Cornell University

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MEng Project Report

Abstract

This report documents the comprehensive journey of developing the Hubble HotPod, a portable heating device designed to enhance the daily lives of college students. Our interdisciplinary team employed a design thinking approach to understand student needs and deliver an innovative solution that meets their challenges effectively.

The initial phase involved empathy fieldwork, where user needs were collected through immersion, observation, and engagement. The data revealed key student concerns such as daily commuting, well-being, hassle-free experiences, and effective time management. Unpacking these insights informed our ideation sessions and led to the HotPod concept.

Prototyping began with the Design 0 prototype, exploring a basic convective heat transfer mechanism. Finishing with Design 6 which incorporated all the comprehensive feedback from previous testing to create a functional prototype with a compact form factor and improved air circulation. FEA confirmed the efficacy of the convective heat transfer concept, while analytical calculations guided the optimization of heating elements and fans.

Market analysis and financials identified a target market, emphasizing the importance of social influence, lifestyle compatibility, and pricing. A comprehensive financial analysis and business model ensured the HotPod remains competitive and profitable.

Acknowledgements

We would like to extend our deepest gratitude to our professors, Dr. Robert Shepherd and Professor Sirietta Simoncini, for their constant support, guidance, and expertise throughout this project. Their leadership and wisdom have been invaluable in teaching us the systems design thinking process. We appreciate also the Systems Engineering along with Mechanical and Aerospace Engineering Departments of Cornell University for the constant support.

In addition, we wish to specially thank Young Seong Kim, Kapil Gangwar, Pamraat Parmar and Koushani Das for their time and invaluable assistance in advising our team at critical points during the development of this project. We wish to also thank Aarya Patel for the continued assistance even after moving on from the team. Their perspectives enabled us to overcome obstacles and progress forward.

We sincerely appreciate everyone who participated in our surveys and interviews, providing the critical inputs and feedback that made this a truly meaningful project. It was only through engaging actual users and stakeholders that we were able to ensure our solution addressed real needs and challenges. You all have our utmost gratitude.

Finally, thank you to our friends and families for their unconditional support. Your encouragement gave us the motivation to persist when the road got difficult.

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1. Introduction

The following report summarizes the work completed during the Fall 2023 and the Spring 2024 semester as part of the Innovative Product Design via Digital Manufacturing which was then continued as the Consumer Product Design MEng Project.

1.1 Team and Members

Our team, Hubble (formerly BeeEZ), comprises of seven engineers that are dedicated to developing ideas that enhance the overall student experience by promoting a sense of delight and satisfaction. Hubble includes a mix of mechanical, chemical and systems engineering international graduate students from Canada, China and India. The team comprises of individuals with backgrounds and expertise in engineering, design, statistics, and marketing, ensuring a multifaceted approach to product development. Our team members are:

Systems Engineering Students:

Weiqi Zhai – wz445

Weiqi is a graduate of the University of California, Santa Barbara with a Bachelor's degree in Statistics and Data Science and a minor in Applied Psychology. Her academic program provided extensive experience in statistical and data analysis through courses, projects, and internships. Passionate about using technology to solve complex problems and eager to continue learning, she created and maintains the GoGaucho app to improve campus services by integrating dining, library, and other key features. Weiqi is currently pursuing a Master's degree in Systems Engineering at Cornell University to further her education.

Yixuan He – yh2252

Yixuan is a master's degree student in system engineering at Cornell University. Passionate about applying marketing and data analysis skills to solve complex problems and create value, he is also a co-founder of PowerBee, a startup providing portable charging stations where he led product development and business aspects. Before Cornell, Yixuan completed a bachelor's degree in business administration at the George Washington University School of Business, majoring in marketing, international business, and data science. He gained experience as a product operations intern at Farfetch, a global luxury fashion platform, and as a business operations intern at Forbes China, a leading business media outlet.

Tianjun Wang – tw554

Tianjun is currently pursuing a master's degree in systems engineering at Cornell University. He is interested in using statistical and economic concepts to solve complex problems and

deliver value for stakeholders and customers. He previously majored in economics and statistics at the University of British Columbia where he received his bachelor's degree. Tianjun also gained experience as a research assistant to Professor Zhang at the UCLA Anderson School of Business, supporting her research on bonds and banking.

Peiying Li – pl634

Peiying (Lillian) offers 9 years of experience in procurement and production management, characterized by notable business acumen and strategic insight. Currently pursuing a Master's degree in Systems Engineering, she builds upon her existing Master's in Electrical Engineering, showcasing various technical and analytical abilities. Her proficiency spans all Supply Chain Management (SCM) aspects, including sourcing, planning, inventory management, and quality control. Peiying also holds PMP and CPSM certifications, reflecting her dedication to ongoing professional development

Mechanical Engineering Students:

Niharika Maheshwary – nsm92

Niharika is currently a Master's student in the department of Mechanical Engineering at Cornell University. She did her undergraduate from the Indian Institute of Technology Bombay before joining Cornell in Fall 2023. Niharika's major research interests lie in the area of mechanical design and design for manufacturing. Through various research projects and internships, she has gained a cumulative of 3.5 years of experience. In her free time Niharika enjoys reading, traveling, and playing the keyboard.

Sagar Sanjay Shenoy – ss3675

Sagar is pursuing a Master's in Mechanical Engineering at Cornell University, graduating in 2024, after completing his Bachelor's in Mechatronics Engineering from Manipal Institute of Technology. Through internships and student projects, he has over 4 years of experience designing mechanical systems and robots using CAD, simulation, and hands-on fabrication. He holds an Australian Innovation Patent for an automated areca nut harvesting robot he co-invented. Sagar has proven leadership ability from heading robotic systems for a student group and spearheading the design for a Baja SAE ATV car.

Chemical Engineering Students:

Anne Blue – ab2986

Anne Blue is pursuing a Master's in Chemical Engineering at Cornell University, graduating in 2024, after completing her Bachelor's in Chemical Engineering from the University of Toronto. She has experience working as an R&D Formulation Engineer Intern at MedFluid Co., Ltd., where she optimized lab-on-a-chip production and collaborated with senior researchers on antibiotic formulation experiments. Anne also gained experience as a

Medical Surgical Intern at Medtronic, where she organized large sets of sales data and coordinated cross-team events. She is passionate about contributing to a more sustainable and environmentally friendly world.

Former Team Members:

Aarya Patel – ahp77

Aarya is pursuing a Master's degree in Mechanical Engineering at Cornell University, working on developing Discrete Greens Functions (DGF) for complex geometries to evaluate heat transfer parameters. He obtained his Bachelor's in Mechanical Engineering from Pandit Deendayal Energy University in India in 2022. His undergraduate research focused on applications of Triply Periodic Minimal Surfaces (TPMS), including manufacturing aspects. Aarya completed an internship with the Indian Space Research Organization (ISRO), applying TPMS geometries for thermal applications. For this work, he received an undergraduate research award from ASM Indian National Council. As an undergraduate, Aarya was also an active leader of his university's BAJA student racing team. Outside academics, he enjoys hiking, cricket, and reading.

Agasthya Debnath – ad2246

Agasthya is an aspiring aerospace engineering professional with a rich educational background and diverse experience. Currently pursuing a Master of Science in Mechanical & Aerospace Engineering at Cornell University, Agasthya has excelled academically, obtaining a Bachelor of Technology with First Class Distinction from SRM Institute of Science and Technology, and studying for two years at Delft University of Technology. His expertise spans technical skills in CATIA, SolidWorks, ANSYS, and Python, complemented by fluency in English and Hindi. Agasthya's internships at ITDA-DARC, SCRO, and TU Delft's Lunar Zebro team highlight his practical experience in drone design and aerospace projects. Additionally, his leadership and involvement in projects like Wind Assisted Ship Propulsion and roles in NGOs demonstrate a commitment to applying his skills in varied settings.

1.2 Product Challenge Statement

Our product is named HotPod. The objective of our study was to create and conceptualize a product that would include attributes of simplicity, clarity, and convenience, hence enhancing its use within the daily routines of students. Our Product Design Challenge as part of the Innovative Product Design course during the Fall semester was to redesign the student experience so that they do not just survive but thrive. To elaborate further, we were tasked with designing a product that aids student life and provides a solution to their problems in a manner that is comfortable and convenient.

So, we embarked on a journey of how might we design an affordable and portable product that simplifies and brings joy to the everyday student experience. The solution we produced combines cutting-edge technology with user-centric design to meet contemporary heating challenges.

1.3 Systems Design Thinking Process

During the first semester, our group applied system design thinking to make the state clearer and develop a practical tool tailored for everyday use. Our team understands system design thinking as an organized process. Here, we imagine and sort a system's parts systematically. We aim to make everything work its best and meet what stakeholders expect.

Our project plan covers important parts. First, we learn what our customers want and like. Next, we think of ideas for products that will meet their needs. We list the main features these products should have. Then, we make early models of parts of the system. We build the actual design by trying it out with users. We improve the design using what we learn from these tests. Lastly, we create detailed plans for selling the finished products. This talk elucidates a pragmatic implementation of system design thinking.

2. Empathy Fieldwork

Empathy field work was essential in finding the right product for our customer base. It helped us truly flesh out what the students need.

2.1 Empathy Fieldwork Plan

Our empathy field work consisted of 283 empathy episodes. These 283 empathy episodes showed us that some of the categories that appeared often were daily commute, well-being, relaxing environment, and having a hassle-free everyday experience.

Figure 1. Empathy Fieldwork

2.1.1 Immersion

Immersion involves placing ourselves in hypothetical or simulated scenarios to explore and document our own emotional responses, thoughts, and reactions. By imagining ourselves in various situations, such as the daily commute or studying in a relaxing environment, we were able to gain insight into how students might feel, act, and perceive the world around them. For instance, placing ourselves in a scenario where a student deals with a stressful commute while juggling academic workload helped us understand the anxiety and exhaustion they experience. This exercise provided key knowledge and surprises, helping us identify personal feelings and deeper understanding, which were critical in refining our product.

2.1.2 Observations

Observations involved carefully watching and noting the behaviors, expressions, and actions of others, particularly when they engaged in unique or unusual activities. Through systematic observation, we noticed patterns and emotional cues that enhanced our understanding of the student experience. For instance, observing students' daily routines revealed that a hassle-free everyday experience was crucial. The observer would ask "why" repeatedly to understand the reasons behind specific actions and behaviors. The

observations helped us uncover moments of conflict, surprise, and synergy, providing us with valuable insights into the needs and expectations of our customer base.

2.1.3 Engagements

Engagements involved direct interactions and interviews with individuals to gather firsthand insights into their thoughts, emotions, and perspectives. By interviewing students, we explored their experiences, challenges, and motivations. For example, interviewing students about their well-being and study habits during the pandemic provided valuable insights into the emotional and practical aspects of their everyday lives. The interviewer's comments and notes helped identify patterns of tensions, contradictions, and consistencies within the data. Ultimately, these dialogues provided us with insights and surprises, helping us refine our understanding of students' requirements.

2.2 Unpacking

The unpacking process starts by identifying clear facts from each empathy episode and turning them into personal feelings from our own experiences. After collecting facts and stories, we looked for patterns, conflicts, surprises, and moments that made us think deeply. This led to gaining key knowledge and uncovering new insights and surprises.

Unpacking Immersions: We began by identifying clear facts and turning them into personal feelings from our own experiences. By exploring conflicts, surprises, and other patterns in each immersion scenario, we gained deep understanding and fresh insights.

Unpacking Observations: Observing students in various settings allowed us to understand what they did and how they did it. Observers took notes on why they believed students acted in certain ways. They continuously asked "why," uncovering assumptions, patterns, and unique moments of interest.

Unpacking Engagements: The process of unpacking engagements involved analyzing interview data by synthesizing the user's comments and observable actions. This helped deduce cognitive processes and affective experiences. Identifying patterns of tensions, contradictions, consistencies, and surprises within the collected data provided a deeper understanding of requirements, perspectives, and unexpected revelations.

2.3 Grouping

Our team progressed by transforming our firsthand empathy accounts into clear data points that helped us focus on solutions. We used Miro, a digital whiteboard tool, to share and organize our findings. On Miro, team members posted their insights and surprises using virtual sticky notes. From our research, we identified 129 needs, 104 insights, and 50

surprises. Miro enabled collaboration among team members from different locations, allowing all seven of us to review and analyze the 283 empathy episodes simultaneously. We examined the notes closely, looking for recurring patterns and commonalities. We then grouped the data to identify key themes.

After categorizing our findings, we identified six main topics: a peaceful place, living with others, effective time management, simplicity, daily commuting, and maintaining fitness and nutrition. Within each overarching theme, we delved into smaller subtopics for a more comprehensive understanding.

Figure 2. Empathy Fieldwork Unpacking and Grouping(Miro)

2.4 Modeling

2.4.1 Emotional Data Relationship Map

Figure 3. Unpacked and Grouped EFW Data

Our empathy fieldwork revealed that time management was the most prominent issue, representing 25% of our findings. Fitness, nutrition, and well-being followed at 19%, while hassle-free experiences accounted for 18%. Everyday travel concerns were linked to 17% of our findings, a comfortable setting was noted by 13%, and social and living situations were mentioned in 7% of cases.

Additionally, our survey explored some less prominent elements, and after careful consideration, we decided to give these aspects more focus in our product plans.

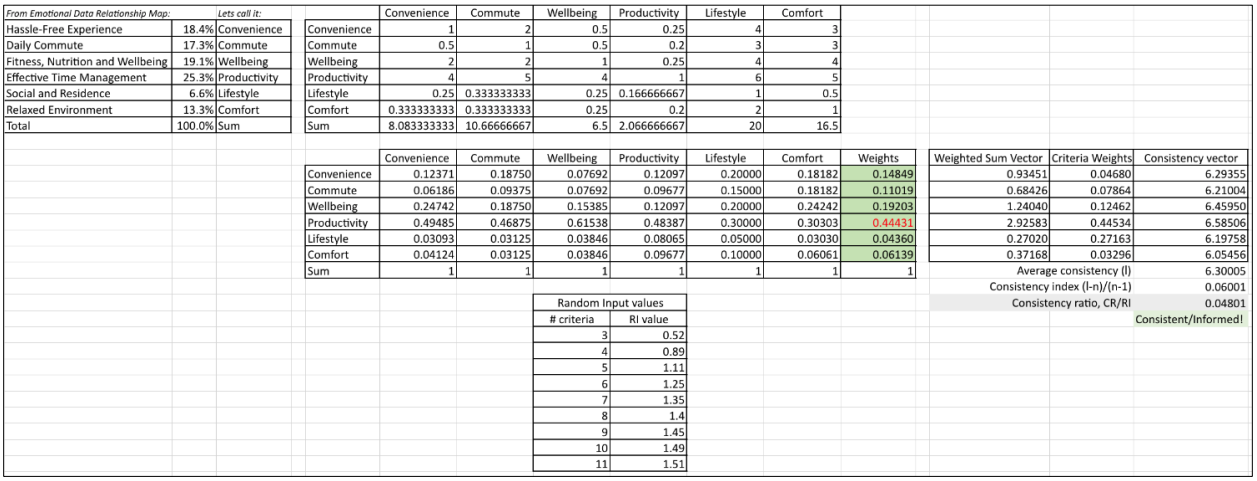
2.4.2 Criteria Comparison Matrix / Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP), also known as the criteria comparison matrix, simplifies decision-making by breaking down complex problems into manageable chunks. Each smaller component can be individually assessed to determine its relative importance. In our study, we used AHP to evaluate the significance of different aspects of our research systematically.

Through careful analysis, we identified that elements like health, smooth processes, and effective time management profoundly impact productivity. We meticulously grouped

various events into categories by following clear steps, which helped us quantify their frequency and better understand their significance.

The AHP methodology involves comparing pairs of categories to determine the relative importance of each based on our primary goal or standard. We don't just count occurrences within each category; we also assess the magnitude and nature of how these events affect the target group's behavior and emotions.



From Emotional Data Relationship Map:		*Lets call it:*
Hassle-Free Experience	18.4%	Convenience
Daily Commute	17.3%	Commute
Fitness, Nutrition and Wellbeing	19.1%	Wellbeing
Effective Time Management	25.3%	Productivity
Social and Residence	6.6%	Lifestyle
Relaxed Environment	13.3%	Comfort
Total	100.0%	Sum

	Convenience	Commute	Wellbeing	Productivity	Lifestyle	Comfort
Convenience	1	2	0.5	0.25	4	3
Commute	0.5	1	0.5	0.2	3	3
Wellbeing	2	2	1	0.25	4	4
Productivity	4	5	4	1	6	5
Lifestyle	0.25	0.333333333	0.25	0.166666667	1	0.5
Comfort	0.333333333	0.333333333	0.25	0.2	2	1
Sum	8.083333333	10.66666667	6.5	2.066666667	20	16.5

	Convenience	Commute	Wellbeing	Productivity	Lifestyle	Comfort	Weights
Convenience	0.12371	0.18750	0.07692	0.12097	0.20000	0.18182	0.14849
Commute	0.06186	0.09375	0.07692	0.09677	0.15000	0.18182	0.11019
Wellbeing	0.24742	0.18750	0.15385	0.12097	0.20000	0.24242	0.19203
Productivity	0.49485	0.46875	0.61538	0.48387	0.30000	0.30303	0.44431
Lifestyle	0.03093	0.03125	0.03846	0.08065	0.05000	0.03030	0.04360
Comfort	0.04124	0.03125	0.03846	0.09677	0.10000	0.06061	0.06139
Sum	1	1	1	1	1	1	1

Weighted Sum Vector	Criteria Weights	Consistency vector
0.93451	0.04680	6.29355
0.68426	0.07864	6.21004
1.24040	0.12462	6.45950
2.92583	0.44534	6.58506
0.27020	0.27163	6.19758
0.37168	0.03296	6.05456
	Average consistency (l)	6.30005
	Consistency index (l-n)/(n-1)	0.06001
	Consistency ratio, CR/RI	0.04801
		Consistent/Informed!

Random Input values	
# criteria	RI value
3	0.52
4	0.89
5	1.11
6	1.25
7	1.35
8	1.4
9	1.45
10	1.49
11	1.51

Figure 4. Criterion Comparison Matrix

Key Insights

- Productivity: Effective time management is closely tied to productivity and overall life satisfaction. Organizing daily tasks smarter provides more time for enjoyable activities, leading to a positive impact on well-being.
- Well-being: Focusing on well-being is crucial because it's frequently mentioned, observed, and significantly impacts academic performance and overall satisfaction.
- Convenience: Hassle-free experiences and smooth communication are vital for reducing everyday stress and enhancing productivity. Improved convenience significantly contributes to the quality of daily life.

The Analytical Hierarchy Process helps us understand how these elements are interconnected. For example, improved time management can lead to reduced stress, and handling daily tasks more intelligently provides more time for enjoyable activities that boost happiness. This ripple effect enhances overall well-being and productivity.

By comparing and sorting categories, we developed a scoring system where each group receives a score representing its importance. These scores are invaluable when making

decisions, determining next steps, and allocating resources to optimize outcomes for those involved.

The AHP offers a transparent and objective framework to understand the interconnectedness of various factors in our study. Grasping the relative importance of each component allows us to make informed decisions that align with our audience's priorities. Our analysis revealed a consistency ratio of 0.04801, indicating that our judgments were stable and reliable assessing the importance of each factor.

2.4.3 Flow of Thoughts

The "Flow of Thoughts" map is a visual tool that organizes people's concerns and preferences into six key areas: managing time effectively, daily commuting, fitness and well-being, healthy eating, hassle-free experiences, calm environments, and social and living situations. Each area is assigned a percentage, reflecting its importance based on our data.

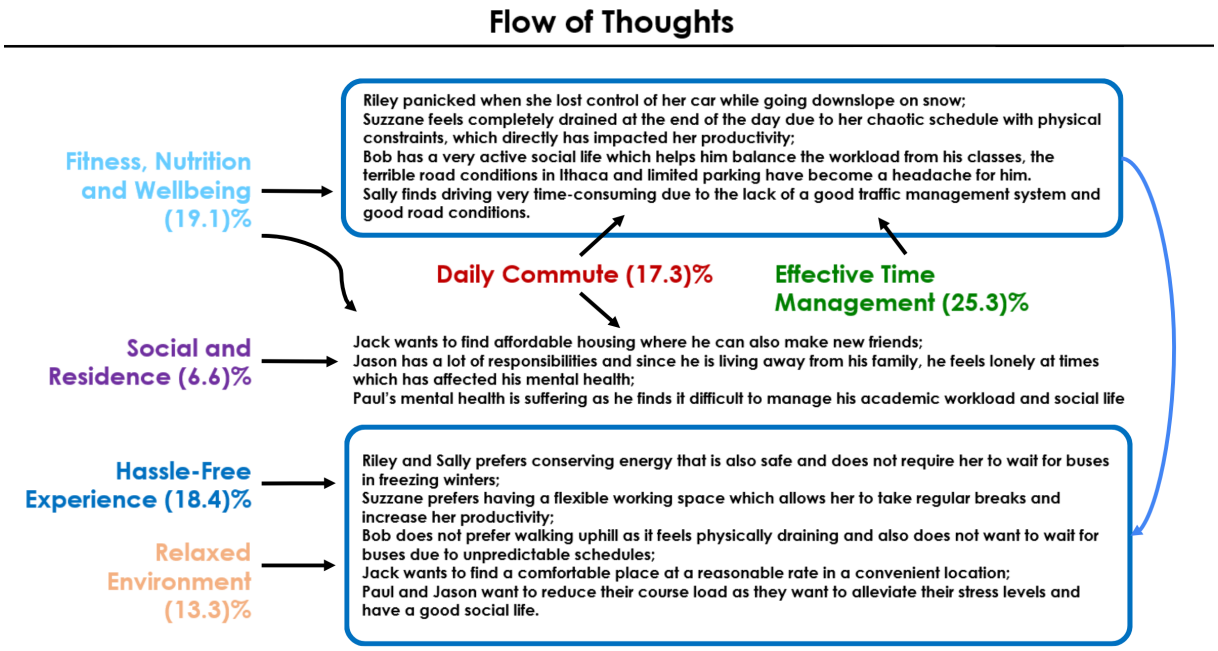


Figure 5. Flow of Thoughts

Key Areas and Insights

Time Management (25%)

- Time management is crucial, representing about a quarter of our focus.
- Many struggle to balance schoolwork with social life and taking necessary breaks to stay fresh.

- Keeping classrooms at the right temperature improves focus and productivity, playing a significant role in managing time well.

Daily Commuting (17.3%)

- Commuting challenges include traffic congestion, inconsistent public transportation, and poor traffic control.
- These travel hassles can cause stress and affect productivity.
- Making commuting smoother could significantly improve daily satisfaction and productivity.

Fitness, Nutrition, and Well-being (18.4%)

- Total health, including physical and emotional well-being, is a priority.
- It's vital to balance school, social life, and health, especially for those far from home.
- People value simplicity, as shown by the desire for easy routines and avoiding physically demanding tasks like climbing steep hills or waiting in cold bus stops.

Hassle-Free Experience (18.4%)

- Simplifying everyday tasks and routines can save energy and reduce stress.
- New, innovative solutions can enhance productivity and improve quality of life.

Calm Environment (13.3%)

- Comfortable, affordable homes and a reduction in homework contribute to a less stressful, happier environment.

Social and Living Situations (6.6%)

- Although the least emphasized, social and living situations highlight the need for connection and belonging.
- Finding affordable homes that foster friendships is essential.

The Flow of Thoughts map demonstrates how different groups are interlinked. Although some areas are more critical, improving one can positively impact others. This emphasizes the importance of considering the entire picture when solving issues, ensuring we address the diverse yet interconnected needs of our target audience.

2.4.4 Personas

After discerning the emotional data connections within the Analytic Hierarchy Process (AHP) and Flow of Thoughts, we have developed seven personas that serve as general representations of the emotional data we have discovered.

Riley is a **junior at Cornell University**, who got a car due to the unpredictable bus schedule & hilly roads.

She enjoys driving her car in the summer since the weather is beautiful. Most of Ithaca is on a hill so it is a pain to walk. There have been times when **driving downslope that she lost control of her car** in the snow for a couple of minutes.

This can be extremely scary not to say **life-threatening** for her and those driving around her. She needs a solution that will ultimately **conserve energy, is safe, and does not require her to depend on the buses in the winter**.

Jack is an **international student** who is **new to the country** and is **overwhelmed** with **decision** of **renting a house** for an **entire year**.

Despite **staying alone** previously and having a lot of friends back at home, Jack **feels lonely** and finds it **hard to adapt** in the **new place**. **Making new friends** is an important criteria for him while renting.

To find a house that, even if slightly **far** away **from university**, is **closer to his peers** while also being **affordable** and a **comfortable** place to stay in for an **entire year**.

Suzzane is an **international student in Canada**, pursuing a master's program in Applied Computing at the University of Windsor. She recently moved to the country and had to **share accommodation** due to a high influx of international students. **Her course is mainly conducted online via Zoom, which she enjoys, but she faces challenges**.

She spends long hours on her laptop attending lectures and **needs to sit near a charging port due to limited space**. Since she lacks a study desk, she sits on her mattress, leading to lower back pain due to poor posture. Her demanding schedule and constrained living conditions leave her physically and mentally drained, **impacting her study productivity and leaving her with limited personal time.**

Jason is an **international student** studying computer science at the University of Victoria in Canada. He recently moved into a new room with three other students on campus. He's upset about **transitioning from online Zoom lectures to in-person classes**, as it means being far from his family in China. He's also **stressed about preparing for graduate school** applications and has turned to smoking as a coping mechanism for his loneliness and anxiety.

Jason is finding it challenging to **adapt to in-person learning** and is reluctant to study and take tests on campus. **To alleviate some pressure, he plans to drop some courses and intends to travel with friends.** Additionally, he's considering paying for assistance from institutions to help him with his graduate school application process.

Bob, a first-year Cornell grad student in downtown Ithaca, **faces traffic/road issues, parking troubles, making him late to class.**

He did not end up getting the campus parking permit, but finding parking is a headache, and alternatives like buses are unreliable due to unpredictable schedule. This has led him to skip class.

Walking to campus is tough due to the hills. He wants to find a solution to this.

Sally is an **international student** attending Boston University studying for a master's degree. She studied at the University of Rochester for her bachelor's degree and made a lot of friends there, who then also moved to Boston either for work or to study there. **Although she has many old friends who moved to Boston, she does not hesitate to meet new friends at Boston University.**

Her sister also studied in Boston at the Babson College. **When deciding where to rent an apartment, an essential factor is to consider renting a place mid-way between both schools.** Due to the bad traffic, terrible road conditions, and shortage of parking spaces on campus, she prefers to Uber rather than drive to school, but she drives when it's a weekend while going out to a restaurant or grocery shopping.

Paul is a German international student who studies in the Netherlands. He visited a university in the US, as an exchange student for a single semester when he was an undergraduate student.

As a regular socialite, Paul regularly visits pubs and restaurants, in and around his college and is a person who knows the lay of the land and is a textbook extrovert. While Paul is a hardworking individual with a strong work ethic, he struggles to understand the work culture around him and wants to find ways to take advantage of his surroundings to be more efficient and socially active.

