomes and Future Potential
Early testing in classroom settings demonstrated that the MagClean Eraser reduced full-board cleaning time by nearly 50% compared to the standard DTC eraser. In tests using a 4,725 in^2 panel, users completed the task in 48–52 seconds with the MagClean, versus 98–105 seconds using the standard felt eraser. In a 35" × 31" spot-cleaning test, the MagClean Eraser completed the task in 8 seconds, compared to 14 seconds with the standard tool. Testers also noted that the MagClean Eraser required less physical effort and provided better reach, especially for taller panels. Visual inspection showed reduced ghosting and clearer surfaces with the MagClean Eraser.

While the current prototype meets the defined performance requirements for cleaning efficiency, user accessibility, and low cost, there is room for further refinement. Future iterations could explore an integrated spray mechanism or modular pad replacement. However, even in its present form, the MagClean Eraser addresses a widespread classroom need with a solution that is fast, low-cost, manually operable, and suitable for large vertical whiteboards.

2. Introduction

In high-use academic settings, like a DTC classroom, whiteboards play a central role in daily instruction, brainstorming, and collaborative design work. However, these large-format boards are often difficult to clean thoroughly and efficiently. Standard dry-erase erasers wear down quickly, leave behind smudging and ghosting, and require significant manual effort, particularly when covering broad surfaces multiple times per day. Instructors, including our project partner

Barbara Egel, the communications director for DTC, reported that board maintenance detracts from teaching time and limits how effectively she can use the full board surface [Appendix C]. This seemingly mundane issue has a large impact on the clarity and fluidity of communication in learning environments, making it both a common frustration and thus a worthy design challenge [Appendix A].

Given this need, Instructor Egel asked Team 32-1—composed of Simon Kaminer, Paul Akpalu, Dominic Belyaev, and Diego Niiler—to design a more effective whiteboard cleaner optimized for classroom-scale use. The project unfolded over a ten-week design cycle within the DTC course.

Existing commercial products often fall short in addressing the constraints and requirements of DTC classroom environments. Many automated or reservoir-based erasers are prohibitively expensive, require electrical power, or are designed for horizontal glass panels in office settings - not for large-scale vertical whiteboards.

In DTC classrooms, where whiteboards span a total area of 33,075 in^2 across seven panels, instructors have a 10-minute transition window between classes to reset the space. However, they are often simultaneously managing other tasks such as loading slides or speaking with students. Therefore, to meet the requirement for speed and minimal effort, the cleaning process should take no more than 3–5 minutes of active use, and achieve ≥85% ink removal on first pass, in line with our performance specification [Appendix A].

Additionally, the solution must be manual and non-electric, simple to operate, and effective for users of all heights, consistent with the defined user needs and constraints outlined in our Project Definition.

This report documents the development of our final design—the **MagClean Eraser**—and the rationale behind its key features. In the sections that follow, we describe the primary users and their needs, explain our design development process, present the final prototype, analyze its performance and limitations, and suggest directions for future work.

3. Users and Major Requirements

Our design was guided by several key requirements: the solution needed to be low-cost, intuitive to use, and manufacturable using commonly available materials. These requirements played a central role in shaping both our concept exploration and our final component choices [Appendix C].

Primary Users: DTC Instructors

The primary users of the MagClean Eraser are instructors within Northwestern's Design Thinking and Communication (DTC) program. These instructors rely heavily on large-format whiteboards to guide group discussions, illustrate design processes, and deliver lectures. Their

most pressing needs include a cleaner that can erase at least one full whiteboard panel measuring 8 feet 9 inches tall by 3 feet 9 inches wide (approximately 33 square feet) in under 10 minutes, reach the top of panels nearly 9 feet tall without requiring a step stool, and leave behind minimal marker residue [Appendix J]. Interviews with instructors emphasized frustration with current solutions, which often require 3–5 repeated passes and still leave behind marker residue.

Secondary Users: Classroom Support Staff

Secondary users include classroom and facilities staff responsible for preparing DTC classrooms for daily instruction. These individuals often conduct between-class resets or end-of-day cleaning, and thus benefit from a device that allows for fast, thorough, and low-effort cleaning without requiring additional training or tools [Appendix E]. Their feedback highlighted the importance of durability and simplicity in any tool left in public classroom spaces.

Stakeholders

Key stakeholders include (a) the DTC instructional team, who must coordinate schedules and classroom use; (b) the Engineering and Communication Program, which supports logistical needs and infrastructure; (c) the Segal Design Institute, which pays for the whiteboards; and (d) the broader McCormick teaching faculty, who may benefit from adoption of the design in future classrooms. These stakeholders value tools that are cost-effective, sustainable, and easy to maintain or replace.

Major Requirements

Reach and Ergonomics

Instructors should be able to reach the top of large whiteboards, specifically the DTC whiteboards, without using stools or stepping on chairs. These whiteboards consist of 7 panels that are about 9 feet tall and 4 feet wide [Appendix A]. Our design uses a telescoping aluminum pole that extends from 1.5 to 3 feet to accommodate users of various heights and classroom board layouts.

Surface Coverage and Pressure

The cleaner must make firm, consistent contact with the board surface to effectively remove dry-erase residue and reduce ghosting. A hinge joint allows multi-angle application of force, while embedded magnets increase cleaning pressure between the pad and the board [Appendix M].

Dry and Wet Cleaning Integration

Instructors often supplement dry-erasing with whiteboard cleaner spray. The final design integrates a hybrid pad: a ring of absorbent microfiber pads that can absorb cleaning solution surrounding two rows of 6 dry erasers, allowing for a seamless transition between dry and wet cleaning without changing tools [Appendix B].

Ease of Use and Maintenance

All components must be intuitive to use, easy to replace, and robust enough to survive regular classroom handling. The design should function without replacement for at least 6 months of regular use. [Appendix G].

Affordability and Scalability

All parts must be commercially available and inexpensive enough to support classroom-wide distribution. The final prototype has a total build cost under $45, making it viable for multiple-unit deployment [Appendix F].

Whiteboard Surface Protection

The whiteboard eraser should not cause any physical damage (e.g., scratching, ghosting, or surface wear) to standard commercial whiteboard surfaces over repeated use.

4. Our Approach

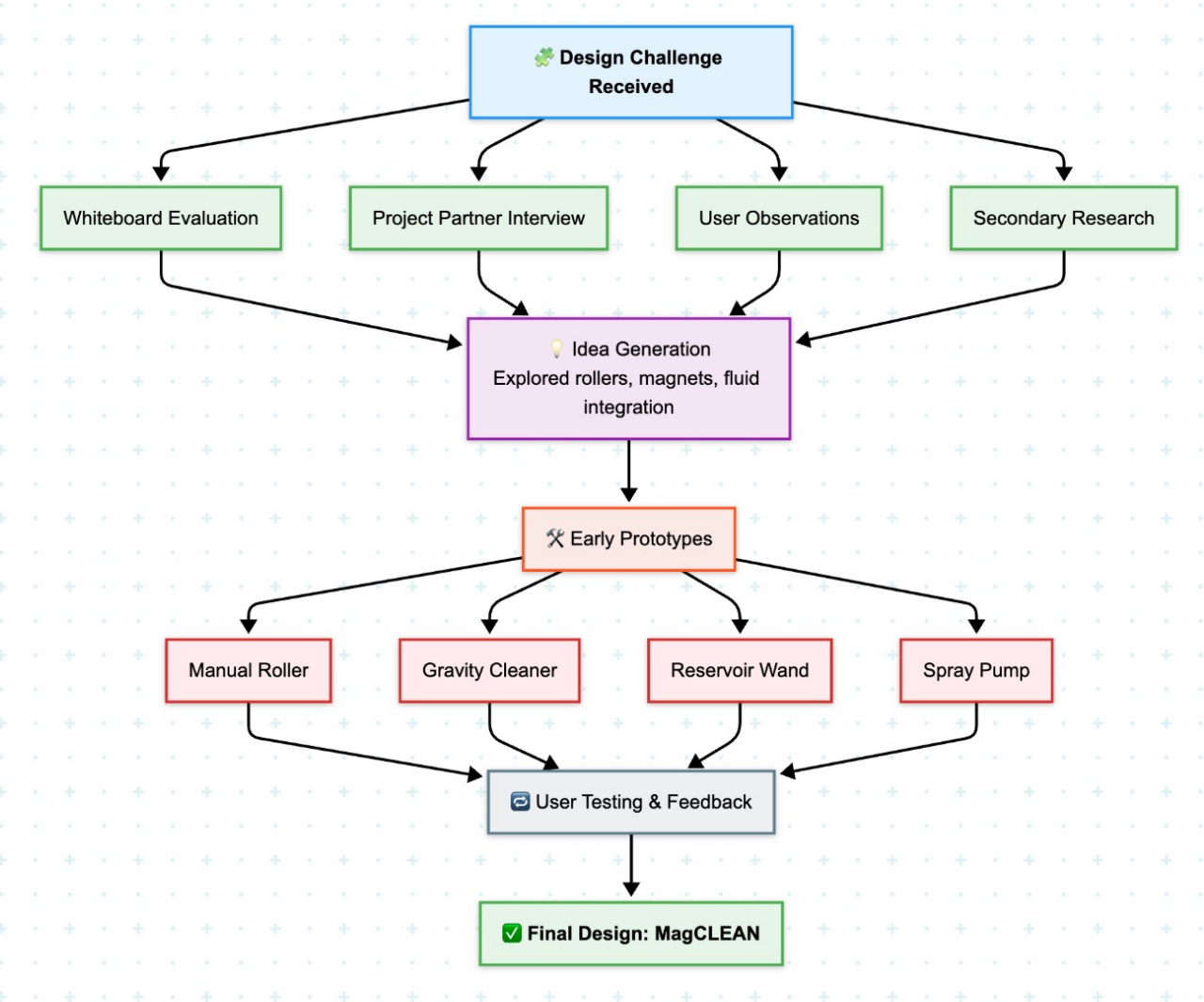


Figure 2: Our Approach Flowchart

5. Design Concept and Rationale

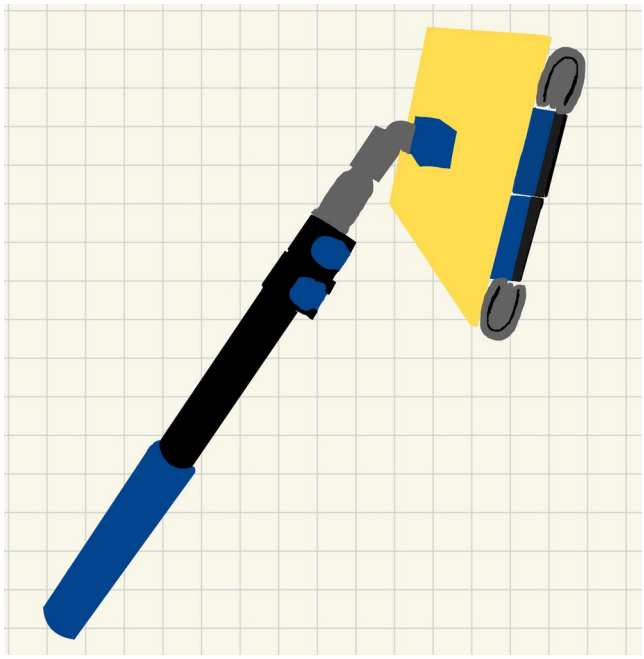


Figure 3: MagClean Eraser

To address the recurring user complaints about whiteboard cleaning in DTC classrooms—namely limited reach, inefficient coverage, and physical strain—Team 32-1 created the MagClean Eraser. The MagClean increases the user's reach, expands the effective cleaning area, and reduces physical effort during use. Each design decision was shaped by user testing, interviews [Appendix C], and performance-based prototyping [Appendix E].

