

ZenPen

The Engineering Monkeys (Team N)

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Executive Summary

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Technical Design Review

Instructor – Ratcliff, GTA – Kling

04/21/2025

The purpose of the ZenPen project within the Technical Design Review as a whole was to give students the opportunity to apply engineering design principles to address a real-world problem affecting individuals with Parkinson's disease and other fine motor impairments. The objective was to create a fully functional writing tool that could reduce the effects of hand tremors and improve writing control. Through the development process, the team focused on creating a user-centered, ergonomic, discreet assistive device that could improve independence and daily life for those with reduced hand dexterity. The project also aimed to provide students with experience in prototyping, user testing, and iterative design, while encouraging teamwork and critical thinking. The ZenPen represents not only a physical product but also a step towards understanding how thoughtful design can lead to meaningful impact.

As a result of the project, the team successfully designed and fabricated a working prototype, ZenPen V9, which features an adjustable modular weight system that allows users to insert or remove steel rods to customize the pen's stability. This feature, not found in any market alternative, helps reduce unintended movement during use. Additional ergonomic features such as a thick contoured grip and built-in finger loop promote a more natural writing posture and reduce hand fatigue. Testing under simulated tremor conditions showed that the ZenPen reduced writing error by 48.65%. The prototype also met several design criteria, including adjustable weight range, durable construction, and a low estimated production cost of \$12.68. These results confirmed that the design was both practical and accessible for users.

In conclusion, the ZenPen project provided valuable insight into user-centered design while equipping the team with hands-on experience in prototyping and user-focused problem solving. User testing confirmed that the pen was effective in improving control and comfort. Based on testing results and user feedback, the team recommends refining the weight adjustment mechanism, exploring the use of rubber grip inserts for improved control, and transitioning from 3D printing to injection molding to improve production efficiency and product quality. The ZenPen represents a promising assistive tool that supports greater independence and accessibility in everyday writing tasks.

Problem Definition Review

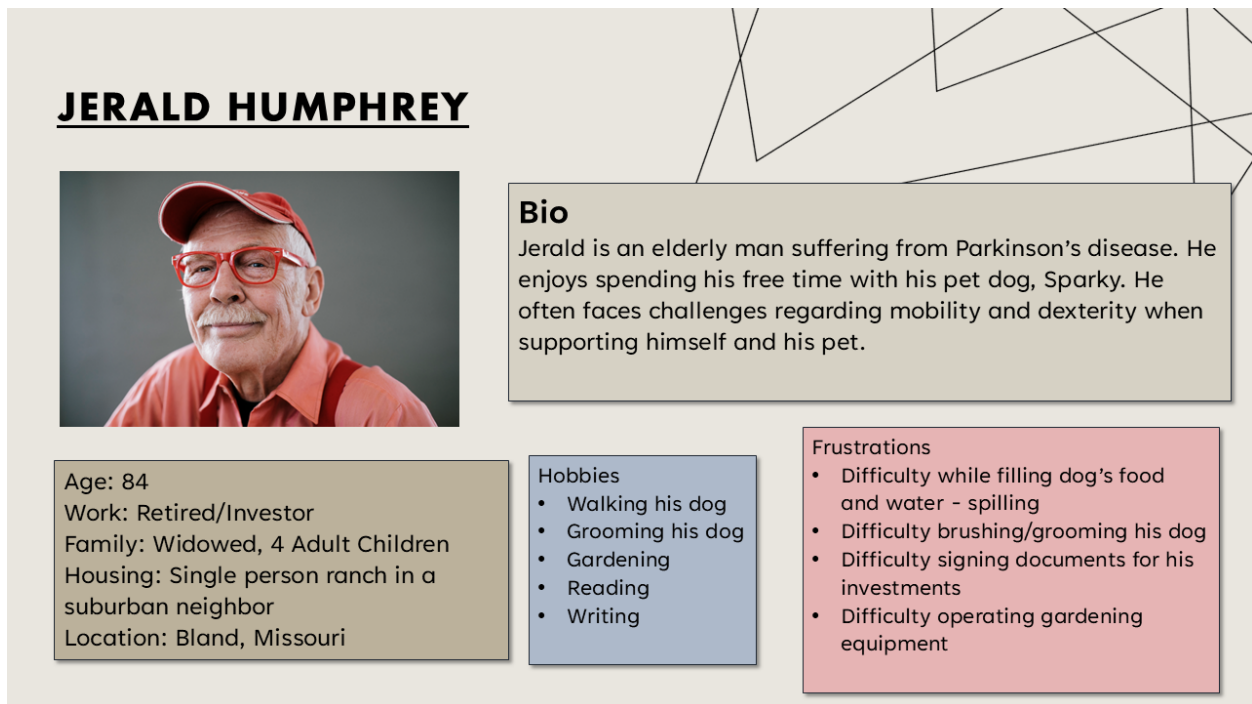
1. Introduction

Parkinson's disease is a progressive neurodegenerative disorder that impairs movement, balance, and coordination, affecting nearly one million people in the U.S. and around 10 million worldwide [12]. In more severe stages, patients often experience hand tremors, making everyday tasks such as writing or holding objects difficult. This challenge is especially pronounced among elderly individuals, as motor symptoms can significantly limit their independence in later life [25].

A pen or pencil sleeve was designed to help elderly patients with Parkinson's disease reduce tremors while writing or signing. The sleeve is compatible with most standard writing instruments and offers a high degree of customization compared to current market alternatives, improving comfort, usability, and independence.


2. Problem Definition

a. User Persona



The graphical user persona for Jerald Humphrey is presented on a light beige background with a faint geometric line pattern in the upper right. The persona is organized into several colored boxes: a large white box for the name and photo, a light blue box for biographical information, a light green box for personal details, a light orange box for hobbies, and a light red box for frustrations.

JERALD HUMPHREY



Bio
Jerald is an elderly man suffering from Parkinson's disease. He enjoys spending his free time with his pet dog, Sparky. He often faces challenges regarding mobility and dexterity when supporting himself and his pet.

Age: 84
Work: Retired/Investor
Family: Widowed, 4 Adult Children
Housing: Single person ranch in a suburban neighbor
Location: Bland, Missouri

Hobbies

- Walking his dog
- Grooming his dog
- Gardening
- Reading
- Writing

Frustrations

- Difficulty while filling dog's food and water - spilling
- Difficulty brushing/grooming his dog
- Difficulty signing documents for his investments
- Difficulty operating gardening equipment

Figure 1. Graphical User Persona

User Group Selection

The selected user group for this project is elderly individuals with Parkinson's disease and others experiencing fine motor impairments. This focus was partly informed by one team member's personal connection to a relative affected by Parkinson's, which helped illustrate the daily

challenges associated with tremors and limited dexterity. The team also recognized the broader need to support aging individuals and those with similar impairments, selecting a problem with design solutions that could be realistically developed and tested.

To begin researching this user group, the team brainstormed tasks and associated pains in order to better understand the user's experience and identify key needs. This process informed the development of a representative user persona that guided subsequent design decisions.

b. Tasks and Pains

- Writing (signatures, journaling, filling out forms, labeling items, taking notes)
 - Difficulty holding a pen due to tremors
 - Difficulty maintaining constant pen pressure
 - Difficulty picking up a pen from a surface
 - Fatigue from prolonged writing
 - Errors caused by jerky movements
- Feeding their Pet
 - Trouble opening food containers due to reduced grip strength
 - Difficulty with spilling food and water when pouring, scooping, and transporting
 - Difficulty bending over to clean up after pets

Parkinson's disease results in numerous challenges for the people it affects. Writing can be difficult due to issues such as difficulty holding a pen, maintaining consistent pressure, or just picking up a pen from a surface. Furthermore, prolonged writing causes increased amounts of fatigue and tremors can cause shaky handwriting, further exacerbating these struggles [20].

Feeding a pet presents a new set of difficulties, such as trouble opening food containers due to their reduced grip strength. Even after accessing the food, it can be difficult to pour, scoop, and transport food and water, especially if bending is required. These challenges create a frustrating experience for the individual and can also diminish their sense of independence and quality of life.

3. Research Plan

The research plan is systemically structured to deepen the team's understanding of the physical challenges elderly pet owners and/or people with Parkinson's disease face during their daily tasks. This research aims to identify the primary pains associated with these tasks that may be improved via an engineered product. The research plan table below represents relevant questions digging to the root of the elderly/Parkinson's experience. The two rightmost columns contain, respectively, summaries of qualitative and quantitative research corresponding to each question. Research sources include scholarly articles and interviews found online and in-person interviews. Through the information compiled in the table, the team plans to thoughtfully incorporate research into achievable solutions to the difficulties these people face. Whilst performing this research and creating solutions, the team will prioritize ethics, respecting the participants and being transparent in the use of their data or opinions to ensure they feel respected, comfortable, and secure in participating as well as always being able to leave questions unanswered or outright leave the meeting.

This research table consists of possible questions that the team will want to take account of when producing a prototype or product for users with fine motor skills. There are also qualitative and quantitative answers to the questions given. Note that not all questions can have both a qualitative and quantitative answer. Some questions are left blank for further research.

Table 1. Research Plan Table

Research Question	Qualitative Data Collection	Quantitative Data Collection
(RQ1) What is difficult about typing and writing as an elderly person? What are the alternatives to typing and writing for an elderly person?	Further research required	Further research required
(RQ2) How many elderly people are there? How is the share of the elderly population expected to change?		The National Council on Aging (NCOA) reports that the U.S. elderly population was 57.8 million in 2022 and is projected to reach 78.3 million by 2040, making up 22% of the total population, highlight the growing share of older adults over time [7].
(RQ3) What are the daily tasks elderly individuals find the most challenging?	Further research required	Further research required

<p>(RQ4) What health conditions are most prevalent among elderly individuals? How do these conditions affect their daily lives?</p>		<p>The study provides quantitative data on 407 elderly individuals, highlighting conditions such as visual impairment (83.29%), hypertension (30.7%), diabetes (12%), and depression (50%). Data was collected via a house-to-house survey [8] .</p>
<p>(RQ5) How does access to healthcare resources vary among elderly individuals based on location or socioeconomic status?</p>	<p>The study explores how elderly individuals experience healthcare, focusing on access, quality of care, and involvement in decisions. Interviews with participants aged 60-85 provide insights into the barriers and challenges they face with healthcare services [9].</p>	

4. Research Results

This section introduces the findings from the team's research and testing phases. It covers user values, market characteristics, observations and trends, gaps in competing products, recommendations and insights. The focus is on understanding the needs of Parkinson's patients and developing a prototype that addresses these challenges effectively. Key insights include the importance of comfort, stability, ease of use, and affordability, as well as market demand and opportunities for differentiation.

a. Creating User Value

i. Pains

- Difficulty holding a pen due to tremors
- Difficulty maintaining constant pen pressure
- Difficulty picking up a pen from a surface
- Fatigue from prolonged writing
- Errors caused by jerky movements

Market research cited below led the team to believe that some of the primary issues Parkinson's patients face when attempting to write are related to picking up the writing utensil and maintaining steady handwriting despite tremors and fatigue [20].

ii. Gains

- Enhanced ability to express thoughts and knowledge.
- Parkinson's patients improve ability to share and preserve their wisdom and experiences through a familiar medium.
- Independence in signing documents and writing letters decreases hassle in patient's and loved-one's lives.
- Parkinson's patients can write on their own without relying on others, reinforcing their autonomy and self-sufficiency.
- Mental stimulation through writing keeps patient's minds active, improving cognitive well-being.

A pen designed with Parkinson's patients in mind can provide meaningful benefits beyond basic functionality. Elderly Parkinson's patients, possess a wealth of knowledge, but may face physical barriers that limit their ability to express themselves through writing. A tool that restores their ability to write independently reduces reliance on others and helps them preserve their thoughts, memories, and identity. This regained autonomy can ease stress for caregivers, promote self-dignity, and support cognitive well-being through the mental stimulation that writing provides [11].

iii. User Needs

- Ergonomics: Large, organic design to help with improved control.
- Stability assistance: Weighted design and grip pads to help with stability.

- **Affordability:** Materials and manufacturing must be cost-effective, to meet the needs of most individuals.
- **Fatigue Reduction:** Product must be easy to operate so that the user can easily control and manipulate it.
- **Error Prevention:** Product must minimize errors for users when writing/signing.
- **Durability:** Product construction must hold up against extended rough treatment.
- **Customizable Options:** Product should be customizable to any given situation (e.g. changeable pen tips).
- **Aesthetically Pleasing:** Product is visibly pleasing to the user and the public.

The team's research, informed by interviews and focus groups, identified key user needs for the ZenPen. The ergonomic design improves control, while weighted features and grip pads enhance stability. Cost-effective materials ensure affordability. The pen is easy to use, reducing fatigue and learning errors. It is durable, customizable with changeable tips, and visually appealing [7],[8],[10].

iv. Pairwise Comparison Chart

Table 2 displays user needs and their importance as ranked by data.

Table 2. Pairwise Comparison Chart

	Ergonomics	Stability Assistance	Affordability	Fatigue Reduction	Error Prevention	Durability	Customizable Options	Aesthetically Pleasing	Total	Normalized	Predicted
Ergonomics		1	1	1	1	1	1	1	7	5.0	8
Stability Assistance	0		0	0	1	0	1	1	3	2.3	3
Affordability	0	1		1	1	1	1	1	6	4.3	2
Fatigue Reduction	0	1	0		1	0	1	1	4	3.0	4
Error Prevention	0	0	0	0		0	1	0	1	1.0	6
Durability	0	1	0	1	1		1	1	5	3.7	7
Customizable Opti	0	0	0	0	0	0		0	0	-	1
Aesthetically Pleas	0	0	0	0	1	0	1		2	1.7	2

These values reflect the team's evaluation of the relative importance of user needs based on a pairwise comparison process. Voting was done anonymously, and team members were unable to see others' scores. The yellow section displays the ranked results, while the total and normalized scores are displayed in green and orange columns.

The final rankings prioritize user needs identified through interviews, focus groups, and literature review. Ergonomics and stability assistance emerged as top priorities, supported by research on motor challenges in elderly individuals [8]. Affordability was also crucial, driven by insights from market analysis and the financial realities of aging populations [7][9]. Fatigue reduction and ease of learning were emphasized to increase accessibility and reduce strain for elderly users [7]. Durability and customizability were important to ensure long-term usability and adaptability to different users' needs. Aesthetic appeal was also considered, as an appealing product encourages consistent use and reduces social stigma of a medical-like device appearance in social settings.

These rankings demonstrate a research-backed prioritization that directly shaped the design of the ZenPen.

The research that the team conducted in the “Creating User Value” section highlights many of the different challenges that people with Parkinson’s disease or other fine motor problems face. These challenges involve writing and can consist of difficulty holding a pen while managing their fatigue. Sources in the research table plan above (Table 1) supports that a Parkinson’s pen should take account for ergonomics, fatigue-reducing and other needs that are highlighted in above (Table 1). While most sources agree on user needs, some suggest differences in ergonomics, weight, and specialized grips to account for fatigue. These additions to a Parkinson’s pen would improve the effectiveness of the product. Also, some sources state that writing aids improve cognitive function as well as introducing voice-to-text features. The team will account for these inconsistencies and gaps in user needs to create a user-centered design to improve the overall experience of writing.

b. Market Character

v. Stakeholders

1. Families

- Strengthens communication with elderly loved ones, especially those who struggle with digital technology.
- Reduced Care Burden: Family members may no longer need to assist with writing tasks, allowing for greater independence.

2. Caregivers and Healthcare Providers

- Less reliance on caregivers for writing-related tasks, reducing workload and stress.
- Occupational therapists may incorporate the tool into rehabilitation plans for elderly patients with mobility impairments.

3. The Environment

- Sustainable materials and production practices can reduce ecological impact.
- If the product is disposable and utilizes non-recyclable components, it could contribute to waste issues.

4. Manufacturers

- Opportunity to develop a specialized product for a growing market of assistive technology.
- Increase demand for assistive tools could drive innovation and profitability.
- Useful, easily manufacturable products drive profits for those associated with the factory.

5. Government and Policy Makers

- May necessitate regulation or incentives for accessibility products under disability and aging policies.
- As elderly individuals retain independence longer, there may be a reduced burden on healthcare services.

- Government may be pushed to fund or subsidize assistive tools to improve quality of life for aging populations.
6. Nonprofit and Advocacy Organizations
- Disability rights groups and aging advocacy organizations may promote and push for widespread accessibility.
 - They can raise awareness about handwriting challenges for elderly individuals and influence policy changes.

vi. Market Size

The primary market includes around 10 million people globally living with Parkinson’s disease or lack of fine motor skills when writing [12]. Secondary markets would include people with arthritis or fine motor problems that would affect writing/signing. There are around 60 million people in the United States with arthritis or problems with motor skills [13]. Although, the team will focus on the smaller percentage of Parkinson’s patients that have more severe tremors and difficulty. This scale down will be due to a large number of patients not having major troubles writing or signing. There is a growing awareness of tools that assist people with general writing difficulties due to many different diseases or motor problems [14].

vii. Current Alternatives

- [SteadyScrib](#): This pen uses an ergonomic grip and magnetic writing board to produce a weighted feel and steady hold [15].
- [Special Supplies Pen](#): This pen focuses on weight and aesthetics, putting ergonomics on the back burner [16].
- [Wentur Pen](#): This pen relies on heavy weights and a large, ergonomic grip to provide stability for the user [17].
- [RinG-Pen Ultra](#): This pen relies solely on a formfitting gimmick to provide for the users’ needs [18].
- [Zephylix](#): This device holds a standard ballpoint pen and provides a “computer-mouse-like grip” to help the user [19].

Competitive Matrix

This chart identifies the strengths and weaknesses of competitors. “x” indicates a missing feature, and “*” indicates a present feature.

Table 3. Competitive Matrix

User Needs	<i>SteadyScrib</i>	<i>Special Supplies Pen</i>	<i>Wentur Pen</i>	<i>RinG-Pen ultra</i>	<i>Zephylix</i>
Ergonomics	*	*	*	*	x

Stability assistance	*	X	X	*	*
Affordability	X	*	*	*	*
Fatigue reduction	*	X	*	*	*
Error prevention	*	*	*	X	X
Durability	*	X	X	*	*
Customizability	X	X	X	X	X
Aesthetically pleasing	X	*	X	*	X

Analysis of Competitive Matrix and Significance of Gaps

The competitive matrix evaluates five alternatives – SteadyScrib, Special Supplies Pen, Wentur, RinG-Pen Ultra, and Zephylix against key user needs, including ergonomics, stability assistance, affordability, fatigue reduction, error prevention, durability, customizability, and aesthetics. By analyzing the table, the team can and were able to identify gaps in the existing options and potential opportunities for improvement.

Market Character research

The research that the team conducted in the “Market Character search” states and highlights the growing demand for assistive writing tools. Most studies agree that people with Parkinson’s or other fine motor skills benefit from the advancements in writing assistance technology and improved design. Also, sources confirm that there are millions of potential users and more to come. In addition, when researching alternative products, there is a wide range of ergonomics, weight, and or factors. Also, opinions vary on whether to focus on affordability over functionality. As a team, they will take account of the previous successes and failures of alternative products and apply those factors to finalize the product.

c. Key Observations and Trends

- Ergonomics: Most alternatives meet this need, except Zephlix, suggesting it may not prioritize comfort and usability.
- Stability Assistance: Steady Scrib, RingG-Pen Ultra, and Zephlix provide this benefit, while Special Supplies Pen and Wentur lack stability support. This suggests that most designs are able to properly accommodate users with motor control difficulties.
- Affordability: Most alternatives are affordable, except for Steady Scrib, which may offer premium features at a higher cost.

- **Fatigue Reduction:** Most options prevent fatigue, except Special Supplies Pen, which may require more hand strain or effort over time.
- **Error Prevention:** While most alternatives support error prevention, RinG-Pen Ultra and Zephlix fall short, potentially leading to usability issues.
- **Durability:** In terms of durability, the SteadyScrib, RinG-Pen ultra and Zephlix are viable options, suggesting proper design and quality.
- **Customizability:** This is the area where all the current alternatives fail. None of the current alternatives allow for much customizability.
- **Aesthetically pleasing:** Among the current available alternatives, the Special Supplies Pen and the RinG-Pen ultra are aesthetically pleasing while the rest are very bulky and unusual in shape.

d. Significance of Gaps

The most striking gap is the lack of customizability, which could limit consumer preference and adaptability. Additionally, stability assistance and error prevention are inconsistent across the alternatives, suggesting that some designs may not adequately support users with dexterity challenges. The lack of aesthetics in some alternatives can detract from their appeal, making them feel less like regular pens and more like medical devices, which may discourage use, especially in public settings due to stigma surrounding Parkinson's [20]. While affordability is mostly met, durability remains a concern for some options, potentially affecting long-term value and brand image.

e. Recommendations and Insights

Given these gaps, an ideal alternative should:

1. Integrate customization to cater to varying user preferences and needs.
2. Enhance stability assistance and error prevention to improve usability, particularly for users with limited motor control.
3. Ensure durability without compromising affordability to maximize values for consumers.
4. Improve aesthetics while maintaining ergonomic benefits.

By addressing these gaps, a new or improved product could gain a competitive advantage in the market, offering a well-rounded and desirable solution that better meets user needs than existing alternatives.

5. Value Proposition

The ergonomic and stabilizing writing tool empowers Parkinson's patients and individuals with motor impairments by restoring their ability to write independently. With over 10 million people worldwide living with Parkinson's and 90,000 new cases annually in the U.S. alone, the demand for assistive writing tools is growing [12]. Addressing tremors, grip difficulties, and fatigue, it enhances control, reduces errors, and promotes cognitive engagement, improving self-sufficiency and quality of life.

While some existing solutions focus on grip or stabilization, they often resemble medical devices rather than a natural writing tool. The design goes further by seamlessly blending functionality, aesthetics, and user comfort to create a writing experience that is both effective and dignified. SteadyScrib [15], for example, is expensive compared to other options, making it less accessible for individuals already burdened with high medical expenses. Furthermore, its design closely resembles a children's toy, which may discourage use in professional or social settings. The team would also like to add customizability by adding adjustable weights to the design which is absent in current market alternatives. In addition, the team wants to source materials cheaper than other alternatives while maintaining quality.

High treatment costs exceeding \$2,500 per year per patient and limited accessibility and knowledge create further barriers. The team may focus on the more sensitive cases of Parkinson's as some cases do not be as severe and thus not affect daily tasks like writing or signing. Innovation provides a cost-effective, durable, and intuitive solution, fostering independence, autonomy, and usability in a market that needs it most.

