Design Report

Miles Ehrlich, Bobby Xiao, Masa Chau, Arthur Chen

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Contents

1 Introduction

The purpose of this design report is to introduce our opportunity, present credible design solutions, and justify the final recommended design as the best through testing and research. Left-handed engineering science students commonly smudge ink on whiteboards in the EngSci common room because of their hand's natural writing motion that forces their hand onto the board. This results in illegibility, additional cleaning, and ergonomic issues if they change their posture to avoid smudging. The primary objective of a solution is to reliably reduce visible smudging while retaining comfort and writing speed. Smudging is defined as the percentage of visible ink removed from the board per standardized sentence. Our final recommended design has the optimal balance of these criteria, while following stakeholder requirements. To address the opportunity, this report will define the stakeholders and their requirements. The Evaluation criteria will then be discussed, followed by the introduction of the recommended design as well as other credible designs. Finally, the proxy tests and Pugh charts that aided us in converging to our final recommended design will be discussed.

2 Stakeholder Requirements

2.1 Defining Stakeholders

To understand what is required of a design, stakeholders' expectations must be made clear. Stakeholders have been consolidated from the original design brief to better reflect evidence we could find and to avoid redundancy.

2.1.1 Left-Handed EngSci Students

They expect to be able to write comfortably on whiteboards at typical speeds without smudging. [Appendix G: *Transcript of Interviews*]. Therefore, when addressing the opportunity, the design must also consider writing speed and writing comfort when using the design in addition to reducing smudging.

2.1.2 Right-Handed EngSci Students Writing Right-to-Left Scripts

Right-handed students writing in right-to-left scripts such as Hebrew or Arabic face similar problems with smudging when writing on a whiteboard [Appendix G: *Transcript of Interviews*]. Therefore, these students' needs also expect to be able to write without smudging using our design. Thus, the design should not be based on handedness to increase the number of users that benefit from the design.

2.1.3 EngSci Students as a Whole

Because students are responsible for damages they caused on the board (1), the use of the design should not cause any damage to or leave non-removable residue on the whiteboard.

2.2 Requirements

Goal 1: Design shall reduce smudging and ensure cleanliness		
Description	Metric	Justification
Less than 50% of the ink removed while writing without the design shall be removed while writing with the design.	% of ink removed from a whiteboard full of ink when performing a writing motion with the design	The area contacted when smudging can be visualized by performing a writing motion on a whiteboard filled in with ink; the removed ink (negative space) represents the area where writing would be smudged. Therefore, the larger this area, the more smudging occurs Reducing smudging by 50% meets an interview expectation [Appendix D].
Any staining from the design shall have $\Delta E^* \leq 1.9$ compared with the whiteboard surface.	The Euclidean color Difference (ΔE^*)	Ensures change in color due to staining after erasing on the board is below perceptible threshold as found in a dental study (2).

Goal 2: Design shall accommodate the writing of current EngSci students		
The time for writing a specific sentence (see Section 6.4) shall not exceed 50% more than the baseline [Appendix D]	Time in seconds	Ensures the interview expectation of balancing writing speed and reduced smudging [Appendix D].
The design shall accommodate a maximum font height of 5.3cm.	Distance between the highest point and the lowest point in a consecutive sentence written on a whiteboard (cm)	These are the maximum values of various examples of handwriting measured in the EngSci common room.

Goal 3: Solution shall be designed for ergonomics		
Handheld designs shall not weigh more than 500g.	Mass in grams	The maximum weight for a handheld tool while performing a precise operation should be 500g to be ergonomic according to (3).
Design shall not cause wrist extension of $> 90°$, wrist radial deviation of $> 20°$, or wrist ulnar deviation of $> 30°$ as outlined in ISO 11226-2000 (4).	Wrist extension, radial deviation, wrist ulnar deviation, in degrees.	These angles reduce strain injuries when adopting a standing stance (4); this will reduce the discomfort that stakeholders expect to experience when using the design [Appendix D].
Design shall accomodate for lateral and dynamic tripod and quadrupod grip style.	Boolean	These represent the primary grip styles when writing (5); thus, the design lets EngSci students write with their natural grip style, increasing comfort when using the design.
Solution shall have maximum dimensions of 10cm x 10cm x 30cm.	Dimensions in cm	This is around the size of a water bottle, an object almost all EngSci students carry with them every day; therefore, it is reasonable to assume that EngSci students could stow the solution in their bags.

3 Evaluation Criteria

3.1 Evaluated Metrics

Metric	Utility Gradient	Justification
Discomfort (Angle Score)	Lower is better	Summing up the scores for the two measured angles (See appendix on metric clarification) yields a numerical score for writing comfort. Higher scores are associated with higher risk of strain injury (6).
Smudged area in %	Lower is better	The area of ink removed from a whiteboard full of ink is a measure of how much a user will smudge while writing; stakeholders wish to have this phenomenon and thus this area minimized.
Writing Speed Decrease in %	Lower is better	When using the design, users' writing speed should decrease by as little as possible in order to meet stakeholder expectations.
Mass in g	Lower is better	Having the solution weigh less makes the design easier to use and prevents injury (3) (6) .
Dimensional Volume in cm^3	Lower is better	Volume is defined as product of device dimensions; the lower this volume the easier it is for stakeholders to stow the solution in the common room or their own bags.

3.2 Metrics not used as Evaluation Criteria

The above ECs were chosen because they can effectively differentiate between solutions. While meeting the requirements for grip style accommodation, board cleanliness, and font height are important to stakeholders, differentiating within acceptable values is not expected from stakeholders, and therefore they are not evaluated as differentiating criteria.

4 Recommended Design - Erasable Permanent Marker

4.1 Overview

The design we recommend is a combination of a permanent marker, a microfiber cloth, a distilled isopropanol solution, and a small towel as pictured in Fig. 1. The marker dries quickly and cannot be smudged or erased by hand. A microfiber cloth covered with a solution of water and isopropyl alcohol effectively removes ink quickly. Subsequently wiping the alcohol off with a small towel removes alcohol residue from board.

Figure 1: Towel, permanent marker, and microfiber cloth. Note that this configuration is the result of several rounds of iterating to ensure an effective and safe design.

4.2 Key decisions made

1. We selected permanent marker ink due to the inability to smudge it on a board. This is because it contains a significant amount of non-polar compounds that do not mix with water or sweat, and so a hand cannot move ink unintentionally (7).

2. We selected isopropyl alcohol for erasing permanent marker ink because it can do so quickly. We initially tested disinfectant wipes containing alkyls, but erasing a short word took over 2 minutes, which we deemed to be an unreasonably long time. Using isopropyl alcohol took just 12 seconds, and so it was chosen to be an element of our design.

3. We decided to use a distilled solution of alcohol to prevent whiteboard damage. While the previous design brief [Appendix G] claimed pure isopropanol damages whiteboards, using a low enough concentration solution (30%-40%) is safe. Evidence for this is that dry-erase markers themselves contain around the same level of alcohol and do not damage boards after repeated use (8).

5 Other Credible Designs

5.1 Pool Noodle

This design, pictured in Fig. 2 consists of a carved out section of a pool noodle. The pool noodle prototype addresses the smudging of written text on a whiteboard by reducing the contact area between the board and the hand. This is done by allowing the user to write between two stubs spaced apart, effectively preventing any undesired contact. The spacing of the stubs is sufficient to allow writing the largest font size in our scope as outlined in our requirements.

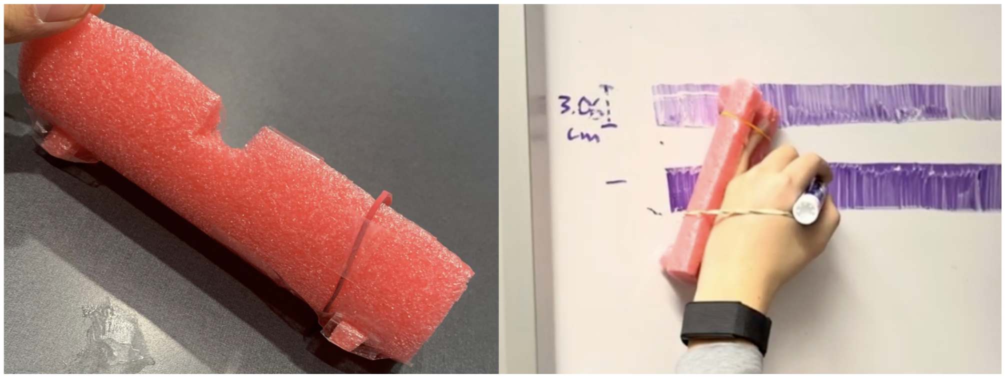

Figure 2: The pool noodle design. Note the two stubs on the left image that reduce contact area with board. This allows writing without smudging between the stubs as seen on the right.

5.2 Wedge

The wedge design pictured in Fig. 3 creates separation between the writing area and the hand by transferring the pressure placed on the board to an area directly below the writing area. The design also limits the ulnar deviation of the hand, creating a comfortable hand rest.

