

Multi-Function Attachable Backboard

Engineering 100 Section 200 Final Report

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Executive Summary

The purpose of this report is to detail the engineering design process of the Multi-Function Attachable Backboard, a bed accessory that provides multiple solutions to common real-world problems university students face. This report will describe our problem, design ideation and evaluation, details of our solution, prototype testing, and our conclusions and recommendations for the future.

Each year, around 11,000 University of Michigan (U-M) students are assigned to live in different residence halls across Central and North Campus. As part of the 11,000 students, our team members across multiple residence halls noticed a major problem with the bed frames provided by U-M: a gap that allows pillows to fall through. Although it may seem insignificant, this problem can pose numerous health issues, such as sleep deprivation, cognitive impairment, and mental health issues. According to our survey on how often students' pillows fell through the gap, there was an overwhelming majority of students experiencing either every day or multiple times a week of this problem happening. These results confirmed our problem as being a major problem that most students across campuses are facing. Therefore, this problem inspired us to create a solution that helps students by preventing pillows from slipping and providing a comfortable space for relaxing.

Defining our problem, our team began by establishing the design requirements and ideation for our potential solution. We started by utilizing our survey results, our own experience with this problem, and group brainstorming that resulted in an objectives tree with six main categories our solution must achieve: comfortable, durable, economical, securable, sufficient storage, and aesthetically pleasing. After defining our requirements, we used a morphological chart and evaluation matrix to evaluate multiple potential designs and to establish our final solution that fixed the problems students are facing.

By defining our final solution, we began by building it using the Fabrication Underground Woodshop materials. Our solution after building included a seamless slide lock feature, a surge protector for charging devices, a lamp, a shelf for storing items, and a cup holder. Also, our final solution solved the main problem of sleep disruptions due to the gap and created a comfortable space. Once completed, we tested our product based on our six main requirements and found that it had met our standards, though there were still improvements to be made.

The total cost of this project was \$25, meeting our requirement of a \$100 budget, as most of our materials were provided by the Woodshop.

For future iterations of this project, we hope to improve the following: stronger wood for more durability, and making the lamp rechargeable, as currently it is powered by batteries.

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1. INTRODUCTION

As E100-200 students, it is vital to understand and learn about the engineering design process and apply the knowledge learned to real-world engineering projects. The best way to accomplish such a task is to engage in the engineering process by being tasked with designing and creating a product prototype that would improve the quality of life in some manner.

The purpose of this report is to present the background of our project and outline the process, from initial ideation to prototyping and testing, used to develop a solution to identified problems, along with our concluding remarks. Please refer to Figure 1-A, Appendix A for the team's Gantt Chart in Word form and Figure 2-A, Appendix A for the timeline form, which shows the schedule of the project and tasks that needed to be completed for the successful completion of our project before the deadline of April 21, 2026.

2. BACKGROUND

This section of the report outlines the problem that inspired our project, the research we conducted to understand the scale and significance of the problem, and the search for existing solutions to the problem at hand, including a patent search.

2.1 Problem of Pillow Slippage

Every year, approximately 11,000 students at the University of Michigan find themselves living in one of the 18 dormitories located on campus grounds. Within these dormitories, the students will eat, drink, study, socialize, and most arguably most importantly for a college student, sleep. However, with the pressures that come with being a student, sleep is often neglected, causing many students to develop conditions such as insomnia. An idea that was corroborated by a study conducted by Prof. Thani Alshammari and colleagues found that insomnia was prevalent in 75.31% of students (Alshammari et al., 2023).

Because students are already experiencing insufficient sleep, it becomes ever more important to minimize factors that could further disrupt a student's ability to sleep, as even slight disturbances could result in a loss of sleep quality. Despite this, many dorm room beds within the university contain a gap between the bedframe and the mattress, where a pillow would rest. This gap allows pillows to slip through during the night, forcing students to wake up to readjust the pillow's position. While seeming minor, according to a study conducted by Prof. David Creswell and colleagues, every hour of lost nightly sleep was associated with a 0.07 reduction in the end-of-term GPA (Creswell et al., 2023). This relationship highlights how even small sleep disturbances, like those from bed design, can contribute to a decline in academic performance, and thus must be fixed.

2.2 Problem of Lack of Function on the Bed

In addition to sleep disruptions, another overlooked issue within dormitories is the lack of functional support provided by the bed. Due to the size restrictions of a dorm room, the bed becomes the central living space, often serving as a place not only to sleep but to eat, drink, and be entertained through different forms of media. However, even though the bed acts as a multifunctional space, the bedframes themselves are not equipped to handle any of these tasks in an efficient manner apart from sleeping. For example, if a student wants to bring a drink onto the bed, they would have nowhere to put it that is both stable and convenient. Likewise, electrical outlets are usually found closer to the floor, thus cutting off students who choose to have a half or full loft from being able to use devices if they have to be plugged in or not adequately charged. As a result, students are left with two choices: take the risk to balance a drink on the bed, or get out of bed and place it on a surface that is out of reach.

This issue is especially important during sleep, as the lack of functionality can cause sleep disruptions such as getting out of bed when needing a drink, thus leading to insufficient sleep. Moreover, according to research, insufficient sleep is linked to challenges in physical health and cognitive performance, two vital factors for a college student (Patrick et al., 2017). Given that many students are already experiencing insufficient sleep, the functionality of dorm beds needs to be improved to not cause any further hindrances to sleep.

2.3 Existing Solutions

In this sub-section of the report, we explore the process conducted to understand existing solutions that helped to influence our later design decisions, in addition to determining the patentability of our solution.

2.3.1 Generative AI Brainstorming

The first phase of research into existing solutions consisted of utilizing Generative AI, specifically ChatGPT, as a preliminary research tool to identify existing solutions that have solved or attempted to solve the issues of lack of functionality on beds and pillow slippage. Through this process, two common products were identified: triangular support pillows and attachable multifunctional bedside tables. These solutions were available in different shapes and forms throughout different websites, however each came with its own set of limitations when trying to solve both issues.

2.3.2 Triangular Support Pillows

Triangular support pillows, also known as wedge pillows, are designed to act as an elevated support that offers many benefits to its user, one of which being preventing pillow slippage. As a triangular pillow is wider on the backside, it would inherently be larger than most gaps on beds, therefore preventing the pillow from slipping. In addition to solving the problem of pillow slippage, triangular pillows have many advantages, such as alleviating acid reflux, reducing back

pain, and enhancing circulation by elevating the legs. These benefits and overall shape of the pillow were found during preliminary market research in which the Deluxe Inclined Wedge Support Pillow by The Pillow Home was chosen as the example product to represent triangular support pillows, due to the labeled benefits on the company website and overall good reviews (The Pillow Home).

However, these pillows do not address one of the core issues of bed functionality. While they do provide benefits to enhance the sleeping experience, they fail to incorporate any stable surfaces or electrical outputs to allow students to have drinks or charge personal devices in their beds. Additionally, over time, these pillows could become uncomfortable due to the angle of the pillow or the material degrading.

It is important to note that a patent did exist for the triangular pillow, see Figure 1-C, Appendix C, however it has since been abandoned, thus not limiting our ability to patent our product in the future if it goes into the market, based on current brief preliminary research.

2.3.3 Attachable Bedside Table

Attachable bedside tables are another common solution that focuses on increasing functionality. These tables are designed to clip onto the side of the bed to offer both a storage space and a sturdy surface to place drinks, books, and other objects that a person in bed might desire. Thus, solving the issue of the lack of functionality of beds, and increasing the comfort of dorms.