6. Design Focus

User Needs and Challenges

This research identifies key challenges that shape the design, ensuring it meets the needs of individuals with Parkinson's disease and motor impairments. The main issue is micrographia, where handwriting becomes smaller and less legible due to diminished fine motor control. The Parkinson's Foundation highlights this as a common symptom that worsens with fatigue, making it essential for the design to support consistent handwriting size [13]. Tremors and involuntary movements also lead to jerky, inconsistent strokes, requiring stabilization mechanisms to improve control [13].

Another major issue is grip weakness and reduced dexterity, making standard pens difficult to hold. Parkinson's UK suggests that individuals benefit from larger grips, reinforcing the need for an ergonomic, balanced design to enhance comfort and control [14]. Additionally, fatigue from prolonged writing exacerbates motor difficulties, requiring a tool that minimizes exertion for extended use.

Existing products like weighted pens and stabilizing grips focus on grip or tremor reduction but often resemble medical devices rather than standard writing tools, discouraging use in social settings. Many lack adaptability, failing to accommodate varying levels of tremors, grip strength, or fatigue.

Customization and adaptability are essential to user experience. To improve functionality, the design will include:

- Adjustable grip sizes – Ensures comfort for different hand sizes and dexterity levels.
- Variable ink thickness – Supports personal preferences, with thicker ink for aesthetics and finer lines for precision.
- Color variety – Allows personalization, reducing the clinical look.
- Integrated eraser or correction tool – Addresses errors caused by tremors, adjusting easier.

By prioritizing adaptability, the pen will be an intuitive, user-friendly, and confidence-boosting tool, not just a functional necessity.

Stakeholder Considerations and Impact on Design

Caregivers and healthcare providers emphasize the need for a tool that promotes user independence, reducing reliance on others for basic writing tasks. Healthcare professionals note that writing helps maintain fine motor function and cognitive engagement, reinforcing its role in neurological well-being [23].

Manufacturers and distributors also influence design choices. The writing tool must be durable, cost-effective, and simple to produce, while government agencies and advocacy groups may support adoption through disability inclusion initiatives.

Evolution of Understanding

Initially, the design focused only on stabilizing hand movements. Research expanded this view, highlighting the need for a balance of function, aesthetics, and adaptability. Users require a tool that restores confidence, integrates seamlessly into daily life, and does not feel like a medical device.

Furthermore, writing is more than a motor function, it is a means of self-expression and cognitive stimulation. A well-designed tool will support both physical and cognitive well-being, improving quality of life beyond just handwriting enhancement.

Conclusion

The design will prioritize:

- Ergonomics – A pen that reduces strain and accommodates various grip styles.
- Stabilization – Features to counteract tremors and improve control.
- Aesthetics – A sleek, non-medical appearance to encourage regular use.
- Adaptability – Customization to meet individual user needs.

By addressing these factors, the design will enhance independence, usability, and confidence, creating a tool that is both functional and empowering.

Concept Development Review

7. Concept Brainstorming and Ideation

a. Process Description

After selecting a target user, the team employed structured brainstorming techniques to generate potential solutions. The brainstorming process began with a review of end-user needs, ensuring that all concepts aligned with the most critical challenges faced by Parkinson's patients. The team used various scoring techniques such as the pugh scoring table to systematically evaluate potential design aspects, ranking key factors such as ergonomics, stability assistance, affordability, fatigue reduction, error prevention, durability, customizability, and aesthetics.

From this analysis, ergonomics and affordability were determined to be the highest-priority criteria, guiding the team's design focus. Constraints were also identified early in the process, including material limitations, cost restrictions, and ease of manufacturability. To address these constraints, the team focused on readily available, low-cost materials and modular design features to streamline production. Preliminary cost and feasibility checks were also used to eliminate impractical ideas before refining concepts further. The team ensured that all proposed solutions adhered to these constraints while optimizing for user benefit.

The brainstorming session resulted in a variety of design sketches, each detailing how the concept would address user needs while remaining within defined constraints. Additionally, as the team engaged with potential users, feedback prompted adjustments to initial need rankings, refining the team's approach to emphasize user comfort and cost-effectiveness further. These refinements are reflected in the team's final design concepts, which prioritize practical usability and accessibility without compromising performance.

b. Brainstorming Results

The team's brainstorming session produced several design solutions targeting Parkinson's disease patients. These designs, emphasizing ergonomic design and stability, explored additional features such as a customizable grip, adjustable tip thickness and color, and automation.

Figure 2 presents a design focused on adaptability, featuring a robust grip and an eraser that can erase ink to allow users to correct mistakes. Figure 3 prioritizes ergonomics, incorporating a comfortable rounded grip and introducing the concept of a sleeve that can attach to a preexisting pen. Figure 4 emphasizes weight distribution and unique ergonomic grips to enhance user control. Figure 5 combines adaptability with additional stability assistance and optimized weight distribution, integrating elements from previous designs to ensure ease of use.

The designs aim to deliver a writing tool which respects users' autonomy and aesthetic preferences while enhancing their life quality and independence (Figures 2-5, found in appendix A).

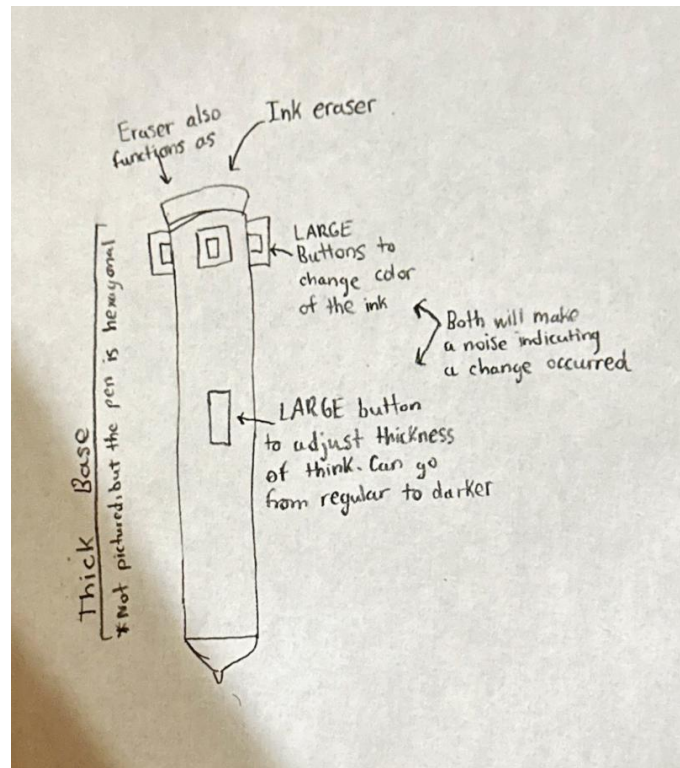


Figure 2. Concept Design by team member 1

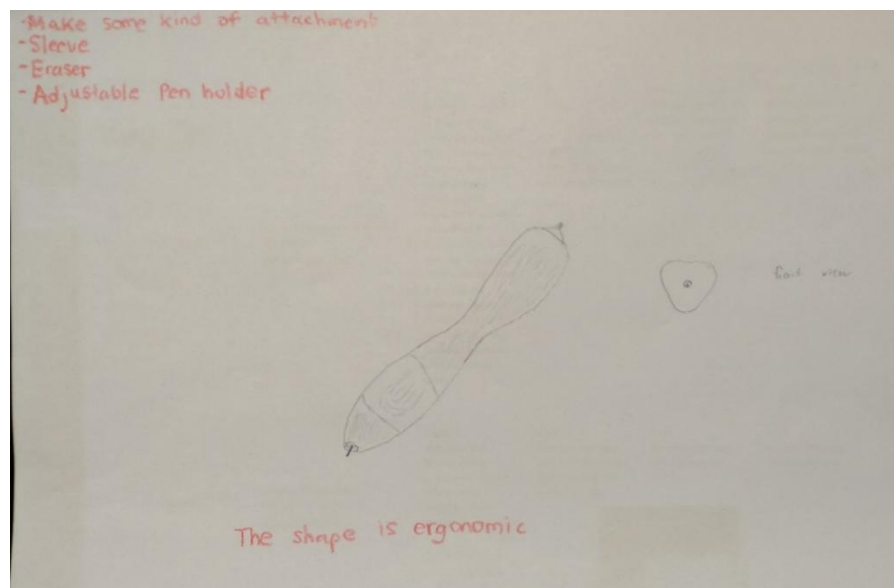


Figure 3. Concept Design by tetam member 2

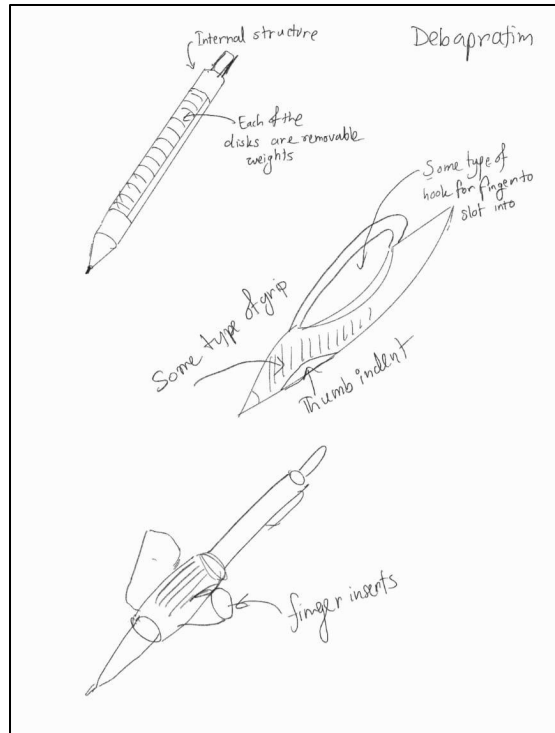


Figure 4. Concept Designs by team member 3

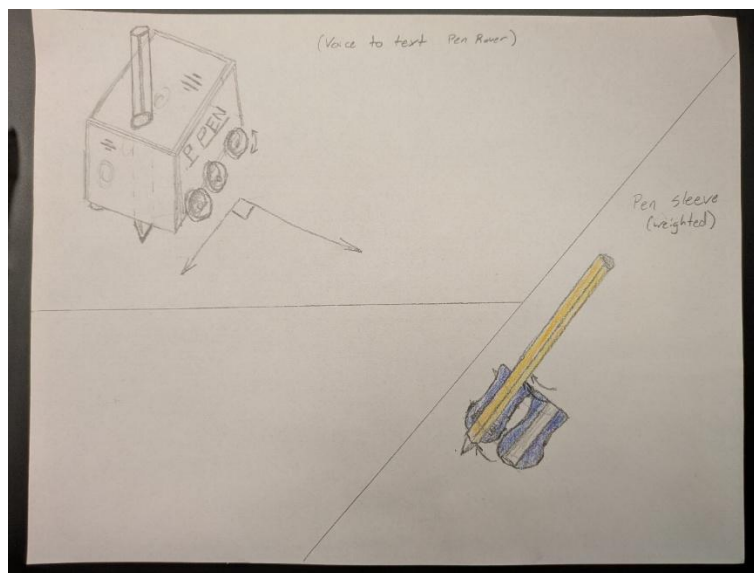


Figure 5. Concept Designs by team member 4

8. Concept Selection

a. Down-Selecting to Two Concepts

With feedback from end users guiding the process, the team has refined its focus to two concepts that best address the needs of individuals facing Parkinson's disease: the design presented in Figure 4, a simplified Parkinson's pen with a supportive, ergonomic structure, and the design in Figure 5, a clip-on sleeve/grip that can be fitted onto any pen or pencil for enhanced grip.

The decision to move forward with these two designs was driven by direct user input and scoring evaluations (Pugh Scoring Matrix, Table 4, found in appendix A) that emphasized the importance of ergonomics, stability assistance, and adaptability. Users consistently highlighted the need for a writing aid that could improve control while minimizing strain and fatigue. The pen design in Figure 4 addresses these concerns with its carefully contoured shape, promoting a natural grip position and reduced effort to maintain control. Additionally, the integrated finger loop provides extra stability, preventing slippage and enhancing overall writing precision.

The clip-on sleeve in Figure 5 emerged as a strong alternative due to its versatility. Feedback from potential users and caregivers suggested that some individuals prefer to maintain familiarity with their existing writing tools rather than switching to a new pen. This design accommodates that need by allowing users to retrofit their preferred pen or pencil with a weighted, oversized grip that enhances control and dampens tremors. The adjustable weighting system was introduced based on user feedback indicating that different levels of counterbalance might be necessary depending on the severity of the user's tremors.

These concepts were selected based on their strong alignment with user needs, offering the greatest potential benefits for individuals with Parkinson's disease and their caregivers.

b. Pugh Scoring Matrix

Table 4 rates the top two designs against a competitor's design and produces weighted scores for each based on criteria important for user needs. This matrix allows for a clear comparison of the designs across key factors and quantitative assessment of how they meet essential needs.

Table 4. Pugh Scoring Matrix

		SteadyScrib		Stephen sketch		Debapratim sketch	
		Reference		Concept 1		Concept 2	
User Needs	Weight (1-5)	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Ergonomics	5	5	25	4	20	5	25
Stability Assistance	3	4	12	3	9	3	9
Affordability	5	1	5	3	15	3	15
Fatigue Reduction	3	3	9	3	9	4	12
Error Prevention	1	2	2	4	4	4	4
Durability	4	4	16	4	16	3	12
Customizable Options	1	1	1	5	5	5	5
Aesthetically Pleasing	2	2	4	3	6	4	8
TOTAL			74		84		90

Table 4 evaluates the top two designs against a reference design using a weighted scoring system. The reference design received a final score of 74, the sleeve concept (Figure 5) scored 84, and the pen concept (Figure 4) achieved the highest score of 90. This analysis confirms that the design in figure 4 outperforms the alternatives across nearly all criteria, except for durability and stability assistance.

To ensure long-term usability, the team recognizes the need for further research into material selection and structural reinforcement to improve durability. Additionally, enhancements to stability assistance will be explored to ensure the final product remains competitive in the market while maximizing user independence and comfort.

c. Final Concept Selection

The team is confident in moving forward with the design presented. This concept demonstrated strong performance across all other evaluation criteria, outperforming or tying alternative designs in every other category, the team believes that further refinement will allow this design to surpass existing market solutions while addressing its current limitations.

The selected design features a smoothly contoured shape that accommodates various grip styles, ensuring comfort for users with limited dexterity. A weighted core is integrated to provide improved control and reduce unintended hand movements [23]. The pen also features dedicated grips made from a non-slip material, enhancing stability and preventing accidental slips.

A distinctive feature of this design is a built-in finger loop, offering additional support by securing the pen to the user's hand [18]. This addresses stability assistance concerns related to grip fatigue and accidental drops. The loop allows users to maintain a relaxed grip while maintaining full control over the writing instrument.

Beyond its functional advantages, this design maintains an aesthetically pleasing, user-friendly form factor, aligning with user preferences for discreet and sleep assistive devices. By refining the material selection and reinforcing key structural elements, the team aims to resolve the durability concerns noted in Table 4, ensuring that the final product is both effective and long-lasting.

9. Grand Concept Design

The team is developing a bulkier, ergonomically designed pen intended for individuals with Parkinson's disease or fine motor impairments. The design aims to improve grip stability, minimize tremors, and enhance the overall writing experience. Unlike traditional weighted pens, this design features a modular weight system and a long, contoured grip that extends along the pen body to provide greater comfort and control.

Functionality & User Interaction

- The thicker pen body ensures a more secure grip, minimizing hand strain and unintentional movements.
- A contoured ring-like attachment allows the user to either slide a finger through it or rest a finger against it for added stability and reduced hand fatigue.
- The adjustable-weight system enables users to insert small and easy-to-grip weights from the top, similar to adding lead to a mechanical pencil but designed for fine-tuned balance control.
- The weights are lightweight, feature a large surface area, and are textured, ensuring easy handling, even for individuals with reduced dexterity

Unique Features & Market Viability

- Bulkier Grip for Stability – Reduces excessive hand movement, providing better control.
- Ergonomic circular hand rest - similar to a ring pen for arthritis [18], this supports the fingers and reduces fatigue, improving control.
- Customizable Weight System - Most weighted pens have fixed weights, but this design will allow personalized adjustments.
- Target Market: This pen addresses the needs of individuals with Parkinson's, arthritis, hand tremors, or other fine motor impairments that affect writing comfort and control.

Challenges in Development

- Weight Adjustment Mechanism – Designing a slim and secure, yet easy-to-use system for inserting/removing weights.
- Contoured Grip Positioning – Ensuring the extended attachment is optimally shaped and positioned to enhance writing stability without restricting natural writing movement, while maintaining a visually cohesive design and accommodating a variety of hand sizes and grip styles.
- Material Selection – Identifying materials that balance durability, lightweight comfort, and user comfort. For the modular weights, the selected material must be dense enough to provide stability while remaining manageable for individuals with limited strength.

Proving Feasibility

- User Testing – Assess how the adjustable weight system and contoured grip affect writing stability and control for users with tremors or fine motor impairments.
- Comfort & Grip Trials – Test various grip sizes and placements of the contoured attachment for comfort and support. Evaluate the ease of inserting and removing modular weights.
- Durability Tests – Ensure the pen remains functional and easy to adjust with repeated use.

These tests will confirm the prototype's effectiveness and comfort. User interaction throughout development will help validate the design and support its appeal in the target market.

Initial Sketch:

Figure 4 shows the team's exploratory concept sketches that were then narrowed down to a single design.

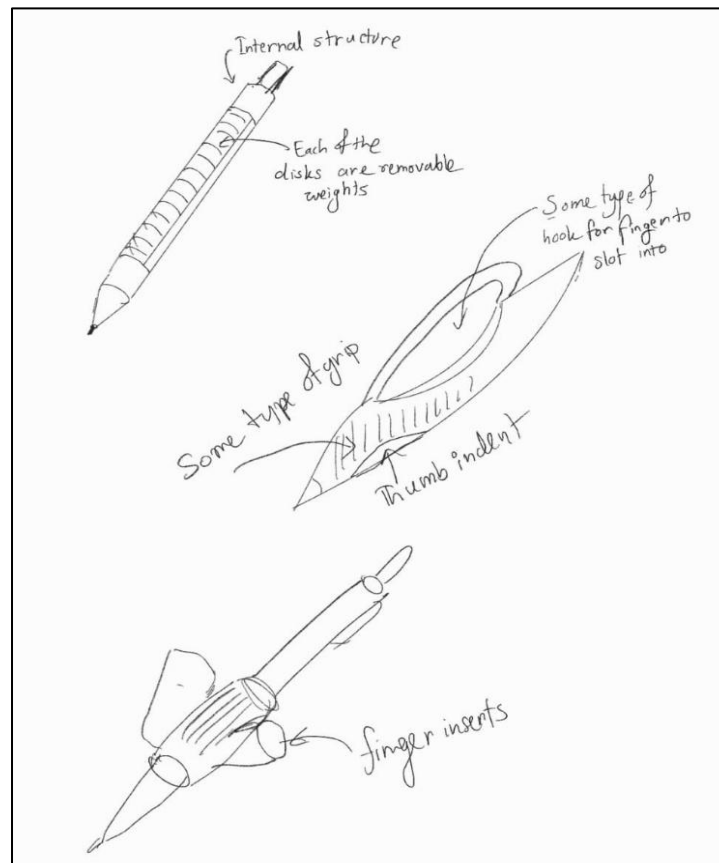


Figure 4. Initial concept sketches

Prototype Description

The prototype under development is a bulkier, weight-adjustable pen designed for individuals with Parkinson's disease or fine motor skills impairments. It focuses on reducing tremors and

enhancing grip stability. The design features an integrated ergonomic grip that spans from just below the cap to above the pen tip, creating a long, contoured surface for controlled, comfortable handling. While writing functionality is not the primary focus, the prototype includes a BiC ink cartridge to enable real writing during testing.

Potential Limitations:

Recreating the ergonomic shape in CAD may be challenging due to its complex curves, requiring multiple iterations to ensure both manufacturability and user comfort.

The integration of an adjustable weight system poses design challenges, as it must be intuitive, secure, and fit within the limited space without compromising durability or ease of use.

If 3D printing is used for prototyping, achieving precise tolerances for weight insertion may be difficult, potentially leading to misalignment or loose fits that affect functionality. Additionally, complex shapes may require extensive support structures, increasing print time and material waste.

Using specialty materials like TPU for the grip enhances ergonomics but could drive up costs and complicate manufacturing, especially if transitioning to large-scale production methods like injection molding.

Delimitations (Scope of Initial Prototype):

The first prototype will focus on ergonomic function and stability rather than full writing capability, ensuring the core design effectively supports users before refining performance.

To streamline development, the design will be simplified, focusing on grip comfort and adjustable weight mechanics before adding additional features like caps and ink cartridge interfacing.

Aesthetic details and other enhancements, while important for user satisfaction, will be addressed in future iterations once fundamental usability and stability concerns have been resolved.

Prototype Development Plan:

The initial phase of development will focus on conceptual and CAD modeling, creating a detailed Onshape model for the pen body, grip, contoured attachment, and weight chamber. This digital prototype will allow for precise dimensional planning and refinements before physical fabrication.

For initial prototyping, the pen body will be 3D printed using PLA due to its ease of printing and suitability for rapid iteration. PLA will allow the team to quickly test the form, and grip ergonomics before transitioning to more advanced materials. Once the design is refined, later prototypes will be fabricated using TPU or resin to enhance grip, comfort, and durability. TPU's flexibility and rubber-like texture with an elongation at break value of 580% [24], will provide a

non-slip surface that improves control for individuals with tremors. Resin printing, while more rigid, enables detailed ergonomic shaping and customizable textures, further enhancing user comfort and stability.

Following fabrication, assembly and testing will focus on evaluating grip size, shape, and contour attachment positioning to determine their impact on user comfort. Usability trials and iterative refinements will be conducted based on feedback, ensuring that the final design offers optimal stability and ease of use for individuals with Parkinson's disease or fine motor impairments.

Over these iterations, the team will refine the ergonomics, grip feel, and overall design to ensure it effectively enhances writing stability. Future prototypes will integrate ink functionality and caps.

This prototype sketch displays the general form of the pen and some of the key features such as the curved handle and finger imprints as well as the size and shape.