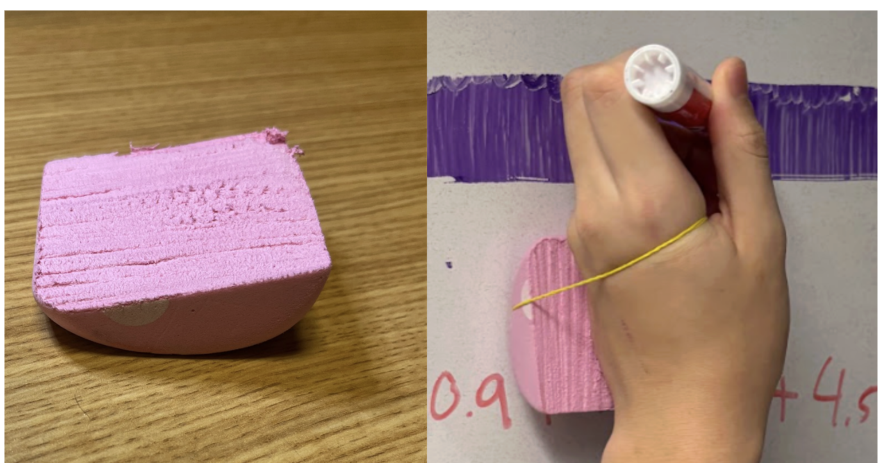

Figure 3: The wedge design; note the transfer of pressure to an area beneath the line of writing.

5.3 Guard

The "guard" design pictured in Fig. 4 makes use of a thin layer of cardboard punctured by a marker; elastic bands prevent the marker from slipping through the hole. Writers can rest their hand against the cardboard and more easily exert pressure onto the point of the marker as opposed to other areas on the board.

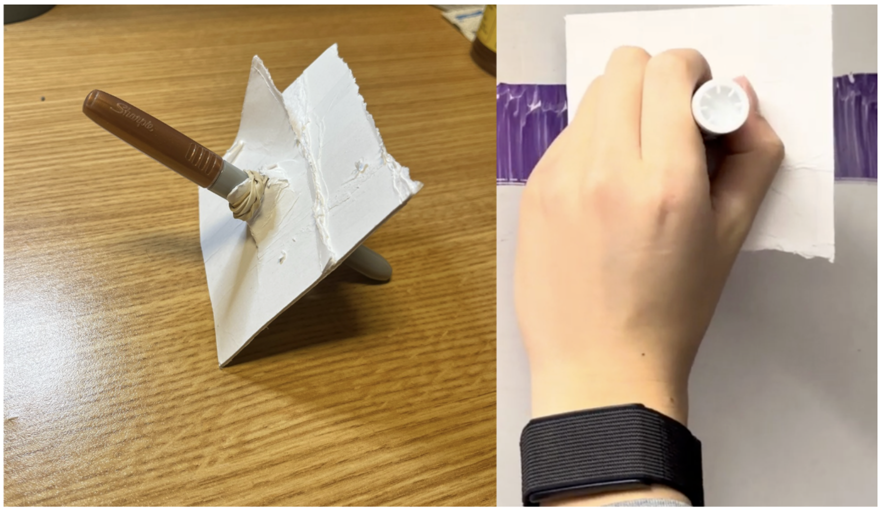

Figure 4: The guard design. Note that the cardboard layer creates a wrist guard that prevents the hand from rubbing on the board.

6 Verification and Proxy Testing

We performed tests and measured metrics to confirm that requirements were met and to set up evaluation criteria results.

6.1 Requirements not evaluated

3 Requirements were tested hollistically, and are not included in EC tables or Pugh charts due to feasibility and time constraints:

6.1.1 Cleanliness

Given the difficulty in measuring ΔE^*, the team decided to judge cleanliness of the board subjectively. All designs were found to leave no noticeable residue after erasing.

6.1.2 Grip Styles

We decided that unless a design had particular features preventing use with certain grip styles, it met this requirement. Because all designs can be adjusted to fit the user (often via elastic bands) we judged that all designs met this requirement.

6.1.3 Font Size

All designs met this requirement based on our observations while writing with them.

6.2 Numeric Test Results for Evaluated Metrics

Measurement Matrix				
Design	Pool Noodle	Wedge	Erasable Permanent Marker	Guard
Discomfort (Angle Score)	1	2	0	1
Smudged Area %	12%	0%	0%	11%
Writing Speed	9%	13%	0%	12%
Mass	34g	39g	20g	25g
Volume	360cm^3	100 cm^3	600 cm^3	1400 cm^3

The goal of proxy tests was to obtain metric values for smudging, writing speed, and writing angle for each design. Weight and volume were also measured directly. Having normalized metric values for each design directly helps recommending a final design based on our Evaluation Criteria.

6.3 Smudging

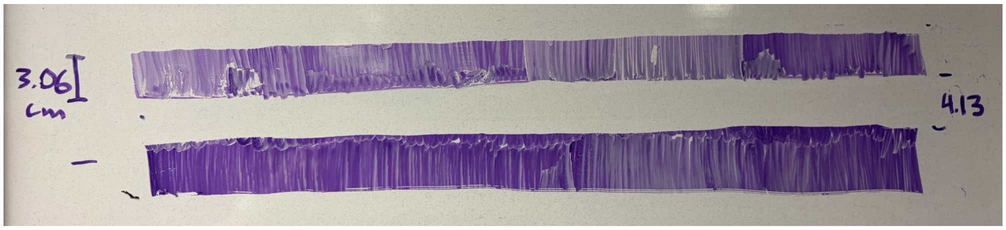

Figure 5: Experimental setup for the smudging proxy test

A left-handed primary stakeholder was asked to perform writing motions along the bottom rectangle, fitted with a different prototype for each trial. The ink area removed due to board contact was measured and compared against the original area. Based on our interview, writing is primarily top-down, so potentially smudging the line above the current one is of concern, but the line below is not in our scope [Appendix D].

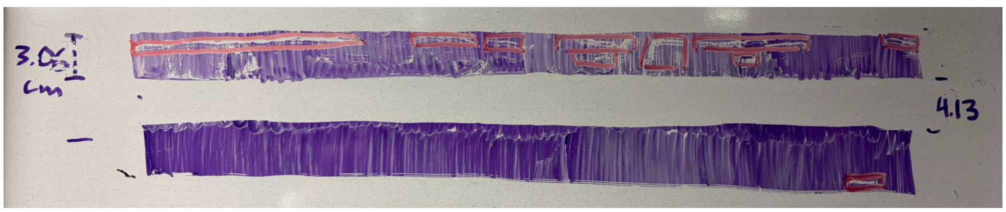

Figure 6: Results from testing the "pool noodle" prototype. Via the rectangles highlighted in pink, we approximated and calculated the total smudging area to get the results in Appendix E. This simplification is reasonable given the time and accuracy constraints of this test.

The test pictured in Fig. 6 yields important information regarding smudging. While it is only an approximate model, it still exposes the magnitude of contact of a device with the board and also accurately shows that certain designs almost do not smudge at all.

The attached video demonstrates the procedure used for the smudging proxy test and shows writing with the different prototypes. This is especially beneficial as writing is an inherently dynamic process best shown in motion. link: **click here**

6.4 Writing Speed

A writing speed proxy test was used to determine how each design could affect a stakeholder's writing speed. Three left-handed stakeholders were asked to write a standardized sentence as pictured in Fig. 7 within the average font width (3.08 cm, Appendix F) we measured in the Engsci common room.

A control test was performed without a prototype for each stakeholder. The following equation was used to determine the change in writing time, in percent, when compared to the control:

$$\% \text{ difference}_{\text{prototype}} = \frac{T_{\text{prototype}} - T_{\text{control}}}{T_{\text{control}}} \times 100\% \tag{1}$$

Then, the overall relative performance for each prototype was determined by averaging the percentage differences of all writers for each prototype.

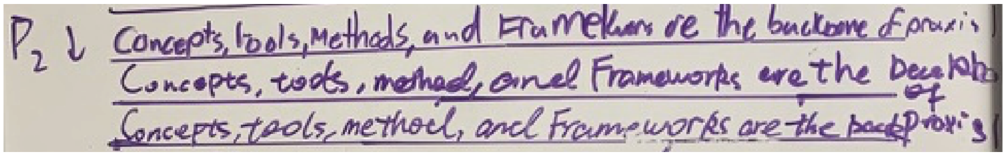

Figure 7: Results from the writing speed proxy test using the "pool noodle" prototype. The sentences were written within the average font size we measured in the common room. The standardized sentence is “Concepts, Tools, Methods, and Frameworks are the backbone of Praxis.”

This test yields important information regarding writing speed. As a proxy test, it is only an approximate model with a limited data pool. Nonetheless, the conditions under which the test was performed very closely match those of everyday real-life use by left handed students. We initially wanted to use the standardized DASH-2 test as recommended by the previous design brief; however, information about exact test details are not publicly available (9). As such, this test is a good model within our ability to test.

6.5 Writing Angles

To measure the angles with which a user writes, we had several left-handed students position their hands in the way that fit their grip style as if writing. Their forearms were kept parallel to the whiteboard so we could accurately measure the angles of the wrist in both the flexion/extension plane and the ulnar/radial deviation plane using a protractor. The average angles were then compiled per design, with the zone number of the two plane angles added up to determine a "discomfort" score based on (6).