Figure 6. Personas

2.4.5 Personas Fleshed Out

The personas were subsequently developed in greater detail through a process known as "fleshing out." This involved making specific inferences for six of the seven personas, thereby enhancing their individuality and realism. This facilitated a more comprehensive conceptualization of the distinct requirements of individuals who may engage with our product in forthcoming instances.

Name: Riley
Age: 21

Social life: She has quite an active social life going out with friends on the weekend. She lives with 2 other roommates in Downtown Ithaca very close to the commons. On the weekends she likes to unwind and go over chores that she did not get an opportunity to do over the week. Occasionally she likes to visit family in New York City.

Work-life: She is a junior at Cornell University studying Electrical Engineering. Most of her weekdays are devoted towards classes as well as looking for an internship. Additionally, she is also working with a professor doing some research thinking of also getting her MEng. degree.

Key Attributes:

- Like to go out with friends and explore new places in and around Ithaca
- Likes to spend her weekends unwinding
- Has watched Mamma Mia! 35 times
- Has a ton of plant babies

Quote: "The couple minutes that I lost control of my car going downslope were super scary, and I kept pushing the brake since I panicked."

Name: Jack
Age: 22

Social Life: He lives in downtown with 2 other random roommates, Tom (25) and Jerry (20) who are now his friends. He found it tough to decide where to stay when he initially came to the country. He is actively looking to socialize, so he attends all events he can fit into his schedule. He also prefers to talk to his friends and family back home over call.

Work Life: He is currently completing his MSc Finance in HEC Montreal in Canada. He also took on the role as an international student ambassador at his university so that he can interact with more people. He is also looking to work part time as a Teaching Assistant when he possible.

Key Attributes:

- He loves to socialize
- He is not afraid of moving to new country
- He feels lonely in new country
- He loves make new friends
- He likes to study

Quote: "Finding a comfortable place at an affordable rate in a convenient location where I can socialize with people since it is extremely tough"

Name: Suzzane
Age: 22

Social Life: She is quite a private person and does not have much social media footprints. But she do enjoys hanging out with few of her close friends on weekends and take a break from a hectic schedule. She tends to complete her remaining household chores like laundry and organizing her space on weekends. She has a jolly nature and understands the importance of personal space and time.

Work Life: She is currently a First Years Masters student in Applied Computing at University of Windsor, Canada. She has a background as a Front End Developer and has worked on several live company projects. Her week is mostly engaged in lectures and assignments. She does love exploring some freelancing project work during her free time and is actively looking out for opportunities to work.

Key Attributes:
- She is a private person and does not like to socialize
- She enjoys hanging out with her close friends during weekends
- She has a jolly nature and always is ready to tackle with life challenges

Quote: "She feels she does not get adequate self-time and it directly affects her productivity in studying."

Name: Jason
Age: 24

Social life: Jason is a person who loves playing video games. He usually spends lots of time playing games with his friends. More importantly, he was less motivated to study in school because of the online class during the Covid-19. He is struggling with his course loads and graduate school applications.

Work Life: He is a fourth year undergraduate student, he plans to graduate in time, then will receive satisfactory graduate school offers. He needs to do his assignments on weekends, after that he would play video games, or sleep at home.

Key Attributes:
- He does not like to socialize with his friend
- He can not adjust the on campus learning way
- He wants to stay with his family
- He likes to eat all kinds of delicious food
- He refuses to do any type of sports
- He is a friendly and dependable guy

Quote: "The first week of school was overwhelming due to challenging classes and a busy syllabus. Unfortunately, you've turned to cigarettes as a stress relief, and you're considering reducing your course load due to the hectic lifestyle."

Name: Bob
Age: 22

Social life: Bob is a people person who loves going out and meeting new people. On weekends, he frequently hosts parties at his home or engages in outdoor activities such as hiking and tennis with friends. He is easygoing and enjoys being around people.

Work-life: On weekdays, he is just like any other Cornell student, preoccupied with schoolwork. He drives himself to class and group meetings at school. He actively participates in group projects and is enthusiastic about what he is learning. He frequently attends career fairs and is always open to new job opportunities.

Key Attributes:
- He is a people person who enjoys socializing.
- His primary way of transportation is his car.
- He has a fairly full schedule every week.
- He is a man full of energy.

Quote: "I have a full schedule every day, and my house is only used for sleeping and partying. I have a heavy workload during the weekdays and a lot of social activities going on on weekends. Since I drive a lot, the terrible road conditions in Ithaca and the limited parking on campus give me a headache."

Name: Sally
Age: 22

Social Life: She lives along on weekdays and with her sister on weekends, about 15 minutes drive from her university. She likes to socialize with schoolmates, but attending clubs is hard since she doesn't like that close to the university. She prefers to drive when the destination isn't to go to school to go to classes.

Work Life: She is currently enrolled in a program where she has to go to the office to work to earn credit for her degree. The work starts around mid-October, so in the current stages, she has to go to school.

Key Attributes:
- She loves to grocery shop
- She lives with her sister
- She hates to drive to school
- She loves make new friends
- She has to go to work regularly

Quote: "Driving to school regularly is time-consuming and really inconvenient."

Figure 7. Personas Fleshed Out

2.4.6 How Might We Capabilities Diagram

The "How Might We (HMW) Capabilities Diagram" provides a structured approach to designing a product aimed at simplifying and enhancing the daily experiences of college students. It asks the core question: How Might We design an affordable and portable product that simplifies and brings joy to the everyday student experience?

HMW Capabilities Diagram

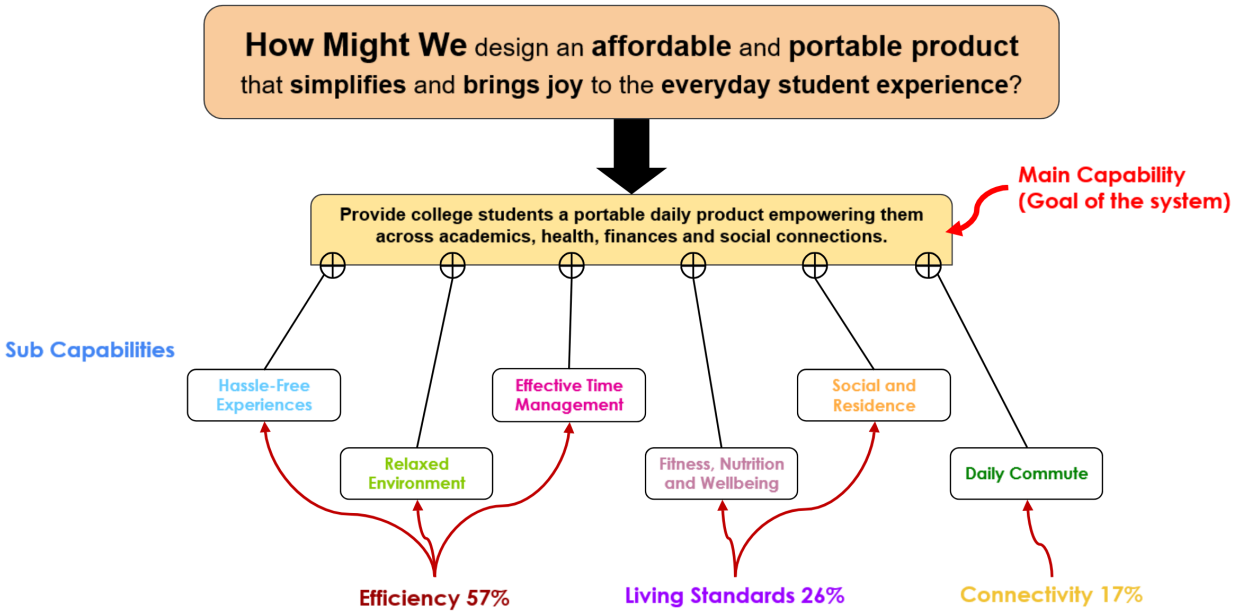


Figure 8. HMW Diagram

Main Capability (Goal of the System)

Provide college students with a portable daily product empowering them across academics, health, finances, and social connections.

Sub-Capabilities and Insights

Efficiency (57%):

- Hassle-Free Experiences: Making everyday tasks simple and intuitive, reducing time and stress.
- Relaxed Environment: Creating a peaceful atmosphere with meditation tips, noise control, and workspace organization.
- Effective Time Management: Tools for scheduling, prioritization, and reminders.

Living Standards (26%):

- Fitness, Nutrition, and Well-being: Providing health tracking and access to fitness, learning, and diet resources.
- Social and Residence: Making it easier to connect with friends and improve living situations.

Connectivity (17%):

- Daily Commute: Features for travel planning, ride-sharing, and linking with public transport to minimize travel hassles.

The HMW Capabilities Diagram illustrates a clear focus on creating a product that simplifies and enhances students' daily lives. Our solution will aim to provide a one-stop platform that empowers students to achieve their goals while fostering well-being, connectivity, and efficiency.

2.4.7 Personas Context Diagram

A context diagram depicts the system being analyzed as a solitary process at a high level and exposes the connections that the system has with other entities. A system context diagram is a comprehensive representation of a system and its immediate surroundings. Creating a context diagram facilitates comprehension of the interactions between a system and other systems, business units, and important persons. Furthermore, it may be used to delineate the extent of a system's functionalities.

A personas context diagram is a modified version of a system context diagram that visually represents the needs, insights, surprises, and perspectives obtained from empathy sessions (personas), as well as the system requirements that may be inferred from the How Might We inquiry.

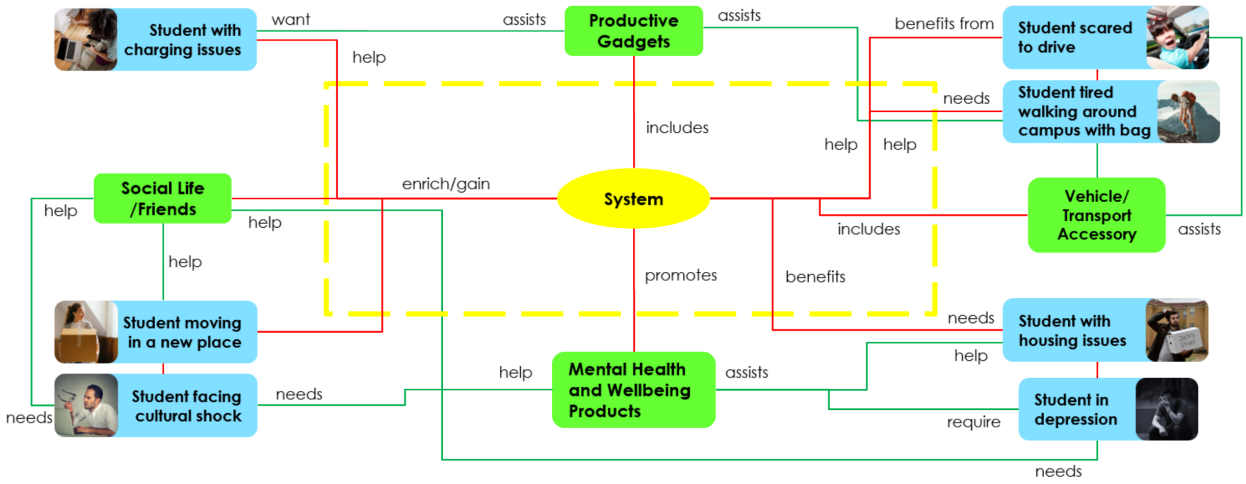
The Personas Context Diagram enables us to do the following actions:

- Determine the connections between the system we need to develop and the external entities.
- Determine the connections between the external entities (these connections are N/I/S that we have analyzed and may need improvement or creation).
- Establish connections between the system and external entities

The personas context diagram was created by our team for a system that offers several benefits, including providing assistance, support, and promotion of an active and healthy lifestyle, property management solutions, and enhancement of mental health.

Subsequently, these criteria were correlated with the primary personalities that were discovered throughout the empathy sessions. The figure illustrates a bilateral relationship between each persona or external entities and the system.

Personas Context Diagram



The Personas Context Diagram is a visualization of N/I/S (subcategories and relationships)+ Personas (POVs) + HMW question. External entities can be anything (people, things…).

- are external entities that are also our Personas (POVs)
- are external entities, but not Personas (in our case we decided to not put those for now, but they might appear later)

Figure 9. Personas Context Diagram

3. Ideate

3.1 Ideate Sessions

3.1.1 Session 1

In our initial ideation session, we explored the daily lives of college students, analyzing their pain points and identifying areas for improvement. Each team member contributed unique ideas based on conversations with students, market research, and current trends in education. Our brainstorming session generated about 15 different concepts, which we grouped into categories like handy study apps, tools to promote personal health and well-being, and products that champion a sustainable lifestyle. We evaluated each idea for its creativity and feasibility, green-lighting any concept that received at least one thumbs-up.

3.1.2 Session 2

The second session focused on breaking the mold and developing unconventional product ideas. We encouraged blue-sky thinking, resulting in eight innovative concepts. After discussing the potential impact and feasibility of each idea, we voted on those with the most promise for further exploration.

3.1.3 Session 3

In our final session, we refined our ideas, combining the best elements from different concepts to form cohesive product proposals. We narrowed the list down to seven ideas:

- HotPod: A portable jacket heating device that reduces the need for bulky layers in extreme winters.
- despac: A backpack with an integrated desk and power bank, making it easy to work on the go.
- Head Massager: A stress-relieving device that helps students relax after a long day. Its measured vibrations are designed to soothe tired minds after classes and work.
- Shady: A portable shade that protects devices from glare and weather, ensuring usability in all conditions.
- WristTap: A student ID wristband that, along with a student ID card, can be used to access buses and doors more easily.
- PortaBowl: An all-in-one utensil that allows students to cook and eat from the same device, eliminating the need for multiple utensils.
- AFirmClock: An alarm clock that delivers positive affirmations to help increase confidence and self-belief.

3.2 Design Space Tradeoff

From the diagram, "Shady" is a highly feasible product with less desirability; "HotPod" has a good balance of desirability and feasibility, making it an attractive option for development. "despac," while desirable, is less feasible. “HeadMassager” has a moderate desirability and the lowest feasibility compared with the other three products.

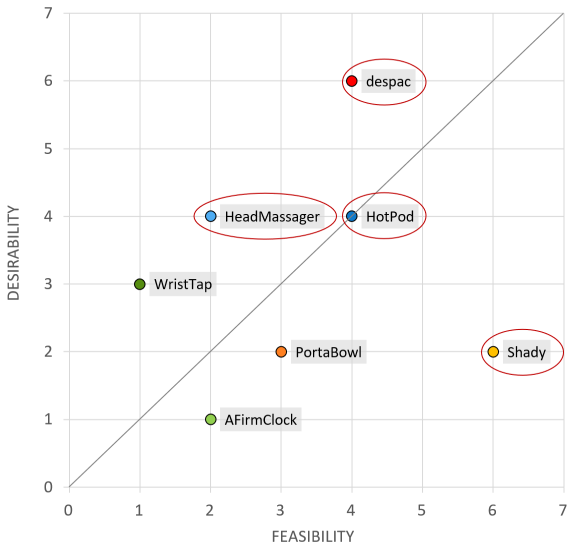


Figure 10. Desirability vs Feasibility Chart

3.3 Personas Concept Sketch

3.3.1 despac

The "despac" is an innovative 3-in-1 solution designed to streamline the mobile study experience for students. Think of it as a super backpack that not only stashes your laptop but also doubles as a comfortable desk and even powers up your tech gear on the go. This backpack tackles typical student hassles, offering a mobile desk that lets you ditch the hunch-over-your-laptop habit and promotes better posture. Plus, you won't need multiple chargers anymore because it comes with a built-in power bank, allowing you to break free from being stuck next to wall sockets. Moreover, the "despac" reduces the burden of carrying several heavy bags by integrating essential functionalities into one compact design.

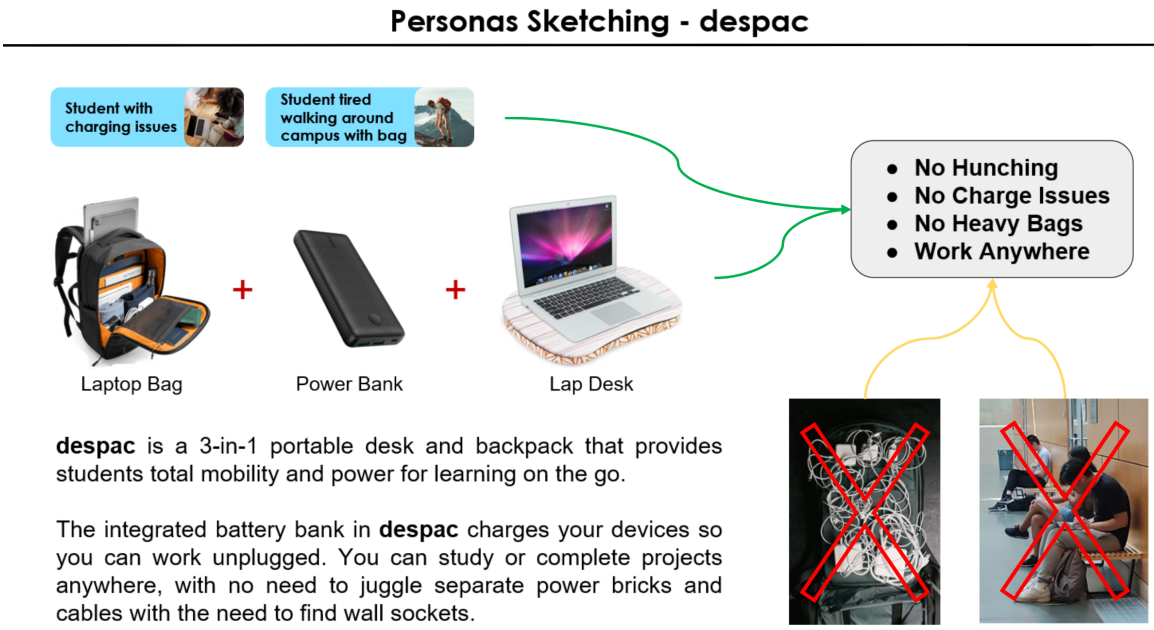


Figure 11. Personas Sketching - despac

3.3.2 HotPod

The "HotPod" is an innovative heating device that snaps into clothing, providing customizable warmth for those braving the cold. Perfect for students and people who spend a lot of time outdoors, the HotPod eliminates the need for heavy layers, offering warmth and comfort in extreme winters.

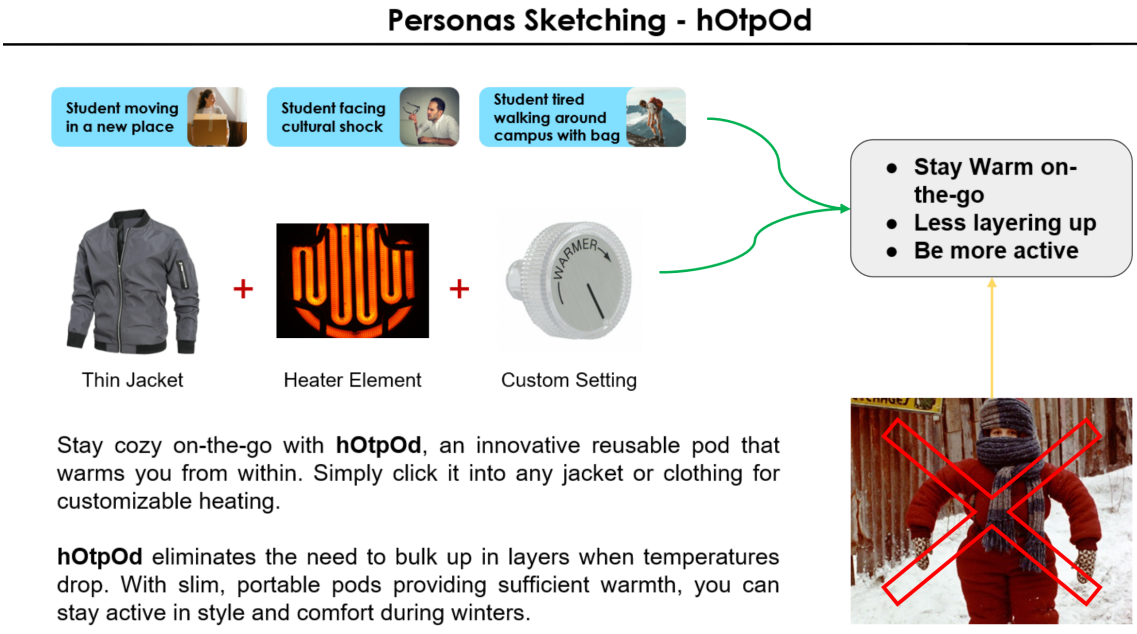


Figure 12. Personas Sketching - HotPod

3.3.3 HeadMassager

The "Head Massager" is a personal wellness device designed to alleviate stress and mental fatigue, particularly for students grappling with the pressures of academic life. The Head Massager provides a customizable massage that targets the scalp with pinpoint accuracy, easing depression symptoms, reducing stress levels, and helping students relax after a long day.

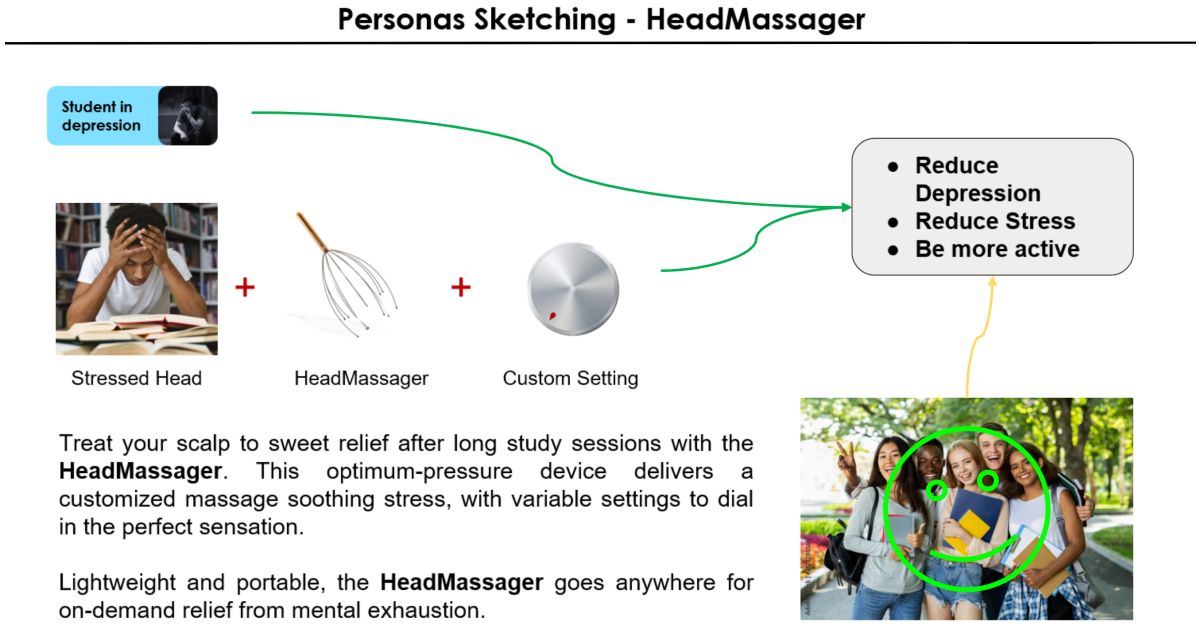


Figure 13. Personas Sketching - HeadMassager

3.3.4 Shady

"Shady" is a practical accessory designed to enhance the outdoor use of laptops and phones by providing shade and weather protection. This accessory ensures clear visibility of screens in bright conditions, reducing the need to squint and allowing users to be more active outdoors without worrying about weather-related damage. It is a simple and effective solution for students and mobile professionals who frequently work in various outdoor settings.

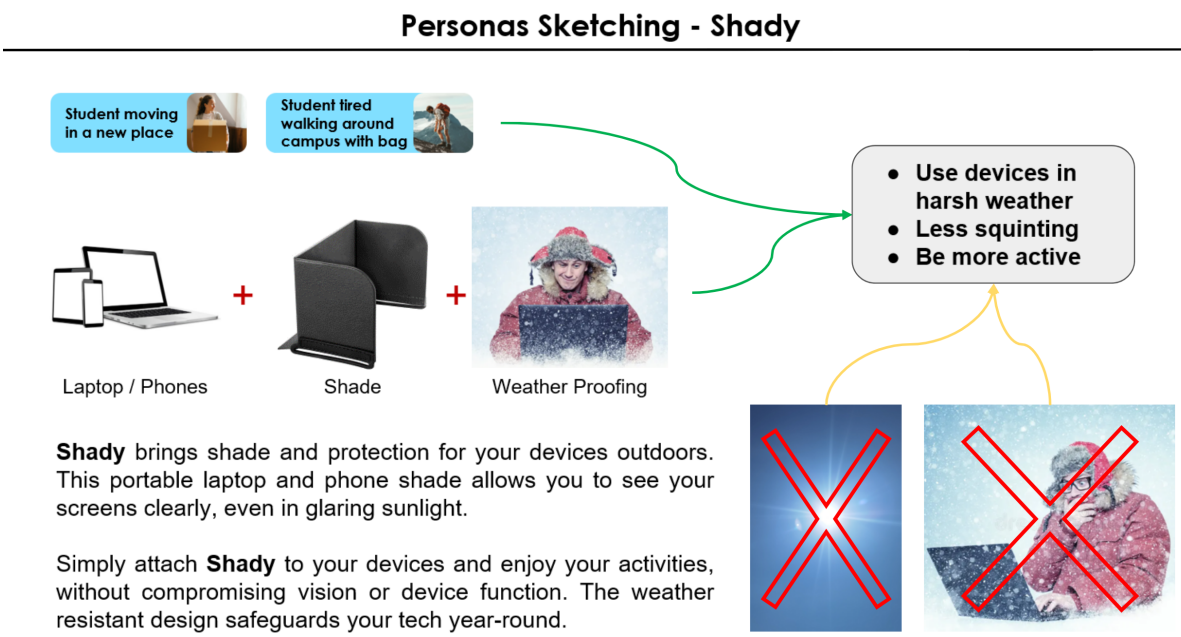


Figure 14. Personas Sketching - Shady

3.4 Design Review 1

We received positive feedback on our branding efforts during the first review with industry advisors. Our team got a lot of kudos for the deep dive we did into understanding our users, and folks really appreciated how well we built and used personas that genuinely clicked with each other. Opinions on our innovative designs were a mixed bag. Our portable backpack desk was compared to a "Swiss army knife," which was a compliment to its versatility, but it came with a caution to evaluate the necessity of all its features. A safer heating system was suggested to reduce burn risks. The head massager was seen as having potential value, while the shade's lack of innovation was questioned.

Our team got solid props for the way we laid out and explained our ideas, showing that we are on point when it comes to sharing on what we have been working. The following showcase the feedback received from the design review 1 held with the industry advisors:

Review 1 Feedback

Branding:

- The team's branding efforts were met with positive feedback.

Empathy Fieldwork and Problem Definition:

- The team was commended for excellent empathy fieldwork.

- The creation and application of personas were noted as well-executed, with personas effectively relating to each other.