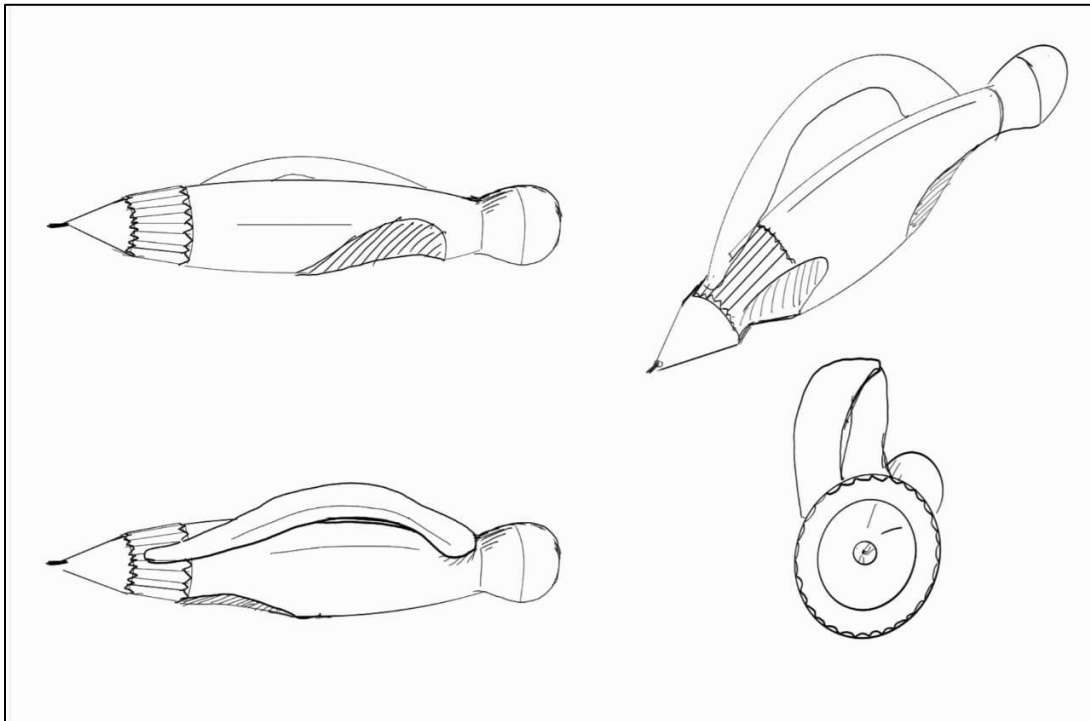


Figure 6. ZenPen Design Sketches

Prototype Preliminary Design & Mock-up:

This mock-up prototype is made of clay and was made to display a 3D version of the team's ideas. This prototype consists of the pen's general form and ergonomic shape.



Figure 7. ZenPen V1 Clay Mock-up

Key Takeaways from the Initial Design:

The curved structure of the pen enhances ergonomics, improving user comfort and grip stability. The thicker body and integrated finger indents make it easier to hold, reducing strain for users with Parkinson's disease or fine motor impairments. Additionally, the larger diameter and balanced shape help minimize tremors by added stability during use.

Mock-Up & Initial Observations:

To evaluate the ergonomic design, a clay-based mock-up was created to approximate the size, grip, and finger rest placement before committing to a 3D-printed prototype. The flexibility of clay allowed the team to quickly adjust grip contours and finger-indentations to explore different configurations.

Key Insights from the mock-up:

- **Grip Thickness Feels Adequate** – The bulkier design provided better stability, suggesting the overall thickness should remain similar in the next prototype.
- **Finger Indents May Need Refinement** – Some adjustments may be necessary to ensure optimal finger positioning for different users
- **Ideal Grip Texture** – The pattern and thickness of the textured grip will have to be reevaluated to ensure optimal comfort for different users.
- **Contoured Attachment Positioning Needs Testing** – The mock-up includes a contoured attachment; further testing is needed to determine the best placement for user comfort and control.

Identified Design Changes & Future Improvements:

- Refining Ergonomics Through Additional Testing – While the mock-up provided an initial feel, continued testing will help fine-tune grip contours and overall hand support for a wider range of users.
- Material Selection for Grip Optimization – The PLA 3D print will replace the clay prototype to improve durability, surface texture, and the overall user experience.
- Weight System Integration and Evaluation - An adjustable weight system is included in the current prototype. Future iterations will focus on optimizing its placement, usability, and impact on writing stability.
- Improving Assembly & Modularity –Ensuring that all components fit together securely and intuitively remains a priority. Adjustments to connection points and modular features will be explored to enhance ease of assembly and customization.

Picture of CAD model:

This is a Preliminary CAD model of the mock-up that shows how the team envisioned the general form of the final product and the placement all the sections including a visual representation of the chamber for the removable weights can be placed to adjust the weight.

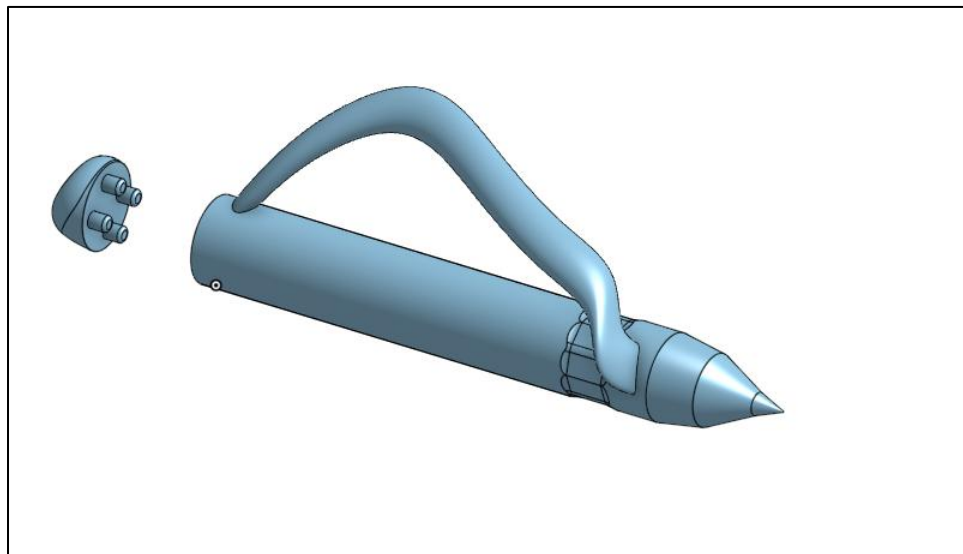


Figure 8. ZenPen V1 CAD Mock-up

10. Prototyping Design

a. Description of Prototype

The ZenPen V2 builds upon previous iterations by incorporating additional slots for weights, allowing the user to insert up to five steel rods, enabling improved weight distribution to help reduce tremors and improve control. Additionally, the contoured attachment has been iterated upon to more naturally cradle the user's fingers, further enhancing grip stability and comfort.

This prototype will not yet include a fully functional ink system, as the primary focus remains on ergonomic refinement and production feasibility before finalizing the design.

b. Prototype Design Requirements

The Prototype Design Requirements table displays design requirements for the ZenPen, measurement metrics for these requirements, acceptable ranges, ideal values, and the motivations behind the requirements.

Table 5. Prototype Design Requirements

Requirements:	Range of Values:	Ideal Value	Applications:
Grip Size	25-40 mm diameter	30 mm	Ensures comfort and ergonomic design
Weight (adjustable)	50-150 grams	75-125 grams	Helps to stabilize movements
Material Durability	Survives 5-10 drops from 4 feet	>10 drops	Ensures long-term use
Customization	Adjustable weights and grip	>5 combinations of weights and grips	Allows users to tailor settings to preference
Error Reduction	Reduces deviation in writing by 35-60% (line test)	70% reduction	Improves writing accuracy
Cost Efficiency	Low-cost production (below \$30)	\$8-15	Affordable products using 3D printing

These requirements guide the design choices to ensure the prototype meets user needs to ensure the best user experience. Optimizing grip size and weight enhances stability, while customization options offer flexibility for different user preferences. The team will refine these parameters through iterative testing and feedback analysis.

c. Testing Methodology and Verification Plan

The team will systematically test the prototype by writing 2-3 paragraphs of text while simulating hand movements or tremors. Additional users will also test the product to provide a broader range of feedback and perspectives.

Measurements of the weight rods will be taken, and the weight apparatus will be designed to accommodate their requirements. Measurements will be acquired using digital calipers and other tools provided by the engineering department.

The prototype will be influenced by comparable products and existing sources. The team will collect data through repeated use and by receiving reviews from Parkinson's patients and other potential users. Based on this feedback, the team will reevaluate and adjust the prototype's measurements and design.

A total of 5-7 prototype iterations are planned. The resulting data will be used to determine whether the prototype meets user needs and design goals. Overall, these tests measuring weight, durability, size and other factors will provide the user with the best possible experience with the Zenpen.

Measurement specifics:

For Grip Size: The grip size for the pen will be measured using calipers. The diameter may vary depending on the measurement position due to changes in weight distribution for ergonomic design.

For Weight: The pen's weight will be measured with a scale. It includes adjustable weights that can be inserted based on the user's needs. As a result, the pen will have a wide range of possible weights.

For Material Durability: Durability will be tested through a series of drop tests from increasing heights, starting at approximately 4 feet. The height will be incrementally increased until the pen sustains physical damage that interferes with the user's experience. The material the pen impacts will also be noted to assess its effect on durability.

For Customization: The level of customization will be determined by whether the pen offers varying weights and grip options. The pen will be considered successful in this area if it provides more than five different combinations of customization features.

For Error Reduction: Error reduction will be assessed using a line test. The user will draw a straight line over 10 cm using a regular pen, and the deviation of the line will be measured. The same test will be conducted using the team's ZenPen. The two results will be compared to calculate the percentage of error reduction. The team will perform this test with several users and average the results for quantifiable analysis.

For Cost Efficiency: The product will be considered cost-efficient if the total production cost per pen, including all necessary sourcing (weights, ink cartridge, body and cap materials), is under \$15.

d. Correlation Matrix and Verification Scorecard

This correlation matrix quantifies the relationship between each design requirement and key user needs based on a weighted scoring system. Higher values indicate a stronger correlation between a particular requirement and user need, helping to prioritize design elements that have the most impact. Each user need was assigned an importance weight based on its relevance to Parkinson's patients and the overall usability of the pen.

Table 6. Design Requirements / User Needs Correlation Matrix

	Grip Size	Weight (adjustable)	Materials Durable	Material Durability	Error Reduction	Cost Efficiency	Requirement 7	User Need Weight
Ergonomics	9	3	0	1	9	0	0	5
Stability Assistance	9	9	0	3	9	3	0	2.3
Affordability	1	3	9	3	3	9	0	4.3
Fatigue Reduction	3	9	3	1	3	1	0	3
Error Prevention	3	9	1	3	9	0	0	1
Durability	3	3	9	3	0	1	0	3.7
Aesthetically Pleasing	3	0	1	3	1	3	0	1.7
Importance ->	98.2	95.7	83.7	47	98.3	57.4	0	

This verification scorecard is used to grade the ZenPen prototype based on design requirements. This holds the team accountable for fulfilling product expectations.

Table 7. Verification Scorecard

Scorecard			
Requirement	Range	Score Rubric	Score
Grip Size	20-40 mm	4 pts if falls in range. -1 for every 3mm outside of range	5
Weight Max	115-145g	5 pts if falls in range. -1 pts for every 5 grams outside of range	5
Weight Min	25-40 g	Add +3 points if the pen minumun weight falls between the range. -1 point for every 5 grams out of range.	3
Material is Durable	4 feet drop test survival	Add +1 point for every foot the pen survives up to 4 feet total.	4
Error Reduction	20% deviance	Add +5 points for >20% decrease in line test deviance. -1 point for every 5% less than 20%	5
Cost Efficiency	\$7-\$15	Add +3 points for falling under the \$15 max	3
Requirement 7	~	~	0

The team will utilize the weighted requirements for the ZenPen to prioritize design decisions based on user needs. By analyzing the correlation matrix, the team can identify which requirements have the greatest impact on functionality and user experience. This approach allows for informed design tradeoffs, ensuring that higher-weighted requirements are prioritized

over lower-weighted ones when necessary. By making strategic compromises, the team aims to optimize the pen's performance and deliver the best final product possible.

e. Prototype Preliminary Design and Mock-up

The ZenPen V2 Cad Mockup shows the team's improved design for the ZenPen. The pen assembly is comprised of a 3D printed body and cap and five steel rods that can be placed inside the pen body to adjust weight.

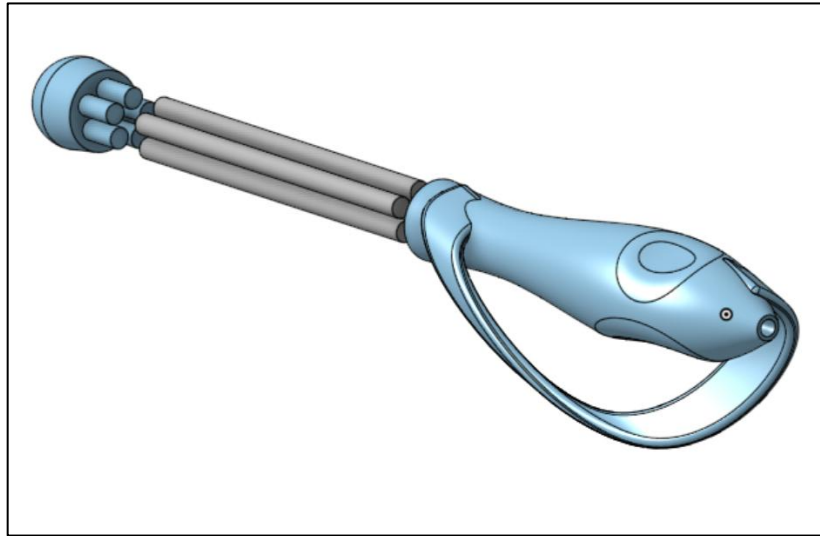


Figure 9. ZenPen V2 CAD Mock-up

The ZenPen V2 Clay Mock-up shows the team's improved design for the ZenPen as a tangible object. The clay mock-up is comprised of three main parts: the body (black), the circular loop to cradle the user's pointer finger (dark green), and the cap (light green).

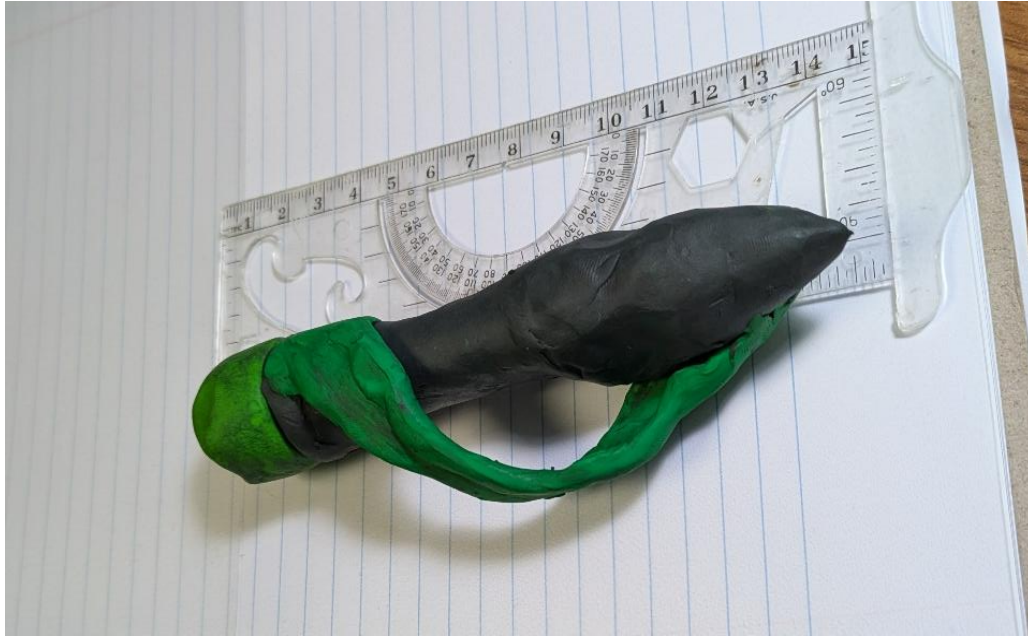


Figure 10. ZenPen V2 Clay Mock-up

Key Takeaways from the Updated Design:

The ZenPen V2 builds upon the ergonomic and stability-focused principles of the original design while introducing an improved adjustable weight system. The semi-hollow body allows users to insert up to five steel rods, allowing for adjustable weight distribution to meet individual preferences.

Mock-up & Initial Observations:

To evaluate the refinements in V2, the team created both a CAD mock-up and a clay mock-up of the design outlined in the design sketches. The clay mock-up provided a hands-on way to assess comfort, balance, and finger support before creating the CAD mock-up. The CAD model allowed the team to visualize precise dimensions and assembly.

Key Insights from the Mock-ups:

- The weight adjustment system is promising. The ability to easily adjust weight with steel rods allows for customizable weight distribution, which could improve control for users.
- The pointer finger loop may require a redesign. Currently, the design may present challenges in 3D printing, particularly in maintaining durability without compromising comfort.
- The cap attachment system may need refinement. Currently, the friction-based attachment may not be sufficient to keep the cap securely in place.
- The ballpoint pen tip still needs a protective cover. Currently, the exposed pen tip could cause issues when not in use.

Identified Design Changes & Future Improvements:

- The team plans to consult the employees at the 3D print shop for advice regarding best printing and design practices regarding the pointer finger loop.
- Adjustments will be made to the CAD model to ensure proper fitment of ink cartridges and weight rods.
- Research into magnet-based latching mechanisms will be conducted to improve cap security beyond a friction fit.
- Research into implementing a sliding or attachable cap to shield the ballpoint when not in use will be performed.

Detailed Design Review

11. Prototype Fabrication and Evolution

Throughout the development process, the team engaged in multiple phases to refine the ZenPen's design and functionality. Based on internal testing and initial feedback, several adjustments were made, such as resizing the grip for improved comfort and modifying the weight distribution system to enhance stability. This was accompanied by an iterative prototyping process, where each version of the pen incorporated insights from the last. These iterations prioritized optimizing the ergonomic shape, improving balance, and enhancing overall usability, particularly for individuals with reduced dexterity.

In selecting materials, the team evaluated various options for both the grip and the pen body. Thermoplastic TPU emerged as the most effective due to its flexible, rubber-like texture, which provided a non-slip surface and greater control—especially beneficial for users with tremors. However, due to time constraints, the final prototype will be fabricated from PLA. To verify the effectiveness of recent design changes, the team conducted preliminary verification testing. Participants performed writing tasks while the team collected data on grip comfort, writing accuracy, and usability. Analysis of this data showed marked improvements in writing stability and user comfort. Notably, the adjustable weight system allowed users to tailor the pen's balance to their individual needs, reinforcing the value of key design choices and confirming the direction of development.

1. Initial Concept and Design: The team began by identifying a significant challenge for individuals with Parkinson's disease or fine motor impairments, who often struggle to write due to hand tremors, grip weakness, and reduced coordination. To address this, the team set out to design a pen that could help reduce tremors and make writing easier.
2. Brainstorming and Ideation: The process began with a structured brainstorming session focused on user needs. The team evaluated various design aspects, including ergonomics, stability assistance, affordability, fatigue reduction, error prevention, durability, customizability, and aesthetics. This helped narrow the team's ideas to the most promising concepts.
3. Preliminary Prototyping: The first prototype was crafted using clay. This tangible model allowed the team to visualize the ergonomic shape and make initial adjustments based on feedback, such as changing the handle's shape and position, reshaping the pen body and cap, and adding grip indents to enhance user comfort.

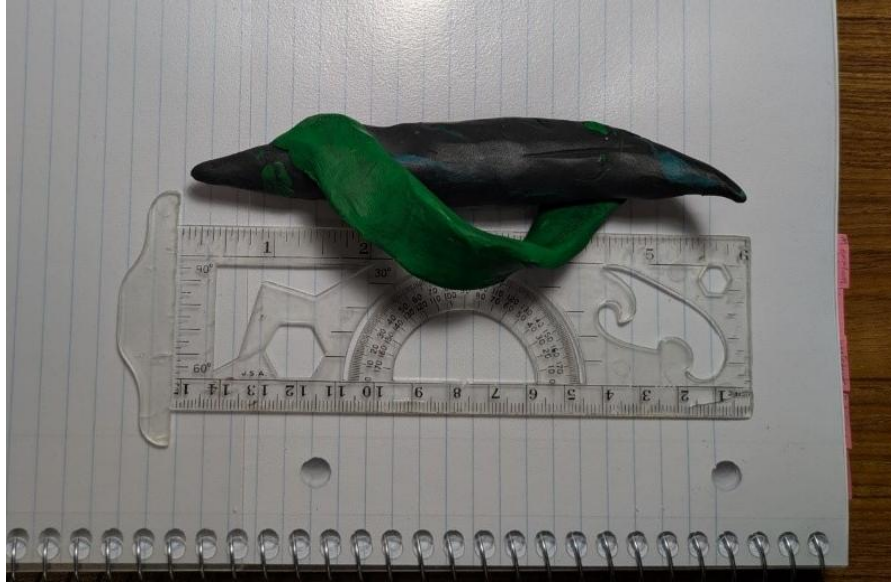


Figure 7. ZenPen V1 Clay Mock-up

4. CAD Modeling: The team created an initial CAD model using Onshape, building on the shape and proportions defined in the clay prototype. This model featured a modular weight system and a contoured grip, allowing for better customization of stability and comfort based on user preference.

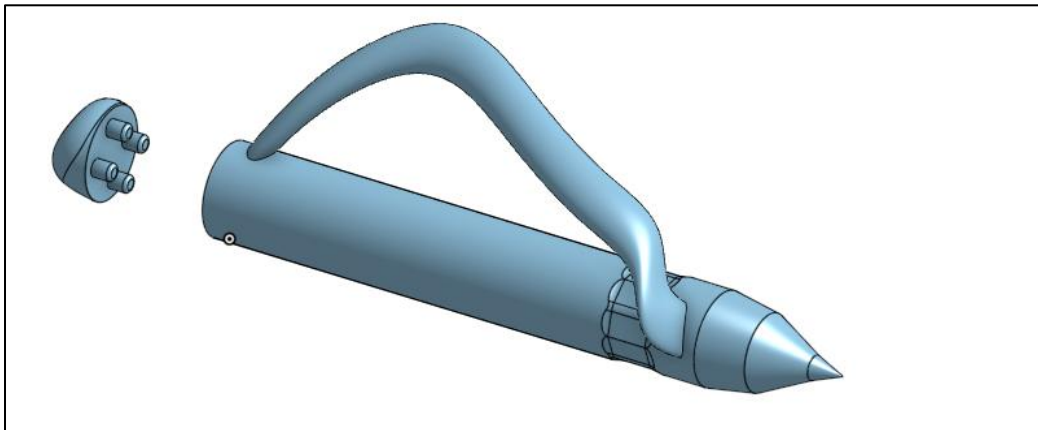


Figure 8. ZenPen V1 CAD Mock-up

The team then iterated on this design, creating a new clay mockup and adjusting the CAD model to more closely resemble the prototype.