This test is imperfect due to the limited data pool and because we measured the angle while the hand was stationary as opposed to moving; however, the test still provided insightful results on the relative ergonomics of different designs. Furthermore, the interpretation of angle data is based on the reliable experience of the authors of an ergonomics handbook.

7 Deciding on our Design

7.1 Pugh Charts

To aid in interpreting the results obtained in Section 6.2 to determine the best design out of the available designs, Pugh charts comparing the ECs of each design were created. The Pugh chart for each design was created by comparing the ECs of that design (the reference design) to every other design and determining whether the other designs performed the same (0), better (+), or worse (-) than the reference. By definition, the entries in the column of the reference design all have values of (0). The Pugh charts are used to better organise the comparative advantages of each design visually.

Pugh Chart: Comparison Relative to Pool Noodle				
	Pool Noodle	Wedge	Permanent Marker	Guard
Discomfort (angle score)	0	-	+	0
Smudged area	0	+	+	0
Writing Speed	0	-	+	-
Mass	0	-	+	+
Volume	0	+	-	-

Pugh Chart: Comparison Relative to Wedge				
	Pool Noodle	Wedge	Permanent Marker	Guard
Discomfort (angle score)	+	0	+	+
Smudged area	-	0	0	-
Writing Speed	+	0	+	0
Mass	+	0	+	+
Volume	-	0	+	+

Pugh Chart: Comparison Relative to Permanent Marker				
	Pool Noodle	Wedge	Permanent Marker	Guard
Discomfort (angle score)	-	-	0	-
Smudged area	-	0	0	-
Writing Speed	-	-	0	-
Mass	-	-	0	-
Volume	+	+	0	-

Pugh Chart: Comparison Relative to Guard				
	Pool Noodle	Wedge	Permanent Marker	Guard
Discomfort (angle score)	0	-	+	0
Smudged area	-	+	+	0
Writing Speed	+	0	+	0
Mass	+	+	+	0
Volume	+	+	+	0

7.2 Final Choice

From inspection of the Pugh Charts, there is no absolutely better design between the pool noodle, wedge, and guard, since each of the three designs are better than the other two in some ECs but worse or equal to the other two in other ECs. The wedge, for instance, has no smudging, but causes greater discomfort and slows writing speed when compared to the pool noodle. If we had to select between these three designs, more specific differentiation would be required. However, the permanent marker design is better than all three other designs in four ECs: discomfort, smudged area, writing speed, and mass. Consequently, based on our tests and experience, it significantly outperforms the other designs in almost all metrics.

The only metric this design is not best in is volume. Because the permanent marker design fits within the volume requirement, it is reasonable to assume that an EngSci student will not be overly encumbered by the size of the design, even though it has greater dimensions than the pool noodle and wedge (when considering its erasing components, see Appendix B). Therefore, the volume criterion is deemed less important than the other criteria.

Thus, our team used experience, prototyping, and numerical testing to decide on the erasable permanent marker as a verified design that best meets our stakeholder's expectations.

8 Conclusion

This report addressed the opportunity of whiteboard smudging for left-handed EngSci students through the analysis of five credible design solutions. To converge to a final design, stakeholder requirements and evaluation criteria were discussed in this report to ensure the validity of each prototype. The evaluation criteria were compared relative to each design with Pugh charts. Then, each prototype underwent rigorous proxy testing to metrically recommend the best design. The proxy tests were designed to minimize bias, and the experimental setups for each proxy test was also discussed in this report.

The results of the proxy tests showed that the erasable permanent marker prototype consistently returned more metrically optimal results compared to the other prototypes. More specifically, the wedge prototype struggled with discomfort, while the pool noodle and guard prototypes struggled with smudging. The Pugh charts further supported the permanent marker as the final recommended design.

Therefore, the final recommended design is the erasable permanent marker design because it meets all core stakeholder requirements, performs well in metric proxy testing, and provides a practical solution for our stakeholders.

9 References

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10 Appendices

10.1 Appendix A: Source Extracts

10.1.1 [1]

III. Other Charges

The University may, as a condition of booking, require that authorized security be made available during the use of the space, including but not limited to where the building would normally be closed at the time of the event. The University may require such security to be provided at the cost of the user and to be arranged by the University.

The University at its discretion may assess additional security requirements and require that the Campus Police be present at any event. These costs are normally the responsibility of the group booking the event.

Over and above the rental charge and security costs, all users will be required to pay any relevant additional costs. Examples of additional costs may include:

a. Use of public address, audio-visual or other equipment or operators;
b. Additional caretaking costs or extraordinary cleaning ;
c. Special arrangements with parking and grounds departments;
d. Special setups where applicable; and/or
e. Damage or undue wear and tear.

Charges for such costs will be reported to the booking office who will forward them to the user for payment.

An external user may be required to carry liability insurance for the event, the provisions and amount of which will be subject to the approval of the University. Proof of this insurance must be on file in advance of the event with the room booking office.

The cancellation policy will be determined by the responsible division and communicated to the user at the time of booking. The user will be required to provide the notice of cancellation in writing in all circumstances. Groups that have booked space and fail to cancel in accordance with the relevant cancellation policy may be charged the relevant booking rates and any additional costs that have been incurred, whether or not they actually use the space.

Figure 8

10.1.2 [2]

Results

The determined color difference values at which 50% of all observers could detect a color difference (50:50 probability) was 1.9 ΔE^* units with a 95% confidence interval and ranged from 1.7 ΔE^* units to 2.1 ΔE^* units. The determined color difference value at which 50% of all observes preferred to replace the tooth because of unacceptable color difference (50:50 probability) was 4.2 with a 95% confidence interval that ranged from 3.9 ΔE^* units to 4.7 ΔE^* units.

Figure 9

10.1.3 [3]

- Use the right tool for the job. Ensure it is the right size and has sufficient power to do the job safely.
- Weight of the tool and distribution of the load affect the way the user holds the tool. Limit the weight of the tool to 1.4 kg (3 lbs) or less for tools operated with one hand. For precision operations, tools should weigh less than 0.5 kg (1 lb). When there is a choice, select a tool of a low-weight.

Figure 10

10.1.4 [4]

Table A.1 — Indications of the limits of joint ranges of motion

Postural parameter	Range of motion limit	Reference	
		Table	Figure
Upper arm external rotation	90°	5	8
Elbow flexion	150°	7	11
Elbow extension	10°	7	11
Forearm pronation	90°	7	11
Forearm supination	60°	7	11
Wrist radial abduction	20°	7	11
Wrist ulnar abduction	30°	7	11
Wrist flexion	90°	7	11
Wrist extension	90°	7	11
Knee flexion	40°	8	12
Ankle dorsiflexion	20°	8	12
Ankle plantar flexion	50°	8	12

NOTE All the figures mentioned are with, respect to an upright standing posture with the arms hanging freely, and the palms of the hands facing the body.

Figure 11

10.1.5 [5]

Mature Grasp Styles

There are four types of mature grasp:

1. **Dynamic tripod**: The pencil is held in the tips of the thumb, index finger, and long finger, resting in the webspace. Writing is done by moving the fingertips.
2. **Dynamic quadrupod**: The pencil is held in the tips of the thumb, index finger, long finger, and ring finger, resting in the webspace. Writing is done by moving the fingertips.
3. **Lateral tripod**: The pencil is held along the lateral side of the thumb by the index finger and long finger. The pencil does not rest in the webspace. Writing is done by moving the fingertips.
4. **Lateral quadrupod**: The pencil is held along the lateral side of the thumb by the index finger, long finger, and ring finger. The pencil does not rest in the webspace. Writing is done by moving the fingertips.

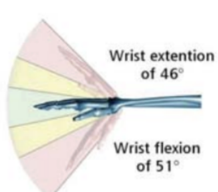
Figure 12

10.1.6 [6]

Zone 0 and Zone 1 are preferred for most movements to occur. Zones 2 and 3 should be avoided when possible, especially for repetitive and heavy tasks. Motion in these ranges puts more strain on muscles and tendons and could lead to the development of musculoskeletal disorders.

Figure 7 shows the ROM for common joint movements. Zone 0 is in green, Zone 1 is in yellow, and Zone 2 is in red. Zone 3 is anywhere beyond the red. Table A3 in the Appendix on page 49 shows the numerical values for each Zone.

Figure 13



	Zone
Green	0
Yellow	1
Red	2
Beyond Red	3

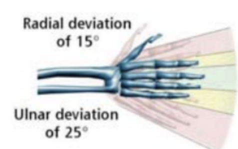


Figure 14

10.1.7 [7]

9. An ink composition resistant to solvent-evaporation comprising:

(a) from about 50% to about 90% of n-propanol;

(b) from about 0.1% to about 10% of 2-pyrrolidone;

(c) from about 0.1% to about 3% of a vegetable derived modified tryglyceride;

(d) from about 5% to about 15% of a terpene phenolic resin;

(e) from about 0.1% to about 2% of a polyether modified dimethylpolysiloxane copolymer;

(f) from about 0.1% to about 2% of a silicone glycol surfactant; and

(g) from about 5% to about 40% of at least one colorant to yield a detectable color when the ink composition is applied to a writable substrate; and

(h) from about 0.1% to about 10% of water.