Product Concepts:

- The portable backpack desk was likened to a "Swiss army knife," with a caution to consider whether all features are necessary.
- For the heating element to jackets, there was a warning about the potential risk of burning, suggesting a careful review of safety measures.
- The portable shade concept raised questions about its innovativeness.
- The head massager was recognized as potentially beneficial for individuals who suffer from
- migraines.

Overall Organization and Clarity:

- The organization and clarity of the presentation/ documentation done by the team were praised.

3.4.1 Survey / Industry Advisor Feedback

After our initial design review, a survey was conducted among industry advisors and students to determine which concept held the most appeal. The results showed that the "Shady" portable shade and the "HotPod" heating device were clear favorites. These preferences matched the insights from our design space tradeoff diagram.

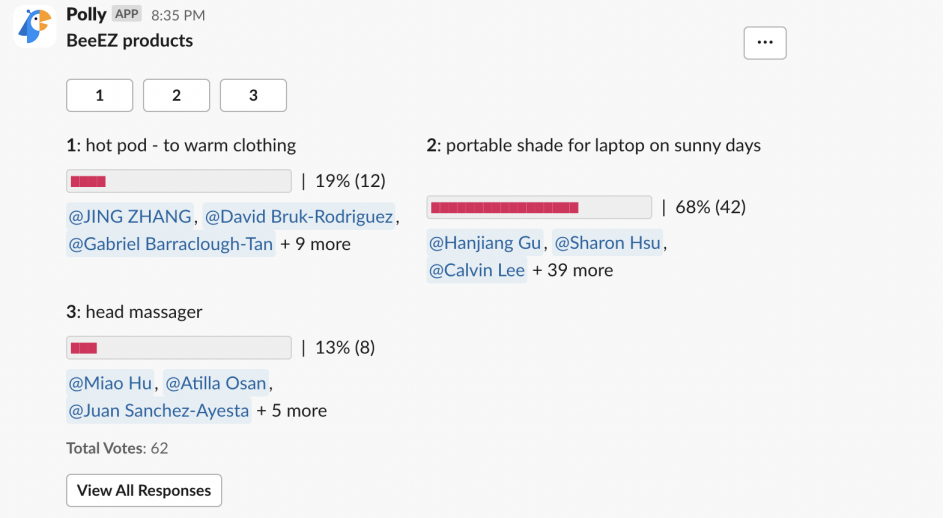


Figure 15. Poll Feedback

Based on additional feedback from industry advisors and conversations with more students about their preferences among our top four product ideas, we concluded that the **HotPod** was the most desired and met the current need of the hour.

3.5 Further Ideation

3.5.1 Historical Solutions

In the past, people have tried different ways to stay warm in extremely cold weather. However, many of these solutions focused on either cooling through direct contact or using heat transfer methods that change from one form to another. Unfortunately, the problem with these approaches is that they often lead to warming only specific parts of the body instead of ensuring an even distribution of warmth throughout.

Looking back, we see a trend of relying on cooling through direct contact or phase change heat transfer to address extreme winter conditions. The challenge, though, is that these methods tend to create hotspots, warming certain areas intensely while leaving others comparatively cold.

Recognizing this limitation, there's a need for new, smarter solutions. We're seeking innovative approaches that go beyond the issues of uneven heating, providing a more consistent and widespread warmth across the body. This pursuit aims to ensure enhanced comfort and well-being in the face of harsh winter climates.

3.5.2 Proposed Solution

To address the challenge of localized heating and prioritize human safety, we devised a solution centered around the principles of convective heat transfer. Our concept involves the strategic dispersion of heat throughout the jacket area for enhanced effectiveness. The key component in this design is a heating element engineered to generate a consistent amount of heat in accordance with its capacity and input power. This generated heat is then conducted to an aluminum wire mesh, effectively transferring thermal energy.

The wire mesh, upon heating, becomes a pivotal element in our system. A cooling fan is integrated into the design, automatically activating to propel air through the heated mesh. Leveraging the expanded surface area of the mesh facilitates accelerated heat absorption by the air, which is then expelled through top vents. This orchestrated process ensures a swift and comprehensive circulation of warmth within the jacket, mitigating the risk of localized heating.

In essence, our innovative product is built on the premise of efficient convective heat transfer. By combining a controlled heating element, thermally conductive mesh, and a strategically positioned cooling fan, we've engineered a solution that maximizes the effective contact surface area, allowing for rapid heat absorption and dissemination. This approach not only addresses the challenge of localized heating but also prioritizes the safety and well-being of the user in cold weather conditions.

4. Prototype & Testing

4.1 Process Overview

Prototyping transforms our ideas into tangible forms, starting with simple models known as 'low-fidelity prototypes,' which can be as basic as sketches or paper models. These evolve into 'high-fidelity prototypes,' which are more refined and closely resemble the final product in terms of aesthetics and functionality.

As we refine our prototypes, user testing is crucial to identify what works and what needs improvement. We presented early versions to users and asked them to complete tasks while thinking aloud so we could understand their thought processes. Their feedback was invaluable, often revealing unexpected design flaws or needs that we hadn't thought.

This iterative cycle of designing, prototyping, testing, and refining continues until we are confident that the product is user-friendly and meets the target audience's needs and expectations.

4.2 Design 0 Prototype

Design 0 is the starting point, representing the initial concept or draft from which the product's design journey begins. It embodies the basic idea without the complexities that will come later in the design process. When working on Design 0, we focused on the core functionality and primary value proposition of the product, setting the foundation for all subsequent iterations and improvements.

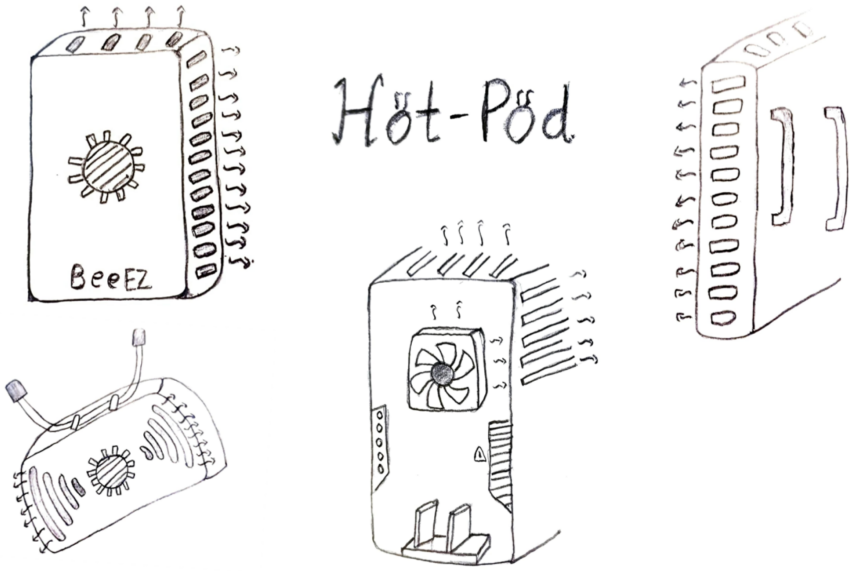


Figure 16. Design 0 Concept Drafts

4.2.1 Overview and Design Concepts

Based on initial research, we decided to utilize convective heat transfer with a heating element and fan for the HotPod to reduce winter layering.

Our first design prototype used cardboard to explore the functional mechanism. From there, we incorporated components like a power source, heating element, fan, control board, and temperature sensor to create a working model.

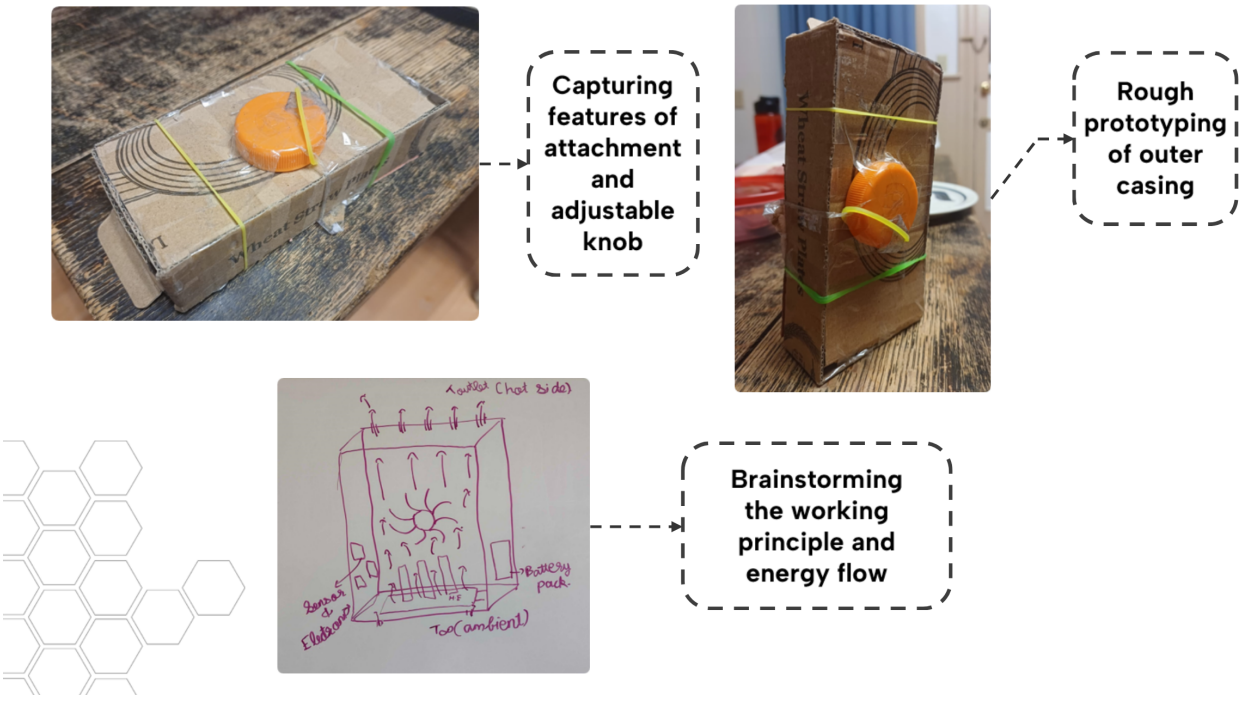


Figure 17. Design 0 Cardboard Prototype

This iterative approach allowed us to evolve the HotPod from an early conceptual model into a more sophisticated design incorporating electrical components for targeted warmth.

4.2.2 Testing

The initial cardboard prototype was tested by various users, and additional empathy field data was collected for Design 0. This feedback will further refine the product concept, identifying areas where the HotPod could be improved.

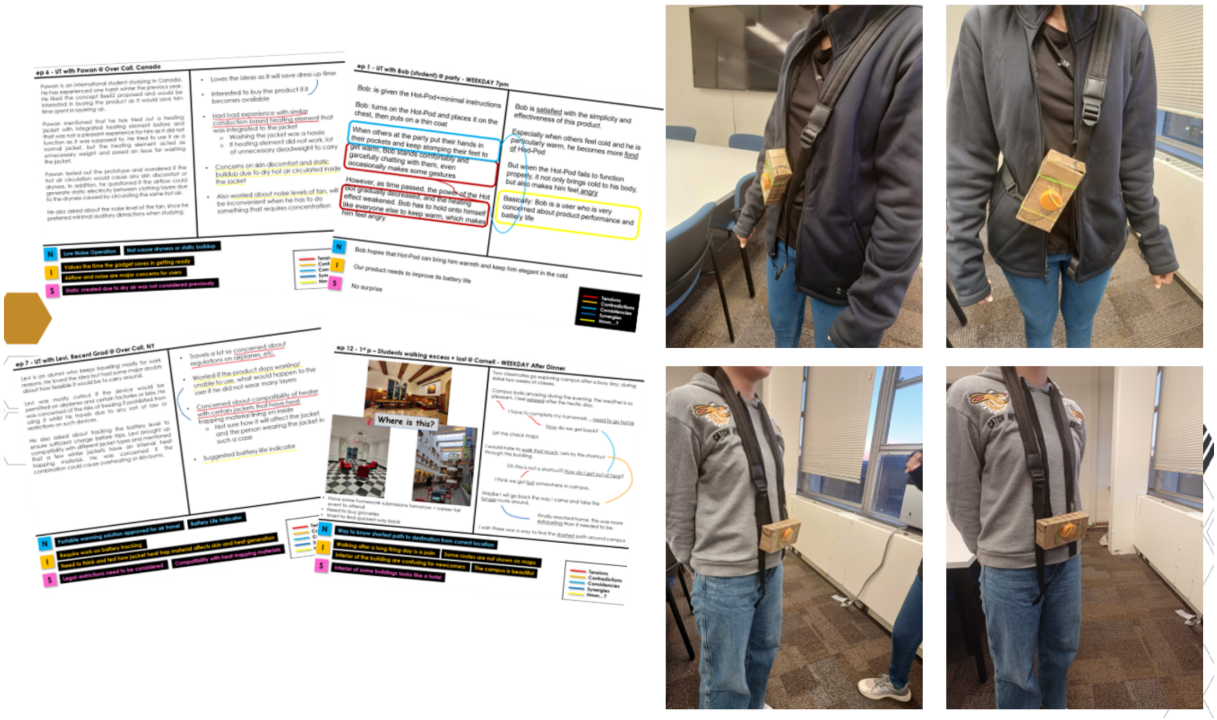


Figure 18. Design 0 Testing

4.2.3 Unpacking

Similar to previous unpacking processes, we analyzed the data collected during testing to identify patterns, insights, and user needs.

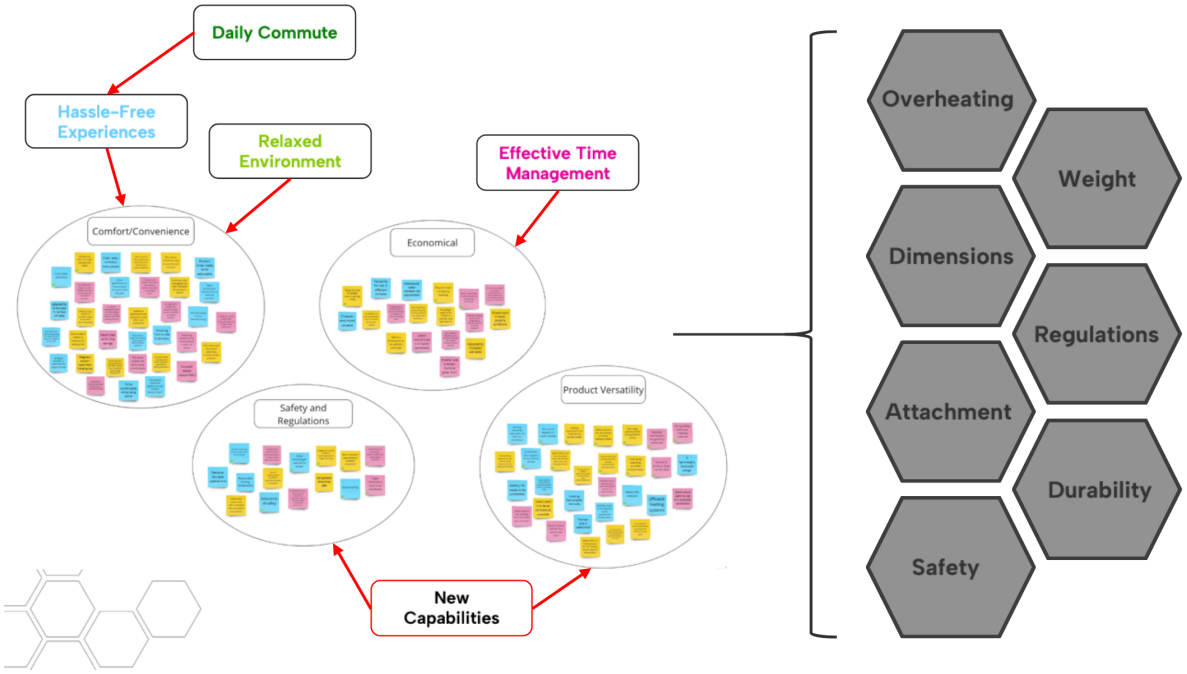


Figure 19. Design 0 Unpacking

4.2.4 Flow of Thoughts

We visualized the connections between user feedback, our initial prototype, and required design changes using a Flow of Thoughts map.

From the Flow of Thoughts, we see a range of inputs essential for refining our product. While users appreciate the HotPod's ability to streamline their winter layering, they voiced concerns stemming from their experiences with similar products.

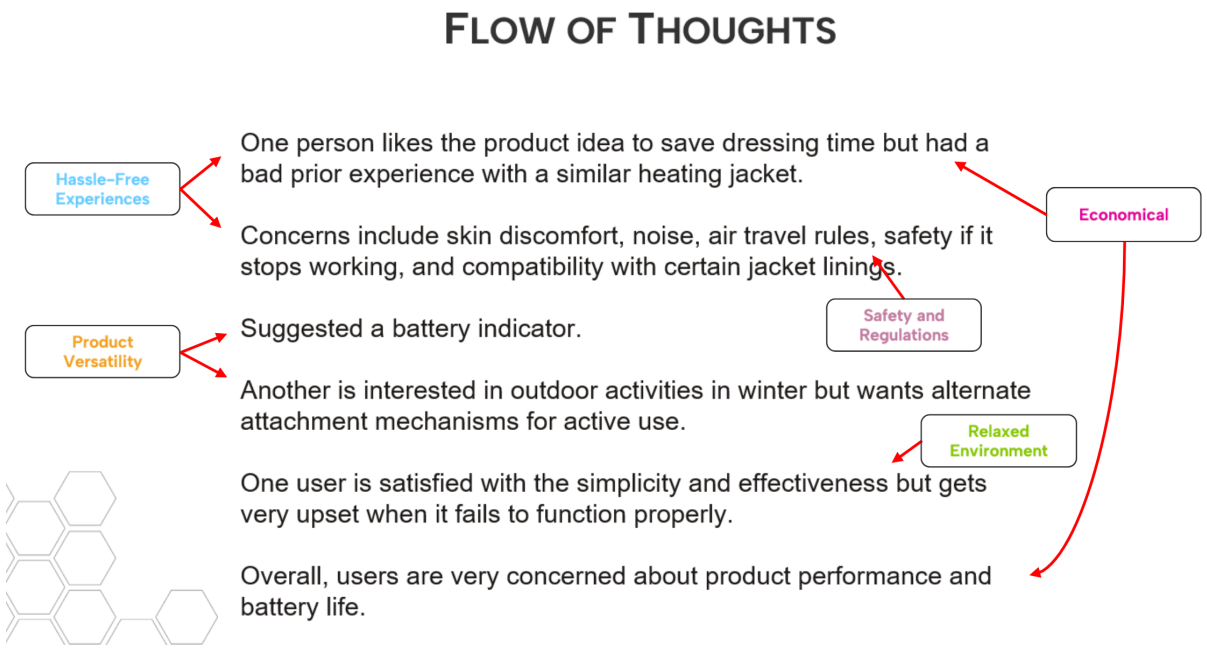


Figure 20. Revised Flow of Thoughts

Key Insights and Adjustments

- Battery Indicator: Users expressed the need for a battery indicator to enhance user-friendliness.
- Secure Attachment Mechanisms: Alternative attachment mechanisms are needed to ensure the HotPod remains secure during physical activities.
- Simplicity and Effectiveness: Users praised the product's simplicity and effectiveness, highlighting that our design direction is promising but requires a focus on reliability.
- Battery Life and Performance: Particularly for the harsh Ithaca winters, ensuring adequate battery life and consistent performance is crucial.
- Comfort, Safety, and Affordability: Enhancing comfort levels, ensuring regulatory compliance, and keeping costs student-friendly are essential to meet user expectations.

4.2.5 Revised How Might We Diagram

Our extensive user testing and fieldwork revealed key concerns around overheating, weight, dimensions, regulations, and durability. These insights enabled us to refine our "How Might We" diagram and prioritize focus areas.

Revised HMW Diagram Key Capabilities

- Straightforward and Hassle-Free: Ensure the HotPod is easy to use and enhances user experience.
- Cost-Effective: Make the product budget-friendly for students.
- Comfort and Stress-Free Ambiance: Provide a comfortable and stress-free ambiance with targeted warmth.
- Safety Compliance: Ensure compliance with safety standards and regulations for well-being.
- Versatile and Adaptable: Design a versatile product that adapts to diverse student lifestyles.

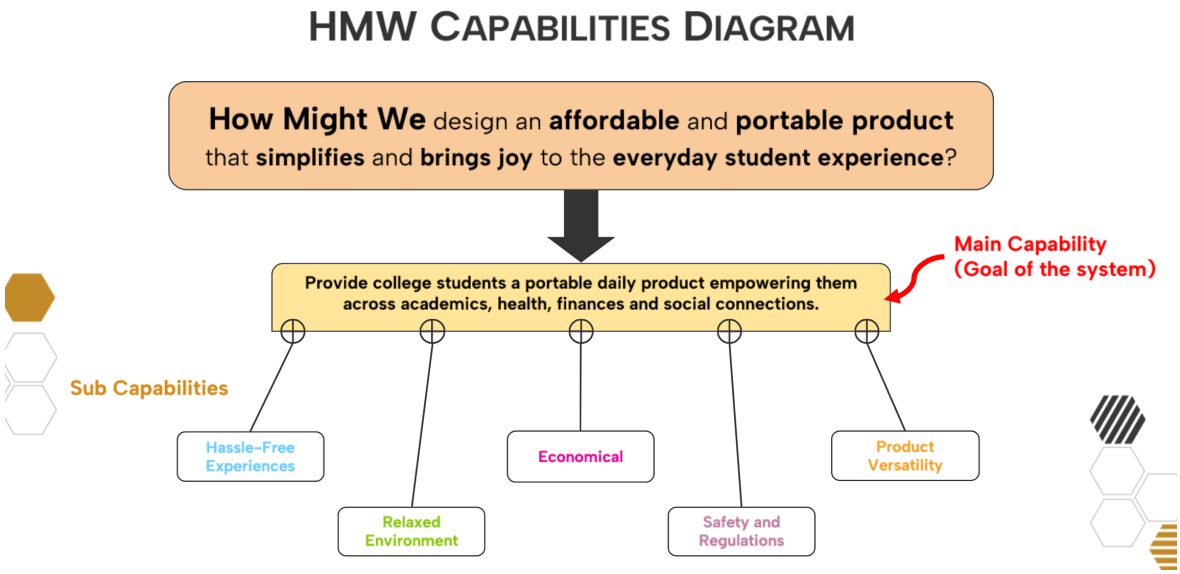


Figure 21. Revised HMW Diagram

4.2.6 Conjoint Analysis

The HotPod is a compact heating device that leverages convective heat transfer. Using a DC fan, it draws in cold air, converts it to warm air, and circulates it throughout the body. In developing the HotPod, we considered several key questions, such as:

- How should it attach to the user?
- How big or small should it be?
- What implications would this have on battery life?

- What should the price point be?

To address these questions, we used the conjoint analysis tool to identify consumer preferences and needs. Here are the top three preferred combinations based on user choices:

Option 1:

- Attachment Method: Lanyard
- Dimensions: 100x100x30 mm
- Battery Life: 8 hours
- Price: $90

Option 2:

- Attachment Method: Belt
- Dimensions: 85x85x25 mm
- Battery Life: 12 hours
- Price: $120

Option 3:

- Attachment Method: Clip
- Dimensions: 85x85x25 mm
- Battery Life: 12 hours
- Price: $180

These combinations emerged as the most popular options among students during the conjoint analysis. They offer a range of attachment methods, dimensions, and battery life to suit varying preferences, highlighting the need for a versatile design that caters to different user requirements.

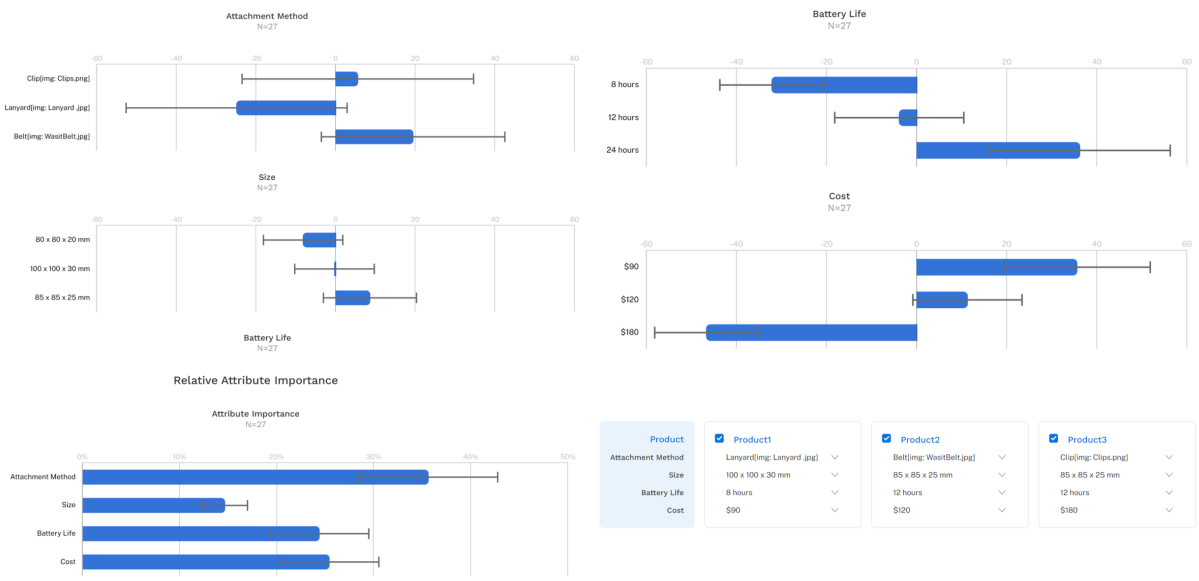


Figure 22. Conjoint Analysis

4.3 Design 1 Prototype

After completing the prototyping process for Design 0, we aimed to refine the product further with our second prototyping iteration, known as Design 1. Emotional data collected during the testing fieldwork with the Design 0 prototype, along with data from the conjoint analysis, guided the changes made in Design 1.

4.3.1 Overview

Based on the outcomes of user testing analysis with the Design 0 prototype, we gained insights into the preferred form factor. The cuboid version was perceived as bulky and inconvenient to carry or wear while walking. In response to this feedback, we decided to adopt a smaller form factor with a square base, featuring honeycomb vents for efficient air circulation and heat dissipation across the jacket area of the body.

Figure 23. Design 1 Prototype

4.3.2 Testing

The BeeEZ HotPod underwent rigorous testing to ensure it meets its requirements. Feedback from our testing sessions with 12 users provided valuable insights into the product's performance and user satisfaction. The following requirements were met:

- Rapid Heating Capability: Achieves desired temperature quickly
- Durable Construction: Withstands regular use
- Overheat Protection and Safety Measures: Prevents overheating
- Even Heat Distribution: Provides consistent warmth
- Adjustable Temperature Settings: Allows customization
- Operable in -20°C Temperatures: Suitable for extreme cold

While the BeeEZ HotPod demonstrated strong performance across key areas, two requirements were not met, providing an opportunity for improvement:

- Lightweight Design: Needs to be more portable
- Sweat and Waterproof Design: Ensures reliability

4.3.3 Design Review 2

The second review was held on November 6, 2023, to discuss the iteration process used to create Design 1. We analyzed customer preferences and market success potential. The BeeEZ team covered user testing results from Design 0, conjoint analysis results demonstrating the desirability of different product attributes, system models, market analysis, and a form and function overview of Design 1.