A key product that we used as an example of the attachable bedside table sector is the Bedside Shelf for Dorm Bunk Beds by Bietrun (Bietrun). The reasoning for choosing this product as the example is that it is primarily designed for dorm beds and offers many functions, such as cable management for devices and a weight capacity of up to 35 pounds.

Despite these benefits, attachable tables do not solve the problem of pillow slippage on beds, thus not addressing all aspects of the problems identified with dorm beds. Moreover, depending on the design of the bedframe, these tables may not be able to be fixed securely or may be prevented from being attached if the bed is in the corner of the room. As a result, while bedside tables do solve the problem of a lack of functionality outright, it falls short in other aspects of the problems identified.

Unlike the triangular pillow, there are no clear patents expired or current on the attachable bedside table in a similar configuration to the product we used to serve as a market example of the space. Due to this, it can be deduced with the current preliminary research at hand that if the product were ever to reach the market, it could be patented beforehand without any other patents restricting it.

2.3.4 Patentability

As part of the search for existing solutions, we too conducted a brief and preliminary patent search to understand whether patents exist that solve the issues we identified. This step was key in identifying whether our product was actually novel. Based on the initial findings, we did not identify any patents that fully solve both problems at hand. While this lack of findings suggests that our product would be novel, it is important to note that a deeper review of existing patents and products would need to be conducted to make such a claim definitively.

3. DESIGN OBJECTIVES AND CONSTRAINTS

This section will discuss the work that supported our ideation phase. It will detail our research into our problem through various methods of communicating with our stakeholders, including artificial intelligence simulated stakeholder conversations, survey questions, informal discussions with peers, and research into student needs. We will then detail constraints we considered and our success at working within them. Finally, we will discuss all the objectives we defined and our prototypes' success at achieving them. We will show objective and morphological charts.

3.1 Stakeholder Considerations

Through interactions with dorm-living university students, we learned a few key facts: the pillow-slippage issue is a common annoyance leading to sleep disturbances, electrical and storage access are unfulfilled necessities in bed, and the budget for this item is relatively low. Through interactions with AI-simulated stakeholders, we learned that university housing is mainly interested in improving the dorm experience to recruit and retain students, and needs a product that follows all safety and fire codes.

3.1.1 AI Simulated Stakeholders

We created prompts and input them into Chat-GPT to simulate various stakeholders, including a student who faces sleep disturbances due to pillow-slippage, a student who enjoys studying in bed, a student who does not face sleep disturbances or enjoy studying in bed, and a university housing representative. The AI showed that students have a low budget for this item, regardless of what they want. It also showed that many students desired it highly, and many buy similar products currently. Even students who do not require this product would enjoy having it available, as it would increase the sleep quality and productivity of their peers, freeing time to socialize. University housing supported the product, as they believed it would increase students' dorm satisfaction. However, they were cautious about the product's ability to maintain safety and fire regulations.

3.1.2 Survey

We conducted a survey to get significant data from a wide variety of students. The survey focused on the problems surrounding sleep disturbances due to pillow slippage. It included the following questions: “Have you experienced difficulties with your pillow slipping or partially slipping off your bed?” “Does your neck hurt after leaning against your bed?” “How often do

you need to adjust your pillow to prevent it from falling off?” “Has your pillow ever fallen to the floor through the gap between the mattress and the bed's structure?” and questions relating to the students' demographics.

We found that a vast majority (84%) of students had experienced the problem, and 100% were aware of it. We also found that most students who struggled with this issue struggled with it often, with 90% of students who had experienced the issue experiencing it once a week or more. 48% of students had experienced the most extreme case of this problem, with their pillow falling off their bed completely on some occasions. This can be seen in Figures 1-B and 2-B in Appendix B. Thus, based on these survey results, a clear need for a solution to this problem was demonstrated.

3.1.3 Informal Peer Discussions and Research

We spoke with peers at the University of Michigan and confirmed that many had faced difficulties with their pillows slipping off their beds. We also found that many of them would only buy a product like this if it were inexpensive due to strict college budgets. If we had more time, we would have spoken with university students outside of dorms to see if similar problems are faced in non-university housing and apartments in Ann Arbor.

All of the information we found from our research is supported by others' formal research into the subject. Kilicaslan (2013) emphasized the importance of a comfortable dorm experience and listed “a countertop”, “desk,” and “shelf/bookshelf“ as required furnishings to complete this objective.

3.2 Constraints

We defined our main constraints based on the budget. We needed to stay within a \$100 budget for the creation of the prototype and keep the cost of the material as low as possible to keep the product affordable for university students. We successfully stayed within the prototyping budget. We used free university scrap wood and facilities to keep costs low, only spending \$25 on a lamp, surge protector, outlet, and shipping.

Our prototype would be more expensive for consumers than we had hoped. We believe we may be able to cut costs by creating a lamp and an electrical access point ourselves instead of outsourcing to another product. We also hope to pursue collaboration with university housing, so that they may take on some of the cost to keep prices low for students. We recognize that we may need to sacrifice material quality for cost - we planned on using oak wood, but may need to use a cheaper material (such as particle board, plywood, or pine) for our final product. This will require further testing.

3.3 Objectives

We created an objective tree to detail our main goals for the project. The entire objective tree can be seen in Appendix D. The tree was split into six main sections: Economy, Storage Capabilities, Comfortability, Securability, Durability, and Aesthetics. We wanted to use a cheap material to keep costs low, such as plastic or wood. We chose wood due to its aesthetics and the lack of large 3D printing access. We mainly created storage through a large shelf that could store miscellaneous items. We wanted our product to create a more comfortable sleeping environment by preventing the pillow from slipping off the bed and by giving students access to electricity, light, and storage in bed to optimize the bed as a study space. We wanted it to be easy to secure through simple systems and light materials. We wanted it to be durable so that it could withstand accidental impacts and long-term weight holding from someone leaning on it or a shelf carrying items. We wanted it to be aesthetic by matching visuals to the current dorm beds and using a high-quality material. Please see Figures 1-8D in Appendix D for more information on our objective tree.

We recognized that we may need to sacrifice our ability to fully fulfill some objectives for other objectives. For example, we may need to use lower quality materials to lower costs, or make the product heavier to increase storage space and durability at the cost of a lower price and ease of securing.

We used our objective tree as a guide while ideating our list of functions and how we would achieve each of them. It increased our understanding of the trade-offs between different objectives so that we could optimize our product to fulfill as many objectives as possible. Considering our objective tree, we created the following list of desired functions: prevent the pillow from falling, create an adaptive study space, store items with a shelf, and organize the bed space. These functions can be seen in *Table 1* below. We were successful with creating all of our desired functions, though we could have optimized the study space further by including some kind of table to hold a notebook or laptop.

Table 1: List of Functions

List of Functions
1. Prevents Pillows from falling from the Bed
2. Adaptive Study Space
3. Stores Items on shelves
4. Easy Organization

4. DESIGN IDEATIONS AND SELECTION PROCESS

This section will discuss our design ideation and engineering design process, where we brainstormed potential design candidates and solutions using a morph chart and design evaluation matrix to help us during the selection. This stage of the design process allowed us to advance to a detailed design of a solution to our problem.