Figure 15

10.1.8 [8]

3. The composition of claim 2 wherein the poly(oxyalkylene) substituted colorant is an ethoxylated polymeric dye; and

wherein the volatile solvent vehicle is at least one alcohol selected from the group consisting of ethanol, n-propanol, isopropanol, n-butanol, sec-butanol, and any mixtures thereof.

the volatile solvent vehicle of step (a) comprises 40-52%;

the binder resin of step (b) comprises 11-13%; and

the poly(oxyalkylene) substituted colorant of step (g) comprises 10-20%, wherein all the proportions are expressed in weight percentages of the total composition.

Figure 16

10.1.9 [9]

Detailed Assessment of Speed of Handwriting, Second Edition (DASH-2) is a reliable measure of handwriting speed for children and young adults. DASH helps identify functional handwriting difficulties and provides relevant information for intervention planning.

Figure 17

10.1.10 [10]

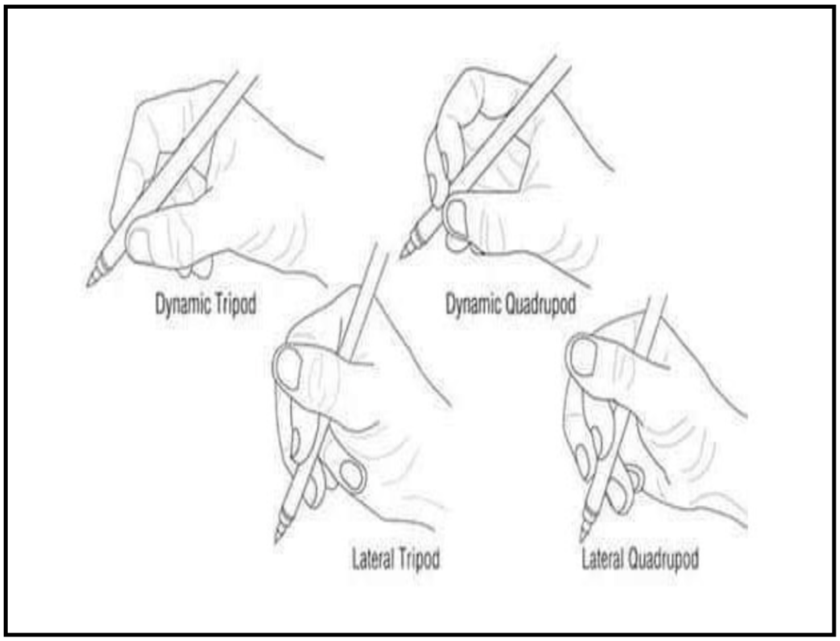


Figure 18

10.2 Appendix B: Metric Clarification

10.2.1 Cleanliness

The metric for cleanliness is the Euclidean Difference ΔE^*. It is the distance between points representing color stimuli in a 3D-space with specific coordinates [color iso]. However, due to the level of complexity of calculating these coordinates we decided that all team members being unable to notice color residue was an appropriate proxy for this metric.

10.2.2 Writing Angle

A hand can move in two different planes relative to the forearm. If the wrist extends upward, this is called **wrist extension**, if it extends downwards it is called **wrist flexion**. Sideways wrist motion towards the thumb is **radial deviation**, motion towards the pinky finger is **ulnar deviation.**

Figure 19: Different hand angles. Note the zones indicating comfort (lower is better) (6).

Fig. 19 shows the comfort "zone" to which different angles belong; higher zones are associated with excess strain on muscles (6). For the evaluation criterion of comfort, we took the sum of the zones for the two angles to measure overall comfort level.

Definition of Zones for Angle Score (in degrees)				
	Zone 0	Zone 1	Zone 2	Zone 3
Wrist Flexion	0-10	11-25	26-50	51+
Wrist Extension	0-9	10-23	24-45	46+
Wrist Radial Deviation	0-3	4-7	8-14	15+
Wrist Radial Deviation	0-5	6-12	13-24	15+

10.2.3 Grip Styles

There are four primary grip styles: lateral tripod and quadrupod, and dynamic tripod and quadrupod as seen in Fig. 20 (5).

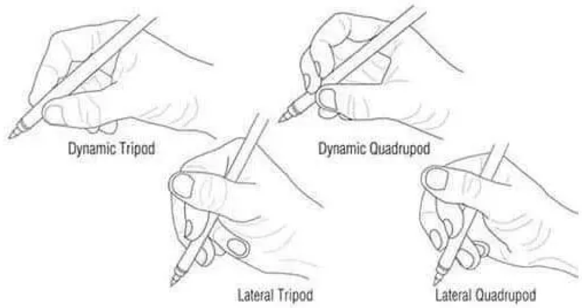


Figure 20: Illustration of the most common grip styles (10). Any solution should work with all of these.

10.2.4 Volume

We consider unmodified dry erase markers and standard whiteboard erasers to be onsite at the common room, they therefore do not count toward volume. If a solution requires different markers or erasers, these will be counted toward volume because students will likely have to store the items themselves.

10.2.5 Mass

Mass here is the total mass of the writing design including markers.

10.3 Appendix C: Need, Goals, and Objectives

The solution needs to reduce smudging in left-handed EngSci students without impairing their ability to write quickly and comfortably.

Table 1: Goals and Objectives

Number	**Description**	**Metric**	**Justification**
Goal 1	**Design must not affect the user's baseline writing ability**		
	Objective 1.1: Cannot inhibit the user's baseline DASH-2 score by more than 15 points.	Score (points) on the DASH-2 (Detailed Assessment of Speed of Handwriting).	A 15-point decrease on the DASH-2 is one standard deviation, indicating a significant drop in handwriting speed [16].
	Objective 1.2: Ensure no risk of strain injury caused by wrist extension 90°, wrist radial abduction 20°, and wrist ulnar abduction 30° (ISO 11226:2000).	Angle of wrist extension, radial abduction, and ulnar abduction (degrees).	Reducing strain injuries during standing writing preserves the user's original writing ability.

Continued on next page

Number	Description	Metric	Justification
	Objective 1.3: Accommodate various grip styles: tripod and quadrupod (lateral tripod, dynamic tripod, lateral quadrupod, dynamic quadrupod).		This represents a general usability expectation and fits under Goal 2 rather than a measurable objective.
Goal 2	**Design must be comfortable to use and carry in the EngSci commons.**		
	Objective 2.1: Less than half the ink removed without the design should be removed when using the design.	% of ink removed.	Matches stakeholder interview expectations [Appendix D].
	Objective 2.2: Should meet 1.1 and 1.2 for the lateral tripod grip style.		Ensures effective use by a wide range of users with differing grip styles.
	Objective 2.3: Should meet 1.1 and 1.2 for the dynamic quadrupod grip style.		Ensures effective use by a wide range of users with differing grip styles.
	Objective 2.4: Should meet 1.1 and 1.2 for the lateral quadrupod grip style.		Ensures effective use by a wide range of users with differing grip styles.
Goal 3	**Ensure no unintentional movement of ink on the whiteboard occurs.**		
	Objective 3.1: Hand should not exhibit a Euclidean Colour Difference greater than 1.9.	Euclidean Difference (ΔE^*).	Ensures the hand stays clean and does not visibly stain.
Goal 4	**Design must not damage the whiteboard.**		
	Objective 4.1: Any new nicks after using the design must meet the defined limitation.		Ensures that any damage can be attributed specifically to the design.
	Objective 4.2: Any staining should have $\Delta E^* \leq 1.9$.	Euclidean Difference (ΔE^*).	Ensures colour changes remain below perceptible threshold (from a dental study where 50% of participants noticed differences at $\Delta E^* = 1.9$).
Goal 5	**Design should be ergonomic.**		
	Objective 5.1: If handheld, the design should not exceed 500 g in weight.	Mass (g).	Based on CCOHS "Powered Hand Tools – Ergonomics," which specifies 500 g as the ergonomic limit for handheld tools that require "precision operations".

10.4 Appendix D: New Interview with Left-Handed EngSci Student

Question: When your writing gets smudged, what is the most annoying consequence?

Answer: I or my audience are no longer able to properly read what was written before, usually because part of the ink has been removed.

Question: How much ink do you think can be removed before the writing is illegible?

Answer: That's kind of a difficult question to answer because of the variation of my writing. Overall, I'd say less than half of the ink that gets smudged when writing normally could be gone before the writing is noticeably harder to read.

Question: Do you find that smudging affects how fast you write?

Answer: Not really, although of course having to go back and rewrite the words that got smudged does waste time.

Question: If a solution were to slow down your writing, how much of a slowdown would be unacceptable?

Answer: It probably shouldn't go down by more than 50%.

Question: Aside from when you smudged something, do you find yourself frequently going back to change things you wrote?

Answer: Well, sometimes I definitely think of something I forgot or an extra little bit of information I want to add to a previous point, so it does happen from time to time. Generally though, that doesn't happen a lot and I spend most of my time editing my writing on fixing the smudging. If that wasn't an issue, I would barely have to go back and change anything.