Telescoping Pole

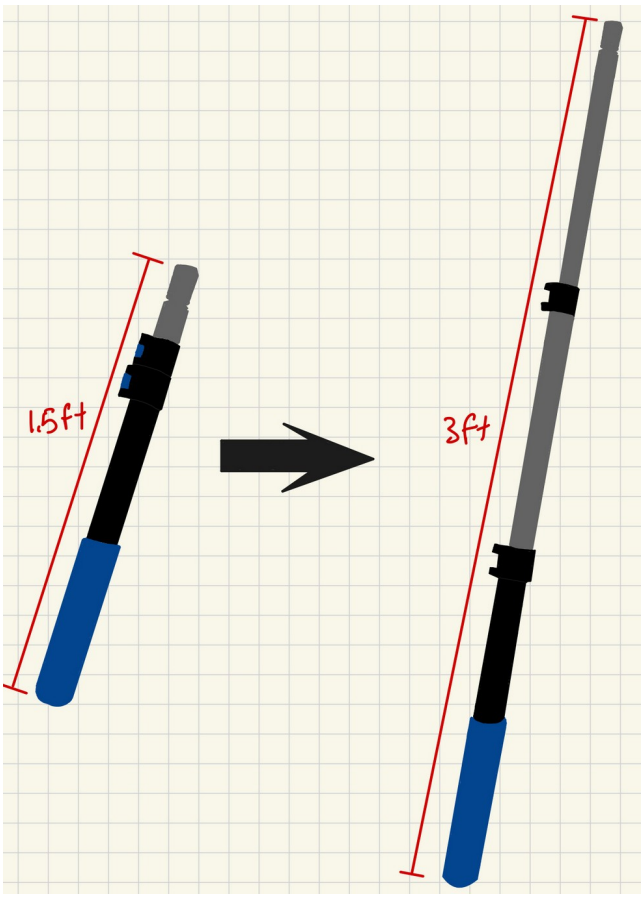


Figure 4: Telescoping Pole. Sketched by D. Belyaev

Description
The MagClean features a telescoping aluminum pole that extends from 1.5 feet to 3 feet. The pole can be quickly adjusted without tools and collapses for compact storage. Its universal locking mechanism connects seamlessly to the rotating head.

Rationale
This design allows users of varying heights—including those as short as 4'11"—to clean the top of 4 to 5-foot-tall classroom whiteboards without stretching or using step stools. The length range was determined through user testing [Appendix I], where we found that a 3-foot reach extension enabled full-board access for most instructors. This component supports our requirement that the device be accessible, easy to adjust, and usable without additional tools or equipment.

Large Eraser Pad with Microfiber Cloth

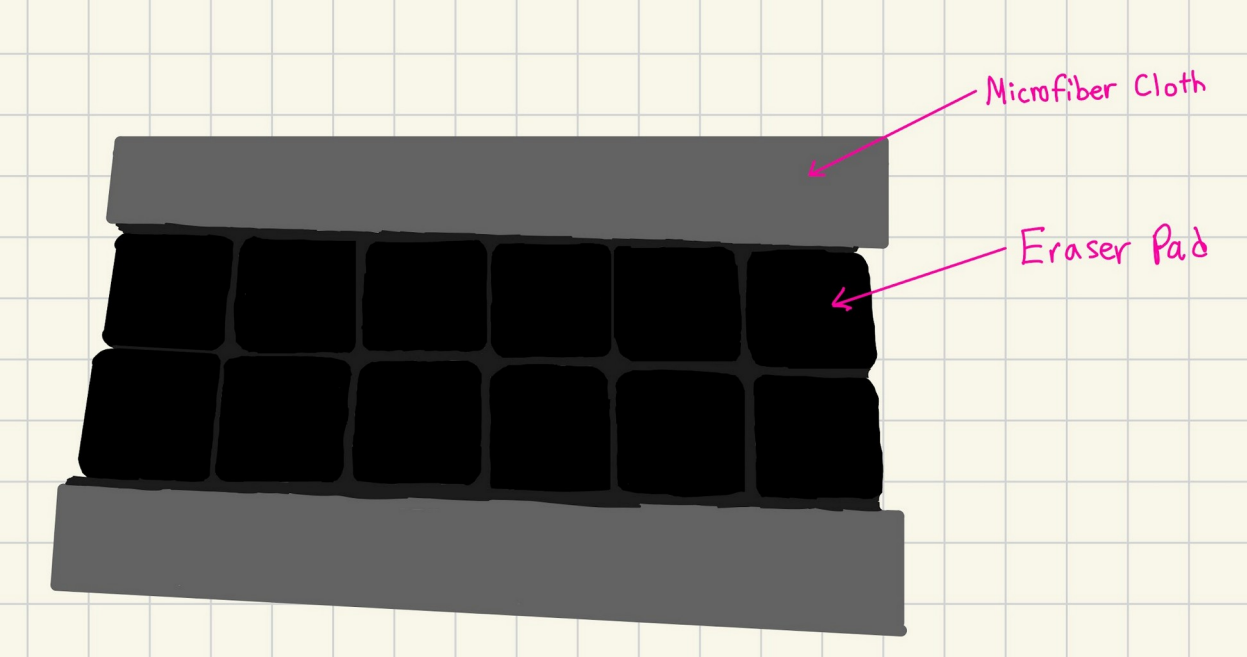


Figure 5: Eraser Pad (see labeled diagram). Sketched by D. Belyaev

Description
The eraser head consists of a central dry-erase eraser section surrounded by a microfiber cloth border. The board mount is made of rigid acrylic for consistent pressure distribution. The microfiber cloth is optimized to hold a light mist of cleaning solution when applied manually.

Rationale
This dual-surface configuration allows users to perform both dry and wet cleaning in a single motion. The wide surface area (~12 inches across by ~7 inches wide) allows users to cover roughly 7x more board space per stroke than a standard classroom eraser [Appendix K]. This feature meets our efficiency, dual-mode cleaning, and surface coverage requirements.

Rotating Eraser Head

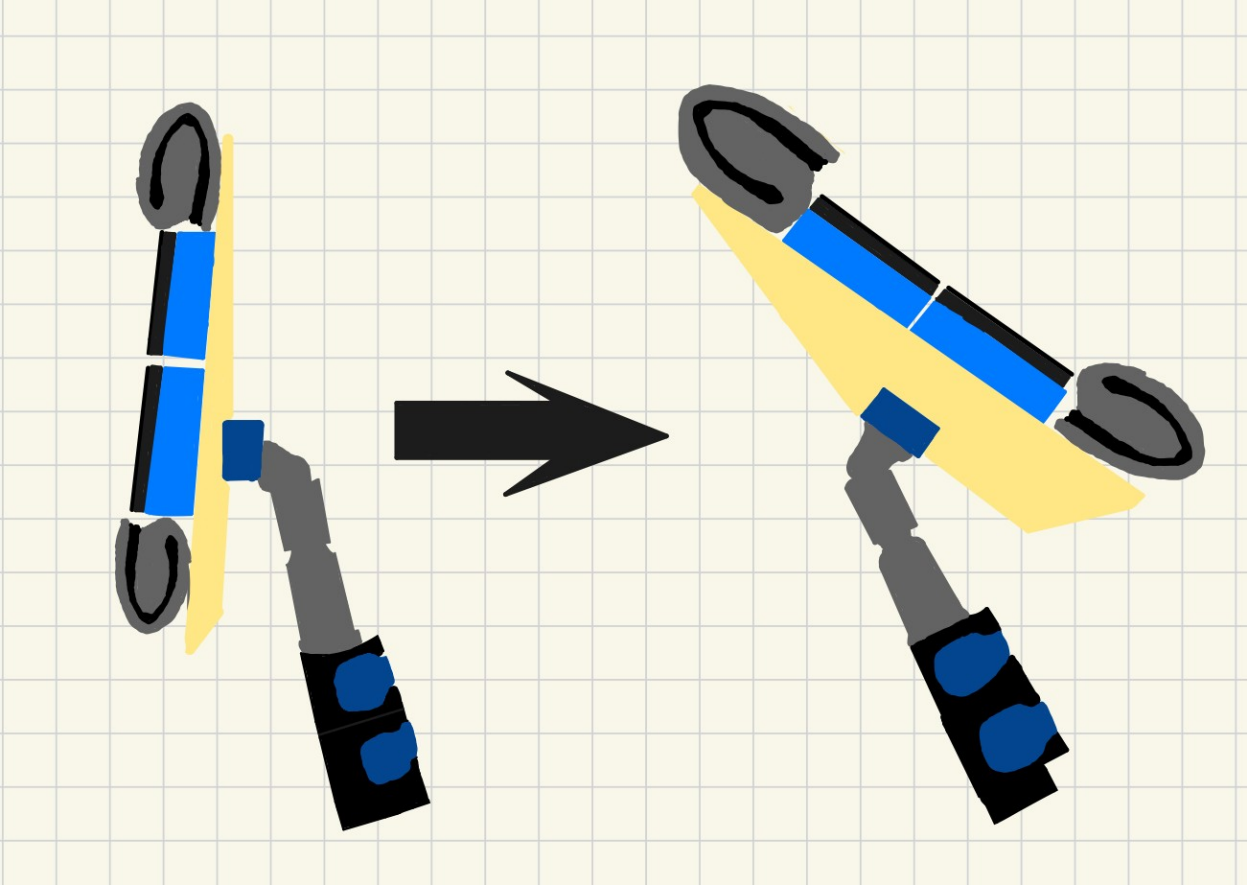


Figure 6: Rotating Eraser Head (with range of motion diagram). Sketched by D. Belyaev

Description
The head is attached to the pole via a hinge joint, which allows approximately 180° of flexion towards and away from the board. This is demonstrated in the above figure. This allows the user to change angles and orientations during cleaning without repositioning their arm or wrist.

Rationale
This rotation makes the device feel natural and smooth to use, especially when cleaning high or

low areas of the board. Users can maintain consistent pad contact across a variety of motion paths. During testing [Appendix K], instructors noted that this feature made cleaning feel more fluid and required less upper body strain. This directly supports our ergonomic handling and consistent cleaning pressure requirements.

Benefits

The MagClean prototype successfully addresses the most pressing classroom cleaning issues reported by DTC users. It reduces the number of cleaning strokes needed, increases user reach without ladders or stretching, and handles both dry and wet cleaning needs in one tool. Additionally, it demonstrates ethical and inclusive design principles by being adjustable, affordable, under $45 in parts [Appendix F], and replicable with off-the-shelf components. These features position MagClean as a practical solution for daily use in high-turnover academic environments.

6. Limitations and Directions for Future Development

While the MagClean Eraser offers a promising solution to the classroom whiteboard cleaning challenge, several limitations remain. The following directives outline how future development efforts might address those shortcomings and enhance the product’s usability, safety, and appeal.

Incorporate storage for classroom settings

Although the current design is relatively compact, it lacks a dedicated or intuitive storage solution. Users must manually place the device in a cabinet or corner, which may not be efficient in high-traffic classrooms. Future designs should integrate solutions like magnetic wall mounts, collapsible handles, or hook-compatible docking features to minimize clutter and enhance accessibility. This issue was noted during mockup testing [Appendix D].