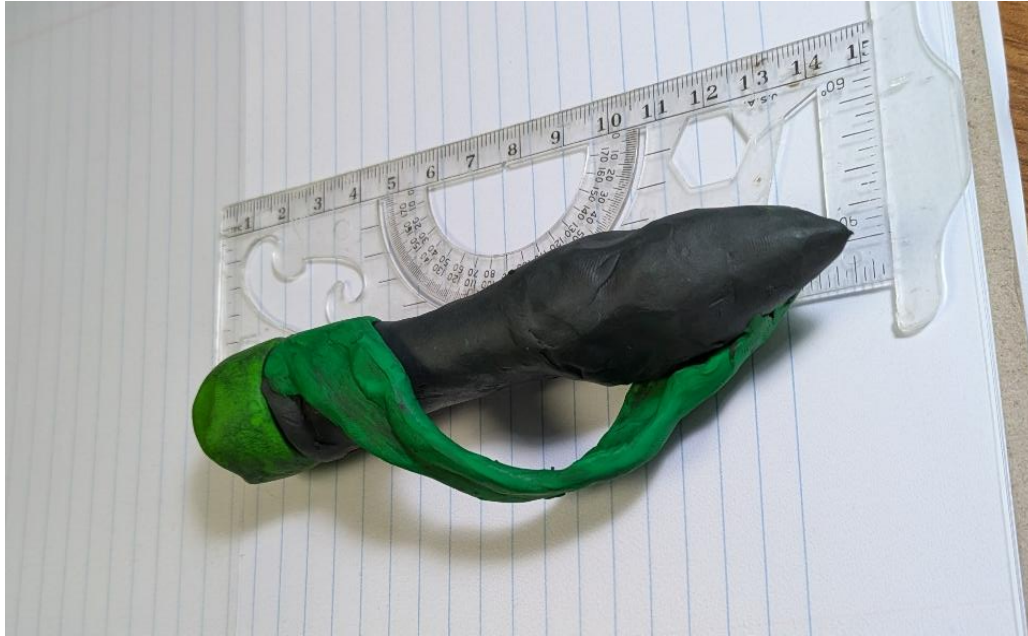


Figure 10. ZenPen V2 Clay Mock-up

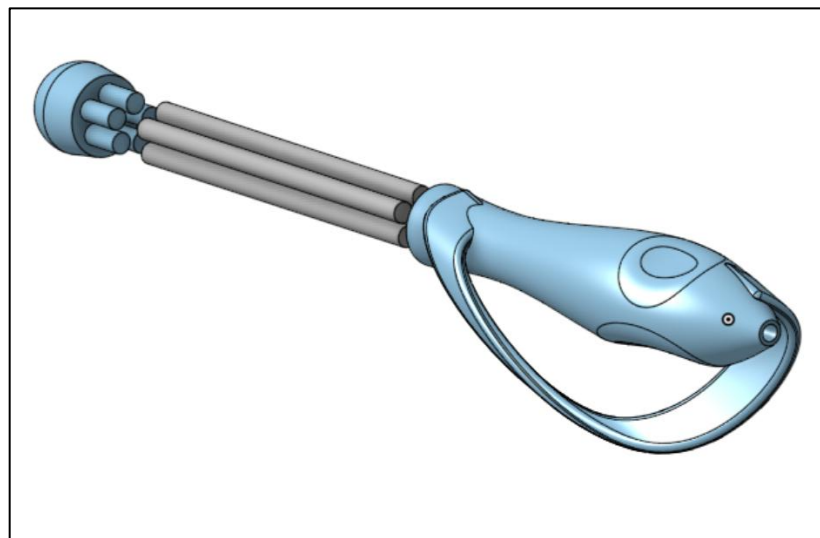


Figure 9. ZenPen V2 CAD Mock-up

5. 3D Printing: The team brought the design to life with a 3D-printed prototype using PLA material. This stage enabled physical testing of form and ergonomics, revealing the need for grip contour adjustments and weight redistribution. The prototype included a BiC ink cartridge to conduct real writing tests, allowing for functional evaluation of comfort.

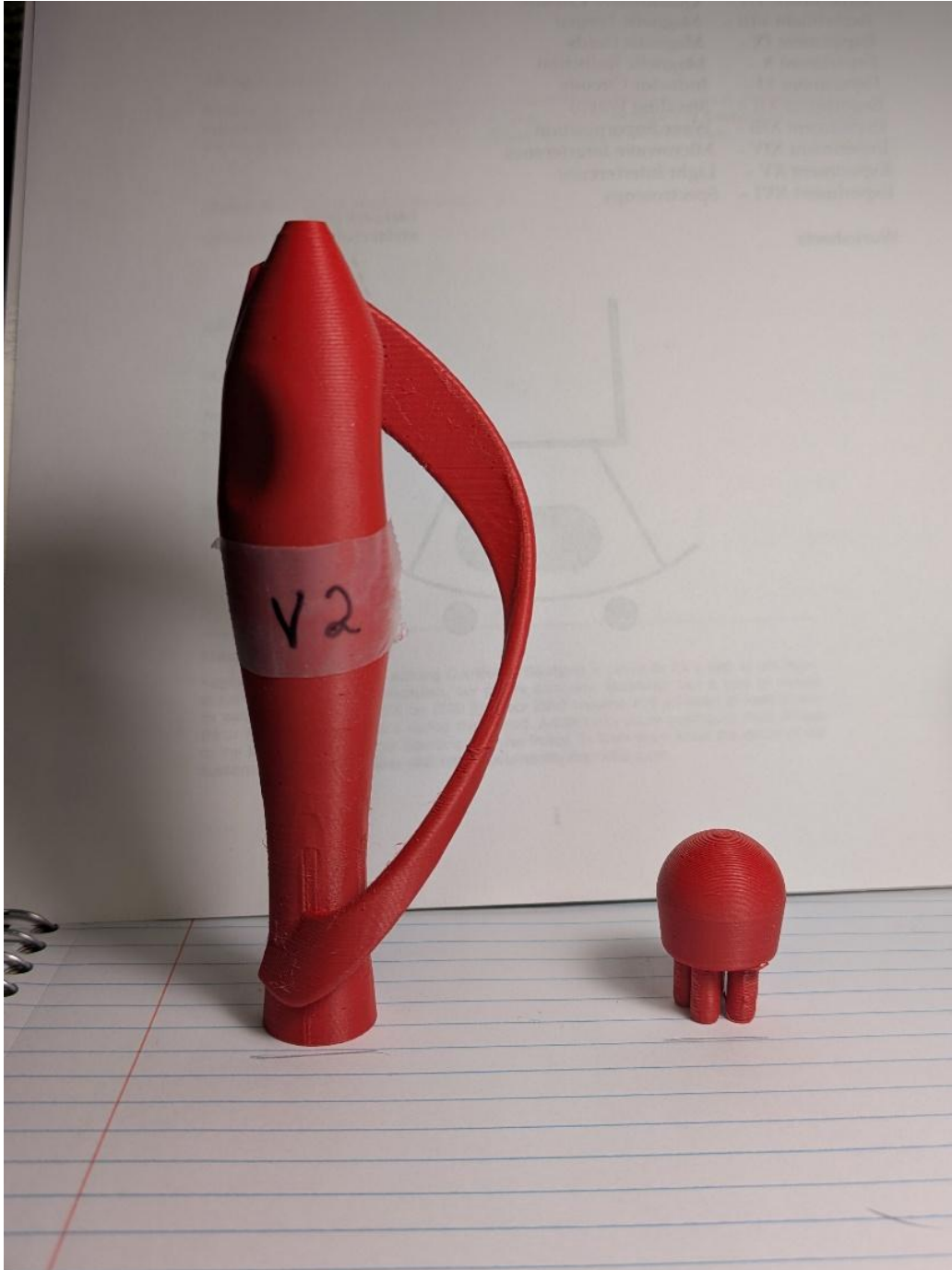


Figure 14. ZenPen V2 Print

The team continued to adjust the CAD model for tolerances and better ergonomics until settling on V7. The team also opted to add a snap-on cap for the ink tip.

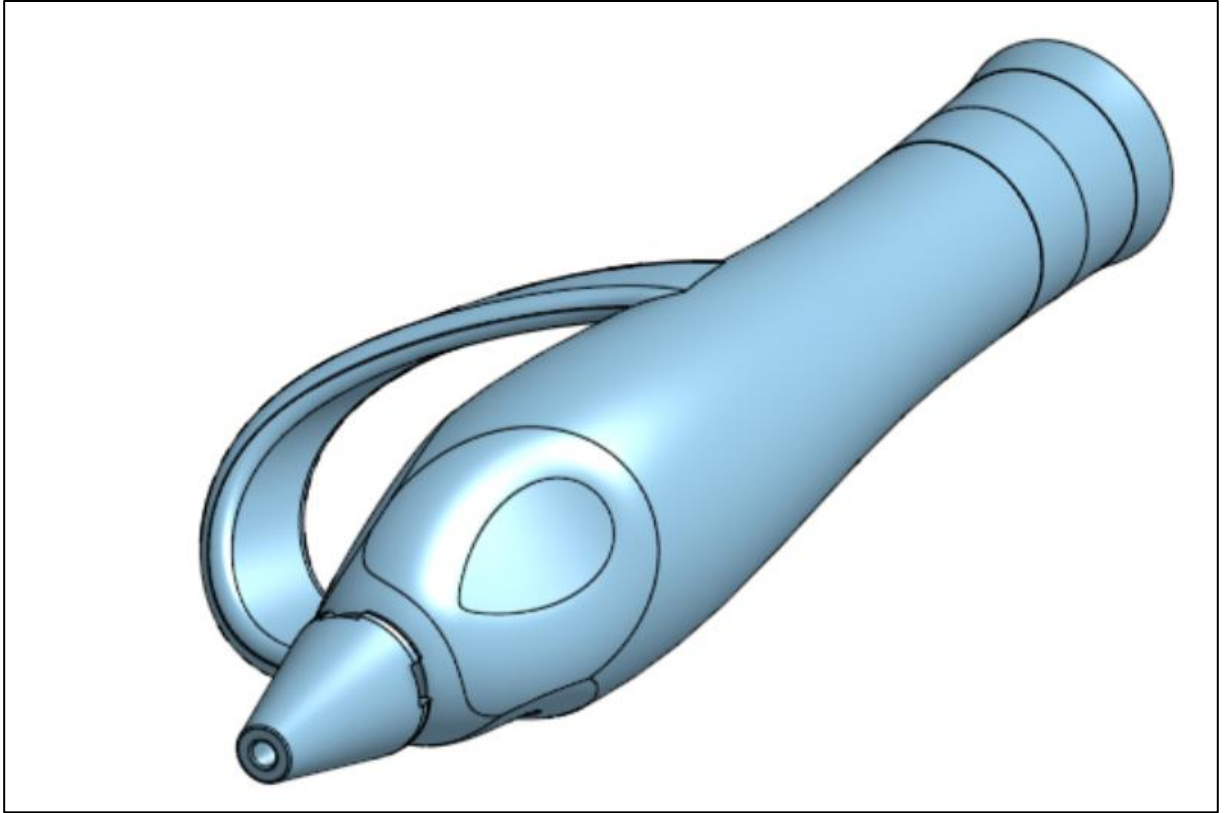


Figure 15. ZenPen V7 CAD Mockup

1. Final Design Adjustments: The final prototype incorporated all major refinements. Grip size, weight distribution, and material selection were optimized to improve comfort, control, and usability.

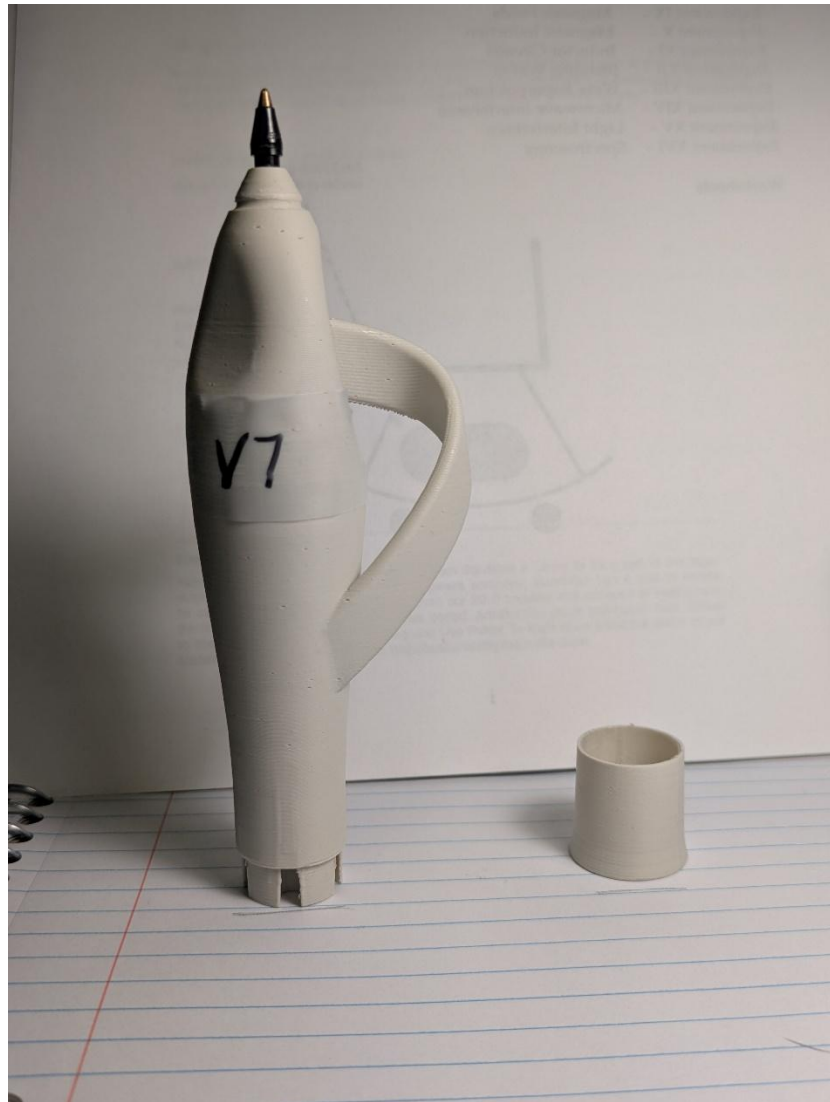


Figure 16. ZenPen V7 Print

2. User Validation: The team tested the final prototype with a broader group of users, including individuals with Parkinson's disease. Qualitative feedback indicated improved writing stability and reduced tremors, validating the pen's core design goals.
3. Project Management: The project management plan included a Gantt chart to track progress and ensure timely task completion. Regular meeting minutes were documented to record decisions and action items, helping the team stay aligned and accountable throughout the project.
4. Trade-offs and Delimitations: The team was limited by the timeframe given to order TPU parts. While the team wanted to use TPU for the prototype due to its increased durability, the final design had not been achieved, thus restricting the team to using PLA for the prototype. 3D printing, while useful for creating complex shapes easily, also caused tolerances to be difficult to settle on.

The team was delimited by restricting the scope of the project to those with Parkinson's disease, not extending to other fine-motor impairments at the present time. Using standard ballpoint ink cartridges ensured uniformity and ease of manufacturing.

When sourcing metal rods, the team faced the challenge of adjusting the design to accommodate larger rods than initially planned for. Having sourced the metal rods sustainably from machine shop scraps, stock was limited, and only larger rod diameters were available.

5. Final Prototype Verification: The final prototype was verified against key design requirements. It met the criteria for grip size, weight distribution, material durability, and error reduction. The design remained cost-efficient to produce, supporting accessibility for a broader range of users.

6. Conclusion: The project successfully developed a pen that enables individuals with Parkinson's disease to write more comfortably and accurately. The iterative design process, user feedback, and verification testing ensured the final prototype met the needs of our target users while promoting accessibility, independence, and ease of use.

12.Detailed Design

a. Final Prototype Design

The final design of the ZenPen prototype, seen in figures 15-16 and Appendix C, is grounded in prior research and user needs specific to individuals with Parkinson's disease. It features a cost-effective, ergonomic PLA grip and a modular weight system to minimize hand tremors. The custom design includes a contoured grip for enhanced control and a distinctive curved shape that follows the natural resting position of the hand. This curvature improves grip comfort and helps stabilize the pen during use, making writing easier, more accurate, and less fatiguing for users.

Moving into scale manufacturing, the team would like to shift to an injection molded plastic design with rubber inserts on the grip indents. Injection molding could reduce costs once scaled, increase consistency, and enable use of multiple materials on the pen, including rubber to increase grip throughout. Overall scale and functionality will remain the same from prototype to production.

b. Revised Grand Concept Design

The ZenPen prototype evolved significantly through iterative testing and user feedback, leading to meaningful refinements in both form and function. One of the most impactful changes was the addition of a modular weight system, which allows users to adjust the pen's balance based on personal comfort and tremor severity, greatly improving writing stability for individuals with Parkinson's disease

Another major shift from the original concept was the transformation of the pen's body shape. Initially designed as a straight cylinder (Figure 8), the form was updated to feature a gentle, ergonomic curve (Figure 16). This curvature aligns more naturally with the resting position of the hand, reducing strain and increasing grip stability. To ensure ease of maintenance and cost-effectiveness, the ink cartridge mount was also redesigned to accept standard, thread-compatible BiC cartridges.

These changes were directly driven by user-centered testing and significantly enhanced the ZenPen's comfort, control, and overall usability. While the final prototype reflects the intended 3D profile, the team anticipates implementing updated manufacturing techniques for scaled production. This includes transitioning from PLA to more durable plastics and incorporating rubberized grip inserts via dual-material molding, improving both functionality and production efficiency.

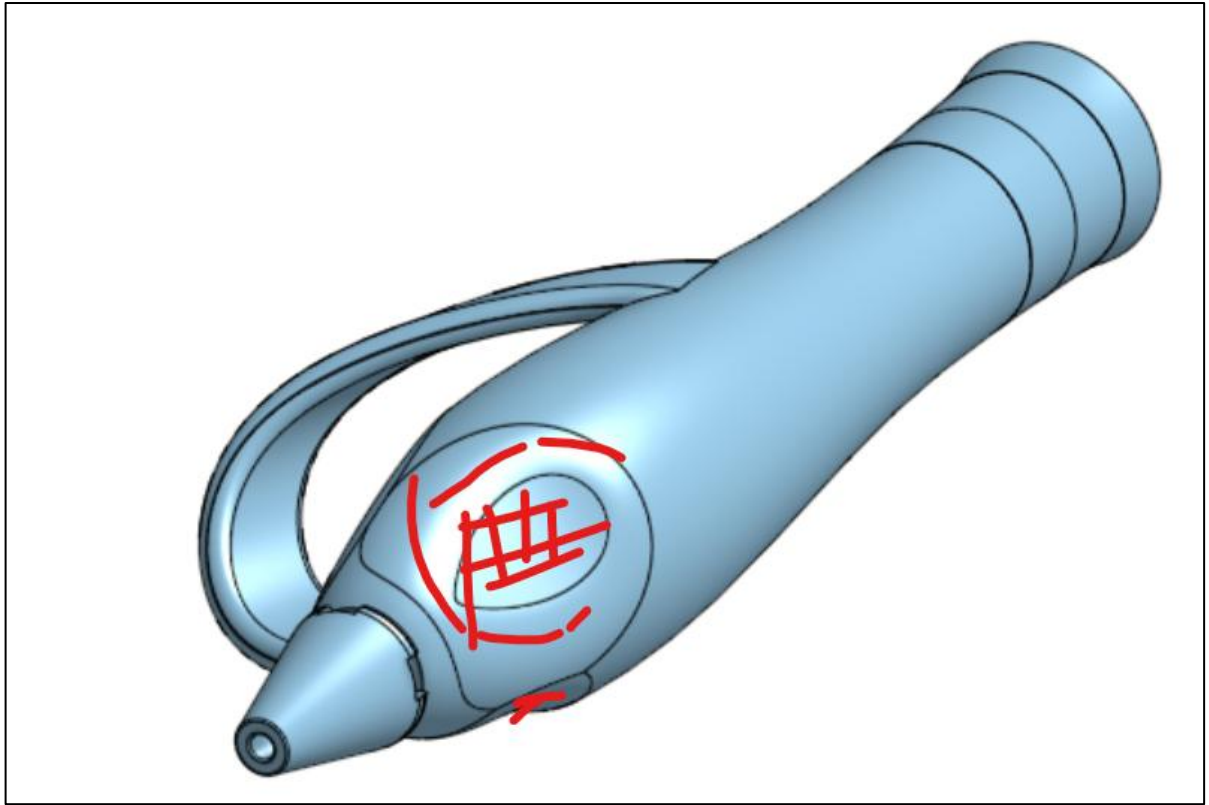


Figure 17. ZenPen V7 with Rubber Grip Inserts

13.Final Prototype Verification

Table 7 shows the verification scorecard used to grade the ZenPen prototype based on design requirements. This holds the team accountable for fulfilling product expectations.

Table 7. Verification Scorecard

Scorecard			
Requirement	Range	Score Rubric	Score
Grip Size	20-40 mm	4 pts if falls in range. -1 for every 3mm outside of range	5
Weight Max	115-145g	5 pts if falls in range. -1 pts for every 5 grams outside of range	5
Weight Min	25-40 g	Add +3 points if the pen minimum weight falls between the range. -1 point for every 5 grams out of range.	3
Material is Durable	4 feet drop test survival	Add +1 point for every foot the pen survives up to 4 feet total.	4
Error Reduction	20% deviance	Add +5 points for >20% decrease in line test deviance. -1 point for every 5% less than 20%	5
Cost Efficiency	\$7-\$15	Add +3 points for falling under the \$15 max	3
Requirement 7	~	~	0

Table 10 shows measurements of the ZenPen's grip size. Grip size was measured from several angles of rotation around the pen body. These measurements were then averaged to give a final grip size to be scored. The average grip size was measured to be 24.05mm which falls within the team rubric's 20-40mm range.

Table 10. ZenPen Size Measurements

	Dimensions (mm)
M. 1	28.06
M. 2	25.17
M. 3	22.53
M. 4	20.44
Avg. Grip Size	24.05
Height	147.37
Width	46.38
Depth	28.19

Table 11 shows measurements of the ZenPen's weight. Weight maximum and minimum were measured with pen fully weighted and then with pen empty. The team's goal was to have a large spread of weights to allow for maximum adjustability. Maximum weight was 128.56 grams,

which is within the rubric range. Minimum weight was 29.48 grams, which is within the rubric range as well.,

Table 11. ZenPen Weight Measurements

	Weights (g)
Weight 1	19.68
Weight 2	19.87
Weight 3	19.78
Weight 4	19.87
Weight 5	19.88
Avg. Rod Weight.	19.816
Pen (empty)	29.48
Pen (fully weighted)	128.56

Material durability was measured via drop test onto carpeted flooring. The drops started at 1 foot and increased until they reached 6 feet. The team was concerned that the pen would fail in its weak points, particularly the thin finger loop. However, the 3D printed pen body sustained zero damage, with the only damage sustained being to the outsourced BiC ink cartridge, which is designed to be replaceable. This outcome aligns with and surpasses the rubric requirement to survive 4 foot drop tests for full credit.