Question: We are thinking of a solution that might cause smudging below the line on which you are writing text. In light of the previous question, do you think this would be a major issue?

Answer: I think as long as the line above the line I'm writing on isn't being smudged too much, the line below really doesn't matter all that much as I'm almost always writing lines top-down.

Question: Do you have any other concerns surrounding potential solutions to this issue?

Answer: When you try to avoid smudging as a lefty your hand can end up in some really uncomfortable positions. I would definitely want a design to consider the ergonomics of writing and prevent stretching or contortion.

Question: Thank you so much for your time!

10.5 Appendix E: Proxy Test Raw Data

Table 2: Smudging test result

	Initial overall area	Smudged upper line area	Smudged writing line area	Percentage of upper area	Percentage of writing area	Total percentage
Pool noodle	367.2	42.3	0	11.5% (0% writing area)	0%	11.5%
Wedge	367.2	0	0	0%	0%	0%
Permanent marker eraser	367.2	0	0	0%	0%	0%
Guard	367.2	7.85	31.4	2.14%	8.55%	10.69%
Control	367.2	5.46	91.4	1.49%	24.89%	26.38%

Table 3: Writing Speed Test Results

Trial(s)	Time (s)			% Difference
	Person One	Person Two	Person Three	
Control	30.8	31.00	30.4	—
Permanent marker	30.8	31.00	30.4	0%
Pool noodle	35.15	36.74	29.1	9.466%
Wedge	34.14	39.00	31.11	12.99%
Guard	34.59	36.78	32.2	12.30%

Table 4: Wrist Angle Measurements and Discomfort Zone Scores

	Pool Noodle	Wedge	Permanent Marker	Guard
WE (°)	10 (zone 0)	0 (zone 0)	—	10 (zone 1)
WF (°)	—	—	5 (zone 0)	—
RD (°)	6 (zone 1)	—	2 (zone 0)	0 (zone 0)
UD (°)	—	13 (zone 2)	—	—
Overall score	**1**	**2**	**0**	**1**

10.6 Appendix F: Engsci Common Room White Board Writing Data

Table 5: Samples of font height in Engsci Common room

Sample #	1	2	3	4	5	6	7	8	9	10	Avg	Max
Average Font (cm)	2.1	3	3.8	3.5	2.2	2.6	1.5	5.3	5.1	1.7	3.08	5.3

10.7 Appendix G: Original Design Brief

Attached is the original design Brief on left-handed use of whiteboards. Not that page numbers here are the original Brief's page numbers, not those of this design report.

IMPROVING ENGINEERING SCIENCE COMMON ROOM WHITEBOARD USABILITY FOR LEFT-HANDERS

***Word count:* 1798**

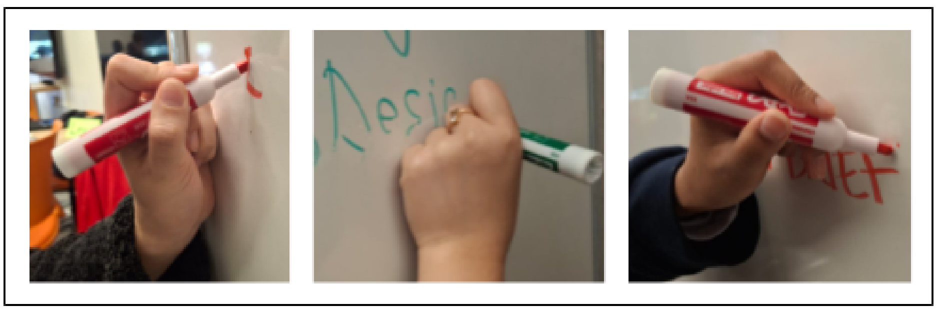
Table of Contents:

I. Introduction

This design brief frames the challenges faced by left-handed writers when using whiteboards in the Engineering Science common room. Left-handers often smudge or erase their written work unintentionally when writing rightwards [Appendix B2-3], [Appendix C]. To limit these effects, left-handers resort to uncomfortable writing postures, resulting in muscle strain and poor handwriting [3], [4], [28]. This brief defines the scope of this problem, discusses stakeholder expectations, and explores the limitations of existing designs to inform needs, goals, and objectives for improving the left-handed whiteboard experience.

II. Using EngSci Common Room Whiteboards as a Left-Handed Individual

As most language scripts in the world are right-oriented [2], left-handers' hands tend to trail over their script and rest on the board (Figure 1), smudging ink (Figure 2) and transferring residue to the palm [Appendix B3], [Appendix C]. The non-absorbent whiteboard surface causes this inconvenient writing experience. For the purpose of this design brief, the whiteboards are a fixed element of the common room that can not be replaced.



1.1 *1.2* *1.3*

Figure 1. Observation of different left-handed pen grips used by students when using whiteboards

Observation and research shows that left-handers often adopt awkward wrist angles when writing [Figure 1.3], [Appendix B3], [Appendix C]. Even on horizontal surfaces, they exhibit greater wrist flexion than right-handers [3], increasing muscle strain and the risk of musculoskeletal disorders [3], [4], [27]. This effect is likely exacerbated on whiteboards, where the arm is unsupported and a standing stance is adopted. Awkward wrist adjustments can also reduce perceived handwriting quality [Appendix B2], [Appendix C3], [28].

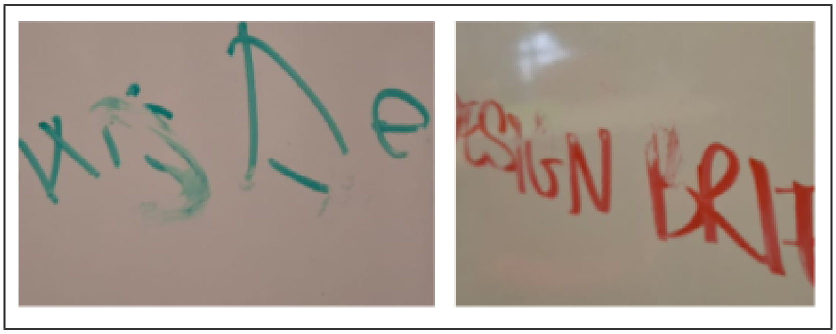


Figure 2. Observations of smudging yielded from left-handers in Fig. 1

Hence, despite posture adjustments, whiteboard writing still causes discomfort and reduced satisfaction for left-handers, emphasizing the need for a design solution.

III. Defining the Working Environment

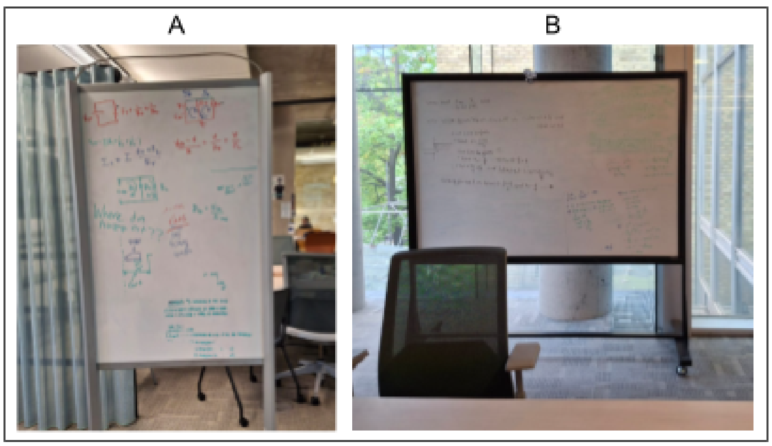


Figure 3. The 2 whiteboard models that were considered for this design brief.

The Engineering Science Common Room is an indoor space with several whiteboards, each with a tray for markers and erasers. While the board material is unconfirmed, it is likely melamine as it accounts for the majority of the whiteboard market (45%) [5].

There are 2 sizes of whiteboards in the common room; tray dimensions were found to be 5.5 ± 0.05 cm (Whiteboard A) (Figure 4) and 4.9 ± 0.05 cm (Whiteboard B). Whiteboard markers in the common room are 17.8 cm [14] in length and the eraser is 13 cm x 8 cm x 5 cm [17] . Design solutions could employ similar dimensions to maintain consistency with standard whiteboard materials, increasing users' adaptability as outlined in Norman's 'The Design for Everyday Things' [24]. Since the common room is frequently occupied by Engineering Science students studying [Appendix C3], the design must also avoid causing auditory disturbance.

Figure 4: tray of whiteboard A.

IV. Understanding Stakeholders and Their Needs

As the common room is a shared educational space, there are many who may be affected by a design solution. Below is a discussion of different stakeholders and their expectations.

a) Left-Handed EngSci Students

The primary stakeholders – users of this opportunity.

They expect to be able to write on whiteboards at the rate as right-handed peers without unintentional smudging of the writing and on the hand [Appendix B2]. The design should be easy and fast to implement into one's writing process without affecting their writing ability. To ensure this, it should prevent hand pain and should be ergonomic [Appendix C1].

b) Audiences and Group Members of Left-Handed Students

Primary stakeholders.