Review 2 Feedback

User Testing and Conjoint Analysis:

- The team received commendations for their excellent job in conducting user testing and conjoint analysis.

Design and Integration:

- Positive feedback was given on the overall design, especially the intelligent use of the convection system.
- It was suggested that transitioning from Arduino to a custom Printed Circuit Board (PCB) could significantly enhance the project.
- The 'amulet style' design for attachment was noted for its cleverness and versatility.

Innovation:

- The marketing approach was praised for being highly targeted and effective.

- Concerns were raised about the convection system's ability to evenly distribute air and its potential to dry out users' skin.

Actionable Improvements:

- Transition from Arduino to a custom PCB for improved design integration.
- Further refine the convection system to ensure even heat distribution and prevent skin dryness.
- Focus on reducing the overall weight for improved portability.

Overall Organization and Clarity:

- The project's overall organization and clarity were commended, with special mention of the team's excellent work.

4.4 Design 2 Prototype

4.4.1 Overview

Following experimental and Finite Element Analysis (FEA) on the operational prototype, we confirmed the efficacy of the convective heat transfer concept. However, feedback from Design 1 user testing highlighted the need to optimize the product's overall size and improve packaging space utilization.

As a strategic move, we transitioned from a square-based form factor to a hexagon shape. This change allowed us to maximize space utilization by creating room around the sides and extending the top diagonal, while keeping a shorter side length. Consequently, the overall size was reduced by approximately 40%, making the HotPod more compact and portable.

The refined Design 2 prototype reflects these improvements, offering a more user-friendly product that caters to the specific needs and preferences of college students. Further testing and feedback will continue to shape and refine the product.

Figure 24. Design 2 Prototype

4.5 TRIZ - Design Improvement

We employed TRIZ methodology to resolve engineering contradictions, ensuring efficient air circulation and heat dissipation while maintaining safety standards.

4.5.1 Functional Decomposition

The HotPod consists of diverse electro-mechanical assemblies and sub-assemblies, requiring a comprehensive evaluation at every level to enhance comprehension and ensure overall functionality. To achieve this, we employed the functional decomposition method, which enabled us to categorize components based on their functionalities. This approach provides a holistic view of the roles and critical importance of each component. Presented below is a functional hierarchy diagram outlining the product's structure.

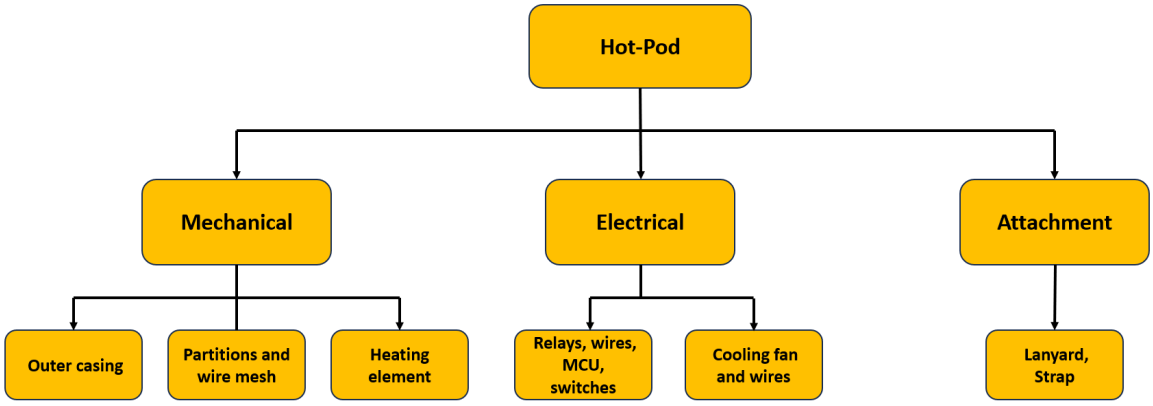


Figure 25. Functional Decomposition Flowchart

The HotPod comprises three primary sub-systems: mechanical, electrical, and the attachment mechanism linking the product to the body. The optimal functioning of the mechanical sub-system depends on the efficient performance of each component within the system, ensuring they fulfill their respective roles effectively. Take, for instance, the wire mesh, which plays a crucial role in convecting heat to facilitate proper circulation of hot air

within the jacket area. Similar critical functions are attributed to both the electrical and attachment sub-assemblies, each contributing indispensably to the overall functionality of the product.

To elaborate further, the wire mesh's effectiveness in convecting heat is pivotal for the efficient distribution of hot air throughout the jacket area, a key factor in ensuring the HotPod's overall heating performance. Similarly, the electrical sub-system plays a critical role, and its components must operate seamlessly to support the product's various functionalities. Additionally, the attachment mechanism, serving as the link between the product and the body, holds equal significance, necessitating a reliable and robust design to maintain the structural integrity and overall functionality of the HotPod. In essence, the synergy among these three sub-systems is vital for the optimal performance and reliability of the HotPod as a whole.

4.5.2 Substance Field Analysis

Through a thorough examination of historical trends and market dynamics, we identified a limitation in existing products that rely on heat conduction. These products tend to cause localized heating, targeting specific areas of the body rather than efficiently addressing a broader portion. Furthermore, the direct contact with the body in these systems may pose a risk of harm due to excessive heating.

To address these shortcomings, we employed a subfield analysis approach to understand the interactions of each element within the system. Our findings revealed an incomplete system, prompting us to enhance its effectiveness by introducing additional elements based on our innovative concept for the HotPod. Below are subfield analysis diagrams. The dotted lines show ineffective systems and solid lines depict a complete and effective system. Other than that, Th stands for thermal, Me stands for mechanical and E stands for electrical.

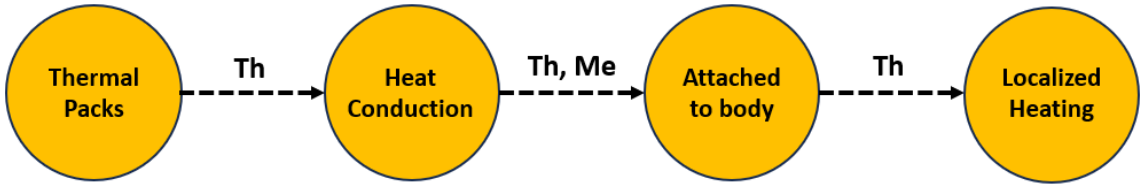


Figure 26. Substance Field Analysis - Existing Systems

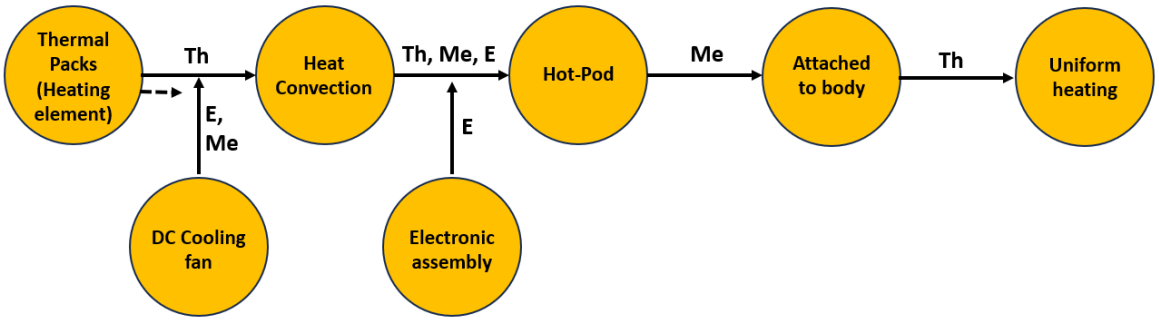


Figure 27. Substance Field Analysis - HotPod

4.5.3 Engineering Contradictions

In addressing crucial performance features for HotPod, including effective air circulation, heat dissipation from mesh, and human safety, the utilization of engineering contradictions and TRIZ methodology proves instrumental. The formulation of engineering contradictions serves as the initial step, denoted as "a" in the flow chart, where conflicts between desired improvements are identified. These conflicts often manifest as trade-offs, such as enhancing air circulation while compromising heat dissipation or vice versa.

Moving to the next phase, "b" on the chart, the contradictions are classified using the TRIZ 39-Parameter Matrix. This matrix systematically categorizes engineering parameters, aiding in pinpointing the specific conflict and aligning it with known inventive principles. For instance, if the contradiction involves enhancing air circulation at the expense of heat dissipation, the matrix guides towards relevant TRIZ principles that historically resolved similar conflicts.

The subsequent step, "c," involves consulting the TRIZ 40 Inventive Principles (40-IP) to propose potential solutions. These principles offer a wealth of inventive strategies derived from extensive analyses of successful innovations. Applying these principles in the context of HotPod ensures a systematic and creative approach to resolving engineering contradictions, ultimately leading to improved performance, efficiency, and safety. This comprehensive flow chart provides a roadmap for dissolving engineering contradictions in HotPod, ensuring a holistic and innovative problem-solving approach.

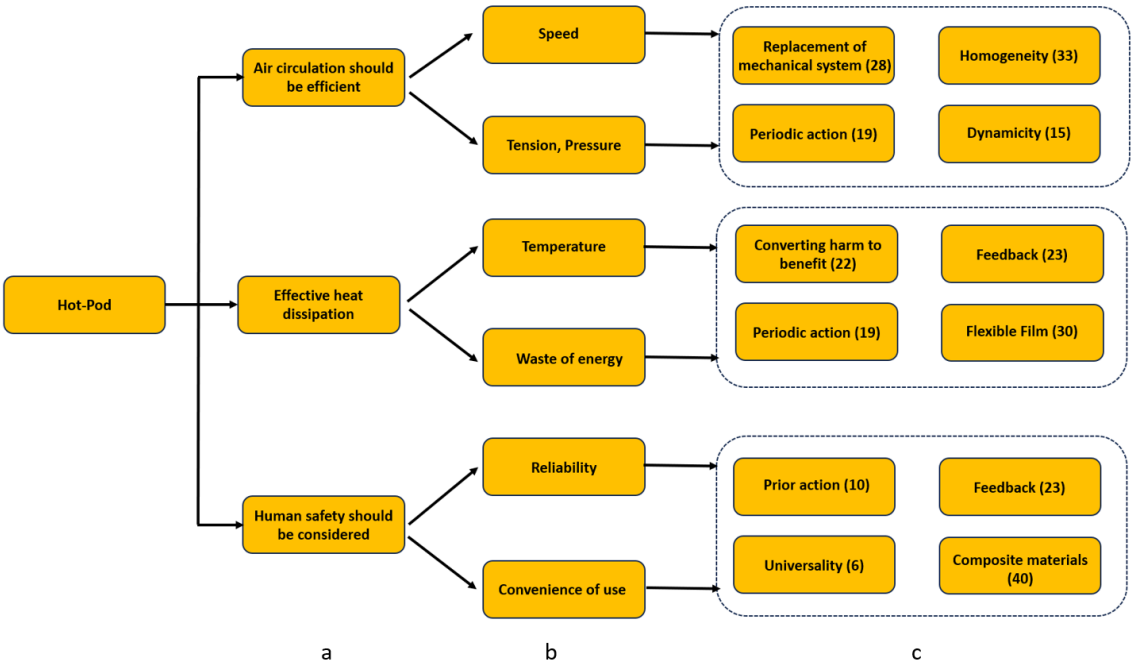


Figure 28. Engineering Contradictions

4.6 Engineering Characteristics

4.6.1 Analytical Calculations

To assess the thermal and mechanical loads of our product systematically, we conducted analytical calculations based on fundamental equations. Our attention was particularly directed towards the heating element and cooling fan, the primary consumers of input power. Utilizing basic convective heat transfer equations, we determined the necessary power load for the heater and the required Cubic Feet per Minute (CFM) for the cooling fan. These calculations provide a grounded foundation for optimizing the performance of these critical components, aligning with our commitment to precision and efficiency in the design and functionality of our product.

Step 1: Calculating the power load of heater

We know that:

$$Q = mC_v\Delta T$$

Mass of input air, $m = 0.01327\ kg$

Specific Heat of air at Const Vol, $C_v = 0.718\ kJ/kgK$

Temperature Difference required, $\Delta T = 40\ K$

We get heat required,

$$Q = 0.381\ kJ$$

We know that:

$$P = \frac{Q}{t}$$

Assume time taken for desired heating element temperature, $t = 180\ s$

We get power required,

$$\boxed{P = 2.117\ W}$$

Step 2: Calculating CFM of fan

Assuming $T_{base} = 40^o\ C$ and $T_{jacket} = 24^o\ C$,

Temperature Difference required, $\Delta T = 16\ K$

Average Temperature required, $T_{film} = 32^o\ C$

Few parameters at average temperature of $32^o\ C$:

Thermal Conductivity, $k = 0.026\ W/mK$

Kinematic Viscosity, $v = 0.0000189\ m^2/s$

Prandtl Number, $P_r = 0.708$

Assume time taken to heat jacket with fan air, $t = 120\ s$

Assuming a few parameters of heat sink:

length, $l = 0.05\ m$

total area, $A = 0.0205\ m^2$

We know that heat transfer coefficient:

$$h = \frac{Q}{tA\Delta T}$$

Substituting and solving, $h = 9.683\ W/m^2K$

We know that Nusselt number:

$$Nu = \frac{hl}{k}$$

Substituting and solving, $Nu = 18.622$

We know that Reynolds number:

$$Re = \left(\frac{Nu}{0.664 * \sqrt[3]{P_r}}\right)^2$$

Substituting and solving, $Re = 990.106$

We know that average fluid velocity:

$$V = \frac{Re * v}{l}$$

Substituting and solving, $V = 0.374\ m/s$

We know that volumetric flow rate:

$$Q_{flow} = A * V$$

Substituting and solving, $Q_{flow} = 0.00767\ m^2/s$

We know that volumetric flow rate:

$$1m/s = 2118.88\ CFM$$

Substituting and solving, $\boxed{CFM_{req} = 16.256}$

4.6.2 Finite Element Analysis Methodology

To analyze and optimize the thermal parameters of the HotPod and visualize its interaction with the environment and user, the Finite Element Analysis (FEA) method is employed. The primary components driving heat generation and dissipation are the heating element and the wire mesh, responsible for efficient heat distribution within the jacket. To simulate the thermal characteristics of the wire mesh under varying conditions of time and heat transfer coefficient, a thermal resistance modeling approach is adopted. The wire mesh, intricately designed using SolidWorks, is then seamlessly imported into ANSYS Workbench as a .iges file, a widely compatible neutral file extension. This enables a meticulous exploration of thermal behavior, allowing for iterative optimization of parameters to achieve an ideal heat-spreading configuration. The synergy between SolidWorks and ANSYS Workbench ensures a robust simulation framework, facilitating a comprehensive understanding and enhancement of the HotPod's thermal performance.

Assumptions:

1) The material is considered as homogeneous and isotropic; hence the values remain constant in all three directions.

2) The thermal conductivity, specific heat capacity etc. does not vary with length and height and remain constant throughout the computational domain.
3) The thermal contact resistance between the heating element and the wire mesh is negligible and does not affect the heat flux and temperature drop.
4) One dimensional heat transfer is considered.
5) External forced convection cases are taken into consideration.
6) Atmospheric pressure conditions are taken for entire calculation and analysis.
7) An initial temperature of 20 degree Celsius has been taken.

Boundary Conditions:

Transient Thermal Analysis:

- The time dependent temperature drop across the wire mesh was studied through this approach. It was carried out in two steps.
- The first step included heating the heating of the heating element to 60 seconds from ambient temperature of 20 degrees by applying a constant power heat input of 10 W to heater. During this step, the fan was kept OFF and it allowed the heating mesh to gain temperature.
- Next step was the time duration for which fan will be kept ON and heater is turned OFF so that it does not overheat. The second time step was iterated in steps of 10 sec starting from 30 sec to 70 sec and temperature drop and heat flux were studied.
- As per the analytical calculations, the coefficient of heat transfer (h) was calculated for the flow conditions and applied to the wire mesh to effectively dissipate the heat using the flow of fan.
- At the end, the temperature range from the wire mesh was compared to the expected temperature values ranges as per the conjoint analysis and those parameters were further finalized for the experimental analysis.

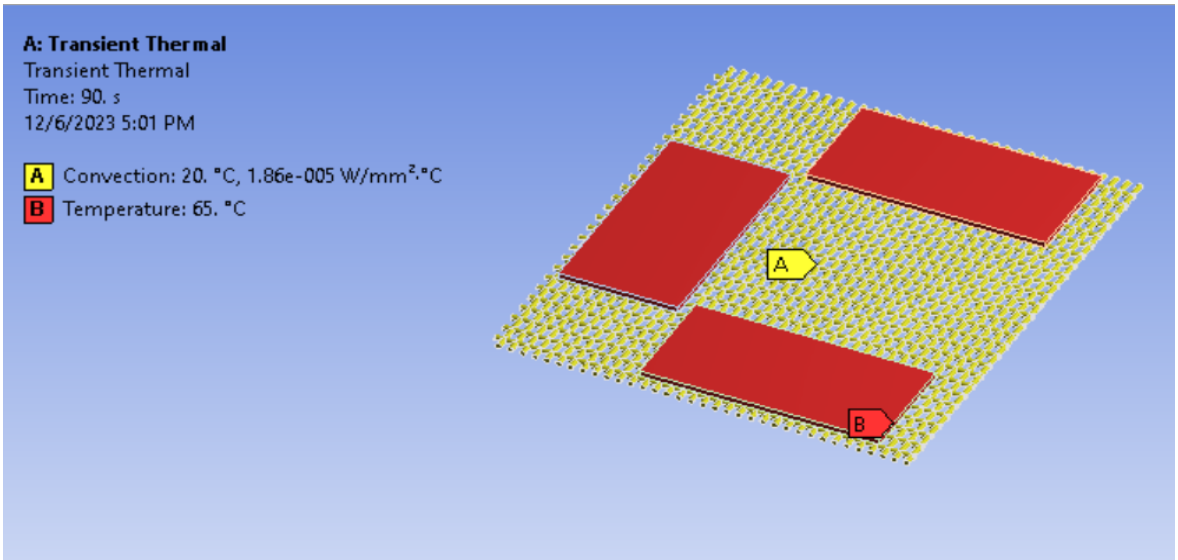


Figure 29. Iteration 1 Transient Thermal Boundary Conditions

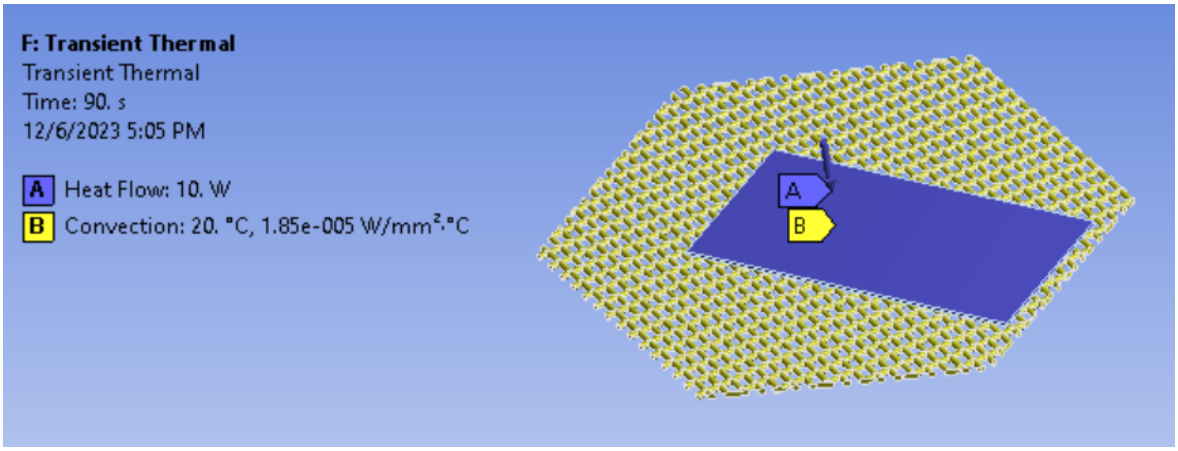


Figure 30. Iteration 2 Transient Thermal Boundary Conditions

Thermal Resistance Modelling:

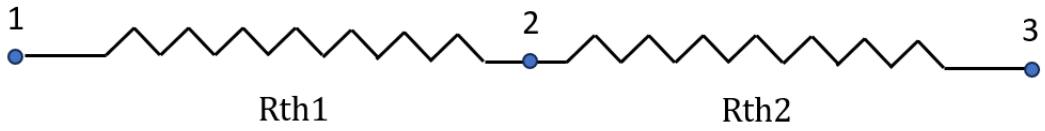
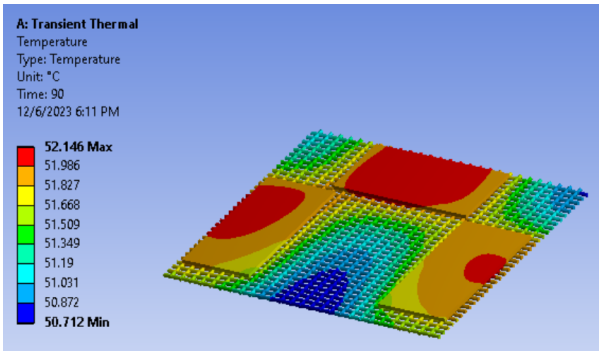


Figure 31. Thermal Resistance Modelling

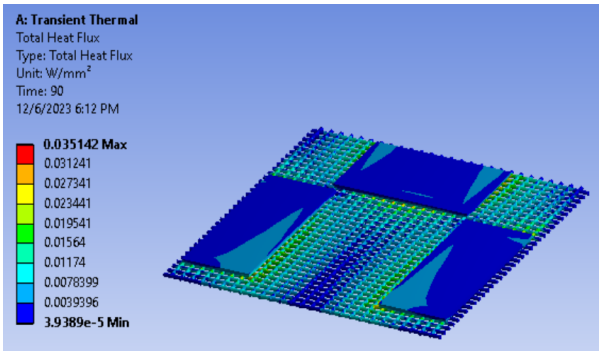
The heat transfer model is visualized using a thermal resistance network. The thermal nodes depict the heat transfer points or junctions from where heat transfer is taking place from one section to another. Here, the first resistance represents the heating element and the other represents the wire mesh to where heat transfer occurs from element. And finally, the third node represents the convective heat transfer from wire mesh to the outside environment i.e., jacket area for HotPod.

4.6.2.1 FEA Iteration 1 (Working model)

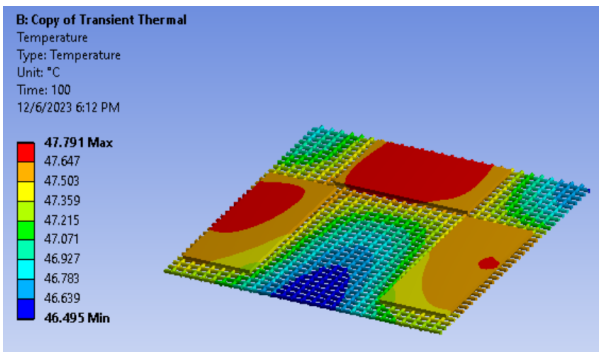
For investigation, five different conditions were taken for analysis by varying the end time steps for ON condition of fan. In the working model, we had 3 heating elements attached in contact with the wire mesh. We started by iterating one heating element with mesh, but the temperature drop achieved was much lower than the expected range. Similarly, we tested for two elements and finally went ahead with three heating elements due to the increase in the physical prototype dimensions. Below shown are temperature profiles and heat flux values for Iteration 1 under five different simulating conditions.