Eliminate pinch risk

Testing revealed a minor risk of finger pinching during rapid extension or collapse of the telescoping handle. While no injuries occurred, future iterations should implement improved locking mechanisms, tactile warnings, or visual guides to support safe adjustment by users of varying ages and strengths. This concern emerged during usability feedback [Appendix I].

Integrate spray mechanism

Users noted that cleaning performance improved when erasing was paired with a spray cleaning solution. This was particularly evident during mockup trials involving the reservoir-integrated model. [Appendix I]. However, instructors indicated during critique sessions that spray functionality is not essential to the core design [Appendix G].

Develop modular cleaning surface system

The current design features a fixed microfiber and dry eraser pad. To support long-term use and varied classroom needs, future designs should allow users to swap or replace cleaning surfaces. A modular system would enable dry–wet switching, material customization, and easier maintenance without replacing the entire head. [Appendix D].

Gamify the cleaning experience

Although not implemented in this prototype, gamification could encourage consistent use. Future concepts could include digital counters to track square footage cleaned, LED indicators to show cleaning zones, or even playful visual or audio cues [Appendix E].

7. Conclusion

The challenge presented to Team 32-1 was to develop an effective, classroom-scale whiteboard cleaning tool that could reduce ghosting, improve ease of use, and support high-throughput instructional environments. After exploring and testing multiple concepts—including gravity-assisted, reservoir-based, and Swiffer-style cleaners—we synthesized our findings into the final design: the MagClean Eraser. This solution combines a telescoping aluminum pole, a hinge joint, and a hybrid erasing pad to deliver fast, ergonomic, and thorough board cleaning.

What makes this design particularly noteworthy is its simplicity and practicality. By using only off-the-shelf components, we created a low-cost tool that can clean large surfaces without requiring electrical components, installation, or complicated mechanisms. The dual-surface cleaning head – combining eraser and microfiber sections – allows users to clean the board with the dry eraser section, or wet the absorbing microfiber sections with spray solution for tougher stain removal. The neodymium magnets enhance contact pressure, addressing both performance concerns.

If adopted more broadly, the MagClean Eraser could significantly reduce cleaning time in educational settings while encouraging full use of magnetic classroom whiteboards. It offers instructors a lightweight, adaptable tool that supports fast turnarounds between classes and reduces reliance on disposable cleaning materials. Its affordability makes it scalable for deployment across campus and adaptable for other shared workspaces.

Looking ahead, future development could explore integrated cleaning solution reservoirs, foldable or wall-mounted storage designs, and enhanced pad durability. While the current design meets core user needs, these additional features could make the tool even more versatile and long-lasting in institutional settings.

Appendix A: Project Definition

Project Name: MagClean: A Whiteboard Cleaning Solution
Client: Barbara Egel, DTC Instructor
Team Members: Jojo Akpalu, Dominic Belyaev, Simon Kaminer, Diego Niiler
Date: June 5, 2025

Mission Statement

To design a physical device that allows users in DTC classrooms to quickly and reliably clean large whiteboards with minimal effort, improving speed, coverage, and comfort while reducing streaking, smearing, and ghosting.

Project Deliverables

- Fully functional MagClean prototype
- Detailed bill of materials (BoM) and sourcing links
- Construction guide with exploded diagrams
- User testing summary with performance metrics
- Visual documentation of key design features

Constraints

- Total construction cost must remain under $150
- Must be completed within the 10-week project window

Users / Stakeholders

- **Primary Users**: DTC instructors and students who write on and clean the boards regularly
- **Secondary Users**: Janitorial staff and facilities workers who may maintain the cleaner
- **Stakeholders**: Classroom operations team, project client, instructors in the DTC program

Requirements and Specifications

Table 1: Requirements and Specifications

Requirement	Specification
Must be effective for users of all heights and abilities	Design includes 1.5 - 3 ft telescoping pole, allowing users of all heights to clean entire board
Must clean effectively with full coverage and minimal effort	Remove ≥85% of visible dry-erase ink on first pass
Must be effective for both dry and wet cleaning without requiring tool changes or additional steps	Design includes both microfiber pads and whiteboard erasers, allowing for spray to stay on while cleaning as well as basic dry cleaning.
Must be simple to operate and maintain, requiring minimal effort, training, or upkeep	Minimal setup to use design - simply adjust the pole and spray. Operable by first-time users with no verbal/written instruction needed
Must be cost-effective to produce and easily scalable for widespread classroom adoption	Total cost of design is <90$. Easy to store and produce.

Appendix B: Cleaning Products and Materials for Large Whiteboards

Introduction

This appendix summarizes secondary research on existing cleaning products, materials, and design strategies used for large-scale whiteboard erasing. The purpose of this research was to identify current approaches, evaluate their effectiveness and limitations, and inform our design criteria by understanding what solutions are already available, how well they work, and where they fall short.

Key questions this research seeks to answer:

- What commercial cleaning tools are most effective for large whiteboard surfaces?
- Which materials or solvents remove long-set dry-erase ink without damaging the surface?
- Are there viable automated or semi-automated cleaning products on the market?

Methods

- **Databases and Websites Used:** Google Scholar, Amazon, Walmart, Hackaday, EcoProLine, Loukin official site, QUALIALL product page, How to Restore and Old Whiteboard on MIT Admissions blog, Instructables
- **Keywords:** "large whiteboard cleaner," "dry erase ink removal," "eco-friendly board cleaning," "automated whiteboard eraser," "melamine foam vs felt erasers," "green cleaning sprays," "whiteboard cleaning robot," "classroom board erasing tool"
- **Date Range Searched:** 2015–2025
- **Inclusion Criteria:**
    - Products or designs intended for large-scale dry-erase boards
    - Solutions targeting long-set or stubborn ink
    - Tools with ergonomic or efficiency-focused features
    - Materials or sprays marketed as safe for classroom or public use
- **Exclusion Criteria:**
    - Small-scale or non-scalable erasers (e.g., handheld felt blocks for personal use)
    - Outdated or unavailable products
    - Patents or concepts lacking physical prototypes or market presence
- **Number of Sources Reviewed:** 6, based on direct relevance to our design goals
- **Assessment Basis:** Product strengths and limitations were assessed based on user reviews, technical specifications, manufacturer claims, and third-party documentation. No physical testing was conducted.

Results

Our research findings fall into three key categories: (1) Existing Cleaning Products, (2) Effective Cleaning Materials, and (3) Automation Concepts. The tables below consolidates relevant product data and is followed by trend insights that shaped our design direction.

Table 2: Comparative Review of Existing Cleaning Solutions

Product / Material	Strengths	Limitations	Source
Loukin All-in-One Magnetic Eraser	Lightweight, compact, user-friendly	Too small for large boards; requires many passes	[1]
QUALIALL Large Eraser	Large surface area, comfortable grip	Cheap-looking; no pad replacement	[2]
EcosPro Heavy Duty Spray	Plant-based, effective over time, safe for classrooms	Needs dwell time; not as fast as solvents	[3]
Melamine Foam (Magic Eraser type)	Excellent for stubborn marks, low cost	Can wear down board surface with repeated use	[5]
Hackaday DIY Robot Eraser	Demonstrates automation potential	Not wall-mounted; limited real-world use	[4]
Instructables Auto-Eraser Project	Functional rail-based prototype	Lacks adaptability; small range of motion	[6]

Table 3: Product Features, Construction, and Cost Details

Product / Material	Dimensions / Size	Materials & Construction	Special Features	Source
Loukin All-in-One Magnetic Eraser	6.3 x 4.3 in	Plastic body, felt pad, built-in magnet	Compact; magnet for storage	[1]
QUALIALL Large Eraser	4 x 7 in	Composite sponge with grip handle	Larger size; easy to grip	[2]
EcosPro Heavy Duty Spray	128 fl oz bottle	Plant-based, non-toxic chemical formula	Eco-friendly; designed for heavy-duty use	[3]
Melamine Foam (Magic Eraser)	Varies (typ. 4 x 2 in)	Melamine formaldehyde resin foam	Micro-abrasive; no chemicals needed	[5]
Hackaday DIY Robot Eraser	< 4x2 in	DIY: 3D-printed chassis, motor, Arduino controller	Experimental automation	[4]
Instructables Auto-Eraser	Rail length ~24–36 in	Motors, rails, microfiber pad	Programmable; limited range of motion	[6]

Observations & Trends

- **Eraser Size Limits Utility.** Most commercial erasers are 4–6 inches wide and intended for small to medium boards [1], [2]. On larger surfaces like those in DTC classrooms (>100 sq ft feet), these tools require excessive repeated strokes to achieve full coverage. Larger erasers such as the QUALIALL model (7 inches wide) [2] offer better reach, but may suffer from poor construction or lack replaceable components.
- **Material Effectiveness and Surface Impact.** Melamine foam (e.g., Magic Eraser) is highly effective at removing stubborn, long-set dry-erase ink [5], [7]. However, it is micro-abrasive and may degrade board surfaces over time [7]. EcosPro Glass Cleaner, a plant-based and non-toxic solution, is safe for classrooms but requires longer dwell time

or scrubbing for best results [3], [8]. Acetone-based removers are extremely effective but pose significant safety and odor issues, making them unsuitable for educational use [9].

- **Limited Viability of Automation.** DIY motorized or rail-guided erasing tools described on Hackaday [4] and Instructables [6] show proof-of-concept automation. However, these models are generally designed for tabletop or horizontal boards, require custom parts or coding, and are not plug-and-play solutions for classroom settings.

Analysis, Discussion and Recommendations

- Standard-size erasers (4–6 in) are not practical for large boards due to inefficiency and repetitive motion demands [1], [2]. Even "jumbo" options can be difficult to handle or appear too bulky and unrefined for professional use [2].
- Melamine foam is excellent for cleaning embedded stains but must be used cautiously to avoid long-term damage to board surfaces [7].
- EcosPro spray is one of the most viable eco-friendly options on the market; its performance improves when used with microfiber or eraser pads to reduce ghosting and staining [3], [8].
- While automation is an exciting avenue, most current implementations are hobbyist-grade and unsuitable for daily institutional use [4], [6].
- Perception matters: some users dismissed certain large erasers as "cheap-looking" or unpolished despite good functionality, suggesting aesthetics affect adoption [2].

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Appendix C – Project Partner Interview

Date: April 10th 2025
Time: 4:00pm to 4:30pm
Location: Ford 2.240
Team members in attendance: Diego Niiler, Dominic Belyaev, Jojo Akpalu, Simon Kaminer

Project partner / Design problem overview

- Barbara Egel
- BA Comparative Literature, University of Illinois at Urbana
- MALit, Northwestern University
- Co-Director, Design Thinking & Communication
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The whiteboards in DTC classrooms are often left uncleaned after class. With little time in between sessions, not all areas of the whiteboard are cleaned. With varying heights in instructors and students, some areas of the board are left completely marked up and can't be reached, which causes permanent staining on the board. These stains require strong chemicals to clean, which damages the board. After our conversation with Professor Egel, we gathered information that can be organized into three categories:

Existing Solutions
With current erasers, it takes a long time to clean the board. The hand wiping motion is very repetitive and is physically draining, especially when one person is left to clean the entire whiteboard, approximately 21 m^2. The cleaning solutions are often missing from classrooms because people take them. Whatever we design should not be able to be taken out of the room.