Table 12 shows measurements of the ZenPen's error reduction capabilities. Three users, a control user, a user with simulated tremors (secondary person used to jerk user's elbow), and a user with dysgraphia, were tested using the ZenPen against a control BiC ballpoint pen. Users were asked to trace over a straight, red, 6 inch line as closely as possible with both pens. Calipers were used to measure the deviation off the red line of the three largest peaks in the user's line and the average of the peak deviation for each test was taken. Percent deviation was calculated using average values in equation, $\frac{D_{BiC} - D_{ZenPen}}{D_{BiC}} * 100$. Percent Deviation reduction always fell well above the 20% threshold stipulated in the rubric.

Table 12. ZenPen Error Reduction Data

	Type	Peak 1 (mm)	Peak 2 (mm)	Peak 3 (mm)	Mean Peak	Percent Deviation Reduction
Control	ZenPen	0.2	0.15	0.32	0.22	65.10%
Control	Bic	0.85	0.54	0.53	0.64	
Dysgraphic	ZenPen	0.66	1.13	1.12	0.97	36.77%
Dysgraphic	Bic	0.82	1.81	1.35	1.33	
Simulated	ZenPen	1.07	1.44	2.05	1.52	48.65%
Simulated	Bic	3.46	2.76	2.66	2.96	

Figure 24 shows the sheet used to gather writing samples in the error reduction testing.

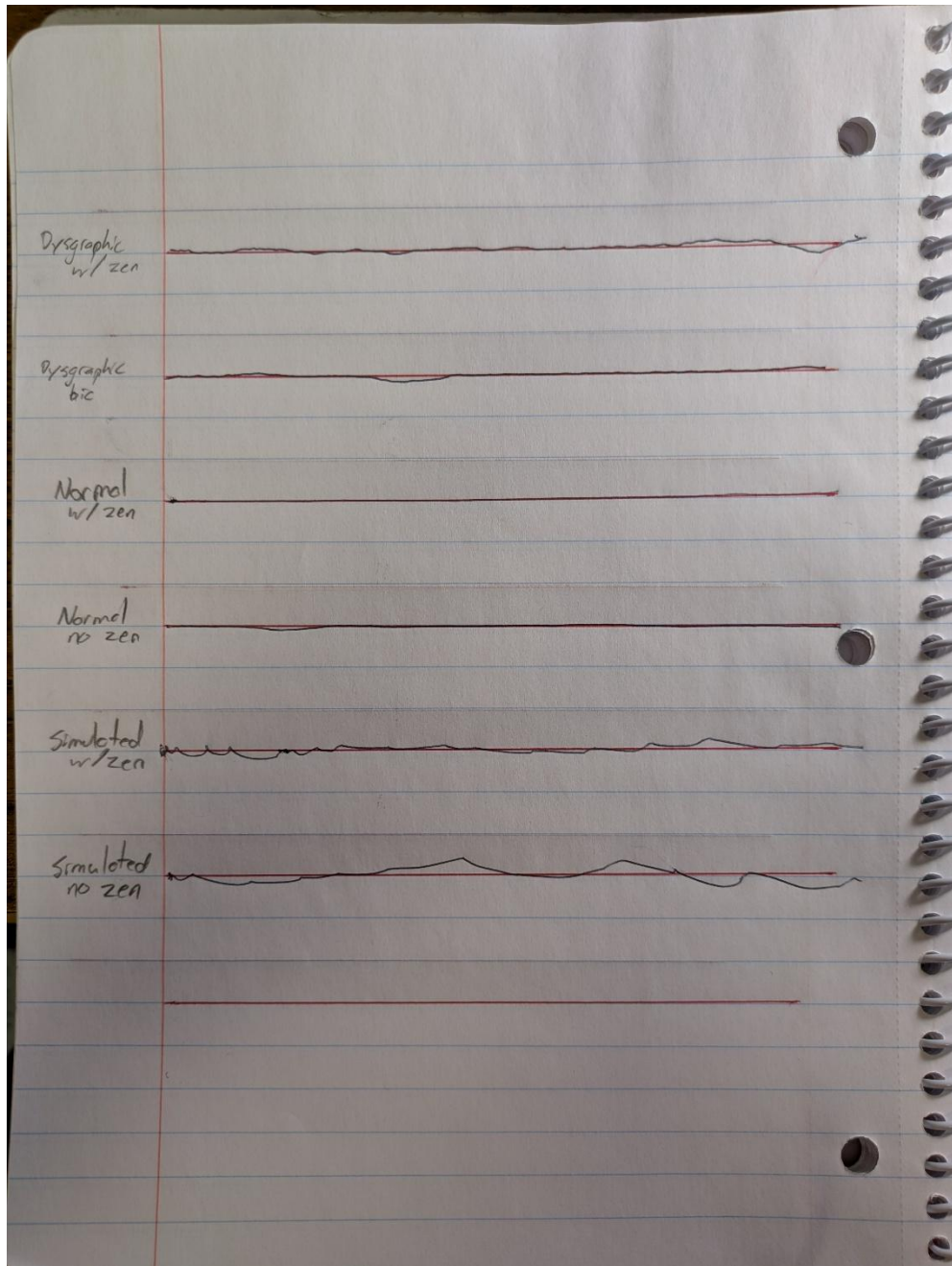


Figure 24. Error Reduction Test Sheet

Table 13 shows an itemized list of expenses to create one ZenPen within a production setting. In the prototyping process, ink cartridges and weights were recycled materials, so the following prices are estimated. The total cost of \$12.68 falls within the rubric range. The team expects that in production, this cost could be reduced. Ignoring that assumption though, the pen could still be manufactured and sold at an estimated \$30, resulting in over 50% margins for the company, while still providing a product significantly more inexpensive than current market alternatives.

Table 13. ZenPen Production Cost Data

	Cost of Pen Production (\$)	
3D print	\$	9.39
Pen Cartridge	\$	0.14
Tape	\$	0.05
Weights	\$	3.10
Total:	\$	12.68

Sustainability was important to the team in the development of the ZenPen, resulting in the use of recycled pen cartridges and recycled steel rod from the machine shop for the pen's weighted rods. To aid in the production of the pen's ergonomic shape, the team utilized additive manufacturing techniques i.e. 3D printing. The team also used the tool shop's drill in some prototypes to increase weight hole diameter.

Figure 25 shows that the team performed an Onshape simulation as an additional stress test for the ZenPen. While a somewhat trivial test in the scope of the team's project, the simulation further showed that the ZenPen's construction can withstand the stresses of daily use.

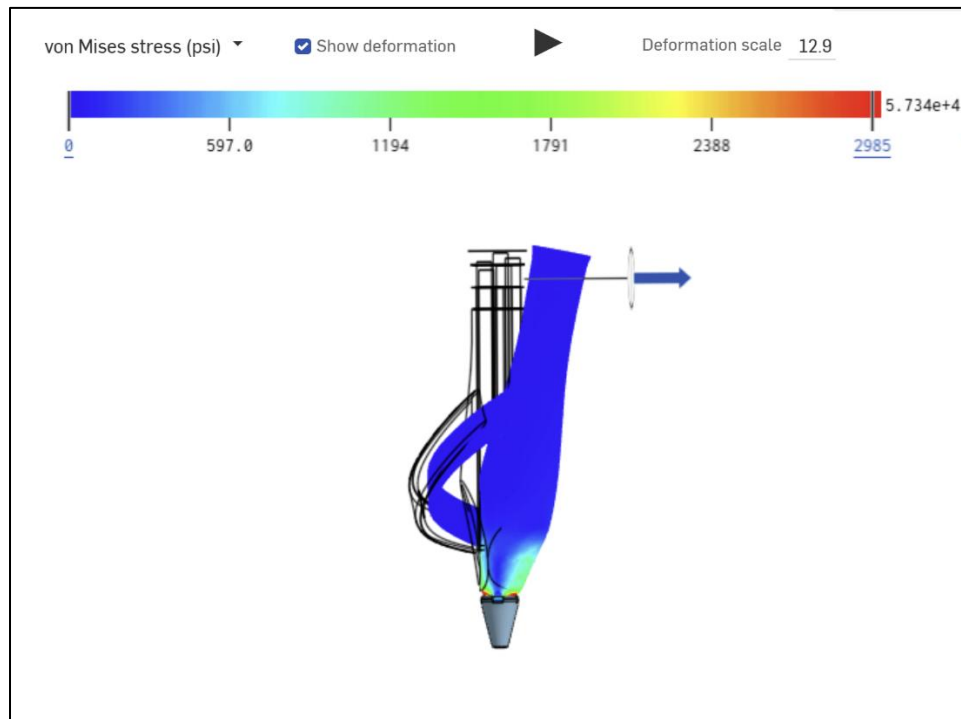


Figure 25. Onshape Stress Simulation

Prototyping was performed iteratively, gathering feedback from a test subject who has a writing disability after each print. Changes were made to satisfy user requests and increase ergonomics.

V2 (first print) (32.34g 2h20m) = \$8.768

- Baseline prototype
- Necessary to gauge future steps/adjustments



Figure 14. ZenPen V2 Print

V3 (32.2g 2h18m) = \$8.74

- Shifted loop higher on pen body to better fit finger contour
- Shifted finger imprints towards pen tip to increase control
- Widened diameter at body mid-portion to eliminate thin walls in V2
- Adjusted pin tolerances (-0.02mm) for better body-weight cap interfacing
- Attempted printing “ZenPen” branding around weight cap for aesthetic appeal



Figure 18. ZenPen V3 Print

V4 (3/30) (35.84g 2h24m) = \$9.5

- Created upward angle on bottom finger loop connector to match angle of pointer finger when gripping the pen.
- Increased radius of loop to provide looser fit
- Added cap for pen tip to prevent stray marks when not in use
- Created new cap without text and with flattened top surface for cleaner printing
- Adjusted pointer finger indentation angle to better fit user position



Figure 19. ZenPen V4 Print

V5 4/2 (64g 4h24m) = \$17.30

This print was used to test two weight rod diameters for the recycled steel rods the team sourced. The larger was designed to accommodate a 7/32" rod, while the smaller of the two was designed to accommodate 1/8" rod.

Big diameter:

- Increased cartridge tolerance (+0.5mm) to reduce post-print sanding of opening to accommodate cartridges
- Increased weight hole diameter to 7/32" to accommodate sustainably sourced weight rods

Small diameter:

- Added 6th weight rod slot to accommodate additional weights
- Increased cartridge tolerance (+0.5mm) to reduce post-print sanding of opening to accommodate cartridges
- Shifted top loop connection down to test a more ergonomic position
- Decreased weight hole diameter to 1/8" to accommodate sustainably sourced weight rods

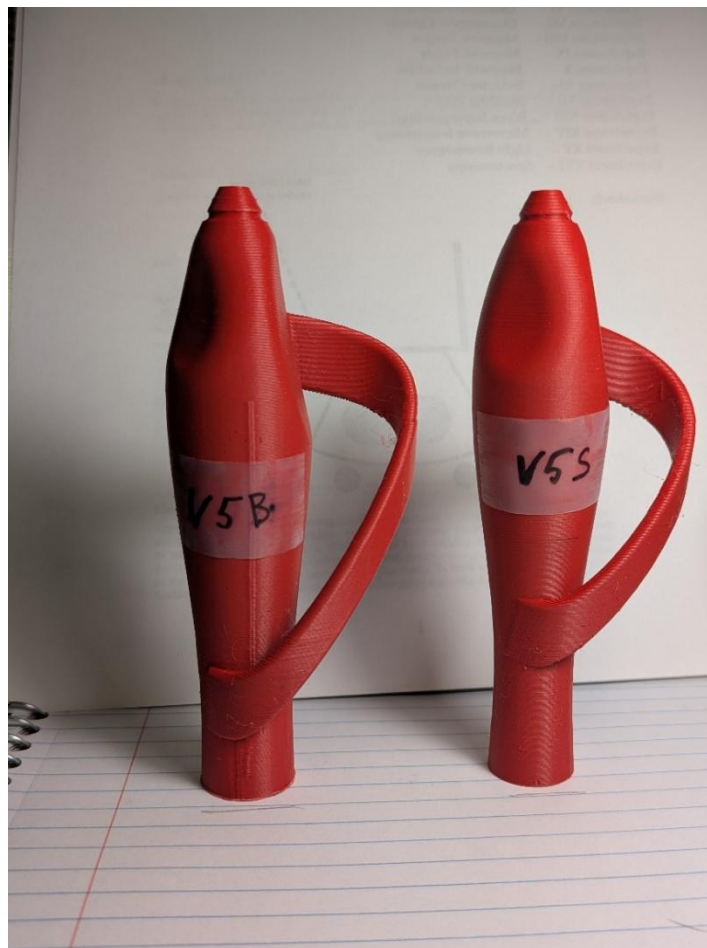


Figure 20. ZenPen V5 Print

V6 (4/3) (38.21g 2h22m) = \$9.98

- Chose big diameter rods based on V5 Large Diameter for additional weight, and to satisfy user feedback
- Redesigned cap to slide over weights rather than have pins slide into the body. This was to increase ease of insertion and removal of weight rods
- Chose top loop connection shifted down based on V5 Small Diameter for best ergonomics
- Increased overall body diameter to provide extra room for larger rod size and to seat into the crook of user's hand more firmly



Figure 21. ZenPen V6 Print

V7 (4/8) (34.02g 2h17m) = \$9.10

- Increased weight rod hole tolerance (+0.1mm) due to user concern over nearly impossible to remove weight rods
- Added cap connector "draft" to increase connection tightness as it is inserted
- Rotated angle of the sweep sketch in Onshape to match the angle of the finger loop curve to the user's finger



Figure 16. ZenPen V7 Print

V8 (4/11) (35.15g 2h20) = \$9.36

- Increased chamfer angle and decreased weight cap tolerance (-0.2mm) to provide a tighter fit
- Added chamfer to weight holes for easier rod input to aid in sliding weight rods into holes

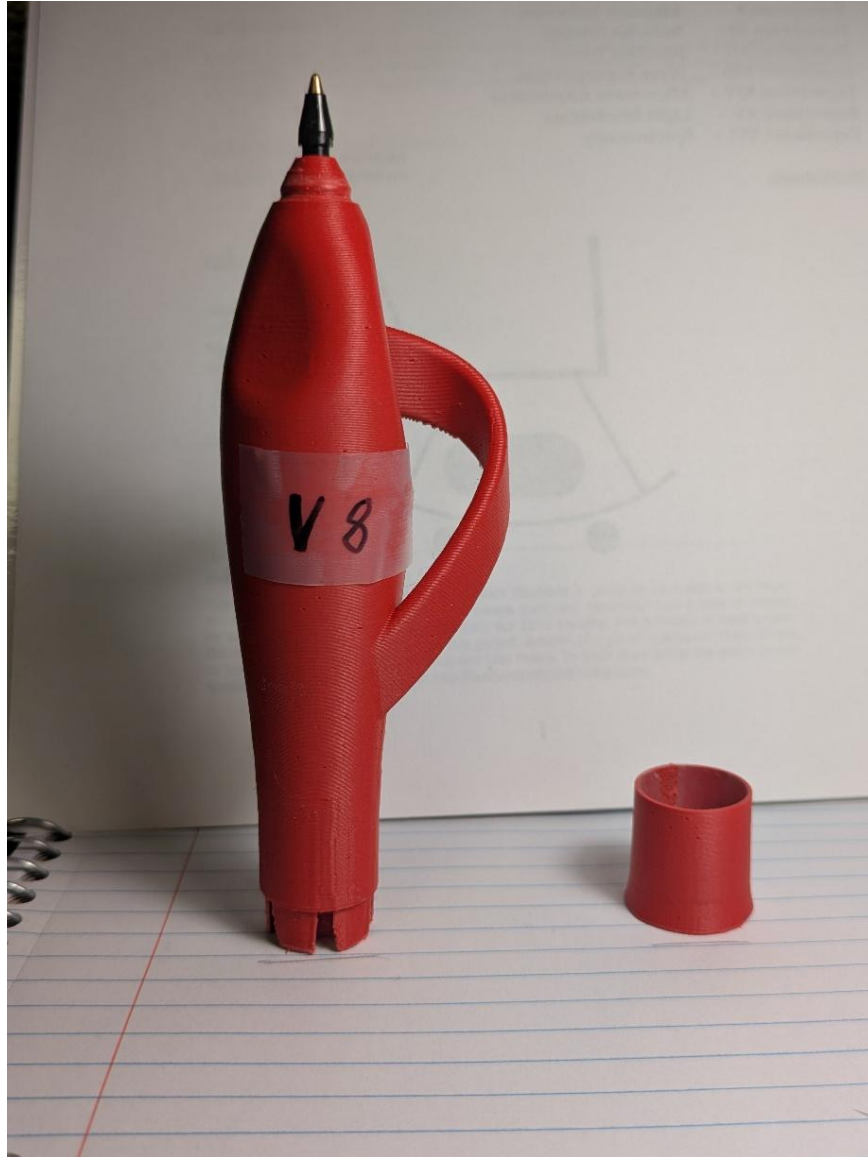


Figure 22. ZenPen V8 Print

V9 (4/15) (35.27g 2h20m) = \$9.39

- Reduced tolerance on weight cap to (+0.0) due to continued looseness in fit leading to weights and cap dislocating when held upside down
- Removed chamfer from weight holes as it did not come across in print



Figure 23. ZenPen V9 Print

Table 9 shows the team's itemized list of all expenditures for the ZenPen project. Expenditures total \$82.70. Well within the \$120 budget.

Table 9. Itemized Budget

Item	Additional Notes	Cost
V2 print	32.34g 2h20m	\$ 8.77
V3 print	32.2g 2h18m	\$ 8.77
V4 print	35.84g 2h24m	\$ 9.57
V5 print (two variants)	64.3g 4h24m	\$ 17.26
V6 print	38.21g 2h22m	\$ 9.97
V7 print	34.02g 2h17m	\$ 9.11
V8 print	35.15g 2h20m	\$ 9.36
V9 print	35.27g 2h20m	\$ 9.39
Tape to reduce tolerance of cap	1ft	\$ 0.50
Bic cartridge	\$0.14 for 1 Bic cartridge. These pens were recycled	\$ -
Steel Weights	Recycled metal rods from machine shop for weights	\$ -
	TOTAL:	\$ 82.70

14. User Validation

Introduction and Goals

This user validation plan outlines the team's strategy to determine how well the final prototype solves the intended problem and satisfies key user requirements. The plan focuses on evaluating the prototype through realistic user testing scenarios that reflect its intended use.

The team's objectives are to:

- Confirm that the prototype addresses the user's core problem.
- Validate whether the highest-priority needs are met through design.
- Assess whether the product delivers tangible value to its intended users.

Feedback from these evaluations will guide any final design modifications and ensure alignment with real-world expectations

Top 3 User Needs

Based on the pairwise comparison and user need chart from the Problem Definition phase, the three most important user needs are:

1. Ergonomics

The pen must be comfortable to hold and use for extended periods. This includes appropriate grip sizing, weight balance, and a design tailored to users with reduced fine motor control.

2. Affordability

The final product should be cost-effective to produce and affordable for the end user. It must strike a balance between performance and price to ensure accessibility without sacrificing quality.

3. Durability

The prototype must be able to withstand regular use and handling. Material choice and structural integrity are essential to ensure long-term reliability under both normal and stressed conditions.

Methodology

To evaluate whether the prototype meets the intended user needs: ergonomics, affordability and durability. The team has developed a structured, user-centered testing approach. Each method simulates realistic use scenarios, allowing us to collect both qualitative and quantitative data from representative end users.

1. Ergonomics Test: Writing Task and Tremor Simulation

Method: Users will complete two tasks using both the prototype and a standard BiC pen. First, they will draw a series of straight lines and curved lines across a page to evaluate control and precision. Then, they will write two to three short paragraphs under normal conditions. These same tasks will be repeated while simulating hand tremors, either through intentional shaking or by holding the pen with an unstable grip. Observers will monitor grip behavior, writing control, and signs of strain throughout the process.

Data Collected:

- Ratings for comfort, control, and fatigue (scale of 1-10)
- Observational notes on grip adjustments, hand strain, and task accuracy
- Comparison of line straightness and legibility between pens
- Qualitative feedback on ease of use, pressure required, and hand fatigue

2. **Affordability Perception Survey**

Method: After testing, users will be informed of the prototype's projected cost and asked to evaluate its affordability in comparison to pens they currently use.

Data Collected:

- Likert-scale affordability rating (1-5)
- Open-ended responses on cost expectations, willingness to purchase, and value perception

Tools: User feedback survey

3. **Durability Evaluation: Repeated Use and Stress Simulation**

Method: Users will interact with the prototype in common and slightly stressful ways, such as removing and replacing the cap repeatedly, twisting or tapping the pen, and simulating mild drops from increasing heights. Observers will monitor the prototype for any signs of wear or mechanical failure.

Data Collected:

- Durability confidence rating (1-10), framed as "How confident are you that this product would last through regular use without breaking?"
- Follow-up response: "What specifically made you give it that rating?"
- Comments on perceived material strength, reliability, and quality.
- Observations of visible damage or structural issues
- Tools: Durability checklist, user comment form

Tests will be conducted with a sample group of 5-10 users, and all feedback will be documented in a consistent format for comparative analysis. The results will be used to assess how well the final design aligns with user expectations and meets critical functional needs.

Ethical Considerations:

All user validation activities will be conducted in an ethical and respectful manner. Participants will be fully informed about the purpose of the testing, the type of data being collected, and how their feedback will be used to improve their feedback will be used to improve the design. Participation will be completely voluntary, with the option to withdraw at any time without consequence.

No personally identifiable information will be collected unless explicitly consented to. All responses and observations will be anonymized to protect user privacy. Data will be stored securely and only used for the purpose of design evaluation and improvement. The team will ensure that participants are treated with respect and that all testing procedures prioritize their safety and comfort.

15.Value and Impact

The User Value Matrix displays several stakeholders in the ZenPen project and displays economic and social impacts implicated on the corresponding stakeholders.