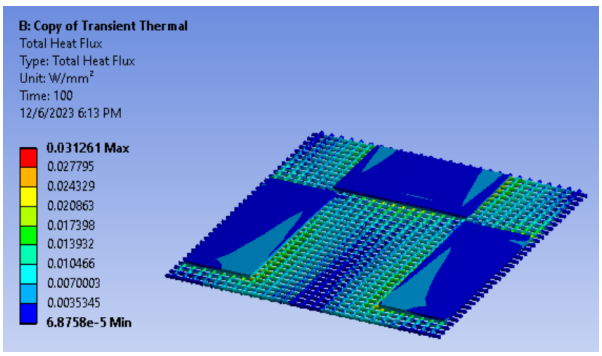
(a)



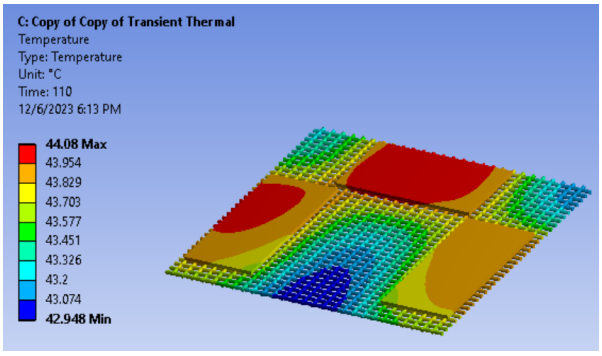
(b)



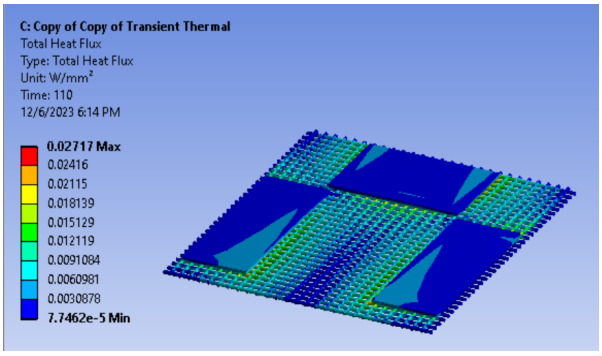
(c)



(d)



(e)



(f)

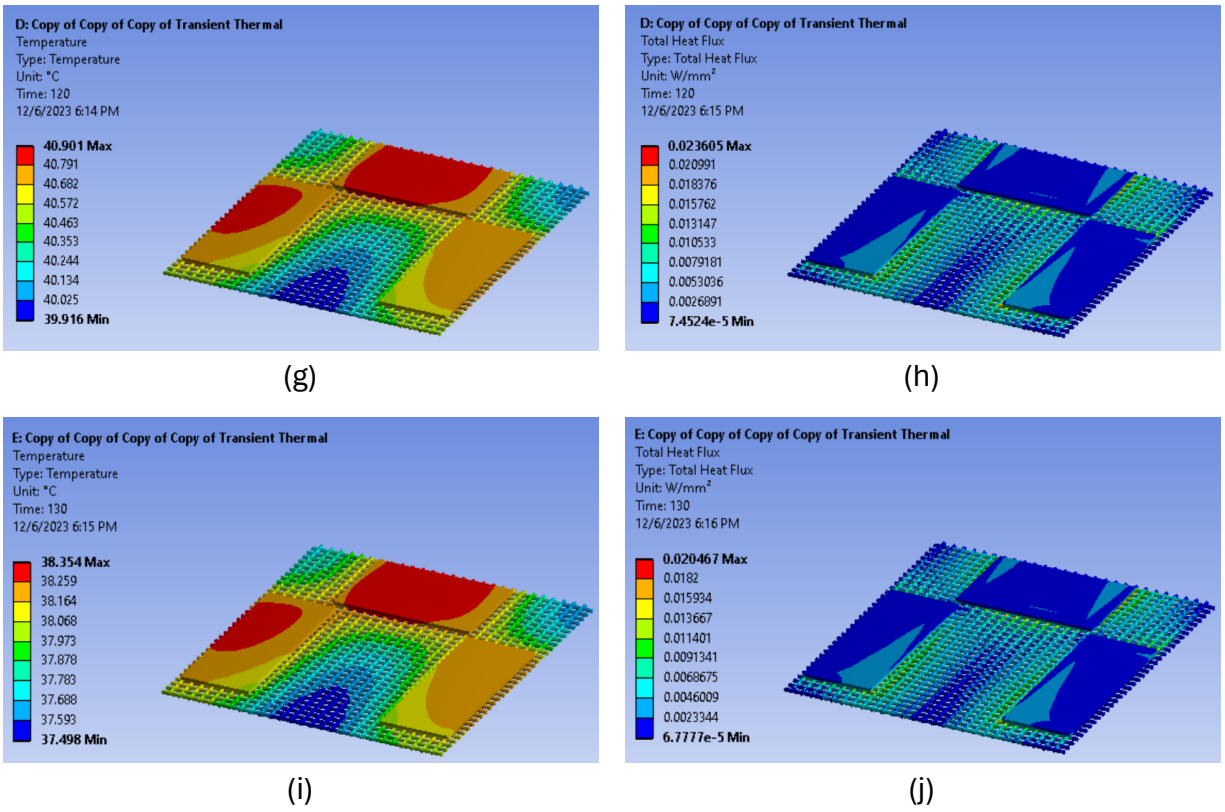
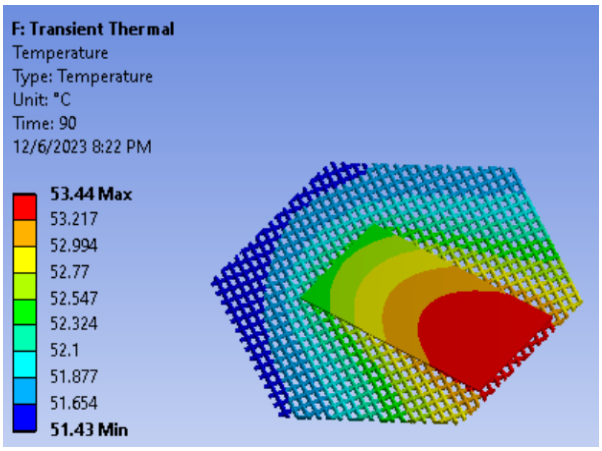


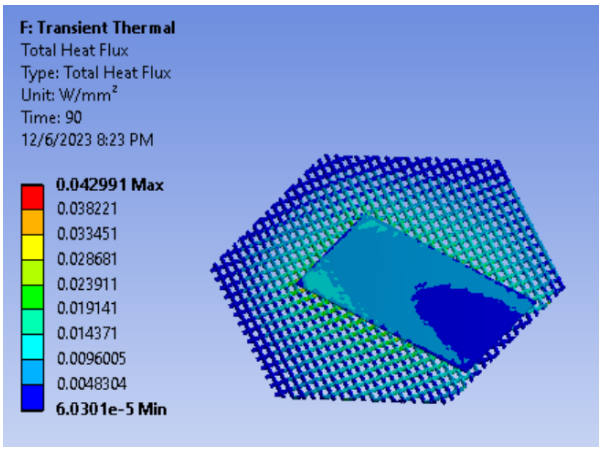
Figure 32. FEA Iteration 1
(a), (c), (e), (g) and (i) are for Temperature and (b), (d), (f), (h) and (i) are for Total Heat Flux

4.6.2.2 FEA Iteration 2

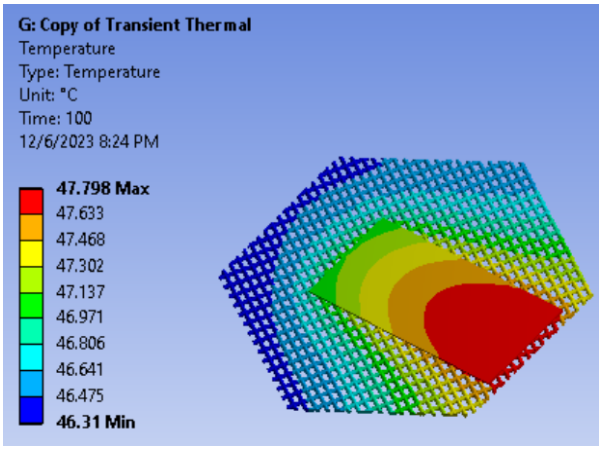
Upon examining the experimental model, it became evident that the utilization of three heaters was spatially inefficient. To enhance space utilization and compactness, a strategic decision was made to downsize the wire mesh and employ a single heating element, ensuring effective heat distribution across the honeycomb structure. To investigate this modification, the same thermal resistance-based transient model was applied, incorporating variable time steps ranging from 30 to 70 seconds, and the subsequent results were meticulously analyzed. In crafting the envisioned prototype, a slight adjustment was made by assigning a constant input power of 10 watts to the heater, maintaining an ON condition for the initial 60 seconds. This modification aimed at optimizing the spatial efficiency and heat distribution performance of the HotPod prototype, reflecting a commitment to both compactness and effective thermal management.


F: Transient Thermal
Temperature
Type: Temperature
Unit: °C
Time: 90
12/6/2023 8:22 PM
53.44 Max
53.217
52.994
52.77
52.547
52.324
52.1
51.877
51.654
51.43 Min

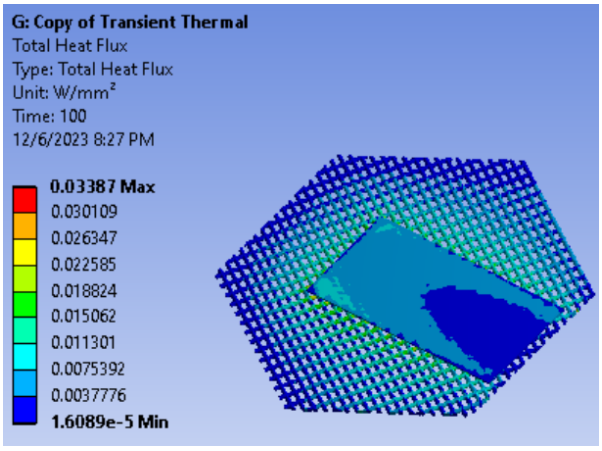
(a)


F: Transient Thermal
Total Heat Flux
Type: Total Heat Flux
Unit: W/mm²
Time: 90
12/6/2023 8:23 PM
0.042991 Max
0.038221
0.033451
0.028681
0.023911
0.019141
0.014371
0.0096005
0.0048304
6.0301e-5 Min

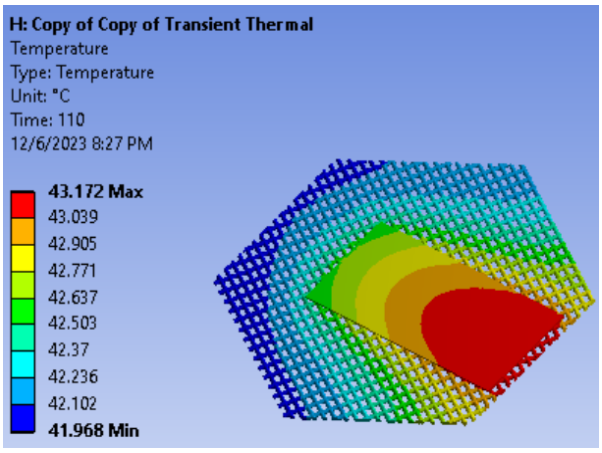
(b)


G: Copy of Transient Thermal
Temperature
Type: Temperature
Unit: °C
Time: 100
12/6/2023 8:24 PM
47.798 Max
47.633
47.468
47.302
47.137
46.971
46.806
46.641
46.475
46.31 Min

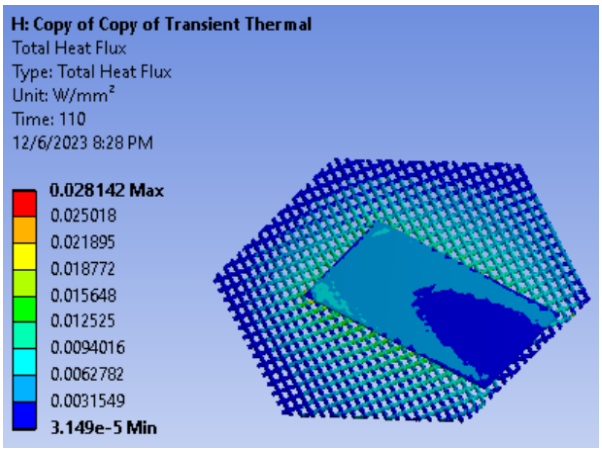
(c)


G: Copy of Transient Thermal
Total Heat Flux
Type: Total Heat Flux
Unit: W/mm²
Time: 100
12/6/2023 8:27 PM
0.03387 Max
0.030109
0.026347
0.022585
0.018824
0.015062
0.011301
0.0075392
0.0037776
1.6089e-5 Min

(d)


H: Copy of Copy of Transient Thermal
Temperature
Type: Temperature
Unit: °C
Time: 110
12/6/2023 8:27 PM
43.172 Max
43.039
42.905
42.771
42.637
42.503
42.37
42.236
42.102
41.968 Min

(e)


H: Copy of Copy of Transient Thermal
Total Heat Flux
Type: Total Heat Flux
Unit: W/mm²
Time: 110
12/6/2023 8:28 PM
0.028142 Max
0.025018
0.021895
0.018772
0.015648
0.012525
0.0094016
0.0062782
0.0031549
3.149e-5 Min

(f)

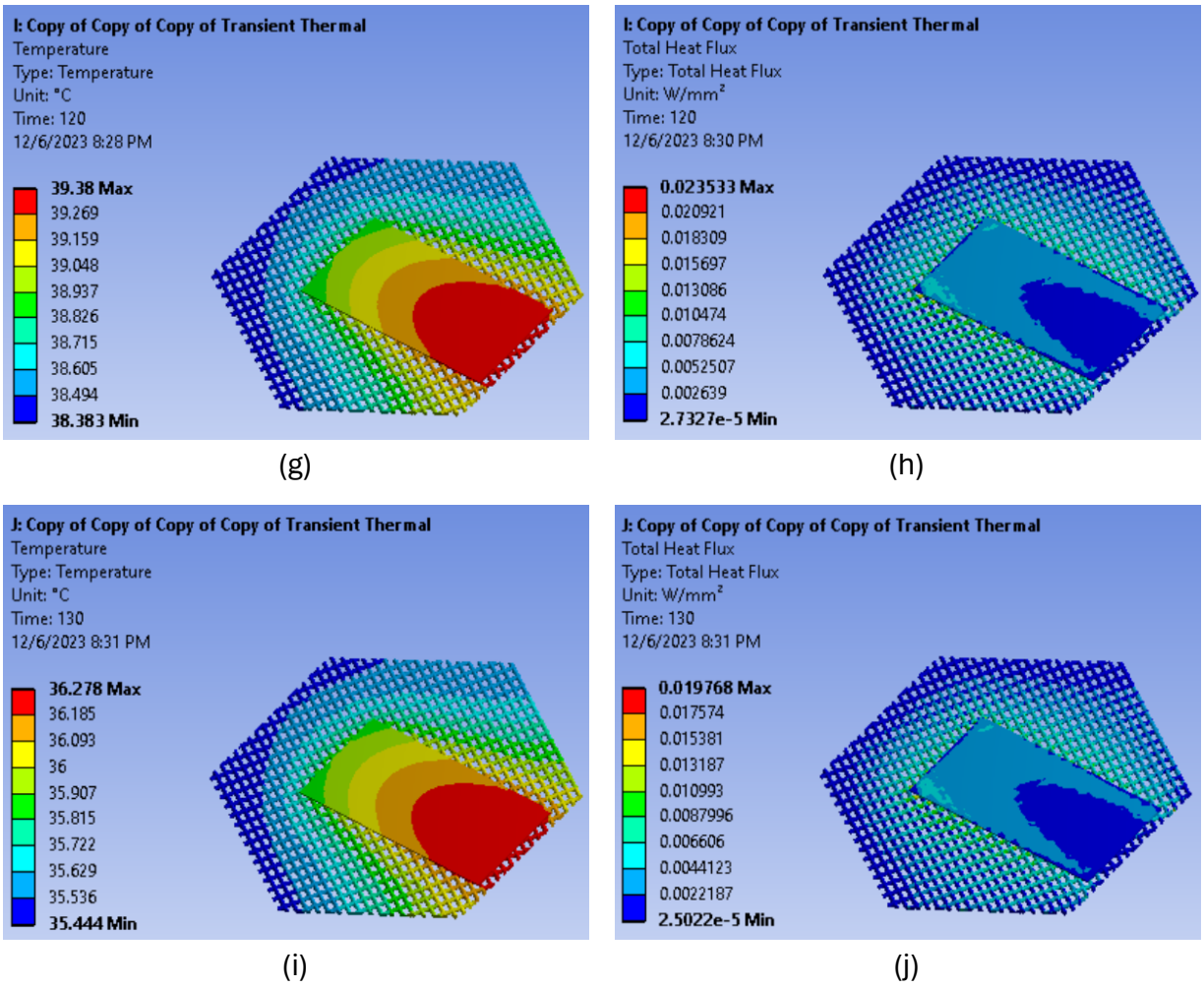


Figure 33. FEA Iteration 2
(a), (c), (e), (g) and (i) are for Temperature and (b), (d), (f), (h) and (i) are for Total Heat Flux

5. Desirability & Feasibility

5.1 Target Market

The BeeEZ portable HotPod is ideally suited for college students, primarily targeting those between the ages of 18 and 24. This includes both undergraduates and graduate students who lead active outdoor lives, moving between classes, participating in extracurricular activities, and socializing. The product's design caters to their need for convenience and portability, offering a practical solution for staying warm in cold weather. Apart from college students, the HotPod also appeals to high school students in colder regions and young professionals who maintain an active, campus-like lifestyle. The product's appeal lies in its ease of use, efficient warmth provision, and stylish design, making it an attractive accessory for fashion-conscious students.

5.2 House of Quality

In the development of the HotPod, we employed the House of Quality (HoQ) matrix to systematically translate customer needs into engineering characteristics. The HoQ provided a structured approach to prioritize features based on direct student feedback and empirical data gathered from our market research.

Customer Requirements (What's)

The vertical axis of the HoQ delineates the consumer requirements, which were ascertained from our empathy research and fieldwork. These requirements include rapid heating, low weight, durable construction, and overarching concerns such as overheating protection and safety. Each requirement has been assigned a weight that reflects its priority from the consumer's perspective.

Engineering Characteristics (How's)

The engineering characteristics, defined on the horizontal axis, represent the technical specifications that will address the customer requirements. These characteristics include but are not limited to the heating element's wattage, the battery life, the overall weight of the device, and the implementation of safety features such as temperature sensors and safety control algorithms.

Relationship Matrix

The core of the HoQ is the relationship matrix, where we identified the strength of the impact that each engineering characteristic has on fulfilling the respective customer requirement. We utilized symbols of varying shapes to illustrate these relationships – a circle for moderate, a triangle for strong, and a filled triangle for very strong relationships.

Correlation Matrix (Roof)

The correlation matrix, forming the 'roof' of the HoQ, enabled us to understand how different engineering characteristics interact with one another. For example, the enhancement of battery life may affect the weight of the device, thereby necessitating a trade-off analysis to achieve an optimal balance.

Importance Ratings and Target Values

The important ratings assigned to each customer requirement guide our focus, with higher-rated needs taking precedence in our design efforts. The target values for each engineering characteristic are derived from both competitive benchmarking and technical feasibility studies. They serve as quantitative goals that our design must meet or exceed.

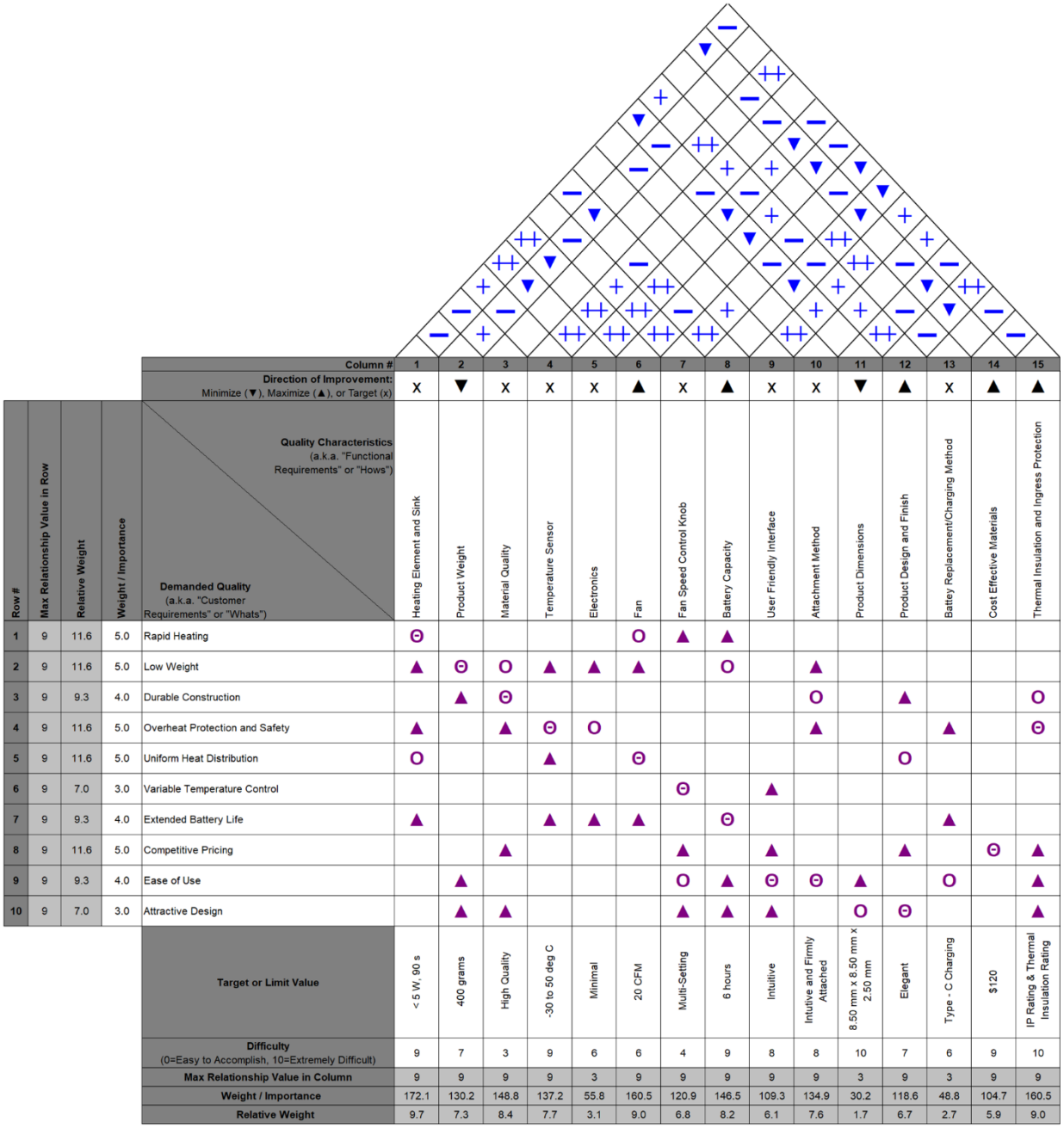
Since this is a CPD project, for the final build to be addressed by the end of Spring 2024 semester, we have set the following targets in the HoQ:

(i) The heating element and sink need to be operated at under 5 W and heat up in under 90 seconds.
(ii) The product weight must be less than 400 grams.
(iii) Material quality needs to be of the highest grade.
(iv) Temperature sensor needs to be operational between -30°C to 50°C.
(v) The electronics needs to be minimal, i.e., custom PCB design.
(vi) The fan needs to be around 20 CFM with a multi-setting knob.
(vii) Battery capacity should be sufficient to last at least 6 hours on full charge.
(viii) The user interface needs to be as intuitive as possible, such that it does not require any training.
(ix) The attachment method needs to be intuitive while also being firm and adjustable.
(x) The product dimensions should not exceed 85mm x 85mm x 25mm.
(xi) The device needs to look elegant and have a premium finish that lasts long.
(xii) There needs to be a rechargeable battery that can be charged via the standard Type C cable.
(xiii) The selling price of the device needs to be under $120.
(xiv) The product also needs to have a thermal insulation certification as well as ingress protection.

By the final showcase of Fall 2023 semester, we were able to achieve (i), (ii), (iv), (viii) and (ix). We were able to provide a certain amount of thermal insulation mentioned in (xiv), it was not certified. In order to achieve (iii), (vii), (x), (xi) and (xii) the parameters of (v) and (vi) need to be met. Parameters (xiii) and (xiv) will be determined based on the above factors.

Difficulty

The difficulty assessment at the base of the matrix informs us of the challenges associated with meeting certain engineering characteristics. For instance, extending battery life while maintaining a low weight profile is marked as more challenging, guiding us to allocate appropriate resources and research efforts to overcome these hurdles.



Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats") \ Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	1 Heating Element and Sink	2 Product Weight	3 Material Quality	4 Temperature Sensor	5 Electronics	6 Fan	7 Fan Speed Control Knob	8 Battery Capacity	9 User Friendly Interface	10 Attachment Method	11 Product Dimensions	12 Product Design and Finish	13 Battey Replacement/Charging Method	14 Cost Effective Materials	15 Thermal Insulation and Ingress Protection
				Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	x	▼	x	x	x	▲	x	▲	x	x	▼	▲	x	▲	▲
1	9	11.6	5.0	Rapid Heating	Θ					O	▲	▲							
2	9	11.6	5.0	Low Weight	▲	Θ	O	▲	▲	▲		O		▲					
3	9	9.3	4.0	Durable Construction		▲	Θ							O		▲			O
4	9	11.6	5.0	Overheat Protection and Safety	▲		▲	Θ	O					▲			▲		Θ
5	9	11.6	5.0	Uniform Heat Distribution	O			▲		Θ						O			
6	9	7.0	3.0	Variable Temperature Control							Θ		▲						
7	9	9.3	4.0	Extended Battery Life	▲			▲	▲	▲		Θ					▲		
8	9	11.6	5.0	Competitive Pricing			▲				▲		▲			▲		Θ	▲
9	9	9.3	4.0	Ease of Use		▲					O	▲	Θ	Θ	▲		O		▲
10	9	7.0	3.0	Attractive Design		▲	▲				▲	▲	▲		O	Θ			▲
				Target or Limit Value	< 5 W, 90 s	400 grams	High Quality	-30 to 50 deg C	Minimal	20 CFM	Multi-Setting	6 hours	Intuitive	Intuitive and Firmly Attached	8.50 mm x 8.50 mm x 2.50 mm	Elegant	Type - C Charging	$120	IP Rating & Thermal Insulation Rating
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	9	7	3	9	6	6	4	9	8	8	10	7	6	9	10
				Max Relationship Value in Column	9	9	9	9	3	9	9	9	9	9	3	9	3	9	9
				Weight / Importance	172.1	130.2	148.8	137.2	55.8	160.5	120.9	146.5	109.3	134.9	30.2	118.6	48.8	104.7	160.5
				Relative Weight	9.7	7.3	8.4	7.7	3.1	9.0	6.8	8.2	6.1	7.6	1.7	6.7	2.7	5.9	9.0

Figure 34. House of Quality

5.3 Market Size

To determine the market size for the BeeEZ portable HotPod in Ithaca, a systematic approach is taken, focusing on the specific demographics of high school and college students in this region, known for its colder climate. The analysis is based on two key data points:

1. Target Demographic Data:

- High School Students: According to data from Niche, Ithaca has approximately 1,300 high school students.
- College Students: From online information, there are around 25,000 college students in Ithaca.

These figures sum up to a total target demographic of 26,300 students in Ithaca.

2. Market Penetration Estimate:
A conservative estimate of a 5% market penetration rate is assumed for the first year. This rate is based on the product's appeal, considering factors like the necessity of staying warm in a cold climate, the convenience of the product, and its fashionability.

3. Calculation of Market Size:
By applying the estimated market penetration rate to the total target demographic, the potential market size can be calculated: with 26,300 students and a 5% penetration rate, the initial market size for BeeEZ in Ithaca is estimated to be around 1,315 units.

The market size for the BeeEZ HotPod is heavily influenced by several key factors. Primarily, it depends on the population in colder climates, particularly in countries or regions where cold weather is prevalent for a significant part of the year. The accessibility of the product, whether through online platforms or retail outlets, also plays a crucial role in determining market reach.

Additionally, the product's affordability relative to the target demographic's purchasing power, the presence and strength of competition from similar warming devices, and the effectiveness of marketing strategies are all critical factors that will affect market penetration. Expanding the market analysis to encompass other regions with similar climatic conditions and demographics would provide a more comprehensive understanding of the product's potential scope and success in the market.

5.4 Consumer Behavior

Consumer behavior, under the specified context, pertains to the behavioral patterns and decision-making processes shown by consumers, namely college students, while evaluating, acquiring, and using the BeeEZ portable HotPod. The following are certain facets of customer behavior that might potentially have significance with regards to the target demographic:

1. Need Recognition: The recognition of the need for warmth in cold weather is often seen among college students, particularly while they are transitioning between courses, participating in outside activities, or engaging in social interactions. The need for a mobile solution that is compatible with their dynamic way of life becomes evident.

2. Product Knowledge: The primary objective of marketing initiatives should be to generate knowledge within the intended consumer base about the many attributes of the BeeEZ portable HotPod. These attributes include its portability, convenience, efficiency in delivering warmth, and aesthetically pleasing appearance. Social media, campus activities, and online platforms that are often used by college students have shown to be efficacious means for enhancing product awareness.

3. Expected Benefits: The trendy appearance of the HotPod is expected to appeal to consumers, especially fashion-conscious students. The advantages of convenience and user-friendliness are particularly significant for persons with demanding schedules who want prompt and effective resolutions.

4. Perceived Risks: Prospective buyers may take into account many considerations, including the longevity, affordability, and efficacy of the HotPod in delivering enough warmth. By using strategies such as product evaluations, testimonials, and assurances, it is possible to alleviate the apprehensions associated with perceived hazards.

5. Social Influence: The influence of peer recommendations and social validation holds considerable weight in the purchase choices made by college students. The use of social media influencers, testimonials, and user-generated material has the potential to augment the social attractiveness of the product.

6. Lifestyle Compatibility: The attractiveness of the HotPod to those leading a dynamic lifestyle reminiscent of a university environment is in line with the desires of the target market. Emphasizing the seamless integration of the product into individuals' everyday routines might augment its appeal.