Cleaning Process
Make it easy for boards to be cleaned after every single class - this could eliminate the need for a deep cleaning spray/chemical if the whiteboards are being constantly cleaned. Using a cleaning solution is fine as long as it is non-toxic. Sustainability is important to the cleaning process. The entire board, top to bottom, needs to be cleaned with speed being the central priority. Also note that the full whiteboard walls are foldable; for whatever happens, the walls need to be able to be stored properly with the design. Nothing should be permanently mounted as the boards need to be moved for the DTC expo. If the process is made appealing / "game-ify" it, more people will want to clean the board. Noise should not be a concern.

Users
Since the design should be able to be used by both students and instructors, there will be a large range of users. The design should be able to accommodate persons in stature of 4'10" and up. The smallest and tallest should be able to maneuver whatever we create without it being awkward.

Miscellaneous

Email heather.beattie@northwestern.edu to ask for how often whiteboard erasers are replaced.

Analysis, conclusions and next steps

- Speed is the most important aspect of the design
- Needs to be usable by people of all statures
- Next steps would be to talk to different users and take observations on their experience with our mockups
- Schedule follow up interview

Appendix D: Mockups Appendix – Second-Generation Mockups (May 2025)

Objective

These second-generation mockups aim to evaluate core design directions for a large-area whiteboard cleaner. Unlike the first generation, these models represent significant functional improvements and test real interactions with DTC classroom whiteboards. The focus is on validating ergonomic feasibility, coverage efficiency, and integration of active cleaning components. While still non-final, these mockups offer meaningful feedback on what works – and what doesn't – in real use cases.

Mockup 1 – Telescoping Mop-Style Eraser

This mockup uses a large melamine cleaning pad mounted to a telescoping pole with a pivoting mop-style head. It is designed to mimic the form factor of a Swiffer or floor mop but optimized for vertical surfaces. This version covers a large area in a single pass and is light enough to be used overhead. The flexible head pivots to reach corners and board edges easily.

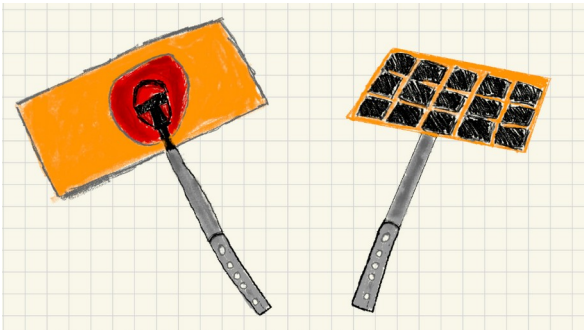


Figure 7: Sketch of Telescoping Mop-Style Eraser. Sketched by D. Belyaev.



Figure 8: Image of back of swiffer style eraser

Questions this mockup is meant to help answer:

- Can a floor-style mop be comfortably used on vertical boards?
- Does a pivoting head help users clean higher areas without strain?
- Is the pad size effective without compromising maneuverability?

Mockup 2 – Magnet-Aided Sliding Block

This design involves a block with embedded magnets that attaches to the whiteboard and slowly slides down under its own weight, cleaning as it goes. The underside includes melamine foam and microfiber layers. Users start at the top of the whiteboard, and it travels vertically with even pressure due to gravity and board contact.

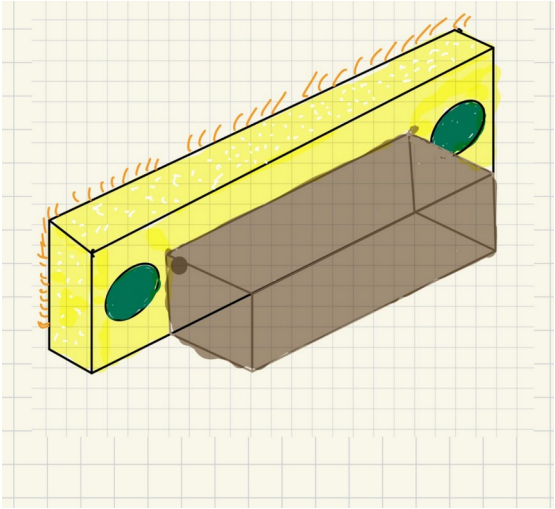


Figure 9: Sketch of Magnetic Gravity Powered Eraser. Sketched by S. Kaminer.



Figure 10: Image of Magnetic Gravity Powered Eraser

Questions this mockup is meant to help answer:

- Is passive cleaning via gravity effective for full board coverage?
- How consistent is the cleaning path and pressure?
- Can this be part of a semi-automated or self-guiding system?

Mockup 3 – Reservoir-Integrated Pad Wand

This design builds on Mockup 1 but adds a built-in reservoir that stores cleaning solution inside the pad block. A sponge-like insert allows the pad to stay moist without dripping. The wand still uses a telescoping pole and pivoting head for ease of use across large boards.

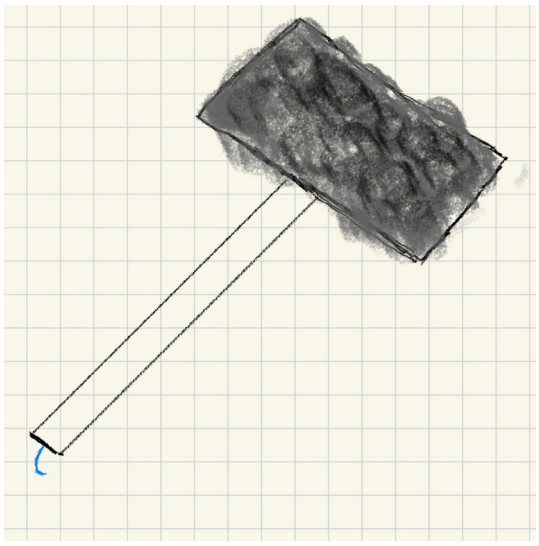


Figure 11: Reservoir Eraser. Sketched by D. Belyaev.

Questions this mockup is meant to help answer:

- How much cleaning fluid is needed per session?
- Does fluid integration improve results on old or dry-set ink?
- Does a constantly wet cleaning surface bring negative effects?

Mockup 4 – Spray Pump Prototype

This standalone prototype tests a manual pumping mechanism that could eventually be integrated into future mockups for spraying solution ahead of the cleaning path. The current prototype includes a small reservoir, a pump lever, and a nozzle system.



Figure 12: Image of hand pump

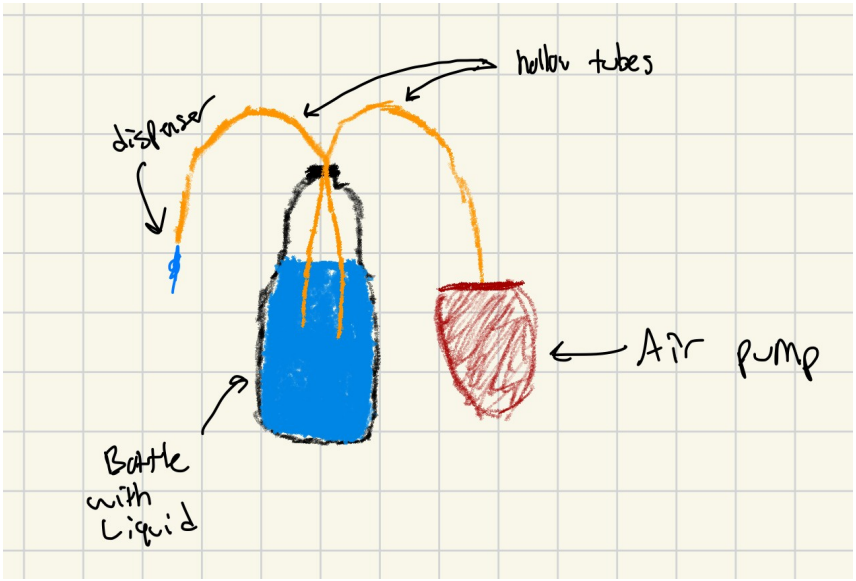


Figure 13: Sketch of hand pump. Sketched by D. Belyaev.

Questions this mockup is meant to help answer:

- Can a low-cost pump deliver consistent spray across the board?
- What orientation and placement works best for vertical surfaces?
- How easy is the pump to actuate during normal use?

Appendix E – User/Stakeholder Motivations and Interactions Assessment

This appendix documents our team's assessment of the key users and stakeholders involved in the context of large-scale whiteboard cleaning. The goal of our project is to design a device that can quickly, safely, and effectively clean large whiteboard surfaces - particularly those in DTC classrooms - while reducing physical effort and improving workflow. The table below synthesizes what different users and stakeholders want from the product and how they interact with it.

Table 4: User/Stakeholder Motivations and Interactions Assessment

Users / Stakeholders	Motivations	Interactions with Design	Wish List
Professors / Instructors	Save time and energy during lecture transitions; maintain a clean teaching surface	Manually or automatically activate the cleaner between classes	Fast operation; minimal effort; ergonomic; doesn't require waiting or drying time
Students (TAs, Presenters)	Maintain cleanliness for presentations; avoid wasting time on erasing	Use between group activities or class periods	Simple interface; quick spot-cleaning option; safe to use around electronics
Custodial Staff	Reduce workload and need for harsh cleaning chemicals	May use cleaner for deep cleaning or ink buildup removal	Durable components; easy refill/replacement; compatible with existing cleaning routines
University Facilities / Procurement	Minimize long-term maintenance; reduce costs associated with surface wear	Purchase and distribute units to classrooms	Cost-effective; safe for frequent use; doesn't damage board surfaces
Classroom Designers / Tech Integrators	Integrate device with other tools (e.g., smart boards)	Position, mount, or support device in classrooms	Lightweight; easy to install or store; non-obstructive
Environmentally-conscious stakeholders	Promote sustainable materials and non-toxic cleaning	Evaluate disposal and energy use of product	Biodegradable/low-waste components; refillable options; energy-efficient mechanisms

Appendix F: Bill of Materials

Table 5: Final Prototype Bill of Materials

Item(s)*	Description	Qty	Vendor*	Part Number	Unit cost	Total cost
Telescoping Pole	1.5 to 3 FT Aluminum Telescoping Pole with Quick-Flip Clamps	1	Amazon	B0CJ5RJ4BQ	$13.95	$13.95
Ball and Socket Joint	1/4 in. Drive x 12 mm Universal Joint Socket	1	The Home Depot	SHD08112	$10.00	$10.00
Acrylic Board	Lightweight rectangular acrylic board	1	Ford Shop	N/A	$0.00	$0.00
Magnets	Super Strong Neodymium Magnets	12	Amazon	12P	~$1.00	$12.00
Microfiber Cloth - absorbent	Microfiber Cleaning Cloth Black, 12x12	2	Amazon	B0DHVFMMMR	~$0.54	$1.08
Erasers	Erasers	1	Amazon	B09BDY72JP	$0.29	$3.48
TOTAL COST:	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**$41**

Appendix G: Design Review Summary

Date: May 9, 2025
Time: 2:00-3:20
Location: Ford G205
Team members in attendance: Jojo Akpalu, Simon Kaminer, Diego Niiler, Dominic Belyaev
Other key attendees: Professor Carmichael, Professor Lake, Team Quackers

Our design review was for four mockup designs that we built: a swiffer-style whiteboard eraser, a hand pump that can siphon whiteboard cleaning solution, an eraser with an erasing head dampened with solution, and a magnetic gravity-powered eraser.