Table 8. User Value Matrix

Stakeholders	Value Categories	
	Economic	Social
End Users	<p>Positive: Reduced costs by minimizing writing errors and material waste, potentially saving money over time.</p> <p>Negative: Initial purchase cost maybe high, posing a barrier for some users.</p>	<p>Positive: Enhances quality of life by increasing independence and reducing frustration during daily activities, thereby improving self-esteem and social engagement.</p> <p>Negative: May carry a potential stigma associated with using a specialized device, harming user confidence in social settings</p>
Manufacturers	<p>Positive: Creates new market opportunities and potential for increased revenue through a specialized product.</p> <p>Negative: Requires upfront investment in new production lines, specialized materials, or tooling.</p>	<p>Positive: Strenghtens support for the Parkinson's community and increases public awareness of accessibility needs through engagement with an impactful solution.</p> <p>Negative: No significant negative social impacts identified.</p>
Nonprofit and Advocacy Organizations	<p>Positive: May attract funding and grants to support promotion, distribution, or integration of the ZenPen as part of their advocacy mission.</p> <p>Negative: No direct economic drawbacks identified.</p>	<p>Positive: Strengthens support for Parkinson's community and increases public awareness of accessibility needs.</p> <p>Negative: None identified.</p>
Insurance Companies	<p>Positive impact: If classified as a reimbursable device, insurance could reduce or eliminate out-of-pocket costs, improving affordability and access, especially for lower-income users.</p> <p>Negative Impact: Without coverage, users may face high upfront costs, limiting adoption and accessibility.</p>	<p>Positive: Improved patient outcomes, reduced claims over time.</p> <p>Negative: Limited or inconsistent coverage may contribute to inequities in access, particularly among underserved populations.</p>
Caregivers	<p>Positive: Reduces time and effort spent assisting patients with writing tasks, potentially lowering caregiving costs or allowing reallocation of time to other responsibilities.</p> <p>Negative: No direct economic disadvantages identified.</p>	<p>Positive: Reduce stress and workload, potentially improving well-being and the caregiver-patient relationship.</p> <p>Negative: No significant negative social impacts identified.</p>
Distributors	<p>Positive: Expands market reach and ncreases potential sales by enabling broader distribution. Offloads operational load by handling warehousing, shipping, and inventory management.</p> <p>Negative: Decreases profit margins and limits control over pricing, branding, and customer interaction.</p>	<p>Positive: Improves accessibility by offering the ZenPen through a wider range of physical and online channels.</p> <p>Negative: May contribute to uneven access if distributors prioritize high-profit or high-demand regions over underserved communities.</p>

Economic Impact Considerations

The ZenPen is designed to be a low-cost, self-sustaining solution. While initial production requires moderate start-up costs, such as materials, prototyping, tooling, and packaging, the use of PLA and TPU keeps expenses manageable. Ongoing operation costs remain low due to its simple modular design and compatibility with widely available BiC ink cartridges. Potential revenue streams include direct sales to users, bulk distribution through healthcare providers, and subsidized access through nonprofits or insurance programs. These models help balance affordability for users with long-term sustainability for manufacturers and partners.

Social Impact Considerations

The ZenPen is intended to improve the quality of life for individuals with Parkinson's disease and others experiencing fine motor impairments. By enhancing writing ability, it supports user independence, autonomy, and emotional well-being. It may also reduce caregiver workload and improve communication for users. However, unintended consequences may include limited access in underserved communities if the device is not widely distributed or covered by insurance, and environmental waste if the pen is not recycled properly. These concerns can be mitigated through nonprofit partnerships and sustainable material sourcing.

16. Project Recommendations and Next Steps

Building on the progress so far, several recommendations are proposed to guide the future development of the ZenPen. The current prototype and Grand Concept should be further refined, with particular attention given to enhancing ergonomics, stability, and user comfort. These improvements should be informed by initial user feedback and guided by principles of human-centered design.

Additional research is recommended to better understand the specific needs of the target user group. In particular, testing the prototype with a large pool of individuals affected by Parkinson's would provide critical insights that the team's initial tests with dysgraphic users and simulated tremors could not accomplish. This testing would allow for more targeted design modifications that directly address user challenges.

Further verification and validation of the design are essential. This includes conducting more comprehensive user testing to ensure the prototype meets established design requirements and performs effectively in real-world use. The feedback gathered from these tests should inform iterative improvements to the design.

Material selection also warrants further research, especially in light of the intended shift from 3D printing to injection molding. Testing a variety of materials may lead to increased durability, comfort, and better suitability for mass production. Ideally, rubber grips on finger indents could be implemented to improve stability in the user's hand. Injection molding is planned to allow for rapid scalability and reduced manufacturing costs and times. Finalizing the current prototype and initiating a new round of user testing are immediate priorities.

Looking ahead, preparations for scalable production should begin. This includes identifying suitable materials, establishing efficient manufacturing processes, and exploring distribution partnerships. Although injection molding is the preferred method for large-scale production, alternative 3D printing techniques may still be viable for small-batch or customizable units. To support continued development and market introduction, resources such as funding, manufacturing materials, and distribution channels will be required. With these next steps, the ZenPen is well positioned to offer a meaningful and accessible tool for individuals living with Parkinson's disease.

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Appendix A. Evidence of Brainstorming

Initial Brainstorming User and Need Ideas:

Workplace:

1. Bricklayers in Pakistan are stuck in the profession with limited alternatives
2. Musicians
 - Multi-page sheet music is hard to keep organized
 - A tape dispenser for attaching pages could help
 - Rachmaninoff's music is impossible for most people to play due to large intervals
 - A hand extender might help
 - Reed players managing keeping their reeds moist could use a solution
3. Electronics Issues
 - Wires often bend at the plug and break

Household And Daily Life:

1. Cooking/Baking Challenges
 - Butter takes too much time to soften
 - Water boils over on the stove
2. Automatic watering system for houseplants
3. Garbage Clip to seal cans and keep out animals outside
4. Milk Jug Stand to hold milk jugs upside in the sink for drying

Medical and Accessibility:

1. Tremor reducing Pen for Parkinson's Patients
2. Wheelchairs are difficult to get in and out of
3. Patients with fractures need a way to use hot and cold treatment on areas under braces

Brainstorm Sketches:

Figure 2 shows team member 1's design, emphasizing adaptable writing options, large grip, and an ink eraser:

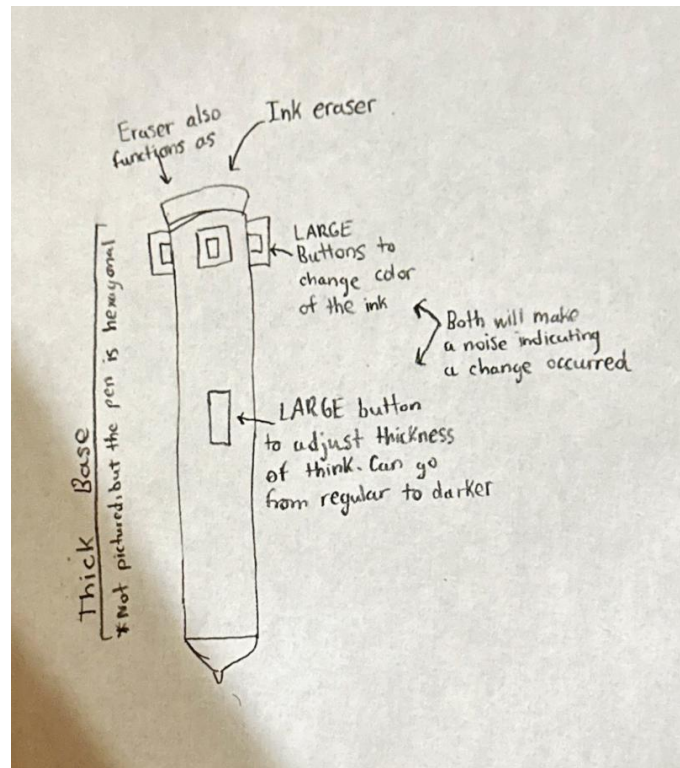


Figure 2. Concept Design by team member 1

Figure 3 shows team member 2's design, emphasizing rounded, ergonomic grip and the concept of an attachable sleeve that works to convert any existing pen to a Parkinson's pen:

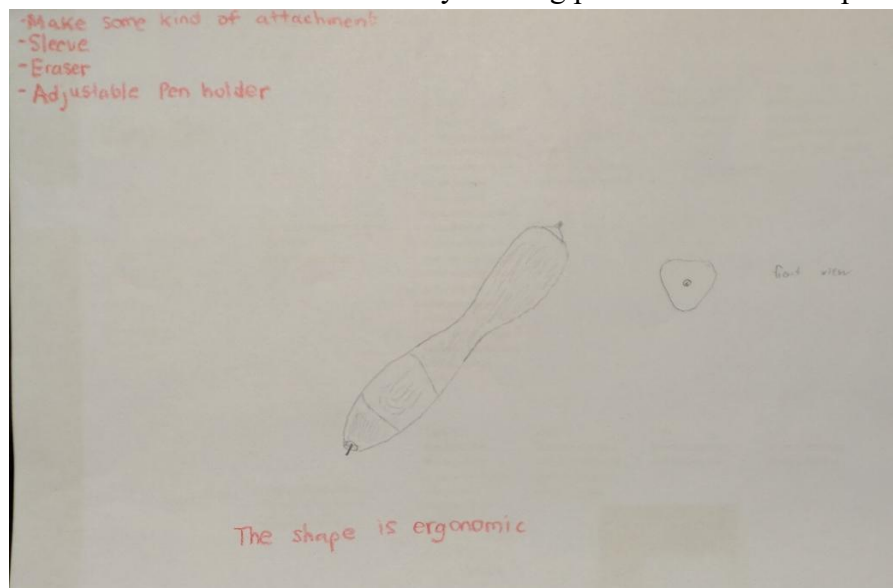


Figure 3. Concept Design by team member 2

Figure 4 shows team member 3's designs. One sketch demonstrates the weighted design common to each team member's concepts. The other two sketches prioritize ergonomics and style:

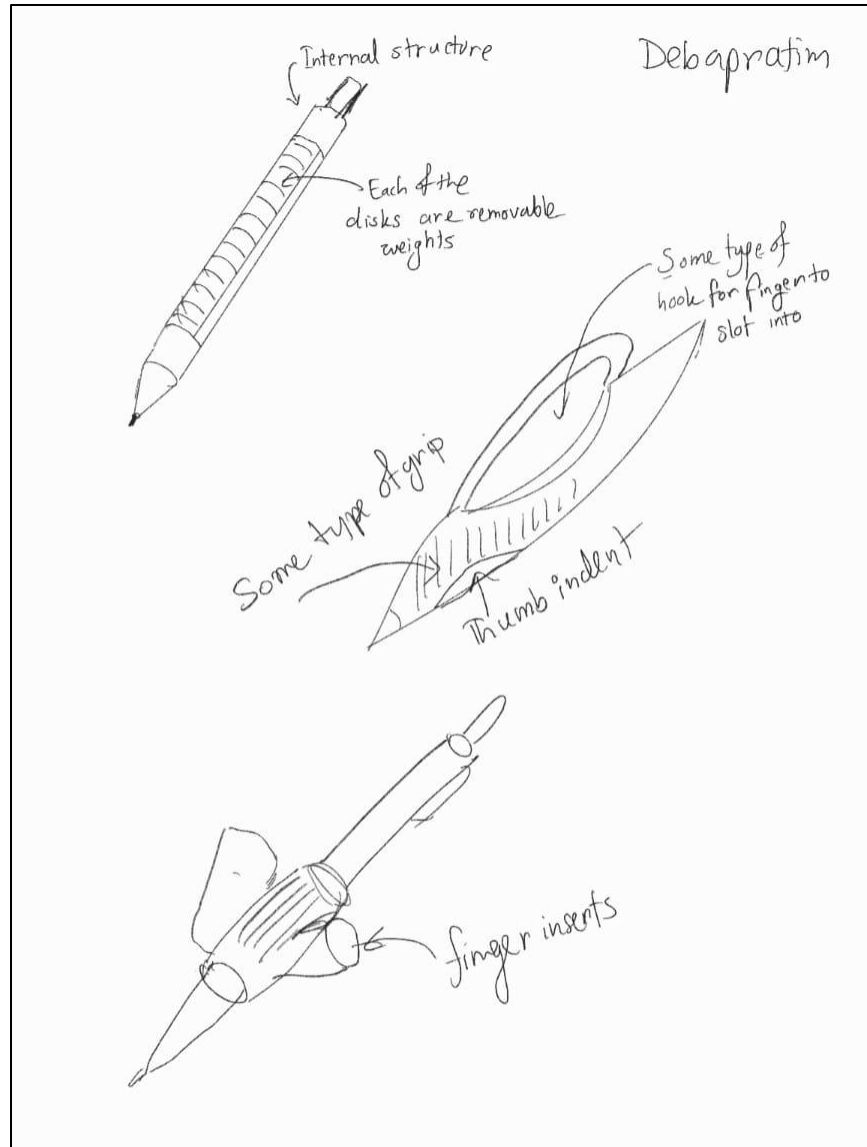


Figure 4. Concept Designs by team member 3

Figure 5 shows team member 4's designs. One of which is a concept for a roving pen holder that would take voice prompts from the user and output onto the page using a G-Code system. The second design shows a clip-on grip with a cavity containing an adjustable number of weights:

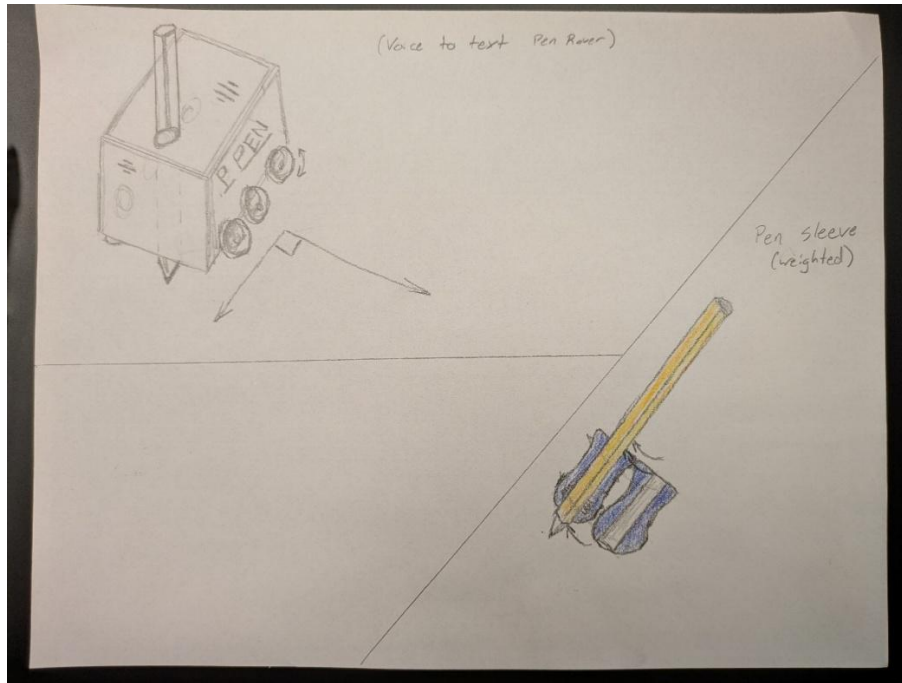


Figure 5. Concept Designs by team member 4

Figure 6 displays further iteration on the chosen design concept, emphasizing the incorporation of adjustable weights.

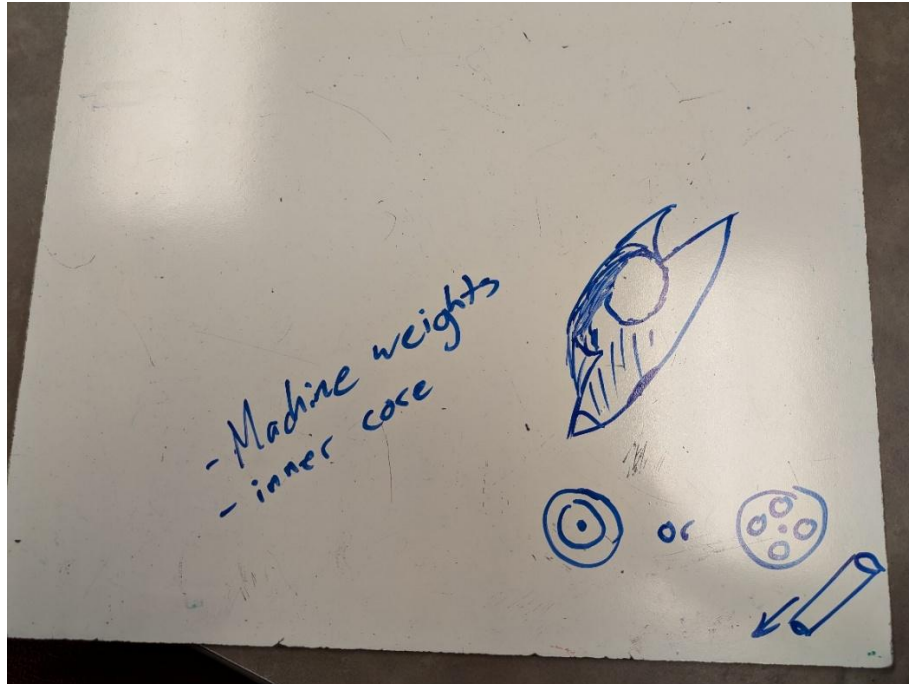


Figure 6. Design Iteration 2

Appendix B. Research Methodologies

The team employed several academic and informal research methods to guide the development of the ZenPen. Initial research explored the broader challenges faced by elderly individuals and pet owners, with the goal of identifying unmet needs that could be addressed through engineering design. As the project progressed, the focus narrowed to individuals with Parkinson's disease, particularly those experiencing writing difficulties due to tremors or reduced fine motor control. To better understand user needs, team members conducted informal interviews with friends who have writing disabilities and spoke with family members affected by Parkinson's. These conversations provided valuable personal insights that supplemented the team's review of scholarly articles sourced through Google Scholar. Topics researched included motor control, assistive writing devices, ergonomic design principles, and the psychological impact of stigma in assistive tools. This mixed-method approach ensured that the ZenPen was grounded in both evidence based practices and real user perspectives.

Appendix C. Prototype Working Drawing Packet

Prototype sketch:

This prototype sketch displays the general form of the pen and some of the key features such as the curved handle and finger imprints as well as the size and shape.

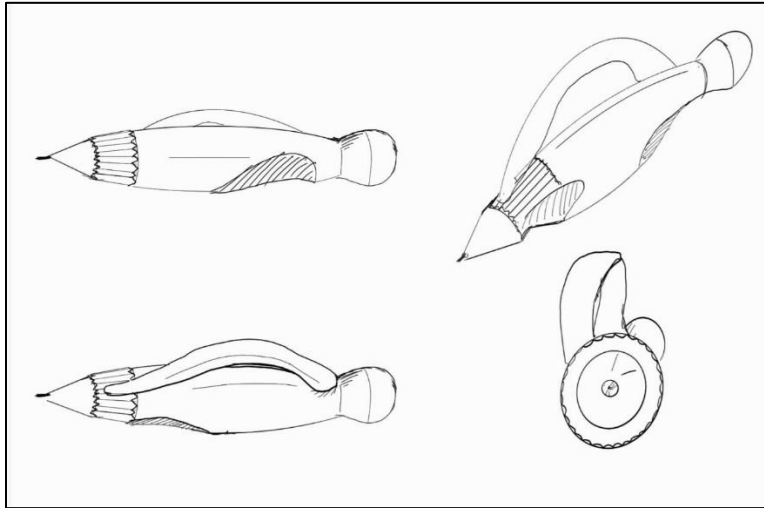


Figure 6. ZenPen Design Sketches

Initial mock-up design:

This mock-up prototype is made of clay and was made to display a 3D version of the team's ideas. This prototype consists of the pens' general form and ergonomic shape.

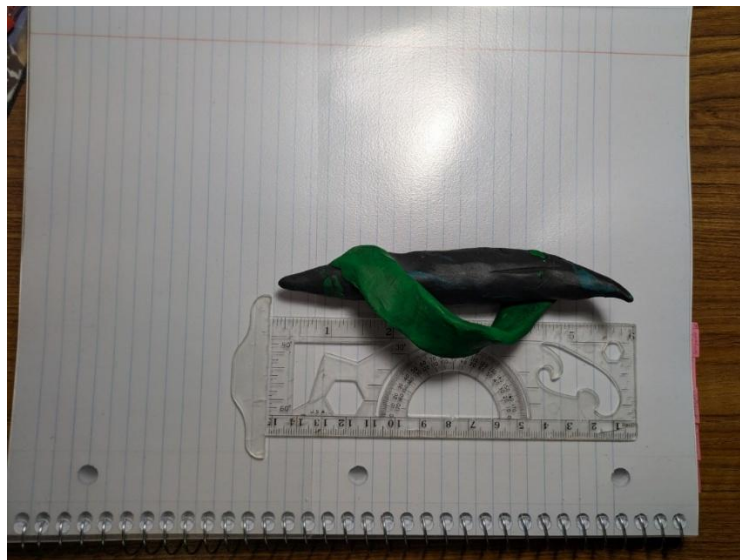


Figure 7. Preliminary ZenPen Clay Mock-up

Picture of CAD model:

This is a Preliminary CAD model of the mock-up that shows the how the team envisioned the general form of the final product and also the placement all the sections including a visual representation of the chamber for the removable weights can be placed to adjust the weight.

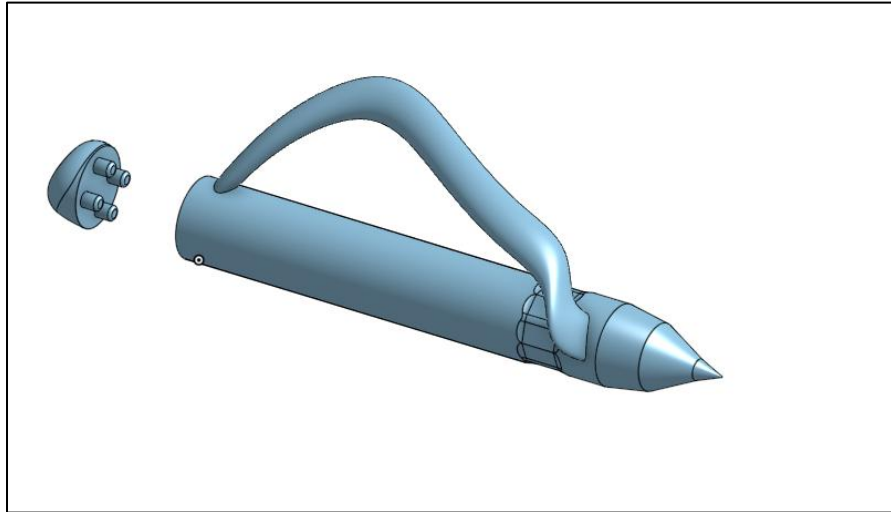


Figure 8. ZenPen V1 CAD Model

The ZenPen V2 Cad Mockup shows the team's improved design for the ZenPen. The pen assembly is comprised of a 3D printed body and cap and five steel rods that can be placed inside the pen body to adjust weight.