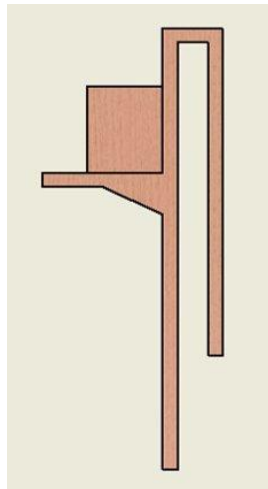
4.1 Morphological Chart

We began our ideation process by discussing with our team about important qualities our design should have in its finalized state. This discussion involved our six main goals from our objectives tree: Economic, Storage Capabilities, Comfort, Securability, Durability, and Aesthetics. Also, this accounted for our list of functions. These two ideas provided us enough detail to produce our Morphological Chart (See Figure 1-E, Appendix E). When creating our potential solutions, our team based our chart on the "Function, Attribute, Objectives, and Constraint" method, deciding on potential solutions. After doing so, we integrated these ideas in a group discussion and tried to create different solutions that served the same purpose of solving our main problem. By doing so, we achieved three potential solutions that covered our six main goals.

4.2 Evaluation Matrix

After deciding on the three solutions, we set our solutions to be evaluated against already existing solutions based on our requirements and by using a Pugh Matrix to give values. During this process, our team defined the weighting scale to be dependent on our requirements for our product, and also for some requirements to be more heavily favored, as it would make our solution more feasible to create and solve our problem. Based on our judgment of the solutions, we assigned values from 1 to 5 to see how our three solutions performed against the already established solutions to our problem. After doing so, we arrived at Solution 2 as the most effective against our other two solutions, as well as the other existing solutions, which is highlighted in yellow in Figure 1-F, Appendix F. *Figure 1* below is a preliminary sketch of Solution 2.

Figure 1: Initial Prototype CAD Sideview



4.3 Selection Process

As for our other two solutions, we had multiple reasons why they were inadequate compared to our choice of Solution 2.

Starting with Solution 1, our team felt that this solution, while solving our main problem of preventing pillows from falling, presented many issues with our other problem of creating a comfortable space for students. Specifically, in our idea of a relaxing space, we wanted everything to be in reach with the student in their bed. For this reason, this solution was quickly overruled in our group discussion. Furthermore, putting a board behind the mattress can cause problems for safety, as the board can fall off the bed or onto the student when they are sleeping. This itself creates the same problem that our team was trying to solve: sleep disruptions. So this solution was quickly scrapped.

For Solution 3, our team all agreed that stitching pillows to our bed sheets would be a bad idea since the stitches can come undone due to stress from preventing the pillow from falling, and create not only the problem of the pillow falling through the gap, but also create an issue of potential stitches in the bed. Again, this solution, like Solution 1, did not effectively solve our other issue of creating a comfortable space for the student to enjoy, as we wanted everything to be convenient for the student. For convenience, we wanted the drinks, chargers, and other items to be at an arms length of the student. Though this solution did provide a good addition to how we wanted to charge our devices, as being on the shelf and therefore prompted the idea of creating an outlet on the board for easier access for charging, as lofted beds are often accompanied by long extension cords that can also fall, but this built-in port will solve that issue as well.

5. DESIGN DESCRIPTION

This section of the report will give specifics on our team's final solution and how we got to it. This includes the major features of our design, the materials and tools we used when building it, our process of CAD modeling and fabricating the prototype, and the potential drawbacks of our finalized design, as well as the refutation of any drawbacks.

5.1 Detailed Features of Final Solution

Our finalized product (See Figure 1-I, Appendix I) consists of a U-shaped headboard designed to lock securely onto an existing bed's headboard, reinforcing and replacing its functionality. Attached permanently to the rear of this core U-shaped component is a built-in shelf, as shown in Figure 3-I Appendix I, which makes use of the underutilized space behind the bed.

Beyond its structural features, our product incorporates several electrically-powered components made possible by the internal space of the U-shaped frame. A surge-protected power extender is permanently mounted within this cavity and connects to a nearby wall outlet via an internal cable routed discreetly out of sight. The extender is oriented so that its surge-protected face points

toward the user's side of the bed, providing accessible charging ports without requiring students to leave their bed, while its opposite face powers internal features. One such feature is the integrated night-lamp, which draws power from this inward-facing side, keeping all cabling concealed within the headboard's inner spacing. The lamp itself is designed with an adjustable, folding arm that rotates and repositions while maintaining stability, allowing students to direct light precisely where needed.

5.2 Materials/Tools Used for Prototyping

For the fabrication of our product's main frame, our team utilized the Fabrication Lab within the Dunderstand Library's basement. To minimize costs without compromising structural integrity, we opted for recycled wood provided by the lab at no charge. However, because the available wood did not come in the dimensions our design required, we constructed the U-frame from five pieces rather than the more structurally sound three-piece configuration. To compensate for this, we joined the two larger panels by gluing two pieces together using wood glue provided by the lab, and reinforced four key connection points with screws, as shown in Figure 2-I, Appendix I. These measures ensured that our modified construction maintained the structural strength our design specifications required. The same wood and adhesive materials used for the core frame were applied consistently to the back shelf, keeping fabrication uniform throughout. At each stage of this process, our team conducted research to confirm that our last-minute design adaptations continued to meet the load-bearing and durability requirements we had originally established for testing.

Finally, within our allocated budget, we purchased a lamp-light and a surge-protected power extender for \$25. To mount the extender, we cut a rectangular opening through the wood panel and secured the unit in place using glue and duct tape, thoroughly testing both adhesives for stability before proceeding. With the extender firmly installed, the lamp was plugged in and secured to the top of the headboard, completing the integrated lighting component of our prototype.

5.3 Major Design Decisions

This section outlines the critical decisions our team made throughout the CAD modeling and prototype fabrication process. As our design progressed, new challenges and insights emerged that required us to reach several consequential conclusions.

5.3.1 CAD Modeling & Prototype Fabrication Decisions

After completing the concept-level evaluation stage of our design process and selecting Option C to advance to detailed design, our team began by virtually modeling the HOS Headboard using Ansys Discovery's CAD software. During this stage, we determined the final dimensions of the product, a 20 in. × 20 in. × 3 in. U-frame, representing a significant reduction from our preliminary prototype, which measured 36 in. × 24 in. × 3 in. and a total surface area of 3,276 sq.

in. This reduction was a deliberate design decision driven by our objective of keeping the product economical and minimizing material waste, while retaining the structural durability confirmed by our CAD stress simulations, which showed a maximum stress of 0.5 MPa against a fracture threshold of 5–80 MPa for oak wood, yielding a safety factor greater than 10. We concluded that the reduced dimensions still satisfied all functional requirements while better supporting our sustainability goals.

The second major design decision during the CAD modeling process was how to mount the power extender within the headboard frame. We initially considered several attachment strategies, but ultimately determined that cutting a rectangular opening directly through the wood panel and securing the surge-protected extender in place using glue and duct tape was the most practical and cost-effective approach given our budget and available materials. We thoroughly tested the stability of both adhesives before proceeding. With the extender oriented so that its user-facing side provided accessible charging ports bedside, and its inward-facing side powered the integrated lamp, we kept all cabling concealed within the interior cavity of the frame. The lamp was then secured to the top of the headboard, completing the electrical component of the design.

Finally, our third major design decision came during the fabrication process. As stated above, we had to opt for connecting smaller wood pieces for the core component, as we lacked wood planks big enough for our intended product. We went back to CAD and checked whether this would still hold the intended forces, and it did. Hence, we moved forward with this design with the note that we would improve it in future prototype iterations.

5.4 Potential Drawbacks to our design

While we were successful in delivering a prototype that accomplished all of our initial goals, there were drawbacks to both our design and prototype. I will first delve into what could be improved in our prototype and then what needs to be addressed in our design moving forward.