7. Price and Discounts: University students, who often prioritize financial considerations, may be influenced by promotional campaigns, reduced prices, or special bargains. The implementation of time-limited promotions and student discounts has the potential to induce a feeling of urgency among consumers, hence increasing the probability of making a purchase.

8. Brand Loyalty: The cultivation of brand loyalty may be facilitated by establishing a correlation between the brand and the values held by the target population, which may include attributes such as adventure, style, and convenience. The use of social media platforms for after-sales support and interaction has the potential to foster enduring client connections.

A comprehensive comprehension of various facets of consumer behavior may provide valuable insights for marketing strategies, product positioning, and communication tactics in order to efficiently engage and connect with the intended target demographic.

5.5 Competitors

The HoQ includes a competitive analysis that benchmarks BeeEZ against competitors on the customer requirements. This helps identify where BeeEZ stands out and where it may need improvement.

From the HoQ, we can deduce that the design team has a clear understanding of the customer's priorities. They are focusing on providing rapid heating in a lightweight design, which are the top-ranked needs. The matrix suggests that there are strong relationships between several engineering characteristics and the top customer requirements, indicating that these technical areas should be the focus of the design efforts. However, trade-offs will need to be managed, as shown by the negative correlations in the roof. The team will need to find an optimal balance between extending battery life and maintaining a low weight, which is not straightforward given their inverse relationship.

Overall, the specific analysis of the HoQ for BeeEZ HotPod indicates a well-planned approach to design, with a clear focus on aligning technical specifications with customer priorities, all while considering competitive positioning. The key to success will be managing the trade-offs between engineering characteristics to deliver a product that meets the highest weighted customer requirements.

The table below lists the various competitors to the BeeEZ HotPod. These competitors were also used to help define what areas of improvement should be prioritized, as well as to gain an understanding of the current market for products similar to the BeeEZ HotPod.

Table 1. Competitor Analysis

Competitor	Description	Feature	Weakness	Price
ActionHeat 	Specializes in heated apparel and accessories like jackets, vests, etc.	1: 3 panel heating system with touch-button temperature control. 2: Charge phones. 3: Diverse product range	1: Expensive 2: Dependency on Technology: If there are issues with the heating mechanism or if the technology becomes outdated, it could lead to product returns or reduced customer trust. 3: A non-removable heating system creates cleaning problems.	$99.99
Ocoopa	Offers rechargeable hand warmers	1: Split-type Magnetic Design for dual usage. 2: Design and aesthetics	1: Product Complexity: A rechargeable hand warmer requires	$30 - $50

	with a split-type magnetic design.	3: Supreme Quality 4: Multiple Use Cases: warming hands + power banks	charging, unlike disposable ones. This added layer of complexity might not appeal to everyone. 2: only warms up a small part of the human body	
THE UNDERWARMER 	Produces single-use, air-activated heating shirts for cold environments.	Single-use and air-activated with up to 12 hours of heating.	1: Uncontrollable temperature 2: Costly 3: Inconvenient to put on or take off	$11.99 - $13.99 per shirt
Mr.Heater 	Known for portable propane heaters suitable for indoor and outdoor use.	1: Portability: can be used for camping, emergency heat, or supplemental room heating. 2: Safety: built -in safety feature such as ODS and tip-over safety shut-off 3: Efficiency: radiant heaters are effective in delivering warmth directly to people and objects.	1: Limited to propane: requires propane canisters, which might not always be convenient for users. 2: Not suitable for personal use	$148.46
HotHands Direct 	Leader in disposable air-activated heat packs that provide safe warmth.	1: Single use 2: Convenience: Quickly activated and ready to use. 3: Ease of Use: No batteries or external power source required. 4: Made of natural ingredients, including iron powder, water, salt, activated charcoal, and vermiculite.	1: Inconsistent heating: some packs might not heat up as effectively as others. 2: Only warms up small part of the human body	$14.90
Handy Heater Freedom	Provides wearable neck	1: Wearable body heater with radiant heat	1: Battery life: requires frequent recharging.	$39.90

	heaters for targeted warmth.	technology for neck & shoulders 2: User-friendly: Easy to wear and adjust. 3: Portable: Allows users to move around while benefiting from the warmth.	2: No suitable for outdoor activities that requires frequent movement	
Milwaukee 	Offers construction tools and heated gear such as jackets and hoodies.	1: Advanced Heat Technology with Quick Heat Function in durable gear. 2: Be able to adapt to harsh working environments 3: Highly reliable for use	1: Expensive 2: A non-removable heating system creates cleaning problems.	$169
Warmies 	Creates comfort products like microwavable heat pads with aroma.	1: Lovely and widely accepted appearance 2: Fast heating time, only need to microwave for ninety seconds. 3: Functional: can be used not only as a heating bag but also as an ice bag. 4: The addition of r aroma will enhance the user's experience of use	1: Requires microwave heating, not particularly convenient for outside use. 2: Faster temperature loss, no continuous heating system. 3: Cannot be washed as it will damage the inner padding which has some unhygienic factors.	$29.99
IRIS OHYAMA 	International company offering a variety of products including heating stickers.	1: Portable and convenient heating stickers that last up to 10 hours. 2: Budget friendly	1: It is so small that it cannot make people feel warm in a short time. 2: If people move their body, the sticker may fall. 3: The heating sticker only works for a small part of the body.	$18.49

Visually this can be represented as:

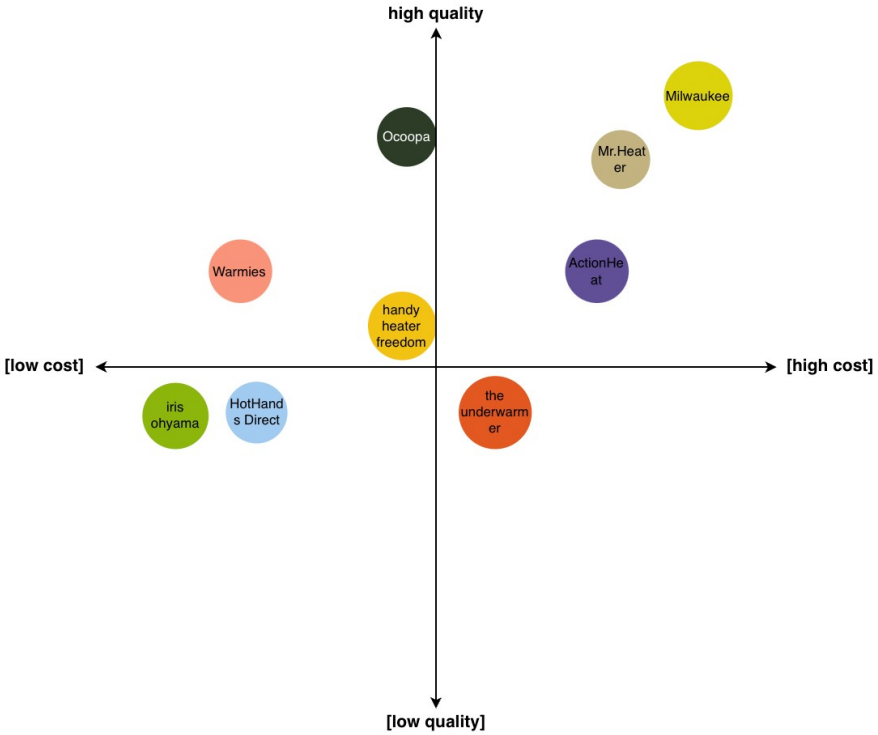


Figure 35. Perceptual Chart

5.6 Net Present Value

The Net Present Value (NPV) of a product serves as a critical metric in determining its overall value and whether it warrants an investment. Essentially, NPV is an internal evaluation tool used by management to assess the viability of committing funds to a particular venture. This financial metric takes into account a multitude of factors, including intricacies related to manufacturing processes and associated labor costs. The NPV calculation enables decision-makers to judiciously evaluate the potential return on investment, considering both immediate and future financial implications.

In essence, NPV acts as a comprehensive compass for management, guiding investment decisions through a holistic lens. By meticulously factoring in various elements, it facilitates a thorough analysis of the overall profitability and feasibility of the investment. Thus, NPV not only quantifies the monetary value but also serves as a strategic instrument for management to make well-informed decisions amid the dynamic interplay of diverse economic and operational considerations.

$$\text{Net Present Value} = \frac{\sum \text{Cash Flow}}{(i+1)^t} - \text{Initial Investment}$$

$\sum$ Cash Flow = Inflow Cash – Outflow Cash

i = Total Discount Rate

t = Time Period (years)

Figure 36. Net Present Value

No of Units: 300 monthly

Initial Investment: 5 million USD

NPV: 6.5 million USD

%NPV change: 32%

5.7 Bass Model Prediction

The model is instrumental in predicting the rate at which new products are adopted in a market, incorporating factors of innovation, imitation, and total market potential. With a substantial investment of USD 5 million and an expected 32% increase in NPV, the model utilizes innovation and imitation coefficients to predict market behavior and forecast a promising market adoption. The 0.03 innovation coefficient indicates early adoption by 3% of the market, driven by the product's uniqueness. The higher 0.38 imitation coefficient suggests a significant influence of social factors, such as online world of mouth, on adoption rates. The model forecasts a slow initial uptake, escalating as the product becomes more recognized, mirroring the financial growth expectations from the NPV analysis. This detailed forecasting aligns the project's technological innovation with its financial strategy, highlighting its potential success in the market.

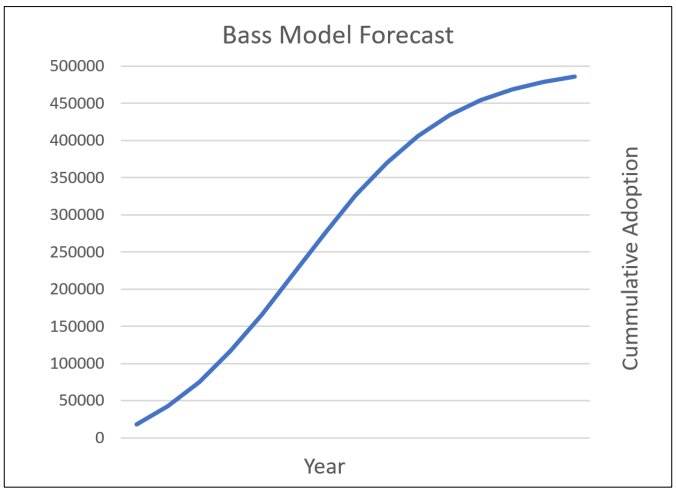


Figure 37. Bass Model

6. Financial

6.1 Pricing Policy

Our revised pricing policy for the HotPod is informed by extensive conjoint analysis and consumer behavior research. The value-based approach remains, setting the price at $120 per unit, aligning with preferences revealed in the conjoint analysis for a compact, efficient heating solution. This pricing ensures affordability for our target market of college students and young professionals, while offering a desirable balance of features like size, battery life, and attachment style. Moreover, insights into consumer behavior, such as lifestyle compatibility and social influence, reinforce this pricing strategy. The policy also accounts for competitive analysis, ensuring our pricing remains attractive compared to similar products in the market. Promotional strategies, like student discounts and bundle offers, are planned to further enhance market adoption, addressing the financial consciousness of our target demographic. This integrated approach to pricing ensures the HotPod is not only technologically advanced but also market-aligned and customer-focused.

6.2 Financial Executive Summary

Our financial analysis indicates a significant initial investment primarily in research, development, and setting up manufacturing processes. The break-even analysis projects that the product will start turning a profit after two years in the market, considering the current pricing strategy and projected sales volumes. We expect a steady growth in ROI, reaching an optimal level in the fifth year, driven by increased brand recognition and market penetration. The initial capital requirement is estimated, covering product development, manufacturing setup, marketing, and operational expenses.

6.3 Income Statement

The estimated income statement for BeeEZ over a three-year horizon paints a picture of a company on a growth trajectory. With projected unit sales of 8,000 in Year 1, 10,000 in Year 2, and 15,000 in Year 3, the forecast suggests an optimistic increase in market demand for the company's product. The net income figures—$175,168 in Year 1, $218,960 in Year 2, and $392,840 in Year 3—reflect the impact of this scaling in sales volume. Despite the increase in sales, the Cost of Goods Sold (COGS) is assumed to remain consistent, which indicates a level of confidence in the company's supply chain and production efficiency. As the business grows, it is anticipated that operating expenses will rise annually, which is typical for expanding operations as they scale up to meet increased customer demand and invest in the infrastructure and marketing required to support larger sales volumes. The interest expense, calculated at an 8% rate, represents the cost of borrowing and is an important

consideration for understanding the company's debt obligations. Finally, a 30% tax rate is applied to the pre-tax income, aligning with corporate tax standards and reflecting the company's fiscal responsibilities. Overall, the estimated income statement suggests a business that is not only expanding its market presence but also managing its costs and expenses effectively to ensure profitability as it grows.

6.4 Operations Headcount

The initial operations team for BeeEZ will be carefully selected to cover the essential stages of labor, balancing expertise and cost-efficiency. Our lean team will consist of versatile individuals who can manage multiple roles, thus minimizing headcount while maximizing productivity. Also, some contractor or part time laborers could be hired to do simple work. Listed is the main headcount:

Design and Prototyping*: Lead Design Engineer*: An experienced thermal systems engineer with 3D modeling expertise will drive the design phase, leveraging CAD software. This role is critical for the creation of detailed and efficient product designs.

Prototyping Technician: A *technician* skilled in operating 3D printers will work alongside the engineer, focusing on the iterative prototyping process. This individual will also evaluate, redesign, and re-print as needed, ensuring design integrity and thermal efficiency.

3D Printing Process: *3D Printing Specialis*t: This technician will be responsible for setup, material selection, and maintenance. They will ensure the 3D printing process runs smoothly, with a sharp eye for quality control throughout production.

Assembly of Electronic Components: *Electronics Assembly Specialist*: A professional adept in integrating electronic components will handle the precise assembly within the 3D printed casings. Their expertise will be vital in addressing technical challenges and ensuring functional integrity.

Quality Control and Testing: *Quality Assurance Engineer:* Tasked with safety and performance testing, this role requires a thorough understanding of electrical safety and performance standards. They will oversee both automated and manual inspections to verify industry compliance.

Packaging and Dispatch: *Logistics Coordinator*: This role will design efficient packaging and handle the logistics of inventory management and dispatch. While less technical, it is crucial for the final delivery of a market-ready product.

Overheads and Administrative Costs: *Operations Manager*: A managerial role that oversees the manufacturing process end-to-end, including the management of finances,

procurement of materials, and facility maintenance. This role will also cover administrative functions, ensuring the company operates seamlessly.

With a startup mentality, each team member will have a cross-functional scope, allowing them to handle various tasks within their expertise domain. This not only minimizes the initial headcount but also fosters agility and responsiveness within the team. The operations manager will play a dual role in handling administrative tasks, while the logistics coordinator will ensure the product reaches customers efficiently and safely. This streamlined approach positions us to manage labor costs effectively while maintaining a focus on delivering a high-quality product.

6.5 Warranties

The warranty provision, estimated at 4% of COGS, would account for potential repair or replacement costs, including parts and labor. A dedicated customer service team would handle warranty claims, with specialized training to troubleshoot issues and provide support, ensuring a smooth customer experience.

6.5.1 Failure Prediction

Since the HotPod primarily undergoes thermal rather than physical stress, we were limited in our ability to use FEA analysis to predict lifespan and durability. We attempted thermal fatigue loading simulations but faced computational issues preventing completion and reliable results for Weibull analysis. Weibull distribution is a widely used reliability analysis tool, which helps us in modeling the probability of failure over the product's lifespan.

To assess potential for thermal degradation and predict the failure, we thoroughly researched the HotPod's ABS material properties. Studies, including the work of Tiganis et al., show ABS can become substantially less durable when exposed for over a year to temperatures exceeding 80°C. Considering this and other research, we chose a 1-year warranty period.

We have set aside a warranty provision fund, which is approximately 5% of the manufacturing cost per unit. This fund will cover replacements or repairs during the warranty period. It is a crucial financial safety net to ensure customer satisfaction and trust.

6.5.2 Product Mishap Handling Protocol

We have established a dedicated customer service team to handle warranty claims and technical support. This team is trained to assist customers efficiently and empathetically, which is critical for maintaining brand reputation. In case of product mishaps, customers can return the product for repair or replacement. We have streamlined this process to be as hassle-free as possible, ensuring a quick turnaround time to minimize customer

inconvenience. The cost of managing product mishaps, including shipping, repair, or replacement, is factored into the overall warranty provision. We aim to keep these costs within 3% of the unit's selling price to maintain financial viability.

6.6 IRR/ROI

The project's IRR should be above industry benchmarks to attract investment, factoring in the innovative nature of the product and the competitive market landscape. An IRR of 20-25% would be targeted. For ROI, the project would aim for a year-over-year increase, with a significant jump expected by the third year due to sales volume growth and cost optimization. ROI calculations would incorporate all cash flow aspects, including initial capital expenditures, operational costs, and net income. The ROI after three years should demonstrate a doubling of the initial investment, considering the project's scale and market potential.

6.7 Capital Investment Required

An extensive investment breakdown would be required beyond the $5 million initial capital. This includes the cost of setting up production lines, which could range from $1-2 million depending on the complexity of the machinery and tooling required. The initial marketing budget could be around $500,000 to establish brand presence and consumer awareness. Working capital, including inventory holding costs, would also be considered, with an allocation of $1 million to ensure smooth operations and mitigate supply chain risks.

6.8 Costs of Goods Sold

6.8.1 Prototyping Costs

Prototyping is a vital phase where several iterations of the product are developed. This involves 3D printing, materials for prototype builds, labor costs for designers and engineers, and expenses for user testing sessions. The budget for prototyping could be around $100,000, which allows for multiple iterations to refine the product based on user feedback and technical testing. This fund would cover:

3D Printing Materials: High-grade PLA or ABS plastics, which are estimated to cost up to $30,000, considering multiple iterations and the potential need for diverse materials to test different thermal and structural properties.

Design and Engineering Labor: Assuming a fully burdened labor rate, the design and engineering time could consume up to $50,000 of the budget. This covers in-depth work by experienced professionals on CAD systems, thermal simulations, and iterative design refinements.

Testing and User Feedback: Allocating $50,000 to in-house and field testing allows for comprehensive feedback loops with potential users, incorporating their insights directly into the design.

Miscellaneous and Unforeseen Costs: A reserve of $50,000 is prudent for unexpected challenges or opportunities to explore additional feat

6.8.2 Production Costs

Production costs would include the costs of raw materials, labor, and overheads such as utilities and facility expenses. A detailed cost model would be built, forecasting a decrease in unit cost by approximately 5% each year as efficiencies improve with scale. including:

Raw Materials: Bulk procurement strategies and supplier negotiations are expected to reduce material costs, especially as order volumes increase.

Labor Efficiency: Streamlining production processes and training staff for multi-skilled roles can lead to more efficient labor usage, thereby decreasing costs proportionally.

Overhead Reduction: Facility and utility costs are expected to become a smaller percentage of the overall cost per unit as production scales up.

Equipment and Tooling Depreciation: As the equipment is utilized more efficiently, the per-unit depreciation cost will decrease, contributing to overall cost savings.

6.8.3 Life Cycle Targets

These targets encapsulate the product's journey from conception to end-of-life, ensuring a focus on customer satisfaction and cost-effectiveness. The budget of $50,000 set aside for installation support is carefully crafted to ensure customers have a seamless DIY installation experience.

6.8.4 Installation Costs

Considering the product's design for ease of use, installation costs would be minimal. However, a budget for customer support and online resources would be allocated, around $50,000, to aid self-installation and troubleshoot any issues. This allocation is detailed as follows:

Customer Support Training ($20,000): This fund is earmarked for the development and delivery of an in-depth training program for customer support teams. The training will equip team members with the necessary product knowledge and problem-solving skills to assist customers over the phone or via digital channels. It will cover common installation queries, troubleshooting steps, and customer service best practices. The aim is to provide

customers with confidence and competence in installing the product themselves without needing on-site professional help.

Online Resources ($30,000): This portion of the budget is invested in creating a suite of digital self-service tools. These tools include:

Instructional Guides ($10,000): Detailed written instructions with step-by-step illustrations will be available for download. These guides will be designed to be clear and easy to follow, even for customers who are not technically inclined.

Video Tutorials ($15,000): High-quality video content showing the installation process in real-time will be produced. These tutorials will address different learning styles and will be accessible from various devices, ensuring customers can view them as they perform the installation.

FAQ Section ($5,000): A comprehensive FAQ section on the company website will address common concerns and questions. This section will be dynamic, updated regularly with new information based on customer feedback and support interaction trends.

6.8.5 Failure Mode and Effects Analysis

FMEA would be conducted throughout the design and production phases to preemptively identify and mitigate risks. This would involve the QA team and could require a budget of $80,000 for the first year, with a decrease in subsequent years as processes mature. This budget is distributed as follows:

Expert Consultations ($30,000): This funding is set aside to hire external industry experts who bring specialized knowledge to the FMEA process. They will work closely with the in-house team to scrutinize the product design and manufacturing process, pinpointing potential failure modes that could compromise safety or performance.

QA Personnel Training ($25,000): A significant investment will be made in training quality assurance staff in the principles and application of FMEA methodology. This training ensures that the QA team can effectively conduct FMEA, analyze the results, and make informed recommendations for design or process changes.

Process Integration ($25,000): The insights gained from FMEA will be integrated directly into the production process. This allocation will cover the cost of modifying existing quality control procedures, implementing new checks, and adjusting manufacturing processes to prevent identified potential failures. This might involve purchasing new testing equipment, modifying assembly line setups, or implementing new software for quality management.

6.8.6 Reliability

Reliability targets would be set high to build customer trust and reduce long-term costs associated with warranty claims. Investments in high-quality materials and thorough product testing would be significant, with a budget allocation of around $50,000 to cover extensive reliability testing regimes. Specifically, it includes:

Material Testing: Rigorous testing of materials to ensure they meet specified durability and performance standards over the product's intended lifespan.

Lifecycle Testing: Simulating extended usage conditions to forecast and improve product lifespan, identifying components that may require additional reinforcement or better-quality substitutes.

Continuous Improvement: Funds to support ongoing efforts to refine the product based on reliability testing outcomes, ensuring the product exceeds industry standards for reliability.

7. Systems Engineering Tools (BeeEZ)

7.1 Originating Requirements

The requirements listed in Table 1 are the originating requirements capturing the desired functionality of our system. An Originating Requirements Table documents the primary, high-level needs and expectations that come from our stakeholders. So, we are talking about the key things our product has to nail based on what our stakeholders - like customers and the market - tell us they need, plus all those rules we have to follow. The table is our guide to understanding 'what' the system is expected to do and includes ways to verify each requirement.

Index	Originating Requirement	Justification Method	Source	Verification Method
R01	Rapid heating capability to achieve desired temperature quickly	User comfort and convenience	User Survey	Test
R02	Lightweight design for portability	User mobility and convenience	Market Analysis	Inspection
R03	Durable construction to withstand regular use	Product longevity	Design Specification	Test
R04	Overheat protection and safety measures	User safety	Safety Standards	Test
R05	Even heat distribution	Consistent performance and user comfort	User Feedback	Test
R06	Adjustable temperature settings	Versatility and user preference	User Feedback	Test
R07	Extended battery life for prolonged use	User convenience	Design Specification	Test
R08	Operable in –20°C temperature	Product usability in Ithaca	Climate Data	Test
R09	Sweat and waterproof design	Usability in diverse conditions	User Requirements	Test

Figure 38. Product Originating Requirements

7.2 Derived Requirements

Table 2 lists the derived requirements along with unique shorthand function names and linkage to the originated source requirement. In the Derived Requirements Table, we list more technical and specific requirements that stem from the high-level originating requirements. These are not directly stated by the stakeholders but are necessary to support and achieve the high-level needs. This is where we specify 'how' the system will meet the originating requirements, breaking down the broader needs into detailed, actionable items.

Index	Derived Requirements	Verification Method	Source OR
DR1	Heat up to desired temperature within 30 seconds	Test	R01
DR2	Total product weight not to exceed 500 grams	Inspection	R02
DR3	Pass a drop test from 1 meter height	Test	R03
DR4	Incorporate thermal cutoff at set temperature	Test	R04
DR5	Maintain temperature variation within ±5%	Test	R05
DR6	User interface for temperature control in 5°C increments	Test	R06
DR7	Minimum battery life of 8 hours on a single charge	Test	R07
DR8	Functionality test at –20°C for 1 hour	Test	R08
DR9	Waterproof up to IP65 standard	Test	R09

Figure 39. Product Derived Requirements

7.3 Subsystem Definition and Allocation

The Subsystem Matrix is a tool we use to ensure that all the requirements identified in the ORT and DRT are assigned to specific subsystems or components within the system. It helps us track which part of the system is responsible for fulfilling each requirement, ensuring that when all subsystems come together, they collectively meet all the identified needs. This matrix is crucial for maintaining a clear overview of the system's architecture and for tracing the impact of any changes to requirements throughout the design process.

System Component	R01	R02	R03	R04	R05	R06	R07	R08	R09
Centrifugal Fan	X				X				
Heating Element	X			X	X				
Control Interface						X			
Battery							X	X	
Casing		X	X	X				X	X
Thermal Cutoff				X					
Feedback Algorithm				X					
Waterproof Sealing									X

Figure 40. Subsystem Definition and Allocation

7.4 Internal Block Diagram

From the internal block diagram, the Heating System and Air Flow System are critical to the product's functionality, with the former containing a heating element and the latter circulating air via a centrifugal fan. What sets the HotPod apart is its clever twist on heat

transfer - it uses convection, while most other heaters stick to conduction or radiation. It is pretty wild how the centrifugal fan flips the script, spreading heat around instead of cooling things off as you would expect from a fan.

In the Electronics System, there is this smart safety feature designed to tackle overheating - we call it a feedback mechanism. This system is intended to shut down the HotPod when it reaches a certain temperature, allowing it to cool before being restarted. The HotPod's physical features, like the robust attachment system and sturdy outer shell, make it ideal for everyday use in different conditions; it is light, tough, and water-resistant. The HotPod's attachment system, it seems, gives you the flexibility to pair it with various outfits or equipment, boosting its adaptability.