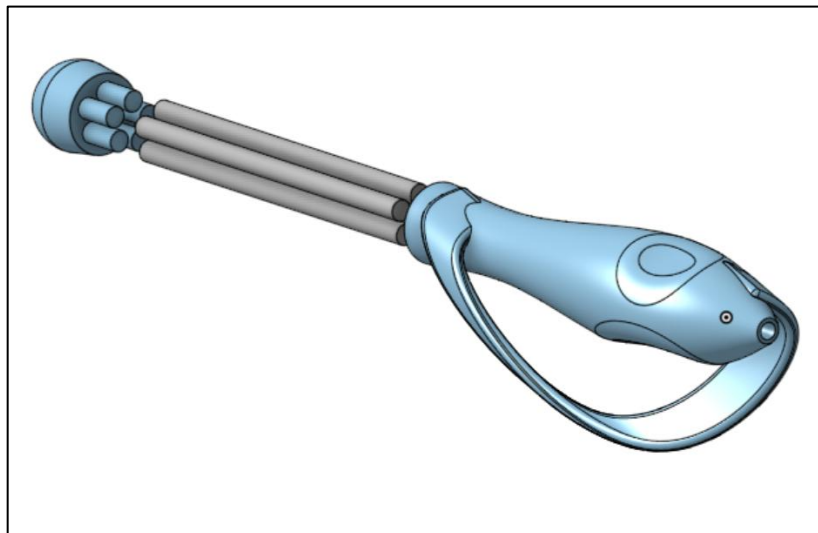
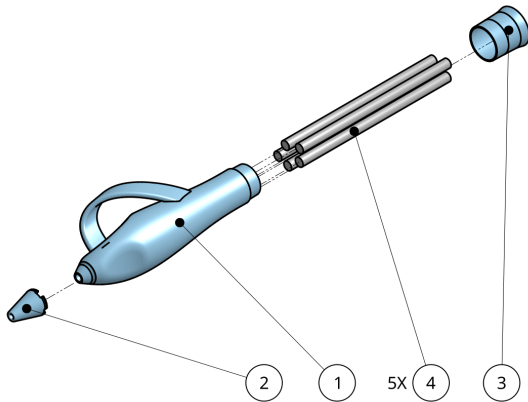


Figure 9. ZenPen V2 CAD Mock-up

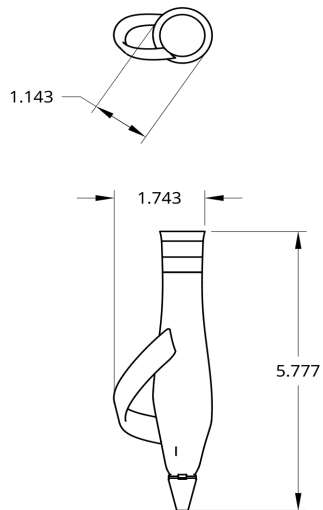


Item	Name	Quantity	Material	Description
1	Pen Body	1	ABS	Central pen body (3D print)
2	Pen Tip Cap	1	ABS	Cap for ink cartridge (3D print)
3	Pen Weight Cap	1	ABS	Cap for weights (3D print)
4	Weight Rod	5	Carbon Steel	Standard part

The Ohio State University
First Year Engineering

Dwg. Title: ZenPen Explode
Drawn By: Team N

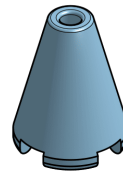
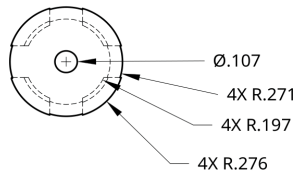
Scale: 1:2
Units: IPS



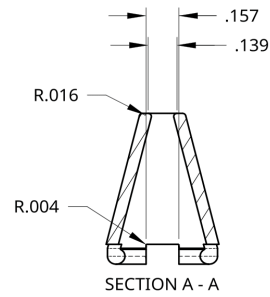
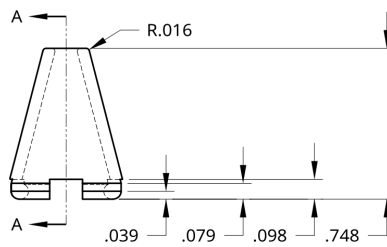
The Ohio State University
First Year Engineering

Dwg. Title: Assembly Multiview
Drawn By: Team N

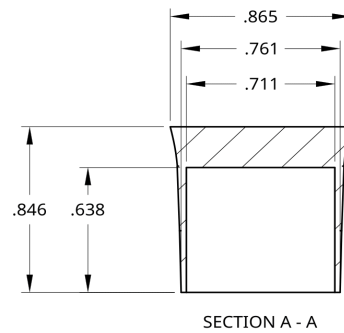
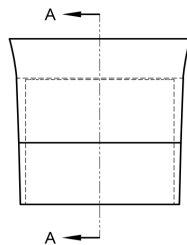
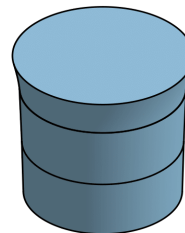
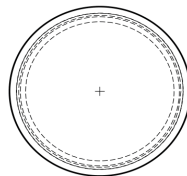
Scale: 1:2
Units: IPS



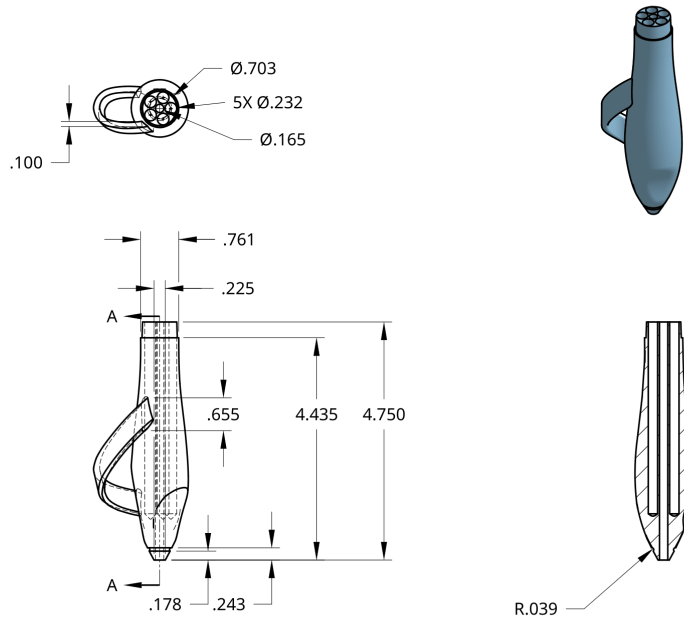
Part is symmetric left to right,
front to back



The Ohio State University First Year Engineering	Dwg. Title: Tip Cap Drawn By: Team N	Scale: 2:1 Units: IPS
-----------------------------------------------------	-----------------------------------------	--------------------------



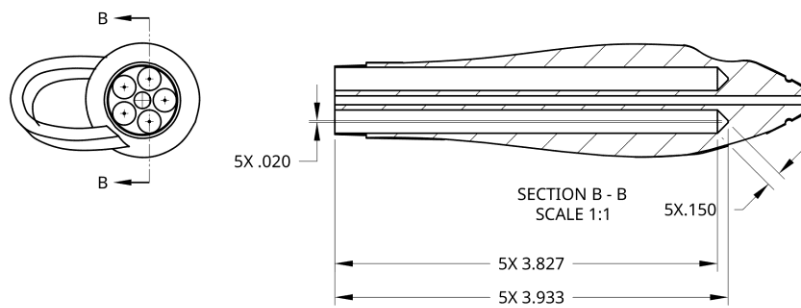
The Ohio State University First Year Engineering	Dwg. Title: Weight Cap Drawn By: Team N	Scale: 2:1 Units: IPS
-----------------------------------------------------	--------------------------------------------	--------------------------



The Ohio State University
First Year Engineering

Dwg. Title: Pen Body
Drawn By: Team N

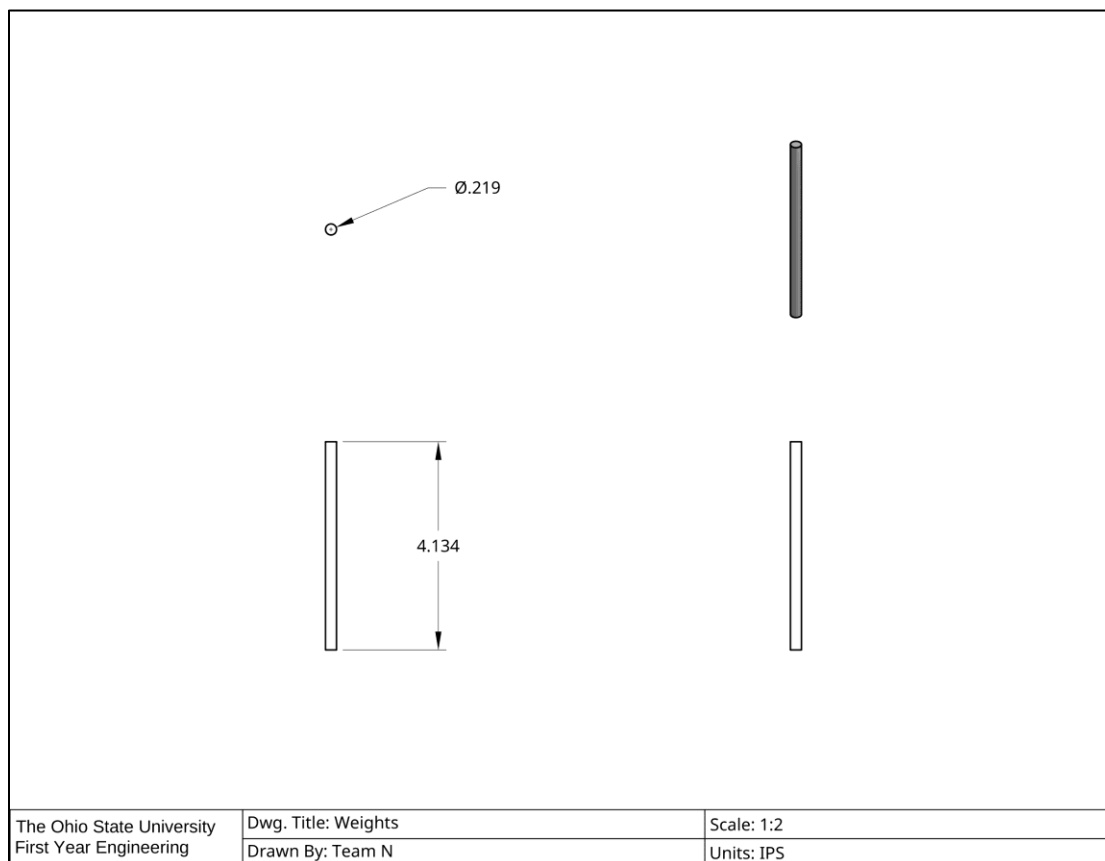
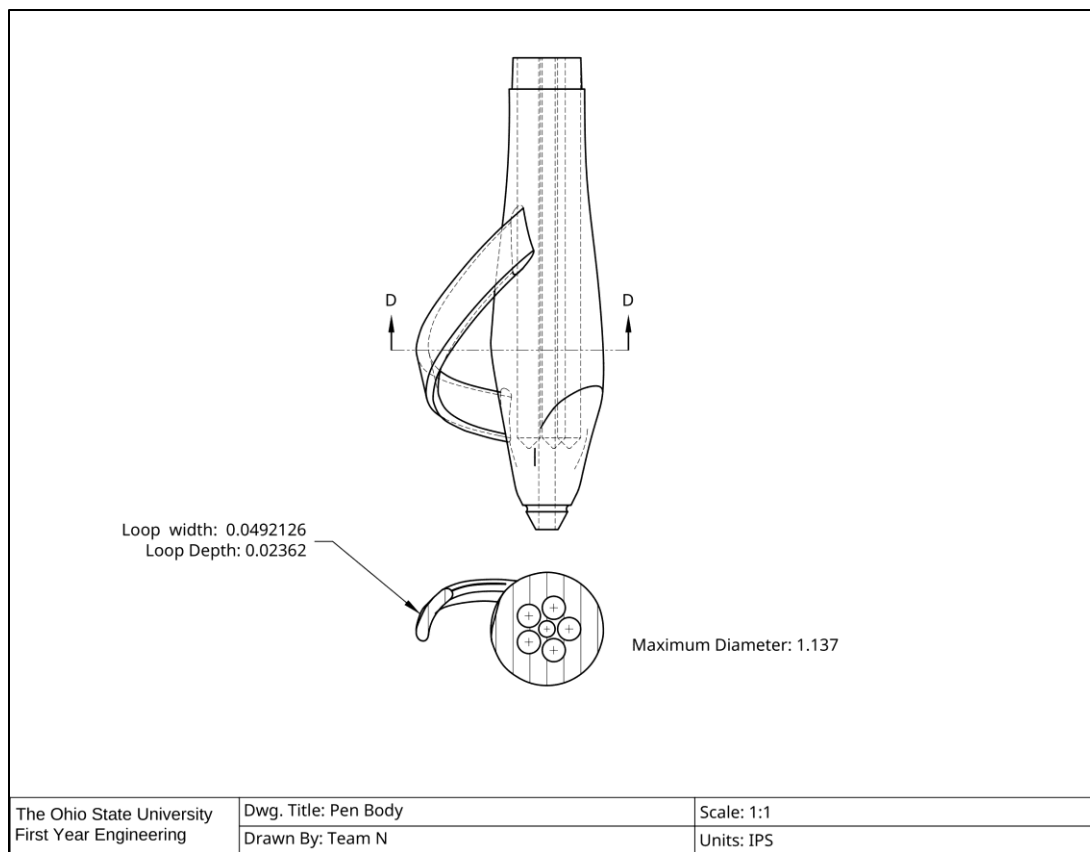
Scale: 1:2
Units: IPS



The Ohio State University
First Year Engineering

Dwg. Title: Pen Body
Drawn By: Team N

Scale: 1:1
Units: IPS



Appendix D. Additional Raw Data

All raw data and measurements collected throughout the design process have been integrated into their respective sections of this report. As a result, no additional raw data is necessary in this appendix.

Appendix E. Project Management Schedule and Meeting Minutes

17. Project Schedule

Figure 11 shows an initial 3D printed prototype of the ZenPen.



Figure 11. Physical Prototype of Design

Limitations:

The use of PLA for rapid prototyping made the pen structurally brittle in some areas, especially the pop cap. 3D printing introduced tolerance issues that required manual refinement, such as widening the pen cartridge opening. Additionally, Onshape's modeling tools limited the ability to fully capture the intended ergonomic shape, which slightly reduced comfort performance.

Delimitations:

PLA was intentionally used to allow for quick prototyping and iteration. The design was scoped specifically for individuals with Parkinson's disease, not all fine motor impairments, to maintain focus. Standard ballpoint cartridges were selected to ensure ease of manufacturing and uniformity.

Major deliverables / Team goals:

1. Prototype Design Requirements

- Establishing precise grip size (target range: 25-40mm, ideal 30mm) for ergonomic support.
- Defining an adjustable weight system (target 50-150g) to accommodate varying user preferences and enhance stability.
- Selecting durable materials capable of withstanding at least 10 drops from 4 feet.
- Implementing customization features with multiple grip and weight configurations to tailor the experience for different users.
- Ensuring a minimum 35-60% reduction in writing deviations, with an ideal target of 70%.
- Ensuring production cost including all outsourced parts falls within the desired range.

1. Initial Prototype Development

- Designing and 3D printing the prototype with modular weight components.
- Conducting preliminary user testing with simulated hand tremors.
- Gathering feedback from users and stakeholders to identify necessary alterations.

2. Testing and Verification Plan

- Measure design specifications (grip size, weight, durability) using calipers, a scale, and the specified stress tests.
- Conduct user trials, measuring error and fatigue levels.
- Analyze user feedback and tests to ensure goals are met

3. Iterative Design Improvements

- Optimize material selection for durability, cost-efficiency, and comfort according to user feedback.
- Refine weight distribution and grip adjustments via tolerances and CAD techniques for better usability.
- Iterate through several printed prototypes to progressively improve functionality and performance.
- Validate final design against design needs, requirements, and overall goals.

a. PERT Schedule

This PERT Diagram visually maps the tasks, dependencies, and timelines for the project development. It helps the team organize workflow, identify critical tasks and manage deadlines by outlining key stages like prototyping, testing, and material selection.

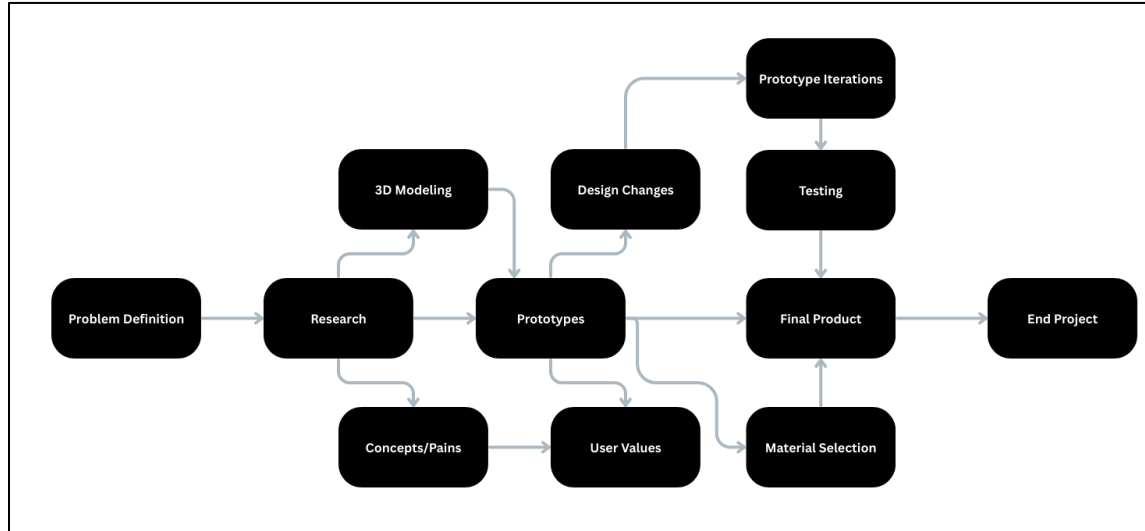


Figure 12. PERT Diagram

This project flow is comprised of five primary subparts along the critical path:

Problem Definition: The early phase of the project in which the problem to be solved is loosely identified. A user group, task, and pains and gains are then identified to allow for further steps.

Research: Deeper research into pains/gains, current alternatives, design features, and user needs were identified. Then, with a clearer concept, research into specifications of a product can be performed, identifying manufacturing techniques, materials, and scalability best suited for the project.

Prototypes: Iterative testing through preliminary physical mockups, CAD renderings, and 3D printed prototypes allow the team to make design changes to better align with user needs and requirements identified previously.

Final Product: After prototyping is finalized, the final product can be produced.

End Project: End of semester – project along with all related reports can be finalized and submitted.

There are several potential bottlenecks to be considered:

3D Printing & Material Availability: Delays and errors in printing could halt prototype iteration and development.

Finalizing Design Before Submitting TPU Print: The team cannot reasonably plan to submit a TPU print request prior to finalizing the design and confirming its validity through a PLA print.

Testing & User Feedback: Obtaining user feedback between iterations is crucial but slows down turnaround time between parts.

Team Coordination & Workload: Finding time to start prints in the print lab while handling scheduling conflicts and workload imbalances could slow progress.

The team will work to overcome these obstacles by utilizing a policy of transparent communication as to actions regarding the projects, and taking early steps to coordinate printing, user feedback sessions, and CAD iteration.

b. Gantt Chart

This Gantt Chart helps the team by providing a clear timeline for the project development, showing task durations, deadlines, and member responsibilities. It helps the team stay on track by visualizing progress, managing overlapping tasks, and ensuring timely completion of each phase, from design to testing.

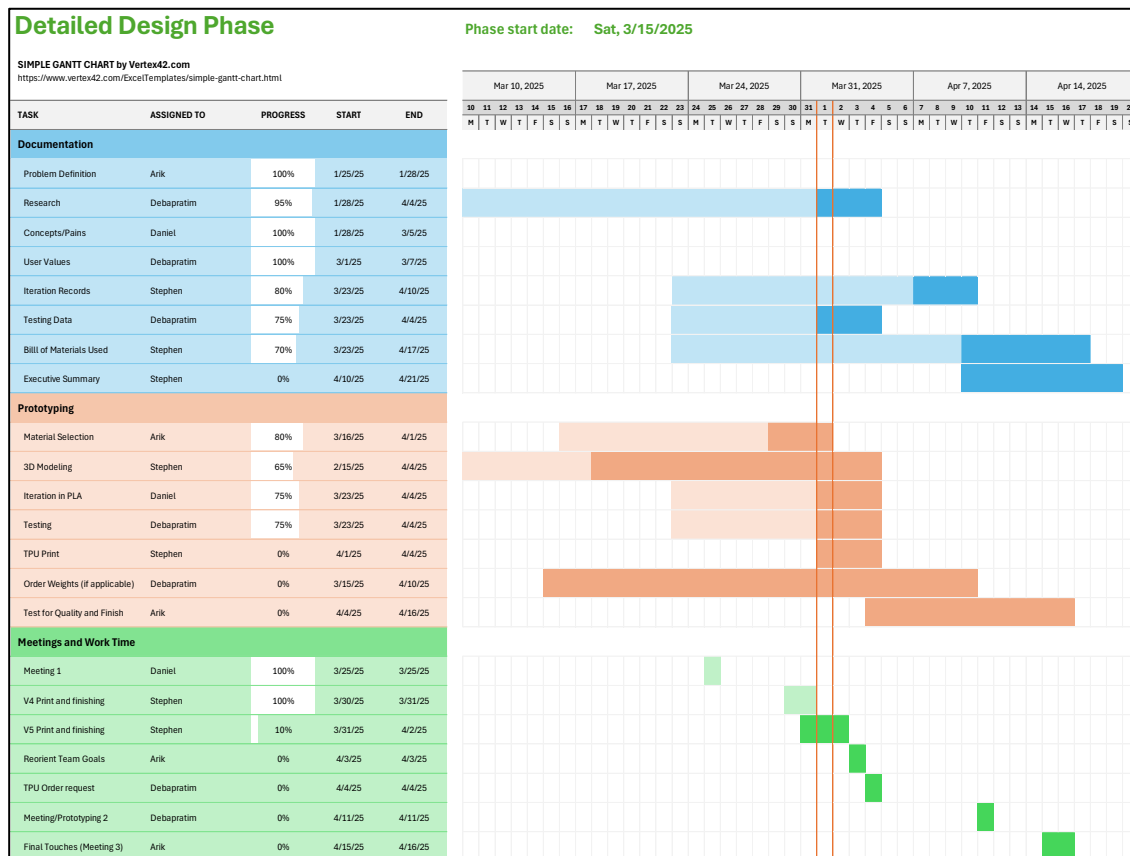


Figure 13. Gantt Chart

18. Prototyping Workday 1 Meeting Minutes

- **What tasks did your team accomplish today?**

Devised a plan on how to get the cap to fit into the pen body and a possible knurling grip to the pen body and or cap.