Table 6: Design Review Responses

Design Attribute (component, feature, etc.)	**Positive feedback**	**Negative feedback**	**Suggestions and additional comments**
Whiteboard solution	Is effective at getting rid of dried marker left on the board for extended periods of time.	Not needed in the design itself, as stains can be removed with added pressure from the eraser.	The whiteboard solution isn't a big part of daily cleaning for instructors.
Gamification of Design	Gamification is a fun idea and should be in the next steps of our project report.	Gamification would be a big use of time and might not be as effective a use of time as we want.	Instead of gamification, appeal to “satisfying” the user with smooth operation.
Degrees of Freedom in Swiffer Eraser Handle	Having rotation in the handle allows for a wide range of users and easier manipulation of the eraser to erase all parts of the board.	Too much rotation can lead to a decrease in the stability of the eraser head, while too little makes it hard to reach the corners of the board.	Do more user testing to find the ideal range of rotation that would allow for the best stability and coverage.

Dampened eraser head	Already has the solution on the eraser, allowing for ease of use when erasing tough stains.	Causes marker ink that's not stained to smear and stain the board more than when it's regularly erased. Also takes a while to dry.	Find a way to make one section of the eraser head dry while another section is wet, so you can utilize the good in both aspects.
Solution in Mockups	Solution can help get out tough stains when they are being addressed with relative ease	It is not always the case that people use a solution, and it is more likely that someone doesn't use a solution as opposed to using it.	Just make a mockup that erases the board well, and anyone who wants to use a solution can use the already-made bottles of solution.
Magnetic Gravity-Powered Eraser	Works well and does its design job of sliding down the board while not falling off.	This design might end up being more work for the user overall, as if they have to reset the mechanism on all 7 DTC panels, it could be a lot of work. Also would be hard for shorter users to reset the device as DTC boards are very tall and it has to be placed at the top of the board.	This design might not be a good one to use for the reasons listed.

Followup

Given the review feedback, Team 32-1 plans the following:

- Conduct 3-5 more user tests to figure out the optimal degrees of freedom and whether solution in a mock-up is useful
- Test how long it takes a fully solution-soaked eraser head to dry in DTC classroom conditions
- Begin to focus on mockups we think will work well as a final design

- Decide on whether we want to focus on gamification or just include it in our next steps for the final report

Appendix H: Methods of Construction

Introduction

The MagClean is a device meant to aid DTC instructors and students effectively and swiftly clean the large DTC classroom whiteboards. The instructions below will guide you through creating the MagClean from different parts. The instructions are divided into a few different sections including:

- Telescoping Pole Construction
- Connector Construction
- Erasing Pad Construction

These instructions require a small background in shop machinery, such as using a bandsaw, sewing machine, and different tools (e.g. drills, screwdrivers, and hammers). To assemble the MagClean efficiently and on time, we recommend having a team that can work on different parts. This prototype should be fully built in approximately 5 hours.

Overview of the MagClean:



Figure 14: A picture of the fully assembled MagClean.

At the end of construction, the fully assembled MagClean will be able to be used to effectively clean large magnetic whiteboards with ease.

Below, find a table of construction materials.

Table 7: Materials used for Construction

Materials	Specifications	Count
Telescoping Pole	1.5–3 ft aluminum pole with quick-flip clamps	1
Ball-and-Socket Joint	¼" drive × 12 mm universal joint socket	1
Acrylic Board	¼" thick, rectangular acrylic (cut to 12" × 7")	1
Microfiber Cloth	12" × 12" and gray	2
Dry Erasers	Whiteboard erasers in the center of pad (2 x 6)	12
Neodymium Magnets	Circular and 1" diameter	12
30mm Zinc Screws	Machine Screw, M6, Zinc, 30mm, pitch 1mm	2
Connector	1" x 2.5"	1

Machines you should be trained on to construct our design:

- Drill press
- Milling machine
- Vertical Band Saw

Telescoping Pole Construction:

1. Take the 1.5ft telescoping pole and clamp it on its side to the vice grip of a mill. Use a straight edge as shown in the figure below to ensure that the top of the telescoping pole is level and straight.



Figure 15: Clamping telescoping pole into mill

2. Attach a ½” diameter drill bit to the mill as shown.

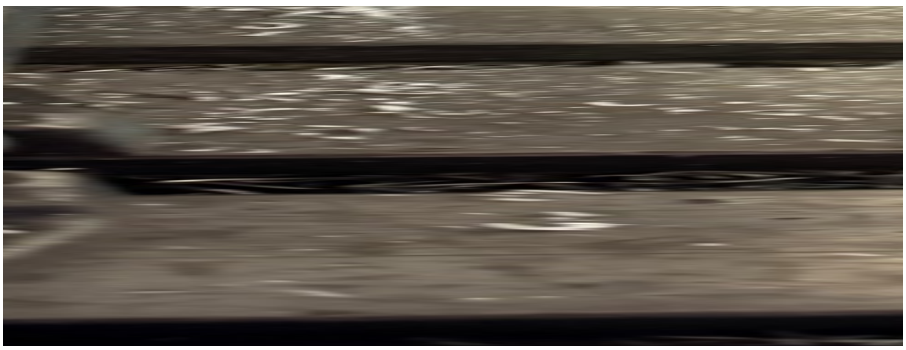


Figure 16: Picture of ½ drill bit attached to mill

3. Lower the drill bit gently, just until it reaches the top of the end of the pole.



Figure 17: The drill bit touching the top of the end of the pole

4. Set this established height as the zero for the mill.



Figure 18: Establishing the new zero for the mill height

5. Take the drill bit out in the x-direction to a distance past the end of the pole.



Figure 19: Changing x-direction of drill bit

6. Decrease the height of the mill by .030 (30 increments) inches, turn the mill on, and begin to mill off the first layer of the top of the end of the pole.

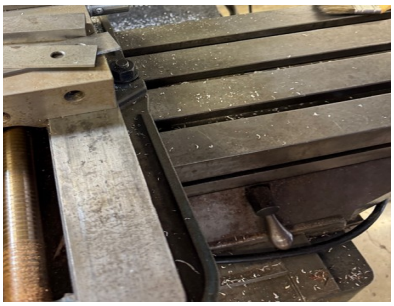


Figure 20: Milling the top layer off of the top of the end of the pole

7. Repeat step 6 twice more until a full .90 inches have been milled off, then decrease the height by the final .01 inches (10 increments), until a full inch has been milled off

8. Rotate the tube to the next side that needs to be milled and repeat steps 3-7.

9. Attach the joint to the end of the telescoping pole using hot-melt adhesive.



Figure 21: Attaching the joint onto the telescoping pole

Connector Instructions:

1. Use a Vertical Band Saw to create a wood block measuring 2.5’’ by 1” by .75”



Figure 22: Cutting wood block with Vertical Band Saw

2. Use a drill press to drill out a hole in the wood block that is .5” in diameter and .48” deep.



Figure 23: Circular hole in wood block

3. Use a chisel to carve out the sides of the circular hole so that it is square and measures .25 square inches.



Figure 24: carving out chiseled sides of circular hole

4. Glue ball and socket joint in the connector by the square end, ensuring that it is tight-fitted.

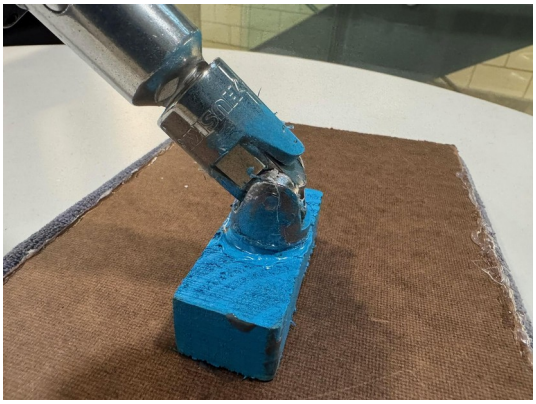


Figure 25: Ball and socket joint glued into connector block

Eraser Pad Instructions:

1. Take an acrylic board and measure it out to 12” x 7”. Use the Vertical Band Saw to cut the acrylic board to the desired length and width.

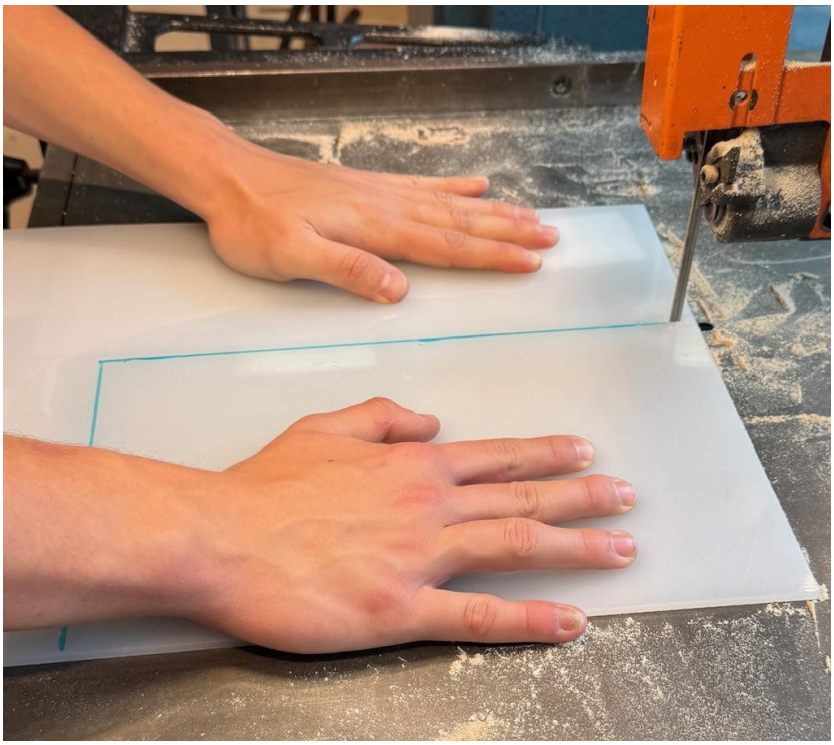


Figure 26: Cutting the board with the Vertical Band Saw

2. Take dry erase pads and mark the diameter of the neodymium magnets on the foam side of the erasers.

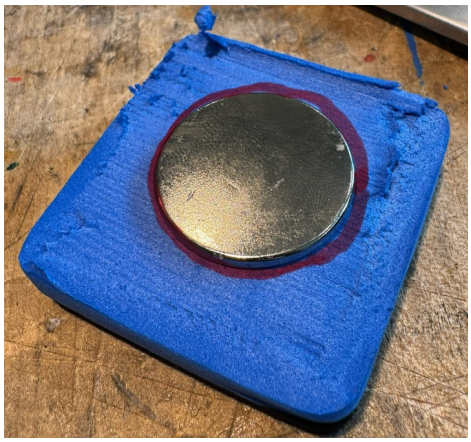


Figure 27: Marking diameter of magnet on dry eraser

3. Using a box cutter, cut the foam out of the dry erase pads. Cut enough to tightly fit the magnets into the foam. Repeat this for all 12 pads.



Figure 28-29: Cutting out slots for magnets in foam erasers

4. Use hot melt adhesive to glue the magnets into the foam of the erasers. Make sure the neodymium magnets are oriented so they don't repel the magnets already inside the erasers.



Figure 30: Gluing magnets into the foam of erasers

5. Use hot melt adhesive to glue the erasers foam side to the board, starting from the outside and working in. Leave the 4 central erasers off for now.



Figure 31: Erasers glued without 4 central erasers.

6. Take the two microfiber cloths and fold both over themselves twice. Use hot melt adhesive to glue the microfiber cloths together in their folds and to the board, one above the erasers and one below.