Our prototype, as mentioned above, lacked the structural integrity we initially required. Given more stress than normal, our current prototype could potentially break at the mid joint of the planks. Thus, it is crucial to revise both the materials used and the size of its planks. Moving forward, prototypes must consist of as few joints as possible and be made of sturdier, more resistant wood.

Our actual design also incurred some drawbacks. We struggled to find a way to incorporate the back shelf without noticeably altering the center of mass. Nevertheless, this design allows the headboard to lock into place and remain stable, though it places further stress on the frame's corner joints. Therefore, with the electrical components integrated in a more methodical and safety-conscious manner, our next design must aim to re-center the center of mass.

6. TESTING

This section of the report details the testing process and methods we used after completing the prototype. Conducting these tests allowed us to determine which design requirements our prototype met and how we can improve the design in future iterations.

6.1 Design Verification

We began the testing process by identifying the design requirements we wanted the prototype to fulfill. We identified that the headboard prototype should be able to hold steady and not fall apart while attached to the bed, be able to hold ample weight on the bookshelf and cup holder, provide a well-lit reading environment, and charge devices safely.

6.2 Durability Tests

Our first test upon completion of the prototype was to make sure that it could hold its own weight when put over the current university bed railing. We conducted this test by placing the headboard onto a dormitory bed. After sliding the headboard onto the board, we waited five minutes to see how the screw and wood glue attachments would hold when subjected to gravity. Throughout the five minutes, the headboard remained stable and intact, proving the prototype can survive the downward force of gravity. The second durability test we ran was simulating a restless sleeper who constantly hit the headboard while sleeping. This test was conducted by applying repeated force on the front side of the headboard using a pillow for another five minutes. After five minutes, the headboard remained intact and fixed onto the bed.

6.3 Electrical Tests

After testing the headboard's durability, we then proceeded to test the electrical components of the prototype. We began this testing by first ascertaining whether the lamp light even worked. Once we confirmed the light would turn on, one of us then lay on the bed and held a book in a reading position to determine whether the light would be useful for reading. Our headboard light passed this test as the book's pages were properly illuminated. The direct light made the pages easier to read than when compared to using the overhead light. The final electrical test was to determine whether the surge protector would work. We conducted this test by plugging the cable into the wall, flipping the surge protector switch to "ON", and then plugging a phone into the outlet via a phone charger. The headboard's surge protector passed this test as the phone immediately began charging quickly.

6.4 Improvements for Future Iterations

Our first iteration through the design process taught our team about how we would approach future iterations of our product's development and parts of the prototype we would improve to produce the best product possible. We created a design FMEA table to visualize the most important improvements and streamline the optimization process. It can be seen in Figure 1 of Appendix J.

Our first improvement would be using a stronger wood. The wood we used for our first iteration came from the scrapwood found in the Duderstadt Fabrication Underground Woodshop. We initially made this choice to save production costs, but as we constructed our prototype, we realized that there were considerable problems with the wood. The first issue was that as we drilled screws into the wood to attach the pieces, the wood began to split. This issue poses durability concerns that our test may not have caught. To fix this problem, we would use a strong hardwood like oak, maple, or mahogany since they are known for their durability and resistance to cracking (Wood Database, 2017), where those three types of wood were rated favorably in the workability category.

Another part of the prototype we would change is making the lamp chargeable. Currently, the lamp is battery-powered, which may present problems for users in the future when the battery dies, and they have to change it. In future iterations, we would use a rechargeable lamp that is charged continuously by plugging it into the part of the surge protector facing inward. We didn't originally make the headboard in this fashion because we never considered charging the lamp until the testing phase after the prototype was completed.

7. CONCLUSION

Our team's goal was to create a functional prototype that fixes a real-world issue by applying the engineering design process. We identified a widespread problem within our community with great potential for creative solutions in the problem of students' pillows falling through the gap in the dormitory beds, which resulted in poor sleep. We then went through the engineering design process and completed each stage to the best of our ability and addressed any setbacks we faced. Finally, we were able to design a functional version of our solution, consisting of a headboard, bookshelf, cup holder, surge protector, and lamp.

Overall, we were able to complete the project on time and within our budget through consistent communication and adherence to the timeline in our Gantt chart. Also, we learned important lessons about woodworking, the engineering design process, and acknowledging stakeholder needs. We are pleased with our work on the prototype and our application of the engineering design process during this project.

8. REFERENCES

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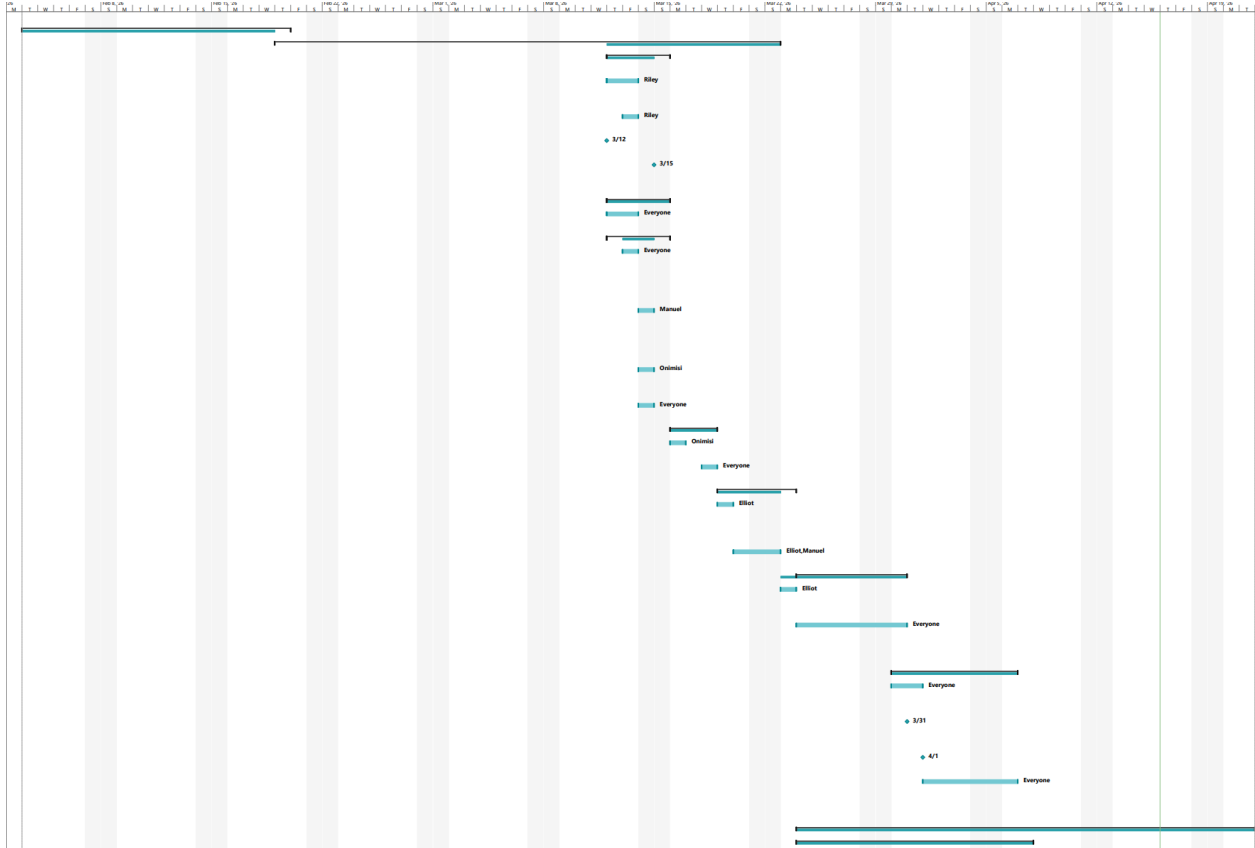
Appendices