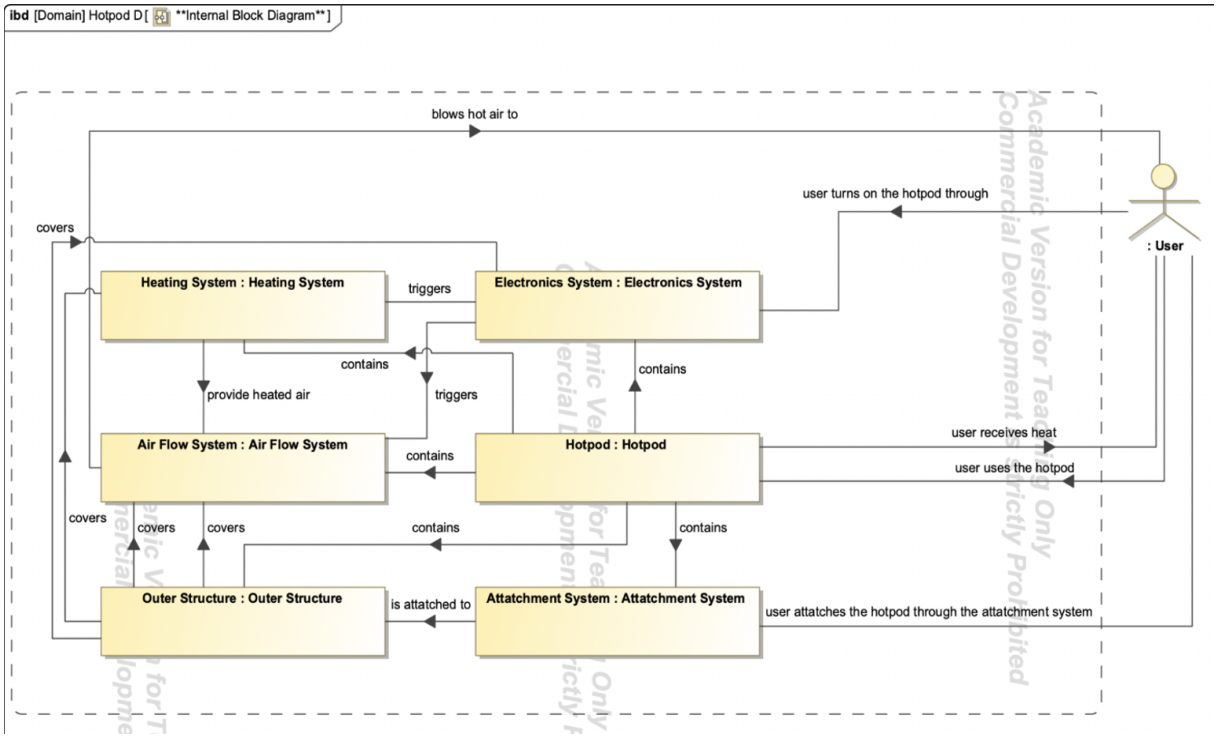


Figure 41. Internal Block Diagram

7.5 Personas Use Case Diagrams

The BeeEZ HotPod use case diagram details the user interactions and features of our product. The 'Use HotPod' case is central to the diagram, and it branches out into a series of actions that the user can take. Attaching the HotPod to the body, adjusting the heating for comfort, and removing the device are all simple and user-friendly processes. The device's simple on/off and charging functions, along with battery monitoring, aim to provide autonomy and convenience.

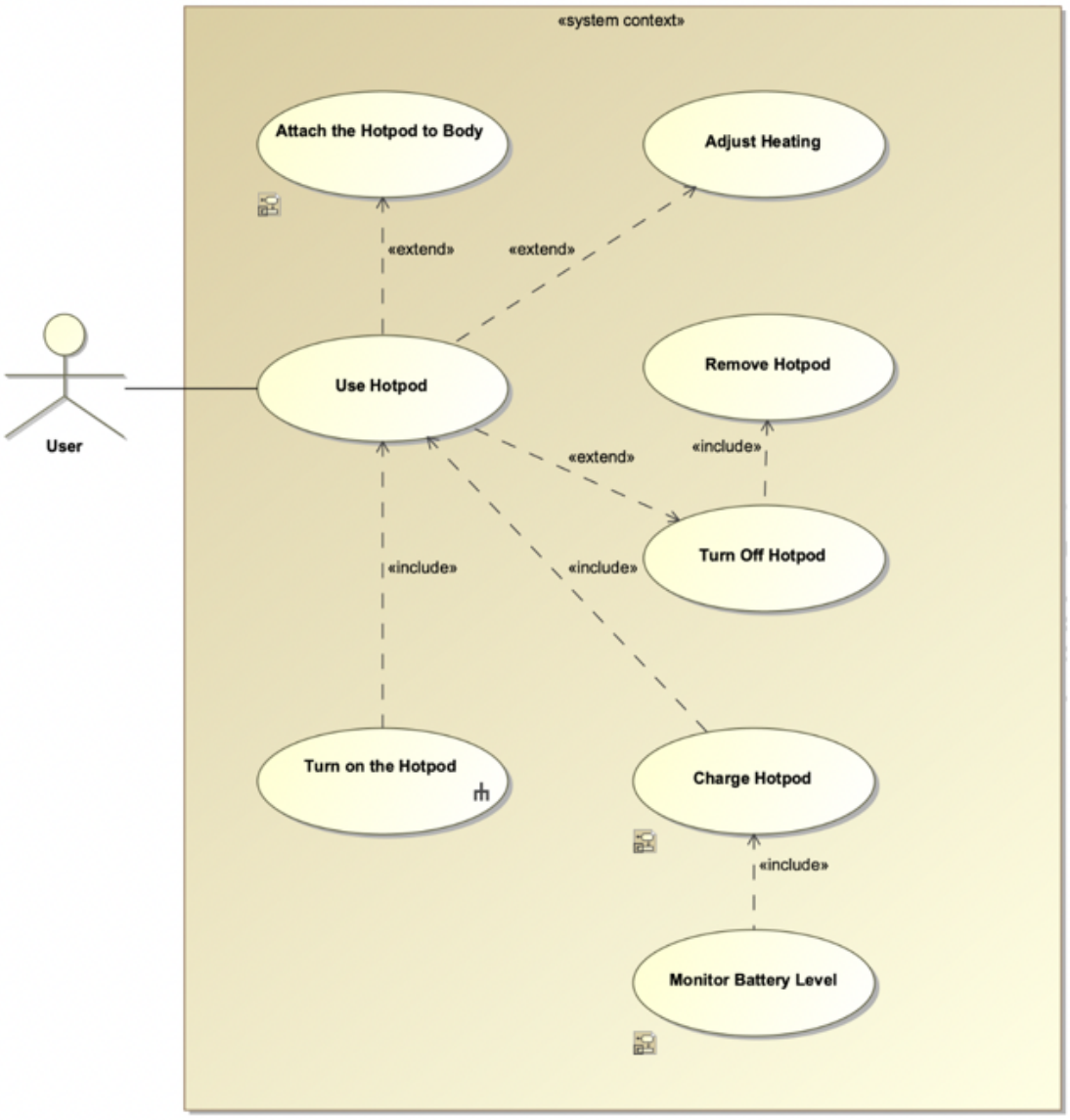


Figure 42. Personas Use Case Diagram

7.6 Activity Diagrams

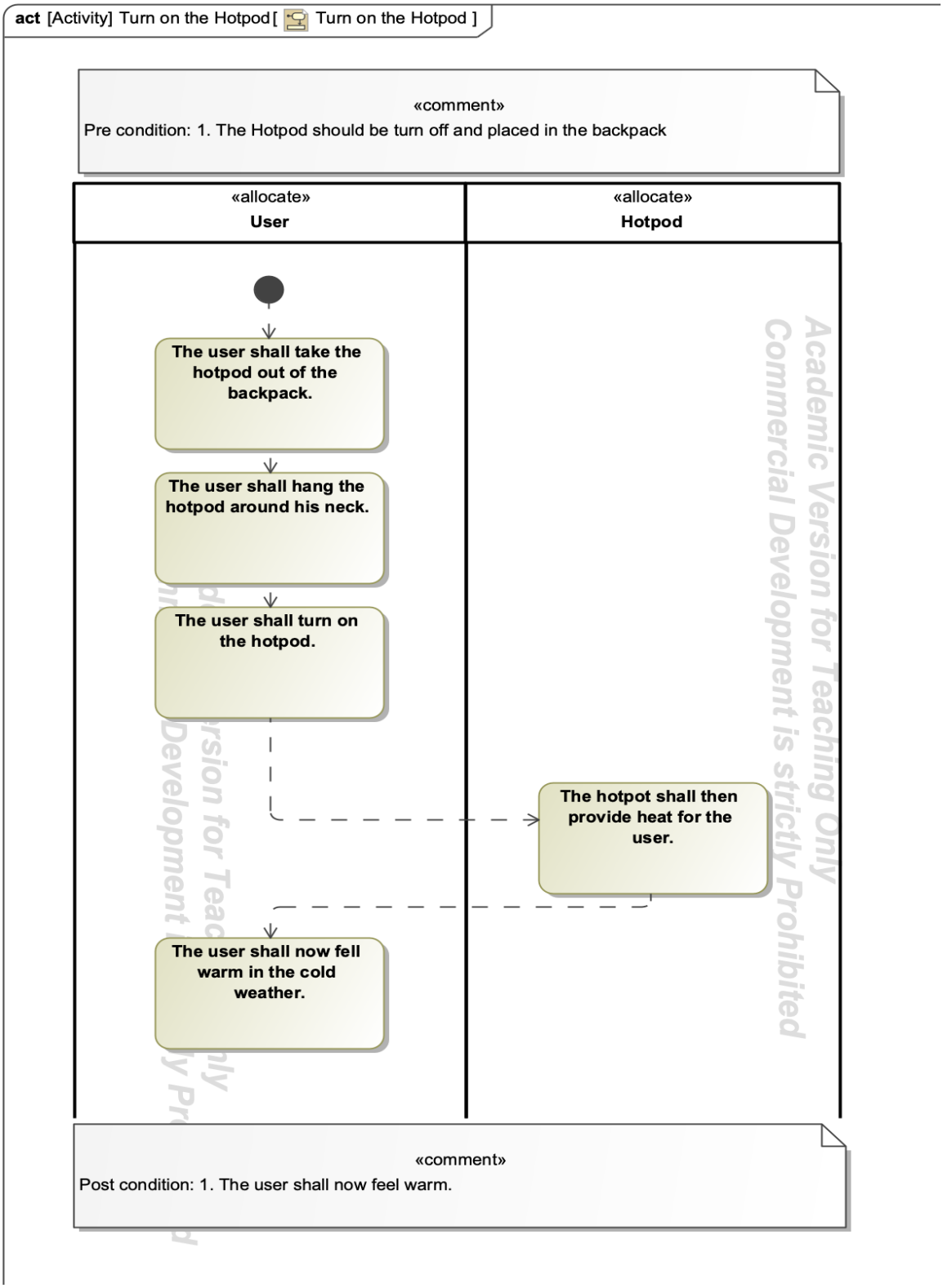


Figure 43. Activity Diagram 1

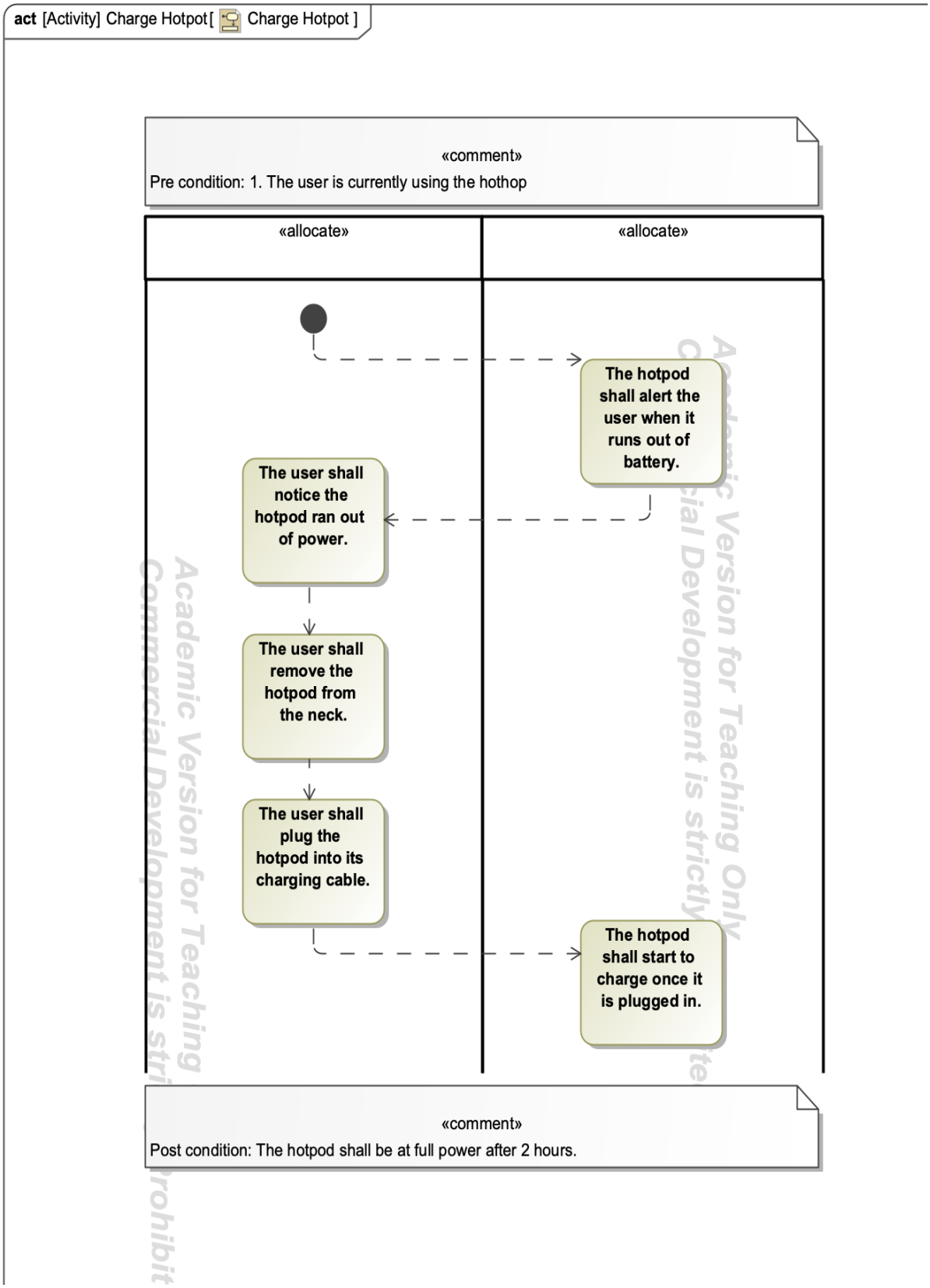


Figure 44. Activity Diagram 2

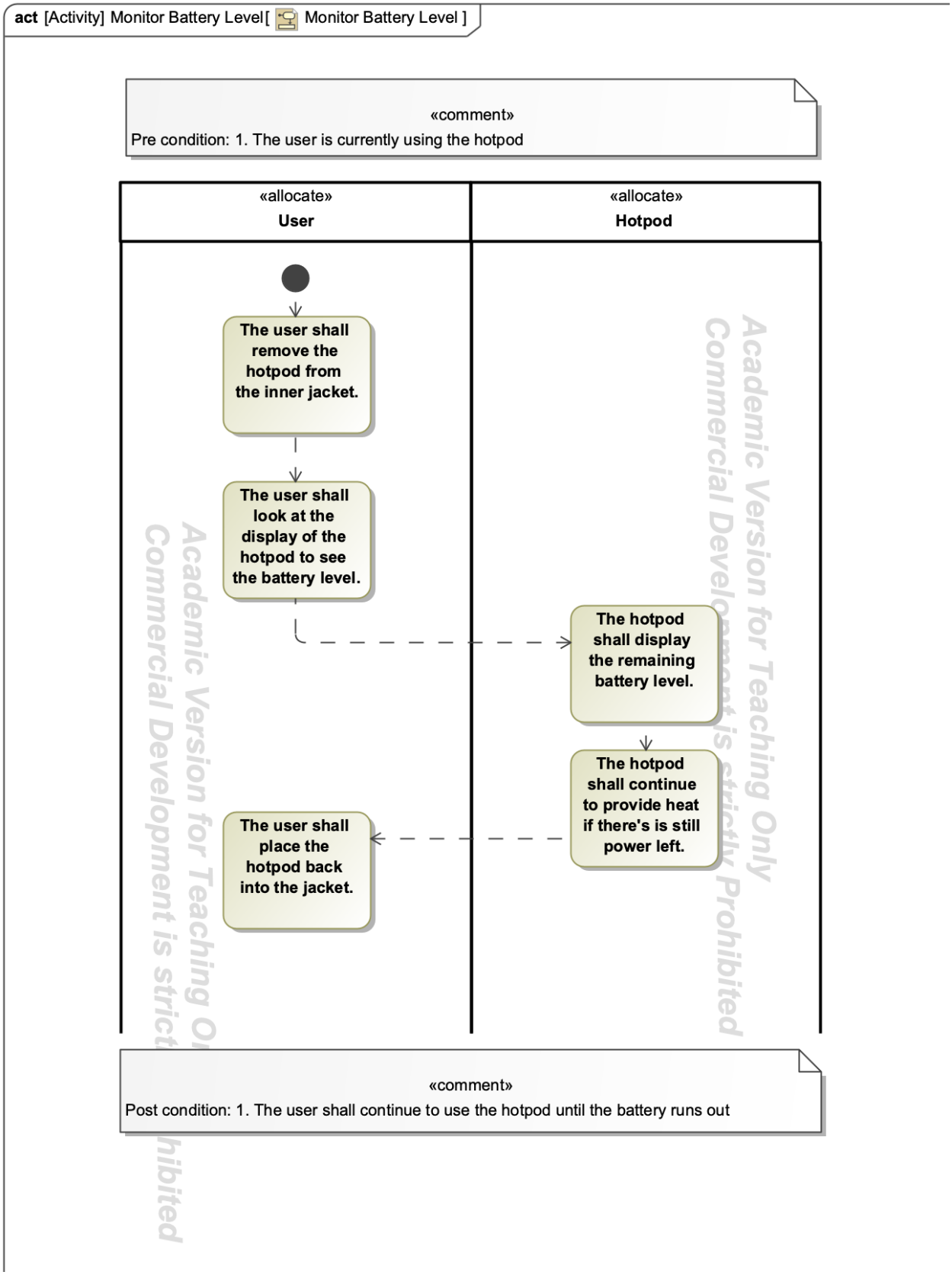


Figure 45. Activity Diagram 3

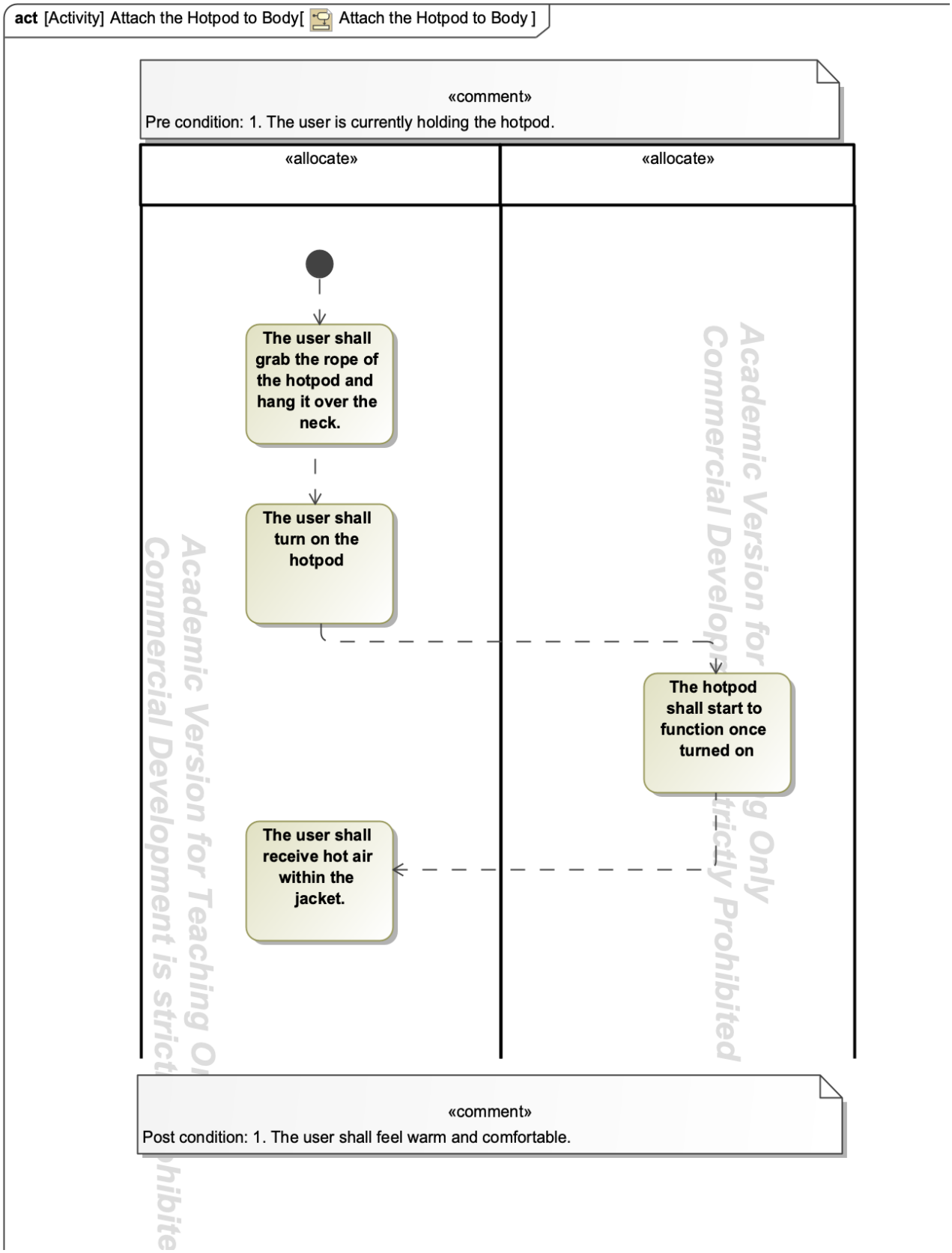


Figure 46. Activity Diagram 4

The four emotional activity diagrams detail the user interaction process with our HotPod; The diagrams give us a clear picture of how the users interact with HotPod under four different aspects: Turning on the HotPod; Monitoring Battery Level; Charging the HotPod; Attaching the HotPod to Body. Overall, the diagrams convey a clear sequence of interactions that align with the product's key performance targets of quick heating, portability, durability, safety, even heat distribution, adjustable temperature, and long battery life.

Here are the detail analysis of these diagrams:

1. Turning on the HotPod:
    - The user initiates the process by taking the HotPod out of the backpack, indicating that the product is stored in a non-operational state for safety and preservation of battery life.
    - The HotPod is then hung around the user's neck, suggesting a wearable design for hands-free operation.
    - The user turns on the HotPod, which then provides heat, fulfilling its primary function.
    - The desired outcome is the user feeling warm in cold weather, showcasing the product's effectiveness.
2. Monitoring Battery Level:
    - The user is expected to remove the HotPod from the jacket to check the battery level, suggesting that the display is not visible during normal use, which could be a point of consideration for design improvement.
    - After observing the battery level, the user places the HotPod back into the jacket, indicating that the product's design requires physical interaction to monitor power levels.
    - The HotPod continues to provide heat if there's still power left, which aligns with the product’s aim to deliver continuous warmth.
3. Charging the HotPod:
    - The user is alerted by the device, which is an essential feature for convenience and safety.
    - The user then removes the HotPod and connects it to a charging cable, indicating a straightforward recharging process.
    - The post-condition states that the HotPod should be at full power after 2 hours, setting an expectation for charging duration.
4. Attaching the HotPod to Body:
    - The user places the HotPod around the neck and turns it on, which is a repeated sequence from the first diagram, emphasizing the simplicity and consistency of the operation.

- The HotPod begins to function and provides heat within the jacket, ensuring the user feels warm and comfortable, which is the final goal of the user interaction.

7.7 Block Definition Diagram

We are examining the block definition diagram for our BeeEZ HotPod to see how each component fits into the overall system architecture. The sketch breaks down our HotPod into five key parts, right? We are talking about five key systems here: the shell, how air moves around, heat management, all the tech stuff inside and how it connects to other devices. Through this graphic breakdown, we are able to confirm that each element of the HotPod pulls its weight and meshes seamlessly with others for smooth operation. For example, the responsibility for managing the convective heat transfer process must be shared by the Air Flow System and the Heating System; The Attachment System is also important because it must securely hold the HotPod in place for the user, enhancing the product's usability and versatility.

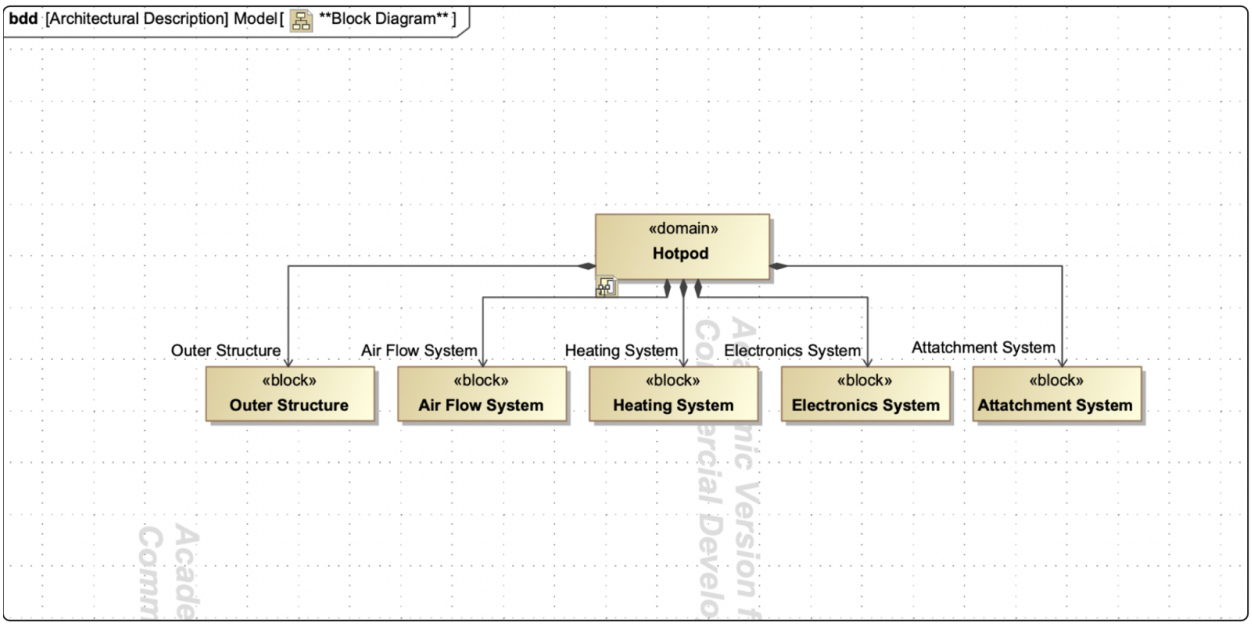


Figure 47. Block Definition Diagram

8. Legal

As Team Hubble transitions the HotPod from concept to market-ready product, we must navigate a complex landscape of legal requirements. Ensuring compliance with these requirements is critical for both the integrity of our product and the viability of our business operations. This section outlines the legal framework we have established to guide the development and commercialization of the HotPod.