They expect to read the writing of the left-handed peers' work on whiteboards without issue. The design should minimize noise to avoid distraction [23]. It must be operable efficiently and quick to access, without hindering the user's working pace.

c) Right-Handed Students Writing Leftward Scripts (e.g, Arabic)

Potential primary stakeholders with similar struggles. [Appendix C3]

They wish to write with satisfactory handwriting and note minimal differences between writing left-ward and right-ward scripts [Appendix C3]. The design could either not consider handedness in design or have a right-handed alternative.

d) Facility Custodians

Secondary stakeholders

They expect that the design can not leave non-removable residue and must not require maintenance multiple times a day, as stakeholders are only on site to clean once daily [Appendix A]. Design must pass the University of Toronto APPA Cleaning Standard [29].

e) Facility Equipment Regulator

Tertiary stakeholders.

They expect the design to not damage the whiteboard or surrounding equipment. This design should pass any standards from the University of Toronto for educational spaces [31].

f) Design Team

Primary stakeholders.

They expect other stakeholders' expectations to be satisfied by fulfilling the Need, Goals and Objectives. This design should carry minimal bias from the team's perspective through in depth research and understanding of other stakeholders.

V. A Discussion of Reference Designs

While some existing products may aid with left-handed whiteboard use, each has shortcomings relative to stakeholder needs.

a) Integrated Eraser Markers

Permanent markers with integrated erasers (e.g., Faber-Castell Multimark [5]) offer a short-term solution: the permanent ink prevents smudging during writing, and the eraser on the back allows removal afterward. While Faber-Castell does not disclose its eraser formula, it is likely alcohol-based since permanent marker polymers are soluble in alcohols such as isopropanol [6].

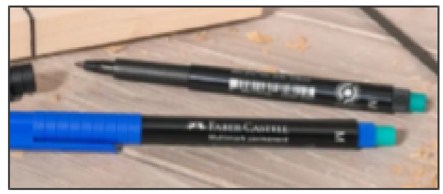


Figure 5. [5]
Multimark pen with integrated eraser on back of pen, in teal.

However, the eraser's small surface area makes cleaning large sections slow. Enlarging it might seem effective, yet another issue remains: alcohol-based erasers degrade melamine whiteboards with repeated use, shortening board lifespan [8]. Hence, while integrated eraser markers address smudging, they are not a sustainable long-term solution – however, they may inspire chemical designs based on how they erase non-smudge ink.

b) Smudge Guards

SmudgeGuard® gloves (87% Nylon, 13% Spandex) [9] are intended for tablet users looking to reduce sweat transfer to screens; thus, they may also prevent ink smudging (Figure 6).

However, this design cannot fully prevent unintentional erasure since it may lift dry-erase ink from the whiteboard due to the design's absorbency. While inspiration can be taken from how they protect the palm, they highlight the need for a solution to prevent erasure.

Figure 6. [9] SmudgeGuard® gloves, which cover the palm, minimising ink transfer.

c) *InstaMorph*

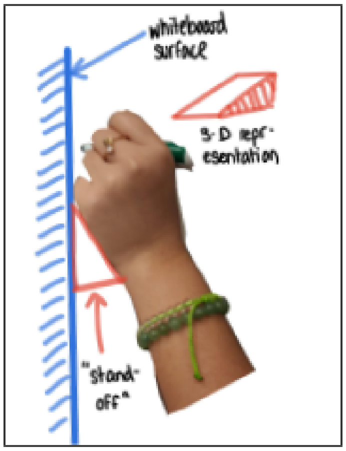


Figure 7. simple representation of what a "stand-off" might mean.

One left-hander expressing annoyance on Quora suggested using InstaMorph, forming a "custom stand-off" (Figure 7) with a lightweight polyester thermoplastic [11], to form to pivot the hand while writing on boards [Appendix B #1].

However, this task requires modeling skills and dedicated time to create a personalized product. The prolonged sensation of plastic against skin is also undesirable [21], and contact with the board risks scratches. While InstaMorph is an impractical widescale solution, the pivot concept could inspire future designs.

VI. Needs, Goals and Objectives

From the stakeholder expectations and reference design shortcomings, we can derive needs, goals and objectives necessary to deem a solution to this *splartz* "sufficient."

Need: Left-handed students are able to write on whiteboards in the EngSci common room without issue.

Table 1: Goal 1 meets primary stakeholders' needs by facilitating their use of whiteboards without harm.

	Description	**Metric**	**Justification**
Goal 1	Design must not affect the user's baseline writing ability		
Objective 1.1	Cannot inhibit the users baseline DASH-2 score by more than 15 points [16].	Score (points) on the DASH-2 (Detailed Assessment of Speed of Handwriting).	A 15 points decrease on the DASH-2 is one standard deviation, signifying a significant drop in handwriting speed [16].
Objective 1.2	Ensure there is no risk of strain injury caused by wrist extended by >90º, wrist radial abduction, >20º, and wrist ulnar abduction, >30º, outlined in ISO 11226-2000 [Appendix A] [13].	Angle of extreme wrist extension, wrist radial abduction and wrist ulnar abduction in degrees.	Reducing strain injuries when adopting a standing stance re-ensures the user's original writing ability.

Objective 1.3	Accommodate for various grip styles on the pen, namely tripod and quadropod grip styles.	Grip styles: lateral tripod, dynamic tripod, lateral quadropod, dynamic quadropod.	Ensures the design is usable by any user with differing grip styles [14]. DfErgonomics [27] emphasises to "anticipate actions."

Table 2: Ergonomics-focused goal that meets the needs of all primary stakeholders through ensuring the device is convenient to use and be around.

	Description	**Metric**	**Justification**
Goal 2	Design must be comfortable to use and have around the commons.		
Objective 2.1	Design width of at most 4.9cm.	Width (cm) of design.	Design must fit onto the marker trays (4.9cm and 5.5cm). so users can have quick access.
Objective 2.2	Design colours are distinguishable, colour difference between the design and the marker rail (silver, #C0C0C0) must have a perceptual $\Delta E^* \geq 20$ according to ISO/CIE 11664-4 [Appendix A], [12].	The Euclidean Difference (ΔE^*).	A visually distinct colour allows users to have quick access to the design.
Objective 2.4	Reduce disturbance by maintaining the common room's sound pressure level to under 60 dB.	Room's sound pressure level (dB).	Research shows that "increasing background sound pressure level to 60 dBA significantly impairs auditory working memory task performance" [22].

Table 3: Goal 3 caters to primary stakeholders. Research suggests that smudging leads to lower legibility in left-handed children [28]; hence, we assume that by reducing smudging, one increases legibility. Further research could be done to confirm.

	Description	Metric	Justification
Goal 3	Ensure no unintentional movement of the ink on the surface of the whiteboard occurs		
Objective 3.1	No accidental contact between design and surface of the whiteboard within 27.73s [19] of the ink being applied.	Ink's drying time (seconds), contact points.	Ensures no unintentional smudging can occur before the ink is dry [19], maintaining legibility.
Objective 3.2	No accidental contact between design and surface of the whiteboard after 27.73s of the ink being applied.	Ink's drying time (seconds), contact points.	Ensures no writing is erased after ink drying [19] so written work can be read.

Table 4: Goal 4 reduces the messiness of the writing experience – an inconvenience mentioned by left-handers [Appendix B, C].

	Description	Metric	Justification
Goal 4	Ensure no ink residue is left on the hand after use of the device		
Objective 4.1	Zero points of contact between the hand of the user and the surface of the whiteboard.	Hand-whiteboard contact points.	Ensures no ink is able to rub off onto the skin of the user, fulfilling stakeholder's expectation.

Table 5: Goal 5 designs for maintenance, satisfying custodians and regulatory staff through reduced damage and stains to whiteboards.

	Description	Metric	Justification
Goal 5	Design must not damage the whiteboard.		

Objective 5.1	Any nicks on the whiteboard surface must be "no greater than 0.005″ (0.01270 cm) in depth and 0.010″ (0.0254 cm) in width."	Depth and width of nicks (inches/cm).	PTI Technologies' Surface Inspection Acceptance Criteria allows for surface irregularities below 0.005″ in depth and 0.010″ in width on "non-functional surfaces", which a whiteboard falls under [25].
Objective 5.2	Any staining from the design should have $\Delta E^* \leq 1.9$ with whiteboard surface.	The Euclidean Difference (ΔE^*).	Ensures color changes remain below the perceptible threshold in a dental study where 50% of participants noticed differences in dentures [26]; design must be below this to avoid visible staining.

VI. Next Steps

In conclusion, left-handed smudging on boards and palms when using EngSci common room whiteboards is a documented issue. A design team addressing this challenge must maintain regular communication with primary stakeholders to ensure that left-handers are satisfied with the final outcome. While literature is available on left-handed struggles, further primary research within the common room environment may benefit the design team. Through divergent thinking and rigorous testing to meet goals and objectives, a design team can effectively address the needs of left-handers and develop a practical solution.

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See Appendix A for relevant source extracts.