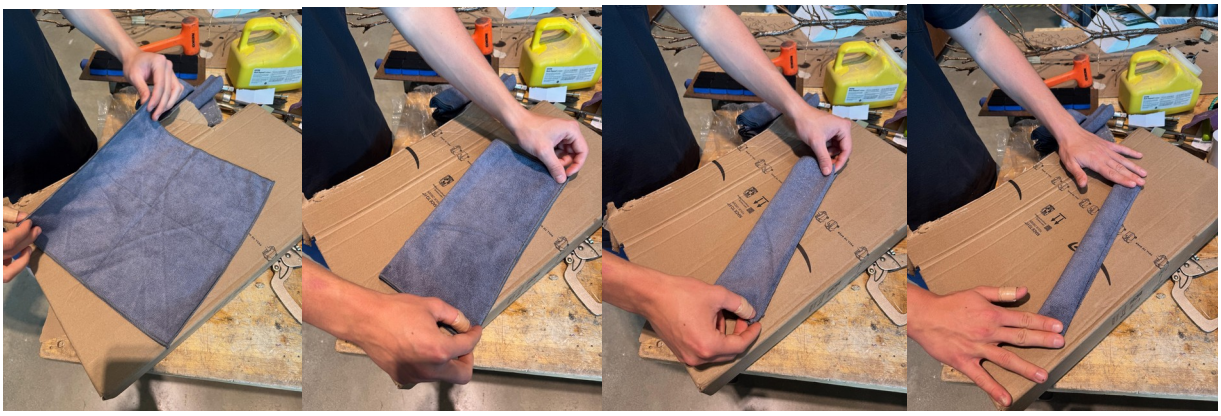


Figure 32: Process for folding microfiber cloths (Left to right)

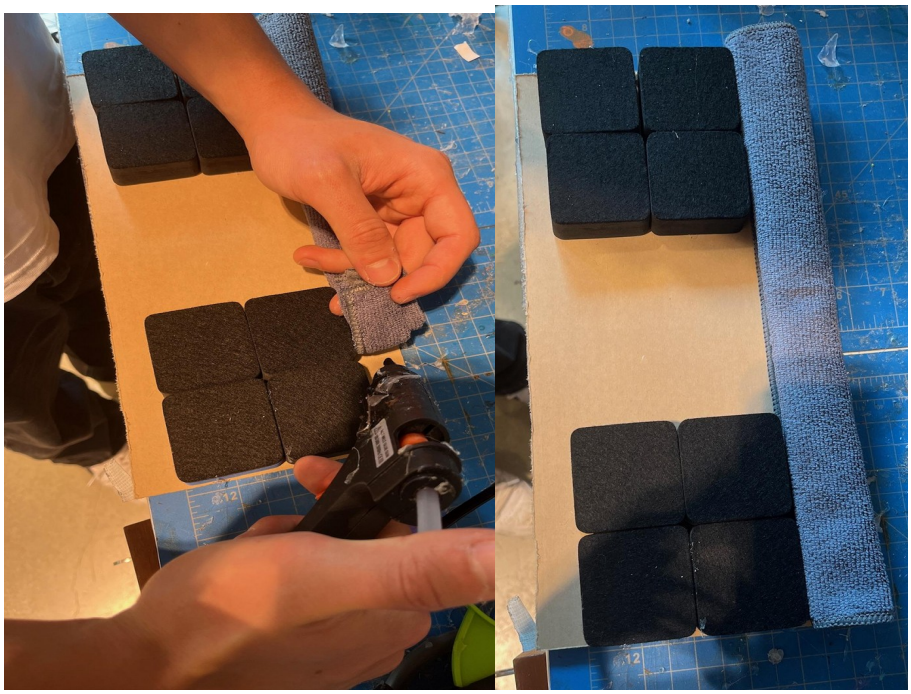


Figure 33: Attaching folded microfiber cloths to the board

7. Use a power drill to drill 2 holes into the acrylic board, each 5.25” from either end of the short side of the board, and 3.5” from the long side.



Figure 34: Drilling holes into acrylic board

8. Using a 5.6mm drill bit, drill holes into the connector. After that, thread the screw through the connector and the board with the head of the screw facing the eraser side.



Figure 35: Drilling screw holes into connector

9. Attach M6 hex nuts to the ends of the screws and fasten with a nut driver.



Figure 36: Screw inserted in the board and connector with nuts attached to the end

10. Cut holes in the remaining 4 erasers so the screw heads can fit underneath. Add hot melt adhesive to each and glue them to the board the same way as the first 8.



Figure 37: Screw heads on the board side

Appendix I: Swiffer-Style Telescoping Eraser & Gravity Cleaner & Reservoir-Integrated Pad Wand (Mop Eraser) User Test

Date: May 10 & 11, 2025
Time: 17:00–17:45 CST
Location: Ford G205, Northwestern University
Team members in attendance: Simon Kaminer, Jojo Akpalu, Dominic Belyaev, Diego Niiler
Other key attendees: Testers Sailor Akohonae, Finn McMillan, and Alexia Sextou (all Northwestern undergraduates)

Objective

The objective of this session was to evaluate the usability, ergonomic performance, and efficiency of the Swiffer-style telescoping eraser, gravity cleaner, and reservoir-integrated mockups. Key goals included:

1. Determine whether users of different heights can clean the entire board effectively
2. Assess cleaning efficiency and physical strain with each mockup
3. Identify design improvements for future iterations
4. Test how well the gravity eraser cleans when sliding down the board autonomously
5. Gauge user satisfaction and perceived effort with the gravity cleaner compared to manual cleaning
6. Identify design flaws in alignment, coverage, and reliability in all mockups
7. Whether integrated moisture helps clean old stains more effectively in the reservoir cleaner
8. How easy it is to maneuver and angle the reservoir-integrated mop head
9. Whether users find the devices comfortable to use for full board cleaning

Testing Conditions

The test was conducted in a DTC classroom environment with full overhead lighting and minimal ambient noise. The room was mostly clear except for nearby chairs and desks. All users reported moderate fatigue or hunger prior to testing, which may have mildly impacted their engagement. No formal instructions were given beyond basic safety and cleaning objectives.

Testing Session Overview

Swiffer: Each user was given the option to test the Swiffer-style eraser with and without cleaning spray. Participants attempted to clean the entire whiteboard surface, and the time to completion was recorded. All participants provided verbal feedback during and after the test.

Gravity Cleaner: Each user was instructed to place the magnetic eraser at the top of the board and observe its descent, then evaluate whether it effectively cleaned the board. Users also attempted a "return pass" by manually guiding the eraser back upward.

Reservoir-Integrated: Users tested the mop-style wand with a dampened erasing head. They attempted to clean the entire board in one pass and were asked to comment on its maneuverability and cleaning power.

Table 8: User Overview

Name	Age	Relevant Notes
Sailor	19	Slight fatigue; eager to complete on time; short (5'1")
Finn	19	Nonchalant; tall (6'2")
Alexia	19	Shorter stature (4'11"); energetic disposition

Observations – Swiffer-Style Eraser

Table 9: Cleaning Task Observations

User	Time (sec) - Swiffer Style	Time (sec) - Gravity Cleaner	Time (sec) - Reservoir-Integrated	Notes	Spray Used for Swiffer Style / Reservoir?
Sailor	41	142	22	**Swiffer:** Had to use tiptoes; mildly distracted; no major complaints **Gravity:** Extremely frustrated. Said, "I'd rather watch paint dry." **Reservoir:** Cleaned quickly out of competition mindset; said it worked fine	No & No
Finn	54	70	23	**Swiffer:** Needed to bend down for the bottom half; spray helped improve cleaning **Gravity:** Hated repeated motion; said result was worse than doing it manually **Reservoir:** Very fast, impressed with overall cleaning speed	Yes & Yes
Alexia	74	44	76	**Swiffer:** Struggled with the top of the board; couldn't reach to spray effectively **Gravity:** Thought it worked well with spray; smoother operation than others **Reservoir:** Struggled due to lack of head rotation; uncomfortable for	Yes & No

				her angle	
Finn (extra test)	29	N/A	N/A	**Swiffer:** Much faster with confident use; emphasized pressure application	Yes & N/A



Photos & Diagrams

Figure 38: Finn McMillan standing next to the board



Figure 39: Sailor cleaning the board



Figure 40: Alexia cleaning the board

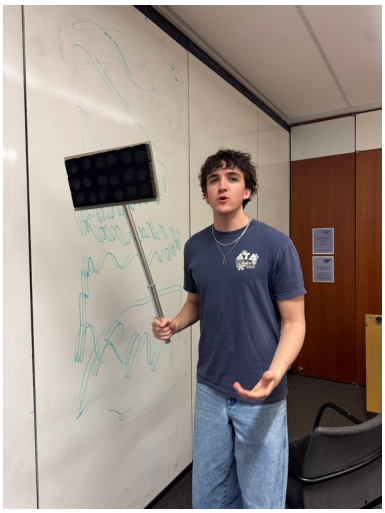


Figure 41: Finn standing next to the board

General User Comments - Swiffer Style

- “You need to go over one spot multiple times to get it clean.” - Finn
- “Pressing down helps a lot, but it takes effort.” - Sailor
- “I couldn’t reach the top at all without jumping.” - Alexia
- “It would be so much easier if the spray was built into it.” - Alexia

General User Comments - Gravity Cleaner

- “Most erasing happened on the way up - not the way down.” - Sailor
- “Didn’t work unless you babysit it.” - Finn
- “Would be cool if it reset itself.” - Alexia
- “Honestly ineffective.” - Finn

General User Comments - Reservoir-Integrated

- “Wanted it to have the ability to bend.” - Alexia
- “It worked really well when I didn’t have to hit awkward angles.” - Sailor
- “Needs a more flexible joint at the head.” - Alexia
- “Would be great if you could switch between wet and dry modes.” - Finn

Analysis and Implications for the Designs

Table 10: Ethical Concerns and Mitigation Table

Design	Key Conclusions	Next Steps
Swiffer	Height was a problem for shorter users- Spray integration was popular- Pressure was key to effectiveness	Add built-in or pole-mounted spray- Test dual wet/dry erasing surfaces- Add light magnets for pressure assist
Gravity Cleaner	Low user satisfaction (esp. Sailor & Finn)- Inconsistent motion- Required manual guiding- Likely not scalable or time-efficient	Likely abandon unless automated- Explore self-resetting mechanism- Consider hybrid magnetic/manual designs
Reservoir-Integrated	Worked well with spray and proper angle- Users cleaned quickly- Head articulation was essential- Spray helped when paired with good handling	Add hinge or ball-and-socket for pivot- Test dual-mode (wet/dry) heads- Add simple spray activation (pump/squeeze)- Integrate with Swiffer-style design

Appendix J: User Observation #1

Date: 4/28/2025
Time: 10:00 PM – 10:20 PM
Location: Ford G205
Team Members in Attendance: Diego Niiler, Jojo Akpalu
Other Key Attendees: Fima Furman

Objective

1. To obtain quantitative data on how long it takes a user to erase a whiteboard using a standard eraser.
2. To gather qualitative feedback on the user experience, what the user liked, disliked, and suggestions for improvement.

Observation Conditions

- Observation took place in a DTC classroom at night; the room was empty, quiet, and well-lit.
- The whiteboard was covered in pink marker to a height of 5'7", across one panel.
- The user, Fima, had been doing homework in Bobb Lounge and appeared alert, possibly aided by an energy drink.
- Fima is 5’6” and was able to comfortably reach the entire section of the board.