- **What data were you able to collect today?**

The tip of the pen's ink cartridge lip is 3.91 mm and the part right below is 3.93 mm

- **What data do you still need to collect?**

1. Checking is comfortable for writing 2-3 paragraphs of text.
2. Check if the ink cartridge fits into the prototype.
3. If the cap fits snugly into the pen body.

- **What are your action items for the next class/team meeting?**

1. Check if the 3D print has the correct size and tolerances.
2. Check if any part needs to be redesigned or modified.

Objective statement — To discuss and determine actionable strategies to implement on the prototype in order to better accomplish user needs.

Completed tasks from previous week or last meeting, including:

(03/25/25), 3D print pen – 3D printing a plastic rod, switched the metal rods to plastic rods (PLA), printing the cap, printing the pen body & handle together, tolerance for pen cap is 0.1 mm

Bulleted list of completed tasks

- 3D print the pen and cap
- Pick up the 3D print
- Check to see if they fit together adequately
- Make modifications to initial 3D print
- Add the cost to our expenditure

Person(s) assigned to each task

All tasks above have been contributed equally between team members. Debapratim started the initial print. Debapratim and Daniel picked up the 3D print. Stephen checked if the fittings were compliant. Stephen started initial modifications on pen for second 3D print. Arik added the cost to the team expenditure.

Short summary of status

Today's meeting was used to discuss the necessary modifications for the 2nd 3D print. Also, time was spent on documentation for the prototype. Some modifications were made such as a change of tolerances as well as conducting measurements.

Tasks to be completed for the upcoming week or next meeting, including:

Bulleted list of tasks

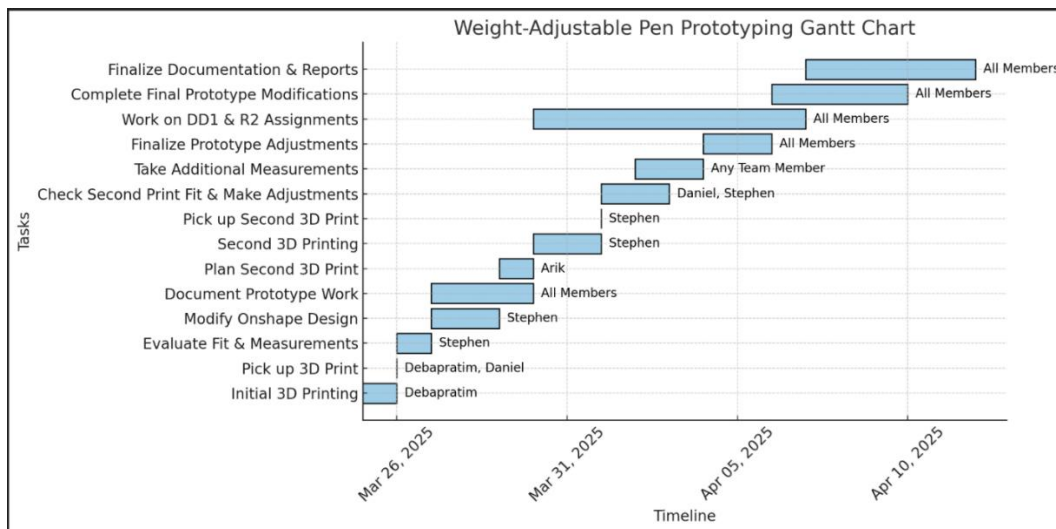
- Start the second 3D print for the prototype
- Collect the second 3D print
- Add additional modifications to the Onshape design
- Work on upcoming assignments such as DD1 and R2
- Take additional measurements if necessary

Person(s) assigned to the task

Stephen is assigned to start and collect the second 3D print. Additional modifications to the Onshape file will either be made by Daniel or Stephen. Upcoming assignments will be assigned to each team member as they are team assignments and require more work. Measurements will be completed by any team member based on what is needed.

Project timeline Indicate major milestones and deadlines using Gantt Chart-

Some major milestones are completing the necessary documentation that comes with the team assignments. Another milestone is completing the modifications for the prototype so that the team can create the final product.



Decisions made by group with key information about how the decisions were made

There were some team decisions made by reassessing measurements on the initial prototype that was printed on Wednesday (03/26/2025). These measurements were made to influence the design to current Onshape file.

19. Prototyping Workday 2 Meeting Minutes

- **What tasks did your team accomplish today?**

V7 of the prototype was 3D printed, and work was continued on DD3.

- **What data were you able to collect today?**

Info was gathered from the new prototype on tolerances. All tolerances are satisfactory except the tolerance for the weight cap. The team also received guidance on dimensioning the parts.

- **What data do you still need to collect?**

1. Specific pen weight and dimensions.
2. User writing testing.
3. Durability testing.

- **What are your action items for next class/team meeting?**

3. Print final version of pen.
4. Begin verification testing.

Objective statement — Complete and submit the remainder of DD3 and clarify questions regarding Onshape/3D printing to ensure progress toward final deliverables.

Completed tasks from previous week or last meeting, including:

(04/09/25), 3D print pen V6, cut steel rods to size, adjusted tolerances.

Bulleted list of completed tasks

- 3D print pen V6
- Pick up the 3D print
- Check to see if they fit together adequately
- Make modifications to initial 3D print
- Add the cost to our expenditure

Person(s) assigned to each task

All tasks above have been contributed equally between team members. Debapratim started the initial print. Debapratim and Daniel picked up the 3D print. Stephen checked if the fittings were compliant. Stephen started initial modifications on pen for new 3D print. Stephen made manual adjustments with sandpaper to the print. Arik added the cost to the team expenditure.

Short summary of status

Today's meeting was used to discuss future steps after achieving a nearly perfect prototype design. The prototype only needs small adjustments to cap tolerances and should be in its final form following the next print. In the meantime, the team can begin testing for durability and writing support.

Tasks to be completed for the upcoming week or next meeting, including: Bulleted list of tasks

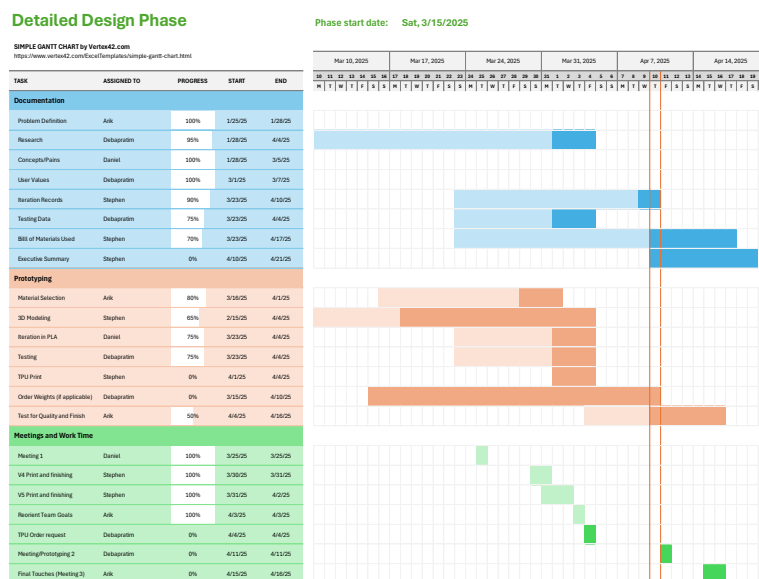
- Adjust Onshape file to reach final prototype form (Team).
- Complete DD3 (Team).
- Start to work on final deliverables and R1/R2 revisions.

Person(s) assigned to the task

Arik is assigned to start and collect the 3D print. Additional modifications to the Onshape file will be made by both Daniel and Stephen. Arik will work on DD3. Measurements will be completed, and user testing will be conducted by Debapratim.

Project timeline Indicate major milestones and deadlines using Gantt Chart-

Some major milestones are completing the necessary documentation that comes with the team assignments. Another milestone is completing the modifications for the prototype so that the team can create the final product. Lastly, networking with professors connected to Parkinson's patients has been a large milestone.



Decisions made by group with key information about how the decisions were made

One key decision made by the group was with how to proceed in creating an ergonomic design. The finger loop was not properly cradling the user's finger, creating more discomfort than control. The team met as a whole and discussed strategies and designs that would eliminate this issue. From that, the issue was resolved. The team also decided not to print in TPU due to unreliability with EED print policy.

20. Prototyping Workday 3 Meeting Minutes

- **What tasks did your team accomplish today?**

Final V8 of prototype was printed, verification testing was continued, and work was started on FD1.

- **How did feedback from users influence your plan?**

User feedback on the weighted nature of the pen significantly reducing pressured needed to write prompted the team to plan testing against a wider range of pen types to better gauge effectiveness.

- **How does mass manufacturing influence your design?**

Mass manufacturing influenced the team's future concept design to include injection molding techniques and rubber grip inserts.

- **What data were you able to collect today?**

The team gathered weight and dimension statistics for the pen.

- **What data do you still need to collect?**

1. User writing testing.
2. Durability testing.

- **Where do you think you might come up short? What are the next steps?**

Durability might be a low point for the team's pen design. The next step would be to account for not having been able to print the prototype using TPU in our measurements and testing.

Objective statement — The team's goal for today is to print the final V8 prototype, gather pen size and weight data, and split up to tackle FD1 and R1/R2 revisions.

Completed tasks from previous week or last meeting, including:

(04/11/25), 3D print ZenPen V7, and complete DD3.

Bulleted list of completed tasks

- 3D print pen V7
- Pick up the 3D print
- Check to see if they fit together adequately
- Make modifications to initial 3D print
- Add the cost to our expenditure

Person(s) assigned to each task

All tasks above have been contributed equally between team members. Arik started the initial print. Stephen and Daniel picked up the 3D print. Stephen checked if the fittings were compliant. Daniel continued working on the drawing packets. Stephen made manual adjustments with sandpaper to the print. Arik added the cost to the team expenditure.

Short summary of status

Today's meeting was used to discuss future steps after achieving a final prototype print. The prototype only required minor finishing touches with sandpaper to bring it to its final state. In the Dimensional testing has begun, and user testing was discussed.

Tasks to be completed for the upcoming week or next meeting, including:

Bulleted list of tasks

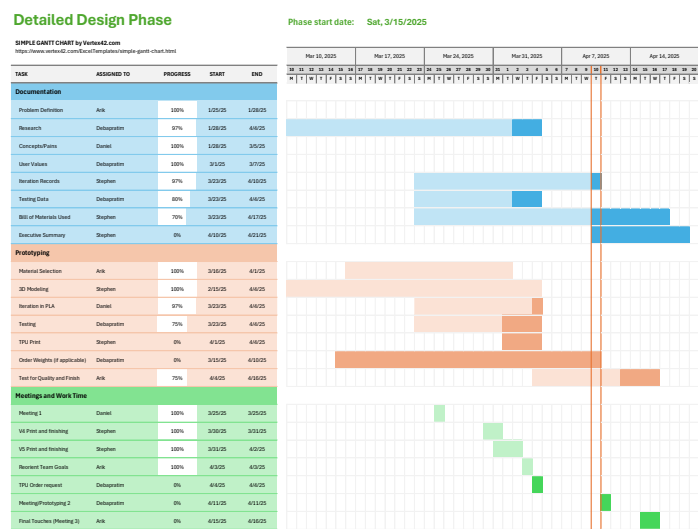
- Complete drawing packet (Daniel).
- Complete FD1 and R1/R2 revisions. (Arik, Stephen, and Debapratim)
- User testing (Debapratim)

Person(s) assigned to the task

Daniel is assigned to finishing the drawing packet. Arik will work on FD1. Stephen and Debapratim will work on R1/R2 revisions. User testing will be conducted by Debapratim.

Project timeline Indicate major milestones and deadlines using Gantt Chart-

Some major milestones are completing the necessary documentation that comes with the team assignments. Another milestone is completing the drawing packet. Lastly, preliminary demonstrations of pen to professors have been important.



Decisions made by group with key information about how the decisions were made

One key decision made by the group was with how to proceed after having finished designing. The team had to assign responsibilities for FD1, R1/R2, and drawing packet creation to team members. These decisions were made by examining all the available options and evenly splitting the workload among team members in a manner conducive to coherent reports.

21. Prototyping Workday 4 Meeting Minutes

- **What tasks did your team accomplish today?**

Final V8 of prototype was printed from last meeting still did not meet tolerance requirements, so new, V9 was printed

- **How did feedback from users influence your plan?**

User feedback on the weight cap not staying firmly in place was used and tolerances were reduced greatly.

- **How does mass manufacturing influence your design?**

Mass manufacturing influenced the team's future concept design to include injection molding techniques and rubber grip inserts.

- **What data were you able to collect today?**

The team gathered durability testing and stability assistance testing.

- **What data do you still need to collect?**

1. N/A

- **Where do you think you might come up short? What are the next steps?**

A neat/smooth finish might be a weak point for the ZenPen. Next steps would be to proceed with other manufacturing techniques in production.

Objective statement — The team's goal for today is to print the V9 prototype and gather durability and error reduction data.

Completed tasks from previous week or last meeting, including:

(04/14/25), 3D print pen V9, and complete FD1.

Bulleted list of completed tasks

- 3D print pen V9
- Pick up the 3D print
- Check to see if they fit together adequately
- Add the cost to our expenditure

Person(s) assigned to each task

All tasks above have been contributed equally between team members. Arik started the initial print. Stephen and Daniel picked up the 3D print. Stephen checked if the fittings were compliant. Daniel continued work on drawing packet. Stephen made manual adjustments with sandpaper to the print. Arik added the cost to the team expenditure.

Short summary of status

Today's meeting was used to test durability and error reduction. As this is the last prototyping workday, V9 print will be the last prototype. If tolerances are not satisfactory, they will be manually adjusted using sandpaper to open it up or tape to shrink it down.

Tasks to be completed for the upcoming week or next meeting, including:

Bulleted list of tasks

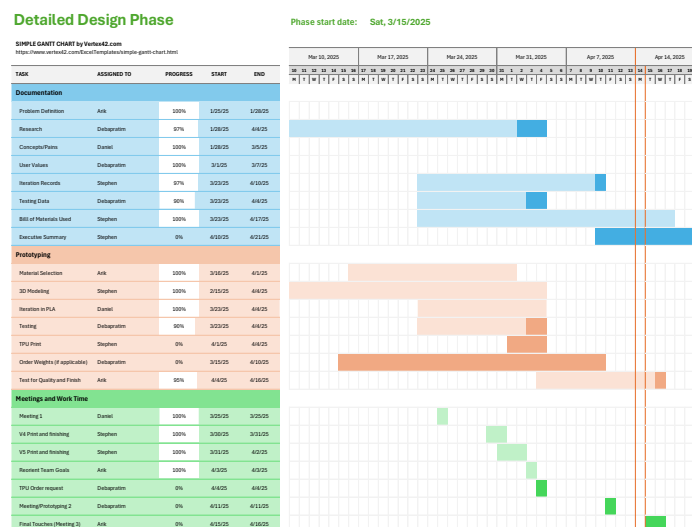
- Complete drawing packet (Daniel).
- Complete FD1 and R1/R2 revisions. (Arik, Stephen, and Debapratim)
- User testing – error reduction (Stephen)

Person(s) assigned to the task

Daniel is assigned to finishing the drawing packet. Arik will work on FD1. Stephen and Debapratim will work on R1/R2 revisions. User testing will be conducted by Stephen.

Project timeline Indicate major milestones and deadlines using Gantt Chart-

Some major milestones are completing the necessary documentation that comes with the team assignments. Another milestone is completing the prototyping. Lastly, preliminary demonstrations of pen to professors have been important.



Decisions made by group with key information about how the decisions were made

One key decision made by the group was with how to proceed after having finished designing. The team had to assign responsibilities for FD1, R1/R2, showcase presentation, and FD2 to team members. These decisions were made by examining all the available options and evenly splitting the workload among team members in a manner conducive to coherent reports.

Appendix F. Team Working Agreement

Team Working Agreement

Term: Spring 2025

Creation: 1/12/2025

Revised: 3/1/2025

1. Group Identification:

Lab section #: 8078

Table Letter: N

Instructors: Dr. Ratcliff and Adam Kling (GTA)

Name:	Email:	Phone:	Other:
Daniel Watts	Watts.553@osu.edu	513-499-1860	Groupme
Arik Patel	Patel.5997@osu.edu	740-606-9115	Groupme
Stephen Connair	Connair.83@osu.edu	937-814-6235	Groupme
Debapratim Talukder	talukder.13@osu.edu	440-212-9459	Groupme

2. Team values and goals:

Values:

- Commitment to quality and accuracy in work
- Mutual respect
- Inclusivity
- Punctuality in meeting deadlines
- Willingness to support and learn from one another
- Being patient and understanding

Goals:

- Achieve an A-grade in the course by collaborating effectively and fairly
- Submit all assignments at least 24 hours before the deadline (Limiting procrastination)
- Ensure everyone contributes and understands all project aspects (or at least enough)
- Ensure all teammates are transparent with their mental health and workload.
- Be sure to answer reminders in a timely fashion.

3. Communication and Meetings:

Communication:

The primary means of communication will be through a group chat where we all have each other's numbers. We can also use each other's school email if needed or call one another. Responses should be received within at most 24 hours. We will each try to send reminders in our group chat. We plan on meeting around every week or so and depending on the assignment due dates for class. The timing will vary throughout the semester. We will also have a rotating system in order and this system will allow 1 person to plan an agenda for a week or for a certain assignment and will update the group on when to work on it and such.

Expectations for communication:

- Precise and concise (but is it better to overshare than under share)
- Respectful
- Listen to what has been said and understand it (asking for clarification if not)

Meetings:

Location of meeting: Drackett Tower lounge or decided area. CBEC can also be a good location.

Mock Meeting Schedule:

Date:	Location:	Time:
1/26/25	Drackett Tower	8:00 pm

Meeting Agenda:

- Discuss assignments that need to be completed
- Discuss graphics applications
- Work on any lab projects or applications
- Work on any other work if applicable

4. General Expectations and Group Norm:

- Communicate clearly and in a timely manner with everyone with deadlines
- Discuss any disagreements / conflicts that there may be
- Follow the academic integrity to the fullest
- Follow the problem-solving outline (DRPIE)
- Be respectful and considerate to every idea/opinion
- Make an effort to include everyone
- Ensure clarity in task delegation
- Provide constructive feedback to peers
- Share resources and help teammates when they struggle
- Team members are expected to behave responsibly and respectfully
- Members are expected to join meetings if available
- Documents will be shared in a document and a onshape folder.

- Teammates should have their portion of the assignment at least 1 day before the due date for review
- Make sure that teammates communicate if struggling

We will have at least 2 students cross check the final assignment with the rubric to check for errors or missing details, who will then update the group accordingly.

5. Individual Responsibilities:

Individual assignments and tasks should be assigned as early as possible so that each member has time to work on it in their own time. Each member will communicate during meetings to ensure that work is evenly divided and to assign roles.

* Individual roles to be rotated through on each group assignment to ensure equal distribution of responsibility. Role titles/responsibilities subject to change as the semester progresses. *

Role	Name
Rubric Evaluator	Debapratim Talukder
Report Writer	Daniel Watts
Report Writer	Arik Patel
Primary Report Editor/presenter	Stephen Connair

6. Conflict Resolution:

Issue: When there are disagreements within our group pertaining to a specific problem, the following steps will be taken in this order until a resolution is found:

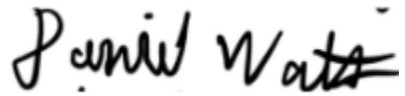
1. Have a break period to organize disagreements.
2. Discuss and make sure each teammate has an open mind towards accepting or changing their disagreement.
3. Attempt all together to work with a solution to the problem.
4. Conduct a vote if no consensus is reached after discussion. If this vote wants to be challenged, move onto step 5.
5. If no solution arises, discuss the problem with a UTA/GTA/Professor.

7. Expectations of Faculty and GTAs

If a team member does not live up to the agreements stated in this document, the situation will be reported to the staff, but the team will still be responsible for submitting a completed assignment. The staff will be able to deal with any major situations that affect the members' ability to learn and complete assignments.

8. Signatures (3/1/2025):

Daniel Watts:

Handwritten signature of Daniel Watts in black ink.

Arik Patel:

Handwritten signature of Arik Patel in black ink, enclosed in a rectangular box.

Stephen Connair:

Handwritten signature of Stephen Connair in black ink.

Debapratim Talukder:

Handwritten signature of Debapratim Talukder in black ink.

Appendix G. AI Prompts and Output

1. What features make a pen easier for someone with Parkinson's to use?

Ergonomic Handle: A specially designed handle that contours to the hand, making it easier to grip and reducing strain during use.

Adjustable Weight: A weight system that can be customized to the user's preference, improving stability and comfort.

Finger Grips: Soft, textured grips that help the fingers stay securely in place, reducing slipping and ensuring better control.

Finger Loops: Convenient loops that help hold the pen in place, preventing the need for a tight grip and reducing muscle fatigue.

Lightweight Design: The pen is light enough to avoid hand fatigue but can be weighted for stability, improving control during writing.

2. How to design a weight-adjustable pen to improve stability for shaky hands?

Adjustable Weight Mechanism: Include a removable or adjustable weight system within the pen's body that users can personalize to their preferred balance.

Finger Loops and Grips: Add loops and soft finger grips to help hold the pen more securely without requiring intense grip strength.

Ergonomic Handle: The handle should be contoured to fit comfortably in the hand, with a focus on reducing tremor impact and improving overall stability.

Easy-to-Use Adjustment: The weight adjustment system could be a simple dial or button that allows users to modify the weight without needing any tools, ensuring ease of use.

3. What user tests should I run to ensure the pen is effective for Parkinson's patients?

Grip Comfort Test: Test the ergonomic handle, finger grips, and loops to ensure they provide secure support and comfort without strain.

Tremor Response Test: Observe how the adjustable weights, grips, and loops affect stability during writing, particularly for users with tremors.

Weight Adjustment Feedback: Allow users to adjust the weight and test how the customizations affect their writing comfort and control.

Loop and Grip Usability: Check that the finger loops and grips make it easier for users to hold the pen without overexerting their fingers.

Fatigue Test: Evaluate if the ergonomic handle and finger grips reduce hand fatigue during longer writing sessions.

Line Test: Test the user's ability to draw straight lines with the Parkinson's pen and compare it that of person without any motor neuron disease.