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VIII. Appendices

Appendix A: Relevant Source Extracts

[3] Page 1

> 1.66±1.19% in right-handers. [Conclusion] As a result of this study, it was discovered that left-handers used more wrist flexion in performance of the writing task with the dominant upper extremity than right-handers, and that the left-handers activated the wrist and shoulder muscles more than the right-handers. These results indicate a potential danger of musculoskeletal disease in left-hander.

[4] Page 1

> **Results** All the derived variables were highly correlated, greater angles and greater forces being associated with greater velocities and higher repetitiveness. A multivariate linear regression model for the prediction of the prevalence of musculoskeletal disorders of the wrist was constructed (R = 0.904). Height, weight, seniority, angles in radial-ulnar deviation, and forces were significant and independent predictors of the prevalence.
> **Conclusions** The prevalence of wrist disorders is significantly linked to wrist angles in deviation and to forces exerted. Due to their high correlation with force, the repetitiveness indices and velocities, as defined, do not appear to play an additional role. Further research is needed to find alternative ways of characterizing repetitive-ness.

[6]

> But what if the board gets stained? It's important to remember that the polymers in both permanent and dry erase markers are water-resistant, so the best way to clean any stubborn smears on your board is to add a little squirt of alcohol. The most effective options contain at least one of the solvents used in the markers themselves, such as isopropanol. This is found in rubbing alcohol as well as nail varnish remover and should quickly disperse the ink before it evaporates, allowing you to rub it off. Since isopropanol is found in dry erase pens, drawing over a whiteboard stain and then rubbing with a cloth can also help remove it.

[21] Page 5

First, we find that greater brush stiffness decreases pleasantness. Indeed, most prior works on pleasantness tend to use only a smooth brush and vary velocity, but changing brush stiffness decreases pleasantness much more, comparatively, than change in velocity. Work is still required to understand exactly why. A likely possibility, is a higher activation of c-nociceptors [27] in conjunction with c-tactile afferents when increasing brush stiffness. In alignment, in our instrumented

The stiffest brush used in this paper was made of "stiff, synthetic plastic," while the others were not, hence supporting that the sensation of plastic on skin is typically seen as undesirable.

[12] Page 7

The CIE 1976 *a,b* colour difference, ΔE^*_{ab}, between two colour stimuli is calculated as the Euclidean distance between the points representing them in the space according to Formulae (19) or (20):

$$\Delta E^*_{ab} = \left[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2 \right]^{1/2} \quad (19)$$

or

$$\Delta E^*_{ab} = \left[(\Delta L^*)^2 + \left(\Delta C^*_{ab}\right)^2 + \left(\Delta H^*_{ab}\right)^2 \right]^{1/2} \quad (20)$$

https://subscriptions-techstreet-com.myaccess.library.utoronto.ca/products/834704

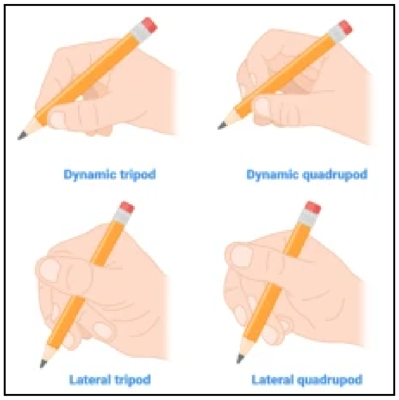
[13] Page 7

Table A.1 — Indications of the limits of joint ranges of motion

Postural parameter	Range of motion limit	Reference	
		Table	Figure
Upper arm external rotation	90°	5	8
Elbow flexion	150°	7	11
Elbow extension	10°	7	11
Forearm pronation	90°	7	11
Forearm supination	60°	7	11
Wrist radial abduction	20°	7	11
Wrist ulnar abduction	30°	7	11
Wrist flexion	90°	7	11
Wrist extension	90°	7	11
Knee flexion	40°	8	12
Ankle dorsiflexion	20°	8	12
Ankle plantar flexion	50°	8	12
NOTE All the figures mentioned are with, respect to an upright standing posture with the arms hanging freely, and the palms of the hands facing the body.			

https://subscriptions-techstreet-com.myaccess.library.utoronto.ca/products/70275

[14] Page 8



https://www.medbridge.com/blog/identifying-pencil-grasp-style-why-it-matters

[19]

In the Drying Time test, the mean time for each of the three inks is indicated above, ink trial 1 has a mean time of 11.45 seconds, 16.37 seconds for ink trial 2, and 27.73 seconds for the industrial ink, respectively, dry on a whiteboard surface. These results show that industrial ink is the most effective in terms of absorbency since it does not dry out too quickly, while ink trial 1 was the least absorbent ink from the absorbency test.

[23]

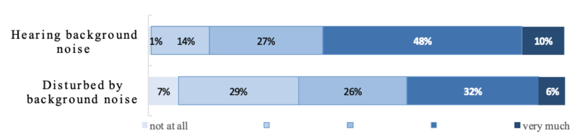


Figure 2.3 Background noise perception and disturbance in open-plan study environments (n=496).

[24]

A discussion of why using similar sizes as a physical constraint will help users intuitively use any solution.

major construction rule. The sizes and shapes of the parts suggested their operation. Physical constraints limited what parts would fit together. Cultural

and semantic constraints provided strong restrictions on what would make sense for all but one of the remaining pieces, and with just one piece left and only one place it could possibly go, simple logic dictated the placement. These four classes of constraints—physical, cultural, semantic, and logical—seem to be universal, appearing in a wide variety of situations.

Constraints are powerful clues, limiting the set of possible actions. The thoughtful use of constraints in design lets people readily determine the proper course of action, even in a novel situation.

[28]

The left-handed children all showed non-standard hand positioning when using the whiteboards, with the higher ability child displaying the 'hook' (Clark 1966; Dallman 1976; Mac Intyre and Mc Vitty 2004) writing position, the middle ability child holding her hand in the air to avoid the ink from smudging, and the lower ability child smudging his hand over the writing as he writes from left to right (Figure 5).

When the children used the magnetic writing boards, there was a clear difference in many of the children's writing.

The left-handers produced better quality writing: the /l/ clearly visible in the higher ability left-hander's writing, the lower and middle ability left-handers producing much clearer writing, and the middle ability left-hander's writing not sloping downwards to the same extent as when the whiteboard was used. Interestingly,

Left-handers produced better writing on magnetic boards than whiteboards, indicating that the issue of poor hand grip due to smudging led to poor handwriting.

[30]

Meeting Spaces (Auditoriums, Seminar / Conference Rooms, and Lounges)	DAILY	2 x PER WEEK	WEEKLY	BI WEEKLY	MONTHLY	ANNUALLY	AS NEEDED
• Wash chalkboard or whiteboards & rails	X						

[31] Section III

III. **Other Charges**

1. The University may, as a condition of bookin
   where the building would normally be closec
   arranged by the University.
2. The University at its discretion may assess a
   normally the responsibility of the group bool
3. Over and above the rental charge and secur
   a. Use of public address, audio-visual or oth
   b. Additional caretaking costs or extraordina
   c. Special arrangements with parking and gr
   d. Special setups where applicable; and/or
   e. Damage or undue wear and tear.

[31] Section V

7. The reserving organization agrees to ensure that no alterations to or tampering with University fabric, utilities or facilities will occur without explicit permission of an authorized University officer. If any such work is approved, it may only be carried out by persons authorized by the University.
8. Only props and displays constructed of nonflammable materials may be used within a University building.
9. No open flame, heating apparatus and/or cooking apparatus may be used without explicit permission of an authorized University officer.

Appendix B: Left-handed Narrative Accounts

1. **Baron Sekiya**
   Studied at University of Hawaii · 10y

   You just have to float your palm over the chalkboard and not let it rest on it smudging things. It's like how a right-handed person may be an artist painting or maybe doing charcoal or pencil drawings. You can't rest your hand on the drawing or it will smudge. This is why when I see people gripe about wanting a stylus with palm rejection for their tablet computers regular artists tell them you're not supposed to rest your hand on there anyway.

   If you really wanted a helper gizmo because resting your hand on the board while writing is a must I guess you could buy some InstaMorph and create a custom stand-off you can attach to your hand so it will be a pivot point to rest on the board.

   From reference [10]

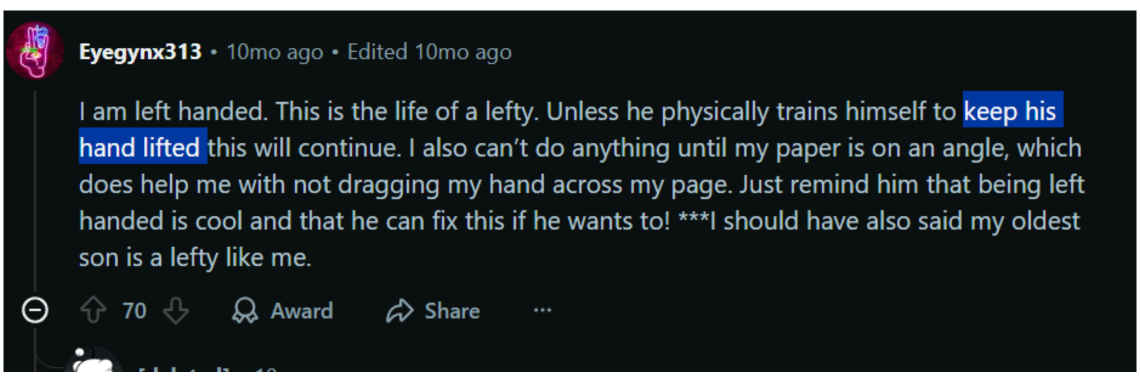
2. **Murray Farrell**
   Lifelong Learner · Author has **1.8K** answers and **3.6M** answer views · 10y

   That was my greatest challenge of later years. Before that it was chalk and a chalkboard. As a left hander, I always had filthy hands using a white board. I managed to write with my hand below the text line with practice. Also managed to learn to hold my hand off the board and write. My letters were often not as well formed as I would have preferred.