Appendix A: Gantt Chart

Figure 1-A: Project Tasks in Word Form

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1						
2		Project Start	13 days	Tue 2/3/26	Thu 2/19/26	
9		Project Proposal	23 days	Thu 2/19/26	Sun 3/22/26	
15		Design Requirements	3 days	Thu 3/12/26	Sun 3/15/26	
16		Acquire Stakeholder Comments	2 days	Thu 3/12/26	Fri 3/13/26	
17		Evaluate the Survey Data	1 day	Fri 3/13/26	Fri 3/13/26	
18		Complete Objectives Tree	0 days	Thu 3/12/26	Thu 3/12/26	
19		Complete List of Functions of Product	0 days	Sun 3/15/26	Sun 3/15/26	
20		Design Ideation	3 days	Thu 3/12/26	Sun 3/15/26	
21		Individual Design Brainstorming	2 days	Thu 3/12/26	Fri 3/13/26	
22		Group Ideation	3 days	Thu 3/12/26	Sun 3/15/26	
23		Brainstorm Potential Solutions to Functions Listed	1 day	Fri 3/13/26	Fri 3/13/26	
24		Use "Function, Attribute, Objective, Constraint" technique	1 day	Sat 3/14/26	Sat 3/14/26	
25		Create Morphological Chart	1 day	Sat 3/14/26	Sat 3/14/26	
26		Evaluate Design Options	1 day	Sat 3/14/26	Sat 3/14/26	
27		Design Evaluation	3 days	Mon 3/16/26	Wed 3/18/26	
28		Create Evaluation Matrix	1 day	Mon 3/16/26	Mon 3/16/26	
29		Evaluate & Choose Best Option	1 day	Wed 3/18/26	Wed 3/18/26	
30		Detailed Design	3 days	Thu 3/19/26	Mon 3/23/26	
31		Create Rough Sketches with Approximate Measurements	1 day	Thu 3/19/26	Thu 3/19/26	
32		Work on Product's CAD Model	2 days	Fri 3/20/26	Sun 3/22/26	
33		Creating Prototype	5 days	Tue 3/24/26	Mon 3/30/26	
34		Identify any Materials and Locations Needed	1 day	Mon 3/23/26	Mon 3/23/26	
35		Contact GSI/IA about access to 3D Printers or Workshop	5 days	Tue 3/24/26	Mon 3/30/26	
36		Prototype Testing	6 days	Mon 3/30/26	Mon 4/6/26	
37		Test Design against Requirements	2 days	Mon 3/30/26	Tue 3/31/26	
38		Receive Stakeholder Feedback	0 days	Tue 3/31/26	Tue 3/31/26	
39		Perform CAE Simulations	0 days	Wed 4/1/26	Wed 4/1/26	
40		Improve & Finalize Design for Final Report & Presentation	4 days	Wed 4/1/26	Mon 4/6/26	
41		Final Report	21 days	Tue 3/24/26	Tue 4/21/26	
44		Presentation	11 days	Tue 3/24/26	Tue 4/7/26	

Figure 2-A: Timeline of Tasks



Appendix B: Survey Results

Figure 1-B: Respondents Experience and Knowledge of Pillows Slipping off Beds

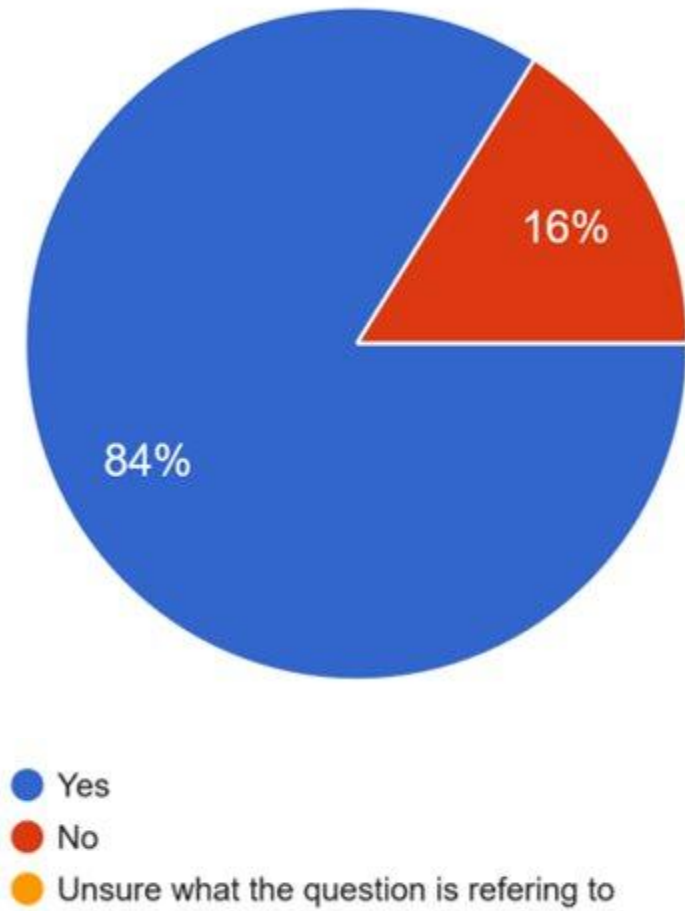
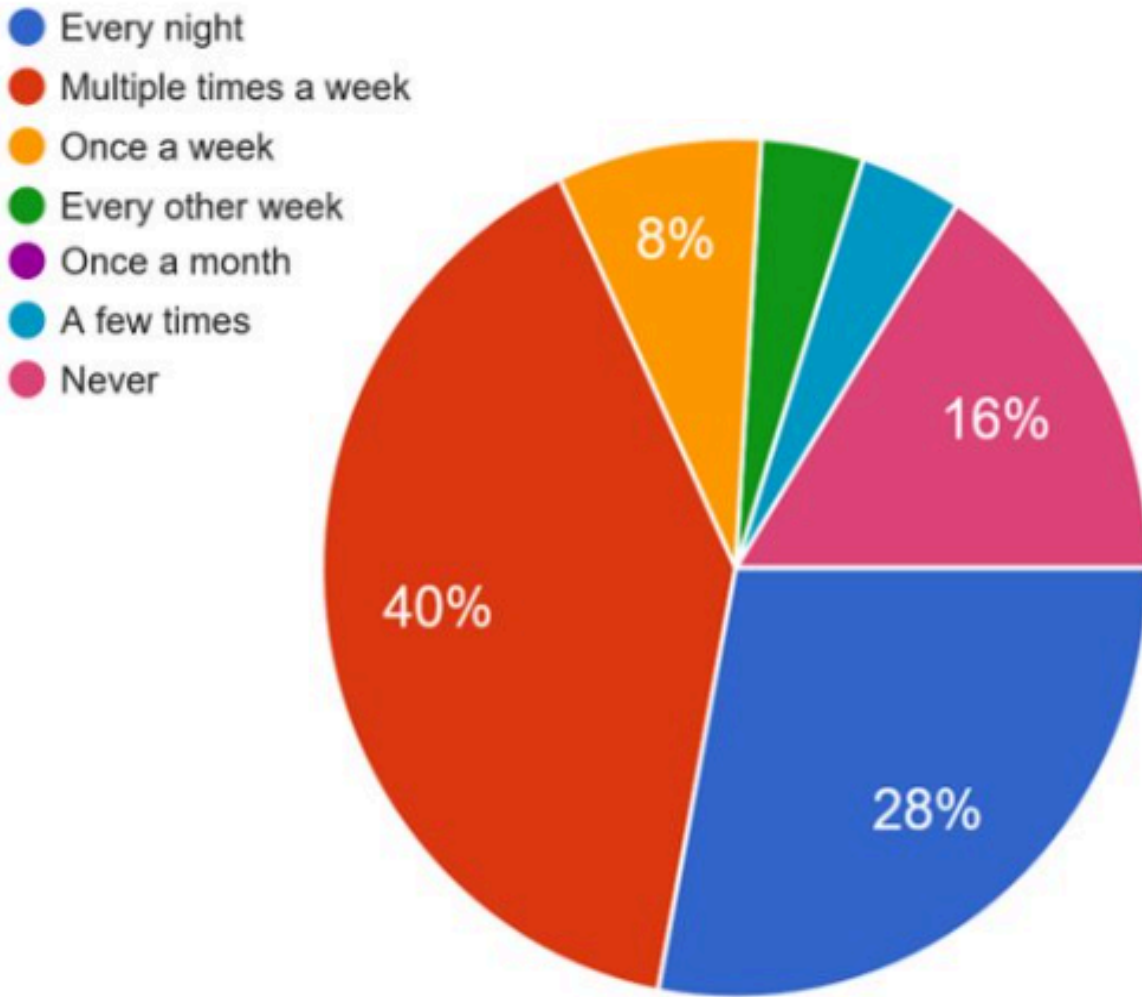