Session Overview

- **User Info:**
    - Name: Fima Furman
    - Age: 18
    - Major: Biology, Pre-medical Track
    - Notes: Fima is known to be particular about whiteboard cleanliness due to her OCD tendencies.
- Fima, a student from Bobb Hall, was invited to participate in a user testing session focused on whiteboard cleaning. Jojo and Diego escorted her to Ford, where she tested one of the mockups by erasing a section of the board marked for the trial. The test area measured approximately 5’7” in height and spanned the width of a single whiteboard panel. Using a standard classroom eraser, Fima completed the task in about 44 seconds. Video footage and a reference photo (Figure 1) were taken to document the session.

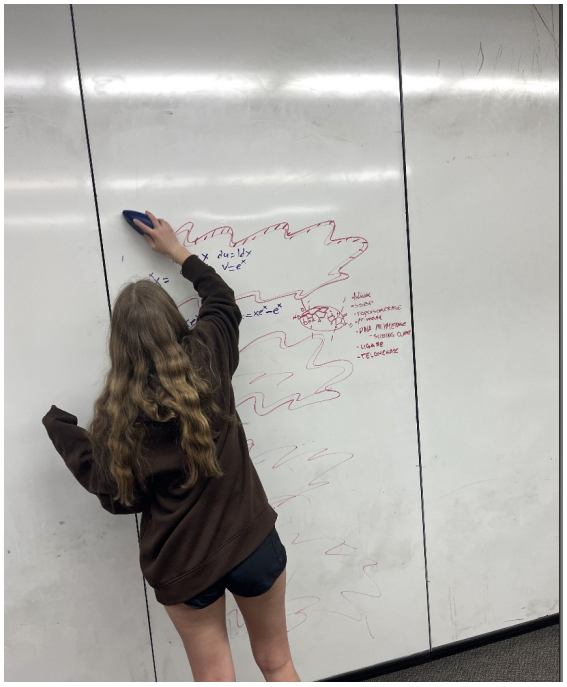


Figure 42: Fima erasing whiteboard

In this image, Fima is erasing the whiteboard with a regular eraser. It took her approximately 44 seconds to erase this entire section of the board.

Analysis

Fima, using a standard eraser, took **44 seconds** to erase a full panel of marker-covered whiteboard (5’7” tall by one panel width).

She noted mild discomfort during the process, citing arm fatigue and the need for repetitive scrubbing to fully remove residual ink. Although she was able to reach the entire height, it was clear that maintaining consistent pressure and effectiveness over the full area was difficult. Her background and personal cleanliness preferences also made her more aware of leftover marker streaks and imperfections.

The observation environment was controlled, allowing the team to isolate the erasing process without distractions or confounding variables like ambient noise or furniture.

Conclusions

1. **Manual whiteboard cleaning is time-consuming and physically taxing** for an average-height user, especially over large vertical areas.
2. **Residual marker streaks** remain even after extended effort, leading to dissatisfaction, especially for users sensitive to visual cleanliness.
3. Users like Fima, who are shorter than the maximum board height or particularly cleanliness-focused, experience **both ergonomic and emotional strain** when using traditional erasers.

4. The **44-second erasing time** for one panel suggests that cleaning multiple panels could take several minutes - too long for efficient turnover in high-use spaces like classrooms.

Recommendations

1. **Develop ergonomic, larger-surface erasing tools** to reduce motion repetition and improve cleaning efficiency.
2. **Integrate cleaning solution reservoirs** or microfiber materials to increase streak removal effectiveness with fewer passes.
3. Include **extendable or angled cleaning designs** for users under 5'7" to comfortably clean high-up areas without strain.
4. Design for **quick-deployment in classroom settings**, so users can clean large areas in under 30 seconds per panel.

Next Steps

- **Conduct additional user tests** with a wider height range and diverse majors to verify if trends hold across different demographics.
- **Benchmark against mockup prototypes** to quantify time savings and user satisfaction improvements over the standard eraser.
- **Refine design mockups** based on feedback to target physical ease, speed, and thoroughness of cleaning.
- **Interview instructors or TAs** who frequently use whiteboards to better understand high-use cases and long-term usability concerns.

Appendix K: MagClean Prototype User Testing – Performance vs. Standard Eraser

Date: May 31, 2025
Time: 3:30–4:15 PM CST
Location: DTC Classroom
Team Members in Attendance: Simon Kaminer, Paul Akpalu, Diego Niiler
User Testers: Lance Lesser (5'8"), Stephen Spoerri (6'1")

Objective

The goal of this session was to evaluate the MagClean prototype against the standard DTC classroom eraser. We focused on cleaning speed, user experience, effort required, and board coverage quality. Both users participated in three tests: full-board erasing with MagClean, full-board erasing with a standard eraser, and a side-by-side spot test using a 1085 in^2 board section.

Testing Conditions

Testing occurred in a standard DTC classroom. Whiteboards were freshly marked with consistent dry-erase ink, and the environment was quiet and distraction-free. The board panel used for the full clean measured 4,725 in^2. All testers were physically well and enthusiastic.

User Overview

Name	Height	Initial Mood	Notes
Lance Lesser	5'8"	“Good, excited”	Well-rested
Stephen Spoerri	6'1"	“Phenomenal, ecstatic”	Energetic, eager to engage

Testing Session Overview

Task 1: Full Board Cleaning – MagClean

- **Lance**: Took 48 seconds, used two hands, ~3 passes per section. “Easy to use - I give it a 7/10.”
- **Stephen**: Took 52 seconds, noted that “a vertical loadout might work better.”

Task 2: Full Board Cleaning – Standard Eraser

- **Lance**: Took 98 seconds. “This is silly to erase with this tiny eraser when we have a much bigger eraser to use.”
- **Stephen**: Took 105 seconds. Needed a chair to reach the top. “We have to use so much more effort in order to erase the board with the normal eraser.”

Task 3: Spot Test (35" x 31") – Side-by-Side

- **Stephen (MagClean)**: Erased the section in 8 seconds.
- **Lance (Standard Eraser)**: Took 14 seconds.
- **Note**: Photo (Figure 1) shows clearly that the board cleaned with the standard eraser (right side) had more residual ghosting.

Table 11: Observation Table

Task	User	Time (sec)	Notes
Full Board - MagClean	Lance	48	Two hands, 3 passes per area
Full Board - MagClean	Stephen	52	Suggested vertical loadout, repetitive motion
Full Board - Standard Eraser	Lance	98	Commented on inefficiency
Full Board - Standard Eraser	Stephen	105	Required chair, noted physical effort
Spot Test - MagClean	Stephen	8	Significantly faster than Lance
Spot Test - Standard Eraser	Lance	14	Slower than MagClean, left ghosting

Cleaning Times by Task and User

The bar graph below visually compares the performance of each user across different tasks. The MagClean significantly reduced cleaning time in both full-board and spot scenarios compared to the standard eraser.

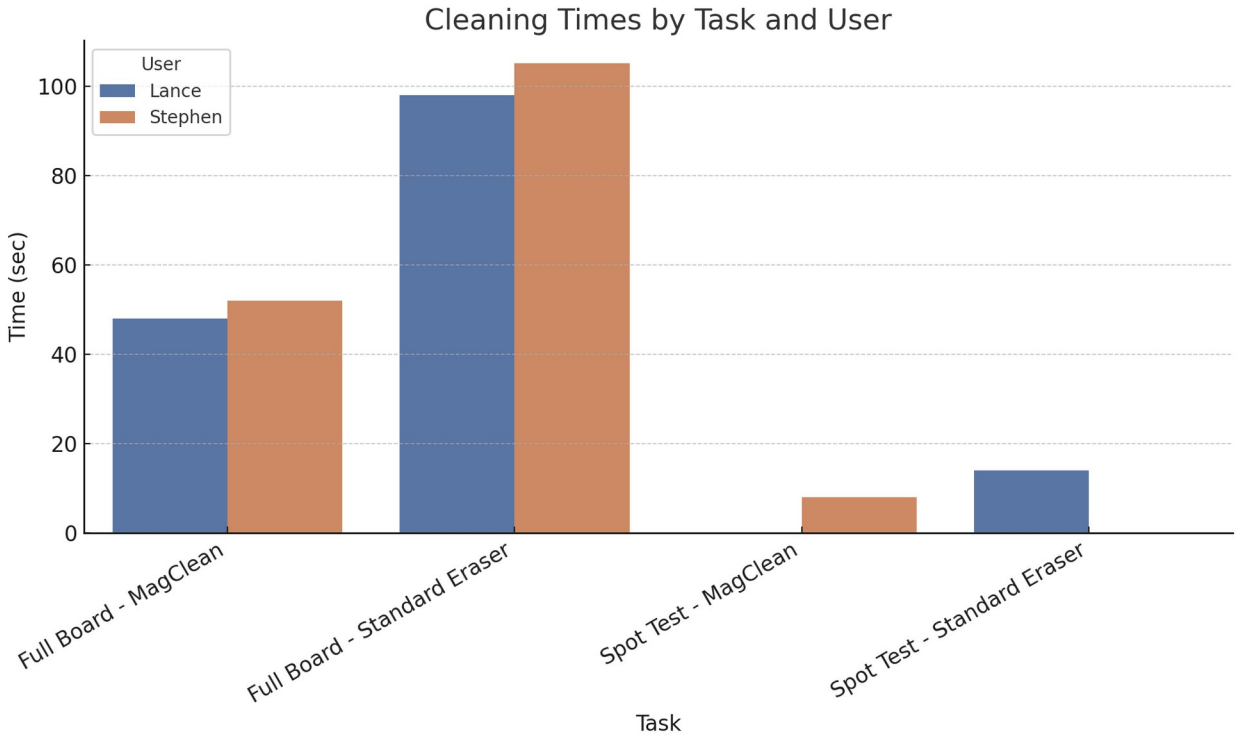


Figure 43: Cleaning Time Comparison Chart

User Quotes & Comments

Lance:

- “Great product, easy to use - much better than the handheld eraser.”
- “Some stronger magnets would help me put even more pressure on the board.”

Stephen:

- “I truly think this should be a staple in every classroom in America.”
- “It helped me clean the entire whiteboard, even parts I couldn’t normally reach.”
- “Compared to the normal eraser, the MagClean is much better. My hands got tired from the standard eraser, not with this.”

- “Maybe a rotatable hinge could help you make the product even better. That said, I think this design is already excellent for what it does.”