From reference [10]

3. 

Source:
https://www.reddit.com/r/Parenting/comments/1hnket6/my_leftie_son_is_struggling_with_dragging_his/
An account of a similar issue to smudging on a whiteboard due to the non-absorbent nature of the surface of a snowboard. Details the annoyances of smudging.

4. 

Source: see #3

5. As a lefty, I think that I have a rather nice handwriting. I think it is because I turn my paper to the right at a ninety degree angle. As you know, the world is designed for right handed people and it makes it difficult for us in many situations. School desks used to always have arm rests on the right side, maybe still do,but I haven't been in a classroom in many years. When a lefty hooks

their wrists and writes with the paper straight up it is cramped and bunched together because it can't flow easily. People sometimes remark that it looks strange because I write 'sideways', but I have always made it fit my world, not the other way around.

12K views · View upvotes · View 1 share 1 of 14 answers

Upvote · 16 2 1

Source: https://www.quora.com/Why-do-the-majority-of-left-handed-people-have-bad-handwriting

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Appendix C: Transcript of Interviews

1. <u>Left-Hander 1</u>

[Interviewer]: When you write on whiteboards, does smudging of the writing ever happen? If so, what do you do to avoid it?

[Anonymous]: "Yes – but what I do is lowkey hard to explain. I use my pinky to prop my hand up. That causes my pinky to be kinda stuck in position and causing discomfort if I write for a while."

[Interviewer]: Do you think this issue is something that bothers you often?

[Anonymous]: "Not as much as pen and paper, because the ink doesn't dry fast enough most of the time. Whiteboard is still an issue though. For writing on paper, I used these "magic" pens that don't smudge, so that idea for whiteboards sounds cool."

2. <u>Left-Hander 2</u>

[Interviewer]: Could you explain some of the challenges you face in general as a left-handed individual that are not experienced by right-handers?

[Anonymous]: "Almost everything is designed for right-handed people. Like things you as a rightie have never even thought of. I'm talking about doors, scissors, binders (you know the ones with the coils)…also I always have to write like [displays ocular occlusion from position of left hand writing] to see what I'm writing. Which sucks if you have just finished writing an idea and you end up smudging all of it. Especially during [references an exam with only pens]. I got ink all over my face and I didn't realize it until after."

[Interviewer]: We are focusing our attention on whiteboards. Could you tell us about your experience with writing on whiteboards as a left-handed individual?

[Anonymous]: "Every time I go to write something, I end up messing up what I have already written. I'm mostly fine when using portable whiteboards, like the one I use as my calendar with tape and stuff, but I don't really use any wall whiteboards. So just let me think here. I think it is just a super uncomfortable experience because you almost have to contort your body and your hand so that you aren't smudging, and my wrist gets sore pretty quickly."

[Interviewer]: So what would you say is the biggest challenge if you had to pick one?

[Anonymous]: "Accidentally erasing stuff I have written, getting whiteboard markers on my hands and face (though that doesn't happen too frequently), and like the awkward writing contorting [mimes increased flexion]. This is something that no-one ever talks about, but is honestly so not inclusive for [left-handed people]."

3. Right-Hander EngSci Student who has written in Arabic script

[Interviewer]: Do you typically face issues when writing on whiteboards in English?

[Anonymous]: "No, I usually don't face any issue when writing on whiteboards. If I'm being picky, it's annoying when whiteboards sometimes don't have an eraser on hand and I end up erasing the writing with the side of my hand because it's inconvenient to go and find one."

[Interviewer]: You have experience writing Arabic before. Did you ever face challenges writing Arabic on vertical whiteboards?

[Anonymous]: "For sure. In school, whenever I had to answer Arabic questions in front of the class on whiteboards, I'd have to angle my hand away from the board so that my palm wouldn't ruin what I was writing. I never really thought about how I don't have to do that for English, but I always felt like my handwriting on whiteboards for Arabic was much worse than on paper. Because I always angled my hand when writing, my sentences would end up completely crooked. By the time I finished a line, I'd realise the whole thing was slanted – like I'd started with the first word of a sentence at the top of the whiteboard, and somehow the last word was halfway down."

[Interviewer]: What do you mean by "ruin" your writing?

[Anonymous]: "I didn't want my writing to get smudged or erased, and I didn't want to have to wash marker off my hands after every lesson because of that either."

[Interviewer]: Do you use the EngSci common room whiteboards now at U of T?

[Anonymous]: "Rarely. I don't really go to the common room much, it's really crowded whenever I've tried to go and my friends and I can never find enough seats."

[Interviewer]: Would you use a design to prevent whiteboard pen smudging?

[Anonymous]: "If I was still writing Arabic often, and something made writing Arabic on whiteboards as easy as writing English – then yes.

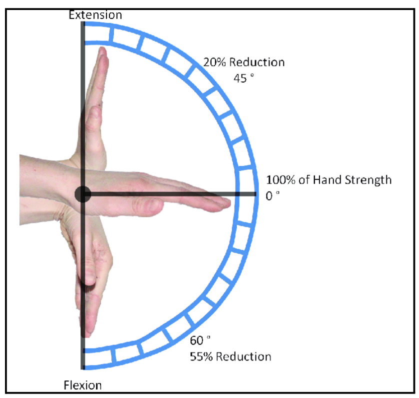
Appendix D: Glossary

1. *Splartz*: an annoyance or an irritant, or a minor problem in your lives, or an opportunity for something that could be better if only we did something about it.

2. Left-hander: An individual who prefers to use their left hand for tasks such as writing, which involve handedness.

3. Wrist Extension: A term describing upwards motion of the wrist.

4. Wrist Flexion: A term describing downwards motion of the wrist
See image below to visualise flexion and extension angles.



Visual representation of wrist flexion and angles of wrist flexion. *Source:* https://www.researchgate.net/figure/Reduction-of-hand-strength-at-different-angles-of-flexion-extension_fig17_317984098

5. Grip types: lateral tripod; dynamic tripod; lateral quadrupod; dynamic quadrupod. See image below.

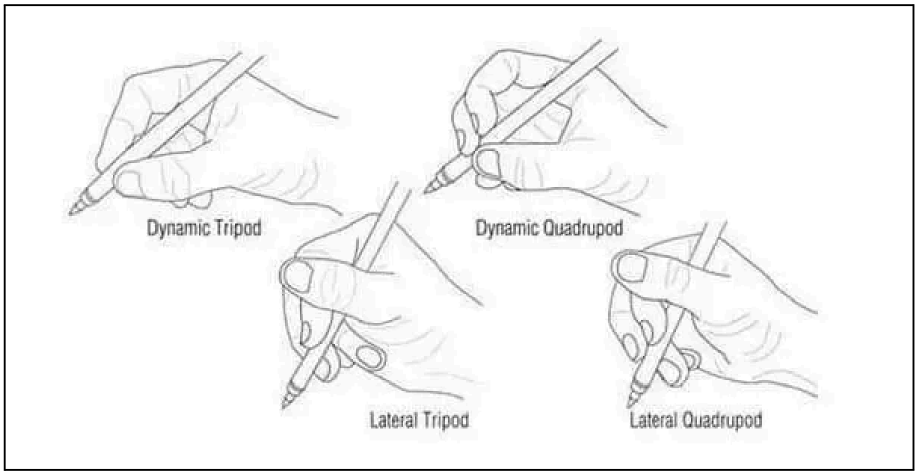
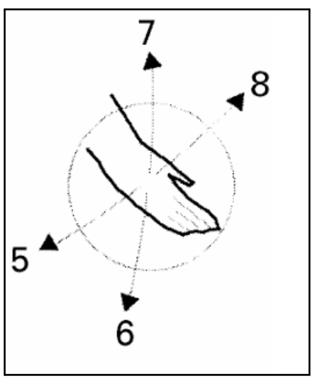


Illustration of grip types.
Source: https://www.themanual.com/culture/different-types-of-pencil-grips/

6. Wrist Ulnar Abduction: little finger moved towards the forearm (ulnar bone)

7. Wrist Radial Abduction: thumb moved towards the forearm (radial bone)



5	Wrist ulnar abduction: little finger moved towards the forearm (ulnar bone)
6	Wrist flexion: palm of the hand moved towards the forearm
7	Wrist extension: back of the hand moved towards the forearm
8	Wrist radial abduction: thumb moved towards the forearm (radial bone)

[13]

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