Figure 2-B: Frequency of Pillow Adjustments to Prevent Pillow Falls Among Respondent



Appendix C: Existing Solutions (Patents)

Figure 1-C: Triangular Pillow (Patent US20080109961 (A1) 2008-05-15)

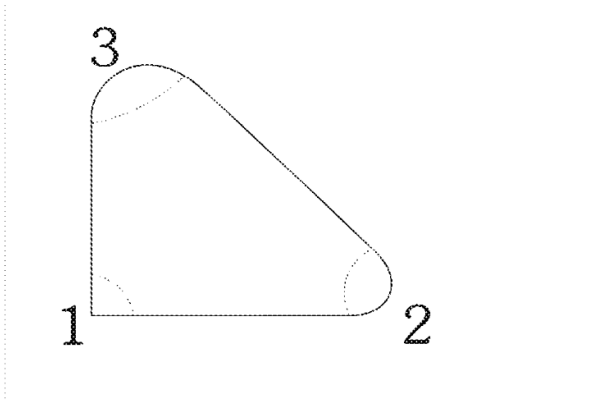


FIG. 1

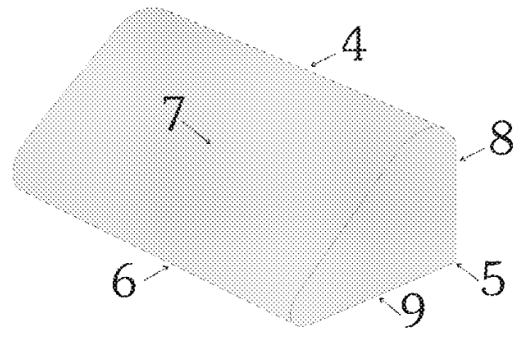


FIG. 2

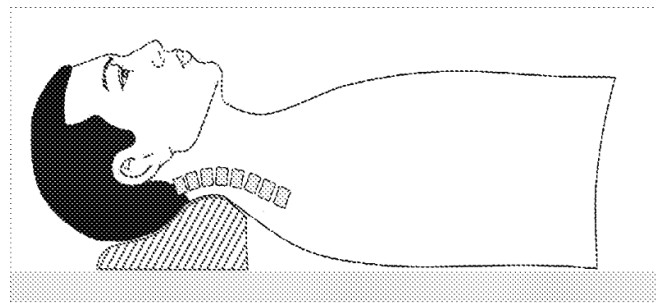


FIG. 3

Appendix D: Objectives Tree

Figure 1-D: Complete Objectives Tree

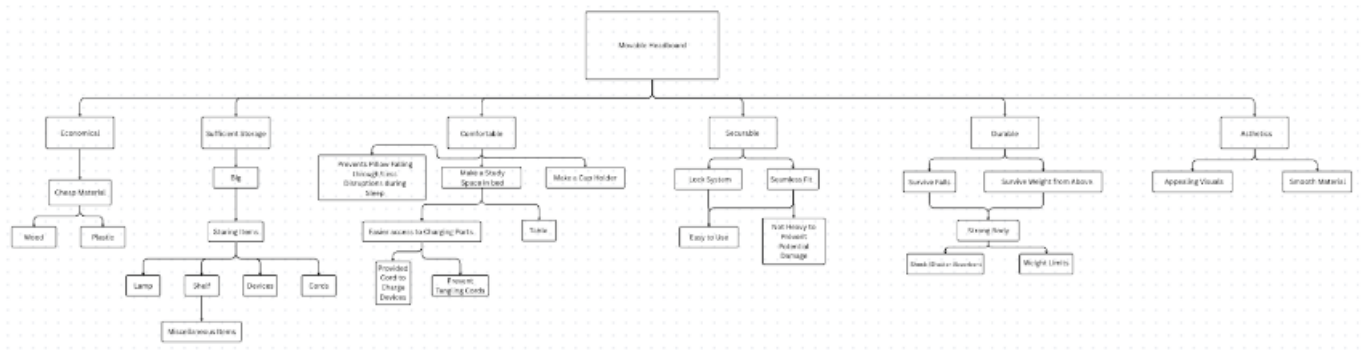


Figure 2-D: Top Level

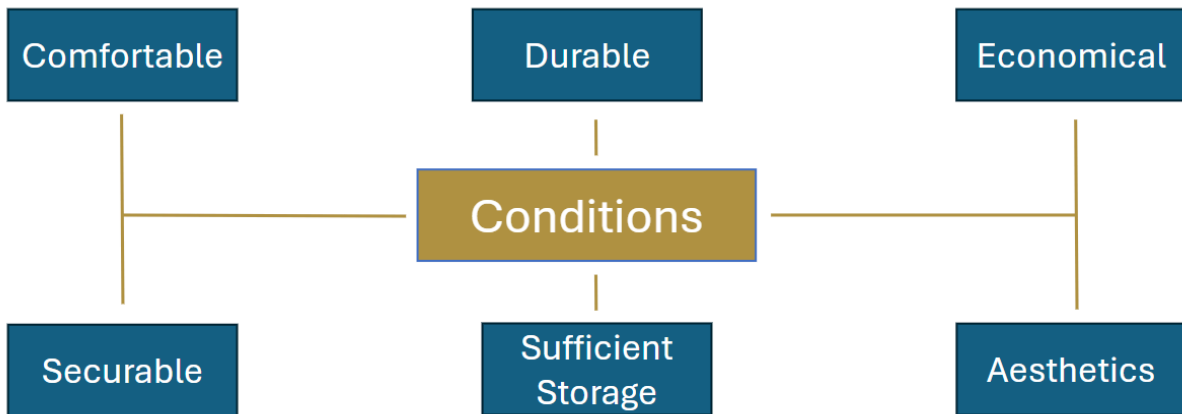


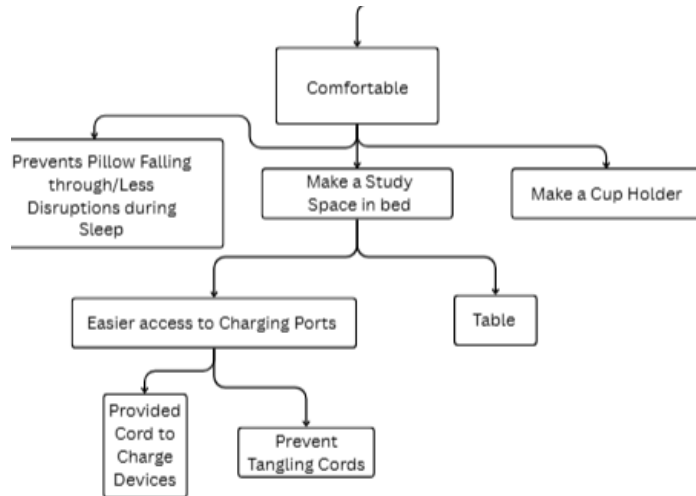
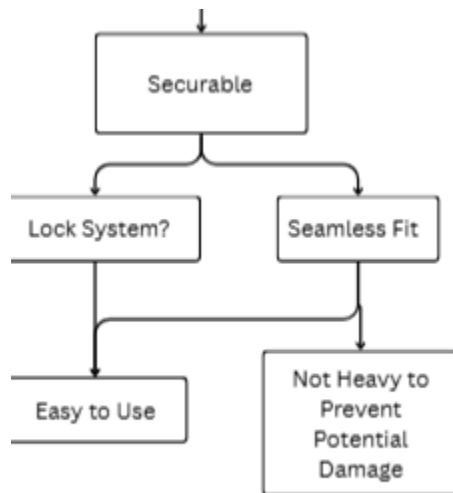
Figure 3-D: Comfortable Branch**Figure 4-D: Securable Branch**

Figure 5-D: Durable Branch

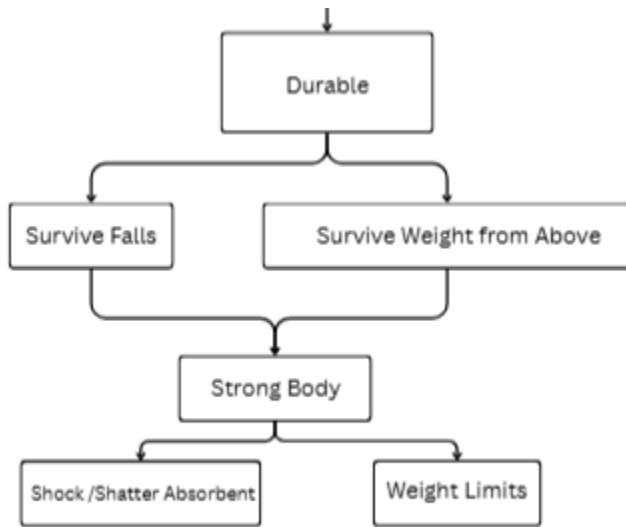


Figure 6-D: Economical Branch

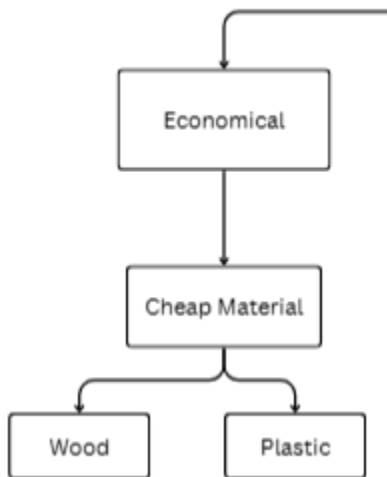