Photos

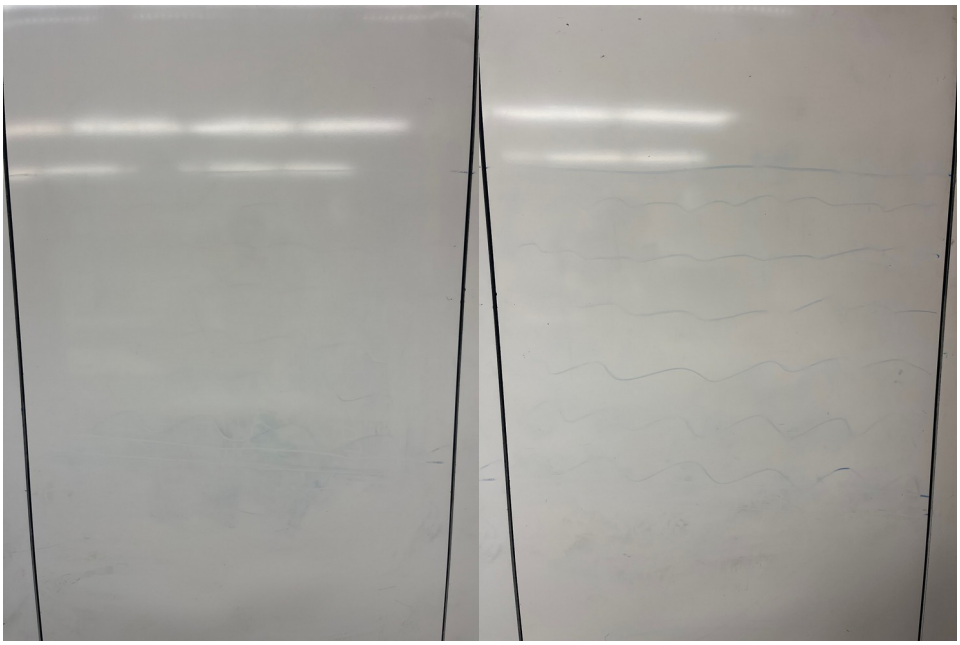


Figure 44: Side-by-side cleaned panels from spot test.

Left side: Cleaned with MagClean - visibly clearer. Right side: Standard eraser - residual ghosting present.



Figure 45: Lance using the MagClean to clean a panel



Figure 46: Stephen using the MagClean to clean a panel

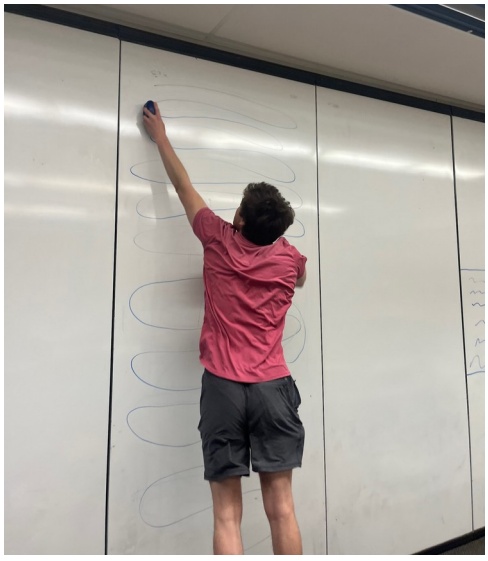


Figure 47: Lance using a regular eraser to clean a panel



Figure 48: Stephen using a regular eraser to clean a panel

Appendix L: Ethics Appendix

Preamble

Our team is designing a whiteboard cleaning solution for use in shared educational spaces such as DTC classrooms. This product will interact with a diverse population of users - faculty, students, custodial staff - with a range of physical capabilities, teaching styles, and expectations. The ethical concerns we face center on ensuring safety, promoting inclusivity, minimizing environmental impact, and maintaining respect for shared classroom content. We have reviewed the NSPE Code of Ethics for Engineers [1] and Northwestern's McCormick Professional Standards [2] to inform our core values and practices.

Core Principles

1. **User Safety**
   Devices must not pose a risk of injury. We aim to avoid hazards such as falling components, pinch points, sharp edges, or harmful exposure to cleaning chemicals. Magnets will be used cautiously, and designs will undergo fall safety tests.
2. **Accessibility and Usability**
   Our solution must be operable by users as short as 4'10", with varying strengths and mobility. This includes telescoping handles, lightweight construction, and intuitive controls.
3. **Environmental Sustainability**
   The product should avoid wasteful disposables and harsh solvents. We plan to incorporate refillable solution cartridges and reusable erasing pads made of microfiber or other biodegradable options [3].
4. **Respect for Autonomy and Shared Content**
   The cleaner should never erase content unless explicitly directed by the user. It must avoid accidental disruption of instructional material.
5. **Originality and Intellectual Property**
   We commit to developing a substantially original design and avoiding patented mechanisms. Our process includes design documentation and regular reviews of existing commercial products to ensure uniqueness [4].

Rules of Practice

1. **Acknowledge the Limits of Our Expertise**
   - Consult classroom instructors, facilities staff, and custodians
   - Seek feedback from experts in ergonomic and assistive design
2. **Understand the Environment Before Proposing a Solution**
   - Learn about classroom layouts and whiteboard materials
   - Understand usage patterns and cleaning workflows
   - Avoid harmful cleaning chemicals by consulting MSDS and safety guidelines [5]
3. **Represent Northwestern Responsibly**
   - Conduct all interactions with users professionally
   - Maintain clear, ethical documentation and design records
   - Uphold standards of conduct in presentations, interviews, and user testing

Response to Ethical Challenges

If a situation arises where a core principle is threatened, we will:

1. **Document the Concern**
    - Include photos, quotes, user feedback, and context
2. **Discuss as a Team**
    - Analyze whether the concern arises from design, usage, or external factors
3. **Notify Instructors**
    - Submit both written and verbal communication, including supporting materials
4. **Pause and Revise**
    - Suspend work on the problematic component until the issue is resolved ethically

Current Ethical Concerns and Responses

Table 12: Ethical Concerns and Mitigation Table

Category	Concern	Mitigation Plan
User Safety	Risk of injury from falls, pinch points, or chemical contact	Rounded edges, enclosed magnets, and avoid acetone-based solvents
Accessibility	Short users may not reach or operate comfortably	Telescoping pole, pivoting joint, lightweight materials
Environmental Impact	Waste from disposable components or toxic materials	Use refillable spray systems, biodegradable pads, and recyclable plastics
Intellectual Property	Design overlaps with commercial devices	Continuous design documentation, comparison with market solutions [4]
Cost/Equity	Device may exceed classroom budgets	BOM capped under $150, simple manufacturing requirements

Design Compliance Summary

The final MagClean prototype aligns with the ethical mitigation strategies outlined in Table 1 and meets all identified criteria:

- **User Safety**: All components incorporate rounded or capped edges to minimize injury risk. Embedded magnets are enclosed in the eraser head housing to prevent exposure. Cleaning is performed using EcosPro Heavy Duty Spray, a plant-based, non-toxic solution approved for

classroom use [3].

- **Accessibility**: A telescoping aluminum pole and pivoting head ensure that users of varying heights can reach all areas of a DTC-scale board without overextension.

- **Environmental Impact**: The design supports refillable spray systems, machine-washable microfiber pads, and minimizes single-use plastic components. Where plastics are used, they are selected for recyclability and durability.

- **Intellectual Property**: The team maintained continuous documentation throughout the design process and conducted comparisons against existing market solutions such as the Loukin All-in-One Magnetic Dry Erase Eraser to ensure originality [4].

- **Cost/Equity**: The final bill of materials is capped under $150, using accessible, commercially available components. The device is simple to manufacture and does not require specialized equipment, supporting equitable implementation across classrooms.

References

[1] National Society of Professional Engineers, “NSPE Code of Ethics for Engineers,” 2019. [Online]. Available: https://www.nspe.org/resources/ethics/code-ethics

[2] McCormick School of Engineering, “Professional Standards,” Northwestern University. [Online]. Available: http://www.mccormick.northwestern.edu/students/undergraduate/professional-standards/

[3] EcosProLine, “Heavy Duty Whiteboard Cleaner,” 2023. [Online]. Available: https://ecosproline.com/products/specialty-cleaner/heavy-duty-whiteboard-cleaner

[4] Loukin, “All-in-One Magnetic Dry Erase Eraser,” Loukin, 2024. [Online]. Available: https://www.loukin.com/products/all-in-one-magnetic-dry-erase-eraser-1

Appendix M: Expert Interview / User Test with Professor Birdwell

Date: May 8th, 2025
Time: 11 AM - 12 PM
Location: Ford 3.331
Team members in attendance: Diego Niiler and Dominic Belyaev
Expert + other key attendees: Professor Birdwell

Expert name, qualifications and, affiliation

Professor Birdwell is a DTC instructor at Northwestern University and has extensive experience with DTC (Design Thinking and Communication) classroom environments. As a regular user of large whiteboards in teaching spaces, Professor Birdwell was consulted to provide expert insights on the functionality, usability, and practical limitations of our proposed whiteboard cleaner designs.

We hoped to get the following insights from this interview:

- How can we make the eraser press better against the board, and what materials should we use?
- How can we make the cleaner easier to use for people of different heights?
- How can we improve our current designs and make sure they work well?
- What parts and tools should we change or add to make cleaning faster and easier?

Before talking about what we learned from Professor Birdwell, here's some background:

- Our design is for cleaning big whiteboards in DTC classrooms. We've made a few test versions (mockups), including a Swiffer-style eraser, a gravity-powered eraser, and one with an absorbent pad.
- So far, we've run into issues like:
    - Not enough pressure being applied to the board to fully erase it.
    - The design feels heavy or awkward to move. Some users are not able to reach all areas of the board.

- We talked to Professor Birdwell because he teaches in these rooms and knows what tools actually work in real classroom settings.
- We brought our current mockup ideas and asked for advice on how to make them more effective and easier to use.
- Professor Birdwell used our current mockups and gave us advice on how to improve. His comments are summarized below.

Main Things We Learned

During our interview with Professor Birdwell, we observed him interacting with our mockups and interviewed him about ideas for next steps and current limitations. These are summarized below.

1. Pressure Problems

- Our eraser needs to press down hard enough to clean well.
- We could fix this by making the eraser smaller or using magnets to help it stick to the board.
- He suggested trying materials like car-wash mitts to help get better contact with the board.
- A ball-and-socket joint would help users adjust the eraser angle easily.

2. Lighter and Easier to Use

- The current version is a bit too heavy.
- Using fewer or smaller erasers and lighter materials could help.
- The pole should have a better grip so it's easier to hold and move.

3. Design Tips

- Use a Swiffer as inspiration, and buy one to reuse the spray part.
- Make the eraser head detachable so users can use it by hand if needed.
- Storing ability matters, and whatever we make shouldn't get in the way of moving or folding the boards.
    - Make the head of our design detachable for this reason, which would make it easier to store

Table 13: Recommended Changes

Component	Recommendation	Rationale
Ball and Socket Joint	Integrate at eraser head	Enhances mobility and user comfort
Magnetic reinforcement	Apply to underside of pad	Increases pressure without requiring more effort
Surface area	Reduce pad size or number of erasers	Focuses pressure for more effective cleaning
Eraser material	Test flexible materials	Conforms to surface irregularities, increases efficiency
Cleaning solution	Consider Swiffer-style or internal reservoir	Eases removal of older dry-erase ink

Table 14: Bill of materials-recommended changes

Initial order plan	Recommended changes	Rationale
Ball and Socket Joint	Add to the connection of the eraser head and telescoping pole to increase degrees of freedom	Allows for increased mobility and wider range of motion when erasing
Swiffer	Use it for its cleaning solution distribution mechanisms	Using an existing working cleaning solution distribution system will allow us to implement an already working method to distribute the solution.

Conclusions and Next Steps

Key Conclusions:

- Pressure application and head flexibility are essential to effective cleaning.
- A lighter, ergonomic design is crucial for classroom viability.
- Magnetic reinforcement could significantly improve usability.
- Cleaning solution integration is helpful but optional; priority should be on effective erasing through mechanical design.

Next Steps:

- Test ball-and-socket joint usability and determine optimal range of motion.
- Experiment with magnetic reinforcement for pressure efficiency.
- Prototype eraser heads using car-wash-style microfiber tendrils.
- Begin integrating a Swiffer-style reservoir system and test moisture distribution.
- Refine the detachable head concept for ergonomic gains and better reach.