Figure 7-D: Aesthetics Branch

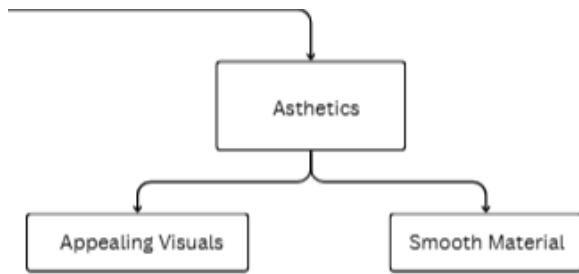
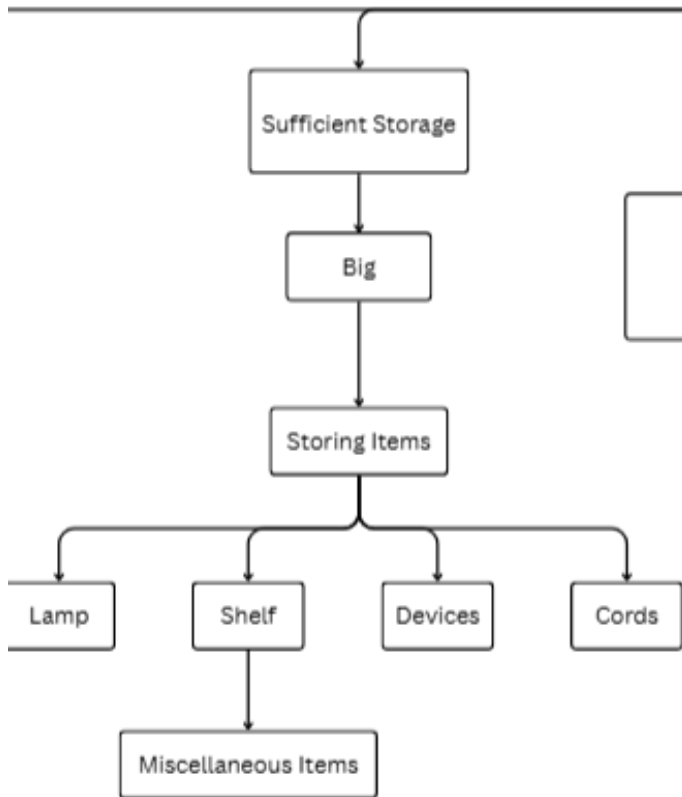


Figure 8-D: Sufficient Storage Branch



Appendix E: Morphological Chart

Figure 1-E: Morphological Chart

Functions	Keep Pillow from Falling	Hold Cups	Charge Devices	Hold Books	Light up the bed area
Solution 1	Put a board behind the mattress	Place cups on the floor	Outlet near the bed	Keep books on the school-provided shelf or desk	Use the overhead light
Solution 2	Install a headboard on the bed	Cup Holder on side	Surge Protector	Bookshelf on the back of the headboard	Attach a lamp to the headboard
Solution 3	Stitch Pillow to Sheets	Place cups on the window ledge	Charge the device on the desk instead of the bed	Keep books in a backpack	Purchase other mood lighting for the room

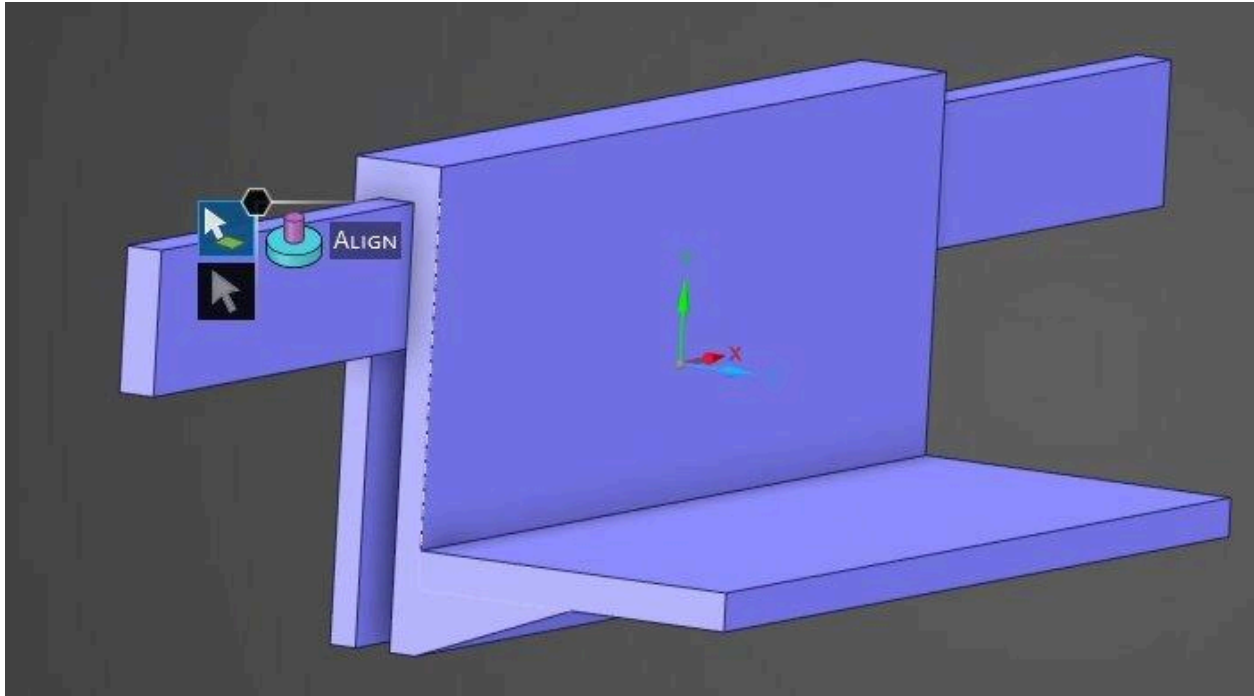
Appendix F: Evaluation Matrix

Figure 1-F: Evaluation Matrix

Product Evaluation Matrix				
Multi-Function Attachable Backboard Team 204-D University of Michigan				
Evaluation Criteria	Weight	HOS Headboard (Our Design)	Triangular Pillow (Existing)	Bedside Desk (Existing)
Pillow support	20%	5	5	1
Storage / utility	20%	5	1	5
Charging access	15%	5	1	3
Cost / affordability	20%	4	5	2
Ease of setup	10%	4	5	3
Durability	10%	4	3	4
Space efficiency	5%	4	5	2
Weighted Total Score	100%	4.55 / 5.00	3.40 / 5.00	2.85 / 5.00

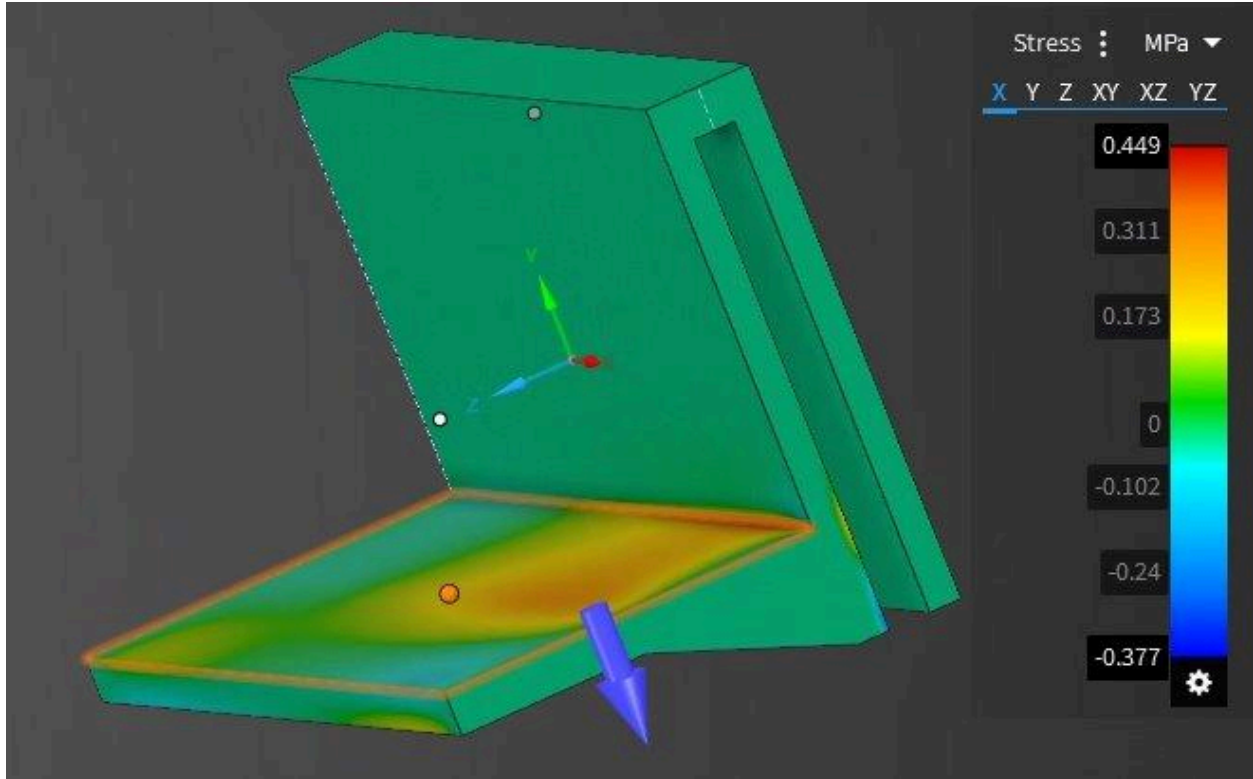
Appendix G: CAD Initial and Final Prototype Images

Figure 1-G: Final Prototype CAD Frontview



Appendix H: CAD Simulation

Figure 1-H: CAD Stress Simulation Results in Ansys Discovery



Appendix I: Finalized Product Visuals

Figure 1-I: Frontside View of the Product on a Bedframe



Figure 2-I: Backside View of the Product



Figure 3-I: Side View of the Product



Appendix J: DFMEA table

Figure 1-J: DFMEA table

Number	Function	Potential Failure Mode	Potential Effect of Failure	Severity (out of ten)	Potential Failure Causes	Rate of Occurrence (further testing required) (out of ten; assumed five)	Probability of Detection (out of five)	Importance ((Severity - Detectability) * Occurrence rate)	Current Preventative Measure	Effectiveness of Preventative Measure (out of ten)	Needs Significant Improvement?
1	Headboard	Catastrophic Failure (Fracture)	Harm to user; Sleep disturbance; Damage to stored Items; Compromised function	9	Material sourcing; Manufacturing defects; Longevity issues.	5	1	40	Material Sourcing	7	Maybe
2	Storage	Warping	Damage to stored items;	7	Material sourcing; Manufacturing defects; Longevity issues.	5	1	30	Material Sourcing	7	No
3	Storage (cont)	Catastrophic Failure (Fracture)	Damage to stored items; Harm to user; Sleep disturbance; Compromised functions	9	Material sourcing; Manufacturing defects; Longevity issues.	5	1	40	Material Sourcing	7	Maybe
4	Electrical Access	Impaired or ceasing of function	Annoyance to user	3	Longevity issues	5	5	-10	None	1	No
5	Electrical Access	Fire	Destruction; Death	10	Manufacturing Defects; Dangerous user error	5	2	40	Surge protector	9	No
6	Light Access	Impaired or ceasing of function	Annoyance to user	3	Longevity issues	5	5	-10	None	1	No