8.1 Safety & Environmental Regulations

8.1.1 Safety Regulations

- Electrical Safety: Compliance with electrical safety standards is crucial. This includes ensuring that the heating element and battery are shielded and properly insulated to prevent electrical shocks and burns.
- Temperature Control: The device should have a reliable temperature control system to prevent overheating. This might include thermostatic controls and automatic shut-off mechanisms to avoid burns or fire hazards.
- Battery Safety: Batteries, especially lithium-ion types, should comply with safety standards regarding their use, charging, and disposal. Overcharging protection and thermal regulation are important to prevent overheating and potential explosions.
- Material Safety: All materials used in the jacket should be flame retardant and must not release toxic substances when heated. The jacket should also be designed to ensure that it does not trap excessive heat around the body.
- Wire and Component Durability: Wires and heating elements should be durable and protected against mechanical damage through normal use. They should also be tested for durability and resistance to wear and tear.
- Emergency Features: Incorporating safety features, such as quick cooling or power cut-off mechanisms in case of malfunction, can enhance user safety.

8.1.2 Environmental Regulations

- Energy Efficiency: The device should be designed for energy efficiency to minimize battery usage and comply with any applicable standards for energy consumption in consumer products.
- Sustainable Materials: Using recyclable or biodegradable materials where possible can help comply with environmental regulations aimed at reducing waste.
- Battery Disposal and Recycling: Proper disposal methods for the batteries used in the jacket should be established. This might involve setting up or participating in a battery recycling program.

- Emissions and Waste: Ensuring that the production process minimizes toxic emissions and waste. This includes following regulations on the use of certain chemicals and solvents that might be used during manufacturing.
- Packaging: Using environmentally friendly packaging materials and minimizing unnecessary packaging can also be important for compliance with environmental guidelines.

8.2 Potential Liability Issues

Product liability is a critical consideration in the consumer electronics industry. Our approach includes:

Risk Assessment: Implementing a risk management framework based on ISO 31000 to identify potential hazards associated with product use. We have already conducted a thorough Failure Mode and Effects Analysis (FMEA) to mitigate risks associated with our product, which shall be updated with each iteration.

Product Liability Insurance: Securing comprehensive insurance to protect against claims related to product defects, malfunctions, or accidents.

8.2.1 Prediction of Misuse Cases

Through user behavior studies, we have identified potential misuse cases that could result in product malfunction or user harm. These include:

- Vents Obstruction: Users might block the vents, causing device overheating.
- Water Exposure: Risk of malfunction if used in wet environments.
- Unauthorized Modifications: DIY fixes could negate built-in safety features.
- Incompatible Chargers: Using unapproved chargers could lead to electrical faults.
- Incorrect Attachment: Users may attach the device improperly to clothing, affecting performance and safety.
- Misinterpretation of Indicators: Users might misread warning signals, leading to continued unsafe use.

Understanding that misuse can lead to accidents or product failures, we address these cases through:

- User Education: Developing clear instructions and safety warnings to prevent foreseeable misuse.
- Design for Safety: Incorporating fail-safes and automatic shut-off mechanisms to mitigate risks from misuse.

8.2.2 Failure Mode & Effect Analysis (FMEA)

An FMEA was conducted to systematically evaluate potential failure modes and their effects on the HotPod, considering:

Severity: The impact of a potential failure on user safety and product functionality.

Occurrence: The likelihood of failure occurring during the product's lifecycle.

Detection: The ability to detect a failure before it occurs or before it poses a risk to users.

	Description	*how it might fail*	*impacts if it fails*	*1=not; 10=very*	*why would it fail*	*1=low 5=high*	*what's already being done to prevent/detect it?*	*1=likely 5=unlikely*	*0-250*		*Action Results*			
No.	**Component / Function**	**Potential Failure Mode**	**Potential Effect(s) of Failure**	**Severity**	**Potential Cause(s) / Mechanism(s) of Failure**	**Occurrence**	**Current Design Controls**	**Detection**	**RPN**	**Recommended Action**	**Severity**	**Occurrence**	**Detection**	**RPN**
1	Heating Element	Overheating	Burns to user; Damage to product	10	Malfunction of temperature control system	2	Built-in thermostat; Auto-shutoff feature	5	100	Use an extra temperature sensor; Implement thermal cutoff switch; Use of thicker and better material to prevent burns in case of failure	8	1	3	24
2	Battery Pack	Short-circuit	Fire hazard; Device failure	10	Faulty battery; Improper handling	3	Short-circuit protection; Durable battery housing	5	150	Integrate Battery Management System (BMS); Better and more insulated circuit connections; More insulation around battery housing to prevent fires/burns	8	2	4	64
3	Micro-Controller Unit	Component failure	Device stops functioning	7	Electrical surge; Manufacturing defect	2	Rigorous testing of components	3	42	Surge protection and redundant design implementation	7	1	3	21
4	Fan	Motor burnout	Inability to circulate heat; Loss of function	8	Overuse; Blockage restricting fan movement	2	Overuse protection	3	48	Introduce brushless motors and debris sensors	8	1	2	16
5	Outer Casing	Cracking or Warping	Exposure of internal components; User injury	7	Impact; Excessive heat; Material defect	2	Use of durable and heat resistant 3D printing materials	2	28	Use impact-resistant materials and conduct stress testing; Increase wall thickness	6	1	2	12
6	Temperature Sensor	Sensor malfunction	Inaccurate temperature reading leading to overheating or underheating	8	Faulty sensor; Software error; Calibration error	3	Regular calibration checks	2	48	Install dual sensor system for redundancy	8	2	2	32
7	Charging Port	Port failure	Inability to charge the device; Loss of function	5	Mechanical wear; poor connection quality	4	Strain relief on cable; Strong adherance of port to device chassis	1	20	Reinforce port structure; Implement magnetic connectors	5	3	1	15
8	Buttons/Knob	Unresponsive interface	User cannot operate the device effectively	6	Electrical failure; wear and tear	3	Robust design; user testing	2	36	Waterproof buttons and include tactile feedback	6	2	1	12
								Total	**472**				**Total**	**196**

Figure 48. FMEA Table

Our FMEA has prioritized potential failure modes, assessed their impact, and provided a guide for future designs to incorporate necessary safeguards, such as:

- Thermal Cutoff Switch: Incorporated to prevent overheating of the heating element.
- Battery Management System: Ensures safe charging and battery longevity.
- Surge Protection: Guards the micro-controller unit against electrical spikes.
- Brushless Motors: Reduces fan wear and extends operational life.
- Debris Sensors: Detect fan blockage to prevent motor damage.
- Impact-Resistant Materials: Enhances the durability of the outer casing.
- Redundant Temperature Sensors: Provide fail-safe temperature monitoring.
- Reinforced Charging Port: Ensures longevity and consistent power connection.
- Magnetic Connectors: Minimize wear on charging mechanisms.
- Waterproof Buttons: Protect against liquid damage and improve user safety.
- Tactile Feedback on Controls: Enhances user interface interaction and reduces errors.

8.3 Intellectual Property Licensing Considerations

Intellectual property rights will be carefully managed to protect our innovations and brand.

8.3.1 Pursuing Patents

We assessed the feasibility of obtaining:

- Utility Patents: For any novel invention or functional aspect of the HotPod, such as a unique heating mechanism or energy-saving feature.
- Design Patents: To protect the unique appearance and aesthetic design characteristics of the HotPod.

We plan to pursue a design patent for the HotPod design. This decision is in part due to the HotPod not having any novel heating mechanism or features that would be applicable for a utility patent. The device operating mechanism exists in other industries and only performed minor tweaks to suit the jacket heating application of our product.

In the future we plan to pursue either utility or design patents for all of our new and useful products involving various processes, machines, or compositions of matter.

8.3.2 Trade Secrets

We will maintain certain proprietary technologies and processes as trade secrets, ensuring confidentiality through:

- Non-Disclosure Agreements (NDAs): With employees and partners to protect the confidentiality of proprietary information.
- Limited Access: Only provide enough information as required to employees and partners to protect core principles.
- Information Security Measures: Implementing robust cybersecurity measures to protect digital trade secrets.

8.3.3 Trademark

Our brand identity will be protected by:

- Trademark Registration: Registering the BeeEZ name and HotPod logo as trademarks in relevant jurisdictions to secure exclusive branding rights.
- Brand Guidelines: Establishing brand guidelines to ensure consistent and correct use of trademarks across all platforms.

We will register our team's name Hubble along with the logo as trademarks to establish our brand identity and ensure brand protection in the marketplace.

We will explore trademarking distinctive product names, taglines, or slogans associated with the HotPod, enhancing our brand's intellectual property portfolio.

9. Project Timeline

9.1 Semester 1 Timeline

Strict adherence to project timelines is imperative for on-time product delivery in the competitive market. This section outlines key milestones guiding the HotPod from concept to full production scale-up.

9.1.1 Timeline and GANTT Chart

A detailed project timeline and GANTT chart track major milestones for the Fall 2023 semester. The tasks mentioned in their timeline include multiple sub tasks such as the prototype design 0 involved rigorous calculations to determine the required volume to be covered, power requirement and other engineering specifications. Another example is the user testing which included a conjoint analysis along with field work. The timeline was created with built in buffers to absorb potential delays.

Timeline

Fall Semester

Review 1

Name	Timeline - Start	Timeline - End	Dependency
Empathy Field Work	08/28/2023	09/14/2023	
Unpacking	09/08/2023	09/21/2023	Empathy Field Work
Modeling	09/15/2023	09/22/2023	Unpacking
Ideating	09/22/2023	09/29/2023	Modeling
Concepts	09/29/2023	10/02/2023	Ideating
Review 1 Prep	10/02/2023	10/02/2023	Concepts, Ideating, Modeling, Unpacking, Empathy Field Work
	08/28/2023	**10/02/2023**	

Review 2

Name	Timeline - Start	Timeline - End	Dependency
Prototyping - Design 0	10/11/2023	10/16/2023	Review 1 Prep
User Testing	10/13/2023	10/20/2023	Prototyping - Design 0
Unpacking and Modeling Testing	10/20/2023	10/27/2023	User Testing
Prototyping - Design 1	10/27/2023	11/01/2023	Unpacking and Modeling Testing
Review 2 Prep	11/06/2023	11/06/2023	Prototyping - Design 0, User Testing, Unpacking and Modeling Testing, Prototyping - Design 1, Review 1 Prep
	10/11/2023	**11/06/2023**	

Final Showcase

Name	Timeline - Start	Timeline - End	Dependency
Iterations and Optimizations	11/08/2023	11/24/2023	Review 1 Prep, Review 2 Prep
Final Build - Design 2	11/08/2023	12/01/2023	Iterations and Optimizations
Showcase Poster	12/02/2023	12/02/2023	Review 1 Prep, Review 2 Prep, Final Build - Design 2
PDS Report	12/07/2023	12/07/2023	Review 1 Prep, Review 2 Prep, Final Build - Design 2
	11/08/2023	**12/07/2023**	

Figure 49. Semester 1 Timeline

The Gantt chart helps visualize this timeline, delineating each phase of development from conception to final build. It charts our course over the Fall 2023 semester detailing task

durations, dependencies, and overlaps. Key milestones and gate reviews are prominently marked, ensuring that each stage of the project aligns with our strategic goals and educational timelines. This chart will be updated to reflect real-time progress and adjustments throughout the next phase of the project in Spring 2024 semester.

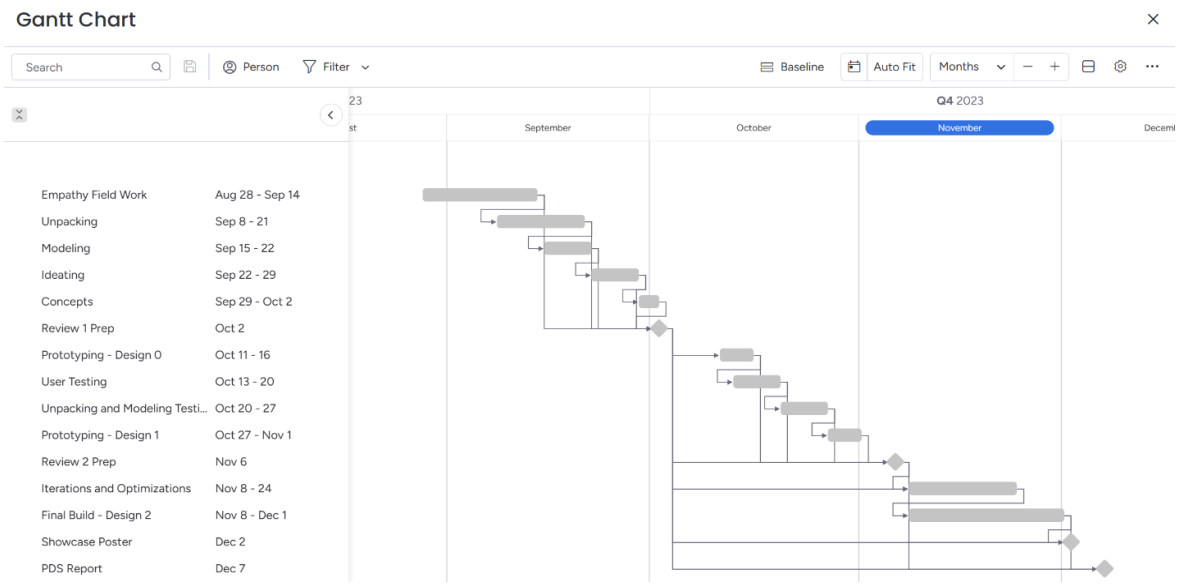


Figure 50. Semester 1 Gantt Chart of Timeline

9.2 Semester 1 Feedback and Improvements

After creating the functional prototype in the first semester, we received feedback and identified several areas for improvement. Four major changes were proposed:

- Improved Heating: In the previous semester, the heater functioned but was not very effective. Enhancing the heating element's efficiency became a priority.
- Battery Issues: We initially attempted to use a battery to power the fan and heater. However, due to power issues, the battery could not handle both components simultaneously, forcing us to rely on wall power. Finding a suitable battery solution became crucial.
- Design Priorities: Toward the end of the last semester, we focused more on design rather than functionality. Moving forward, priority will be given to functionality.
- Integrated PCB: An integrated PCB will be designed to minimize wiring and reduce the number of separate electronic components used.

In addition to these major changes, several minor improvements were identified:

- Transition from assumption-based calculations to those based on previous experimental results.
- Use of better materials for the exterior body along with mesh for ventilation.

- Incorporate Design for Manufacture and Assembly (DFMA) principles.
- Brainstorm and focus on an improved attachment mechanism.
- Utilize system tools to aid the design process.
- Improve the sales, marketing and go to market plans with a business model canvas.

9.3 Semester 2 Timeline

Similar to semester 1, a detailed timeline was created to track major milestones for the Spring semester. The tasks mentioned in their timeline include multiple sub tasks. It is again created with built in buffers to absorb potential delays.

Category	Task	Start	End	Owner	Week1	Week2	Week3	Week4	Week5	Week6	Week7	Week8	Week9	Week10	Week11
Planning	1.1 Project Plan	02/20/24	02/26/24	Lillian[80%];Sagar[20%]											
Design	2.1 Recheck and update mechanical calculations	02/20/24	03/04/24	Sagar;Niharika											
	2.2 Circuit simulation	02/20/24	03/04/24	Lillian											
	2.3 Figure out electronics to create custom PCB	03/05/24	03/18/24	Lillian[80%];Sagar[20%]											
Material Sourcing	3.1 Metal mesh material	02/20/24	03/04/24	Anne											
	3.2 Outer plastic cover material	03/05/24	03/18/24	Anne											
	3.3 Select and Order components	02/27/24	03/18/24	Anne;Niharika;Sagar											
Development	4.1 Redesign for Manufacture and Assembly	03/12/24	03/25/24	Sagar;Niharika;Anne											
	4.2 Perform CFD and relevant analysis	03/19/24	04/01/24	Sagar;Niharika											
	4.3 Production and Assembly	04/02/24	04/15/24	All											
Quality Assurance	5.1 Testing and Improving, FMEA	04/09/24	04/29/24	All											
	5.2 Iterations	04/16/24	05/07/24	All											
Customer Segment	6.1 Emotional Activity Diagram	02/27/24	03/18/24	Adam;Franny;Evans											
	6.2 Block Definition Diagram	04/16/24	05/07/24	Adam;Franny;Evans											
	6.3 Internal Block Diagram	04/16/24	05/07/24	Adam;Franny;Evans											
	6.4 Other System Tools	03/26/24	05/07/24	Adam;Franny;Evans											
Marketing and Business	7.1 Business Model	02/27/24	03/18/24	Adam;Franny;Evans											
	7.2 Branding	02/20/24	03/11/24	Adam;Franny;Evans											
	7.3 Marketing Section	03/12/24	04/15/24	Adam;Franny;Evans											
	7.4 Patent Check	03/05/24	03/18/24	Adam;Franny;Evans											
Documentation	8.1 Final report	03/26/24	05/07/24	All											

Figure 51. Semester 2 Timeline

10. Design Improvements

10.1 Design Changes Overview

This semester, we further analyzed the hexagonal shape of the outer shell and concluded that it is not the optimal shape to fit all of the required components as well as heat flow. There are many edges to the shape in which the square shape of our main components, such as the PCB, battery, fan, and mesh do not fit well into. The air flow output was designed to be at the top of the device instead of the side, and this creates the problem that the air will not circulate well around the body. Instead, it will blow directly towards the jacket, where the hot air can escape through the zippers and decrease the amount of hot air reaching the user's body. In addition, the overall dimension, although ambitious, is much too small to accommodate the components that are capable of delivering the desired air flow and temperature. Therefore, several changes were made this semester for an optimized product.

10.2 Revised Design (details, analysis, prototyping, etc.)

The final product is shown in the figures below. It measures 154 x 97 x 30 mm. The top ⅓ consists of the heating elements, mesh, and fan. The bottom ⅔ includes the PCB, switches, batteries, charging port, and wires.

10.2.1 Electrical

10.2.1.1 Circuit Diagram Design

To enhance the stability and safety of the product's temperature regulation and heat transfer, the internal circuitry was optimized and adjusted. Structurally, the circuit was divided into two parts: the control circuit and the operating circuit.

The control circuit consisted of a control power supply, an Arduino board, temperature sensors, and potentiometers. Its primary function was to receive temperature signals, process and compute temperature adjustment parameters, and generate PWM signals for the automatic control and adjustment of the heating pad and fan.

The operating circuit, which generated hot air, comprised a working power supply, switches, heating pads, fans, and nMOS transistors. This design isolated the control circuit from the operating circuit, thereby protecting the control circuit's stability from the operating circuit's voltage fluctuations and ensuring the safe operation of the control panel.

Functionally, the system was enhanced with automatic temperature and fan speed adjustment features. It utilized PWM and PI control methods for automatic temperature adjustment. The target temperature was set via the position of the potentiometer, and PI control automatically ensured that the output PWM signal maintained the temperature close to the target. Additionally, an independent PWM signal was generated to control the fan, allowing the fan speed to steadily increase as the temperature rose.

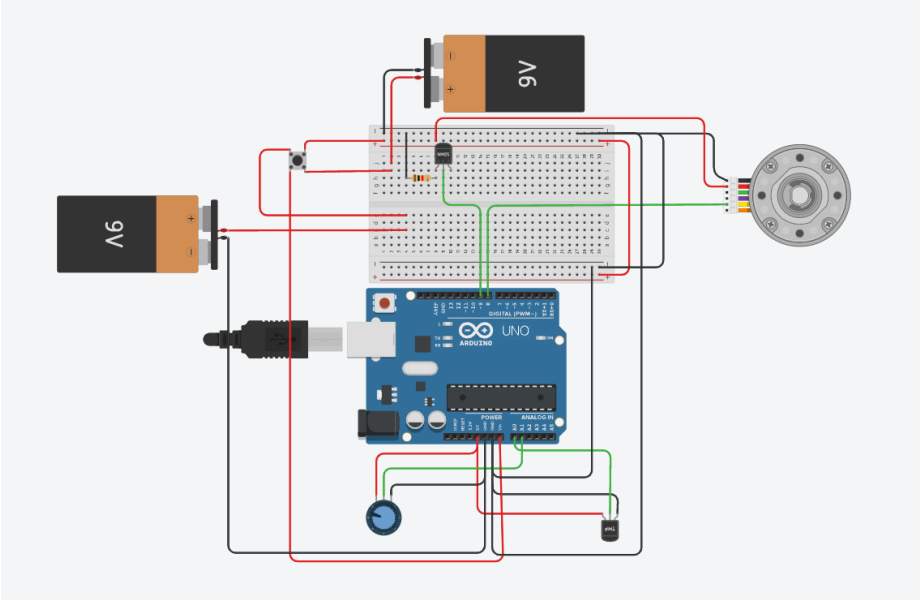


Figure 52. Circuit View

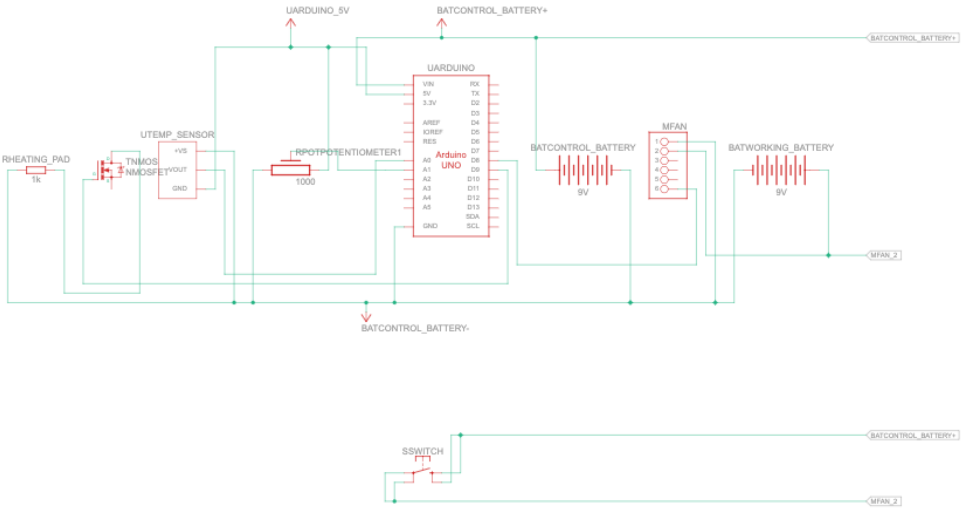


Figure 53. Schematic View

10.2.1.2 Prototype

Based on the circuit design, Table 1 lists the selection of circuit components to ensure optimal functionality:

Table 2. Circuit Components

Component	Product Name
MOSFET	470348-856 (EA) TI-INNOVATOR MOSFET MODULE PK5 - MOSFETMOD5PK

Wires	470110-328 (EA) Jumper Wire Set - WK - 1, Jumper Wire Set
Flat Breadboard	10-PCS 50mm x 70mm Copper Strip PCB Perfboard Universal for Soldering
Arduino Nano	HiLetgo 3pcs Nano V3.0 ATmega328 Type-C Arduino Nano CH340
Fan	Delta Electronics AFB0712LB
Temperature Senso	824-NB-PTCO-029 - RTD Temperature Sensor
Power Supply	12V 2A rechargeable battery. 12V 1A battery
Potentiometer	Nidec Components CRV16-00-502 Potentiometer
Switch	toggle switch
Heating Pad	PTC Heating Element AC/DC 12V Constant Temperature Heater (80C: 2W-5W)

To verify the accuracy of the circuit connections and component selection, we initially constructed a prototype on a breadboard. The prototype circuit connections are consistent with the design, with a toggle switch controlling both the operating and control circuits simultaneously. The Arduino generates PWM signals to control the parallel-connected fan and heating pad, thereby achieving automatic control of temperature and fan speed.

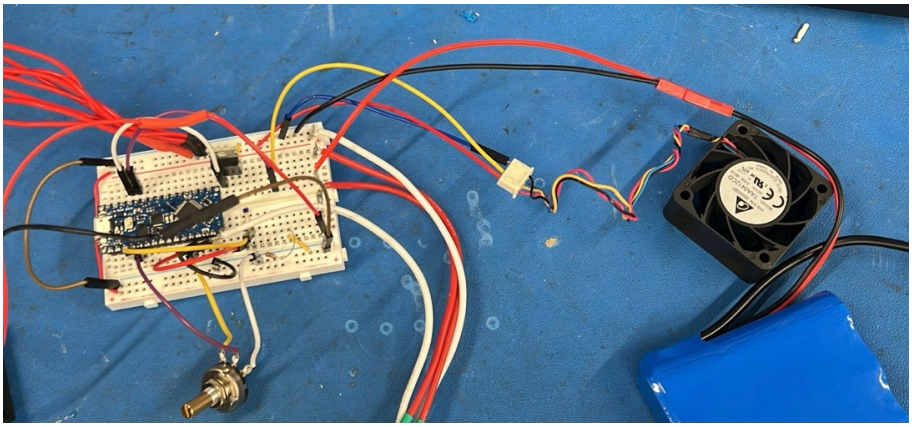


Figure 54. Breadboard-based Prototype Circuit

10.2.1.3 PWM Control and PI Control

In this section of the report, we delve into the control theory underpinning the temperature and fan speed regulation in our prototype circuit, as depicted below. The control strategy utilizes both Proportional-Integral (PI) and Pulse Width Modulation (PWM) techniques to achieve precise and stable environmental conditions.

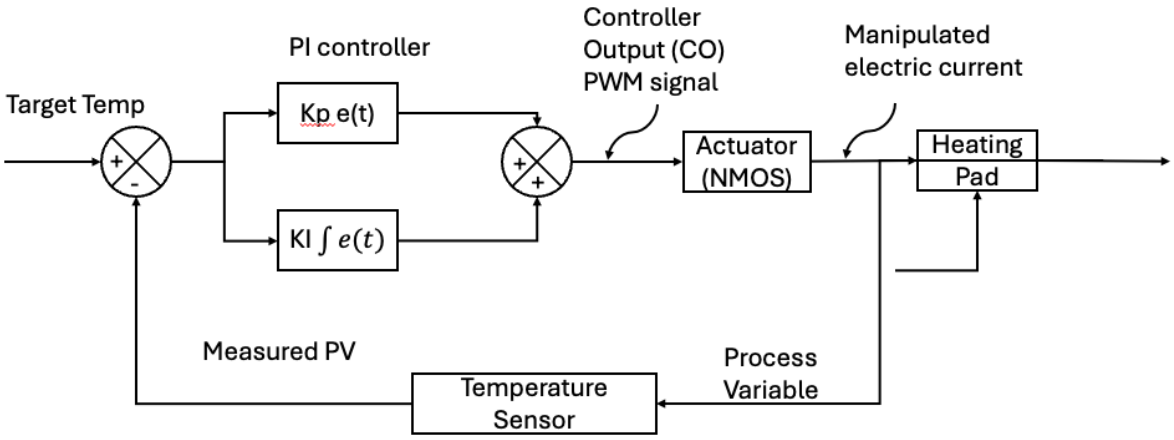


Figure 55. Block diagram of Heating Pad Temperature Control System

The above block diagram illustrates the PI control loop implemented for the heating pad. The system began with the PI controller receiving the target temperature setpoint and the actual temperature from the temperature sensor (Measured Process Variable). The PI controller calculated the error between these two values and adjusted the control output. This output, in the form of a PWM signal, was used to drive the actuator (NMOS), which in turn regulated the current flowing to the heating pad. The key parameters in this control loop were the proportional gain (Kp) and the integral gain (Ki), which were tuned to optimize the system's response to temperature variations, ensuring that the heating pad maintained a consistent temperature.

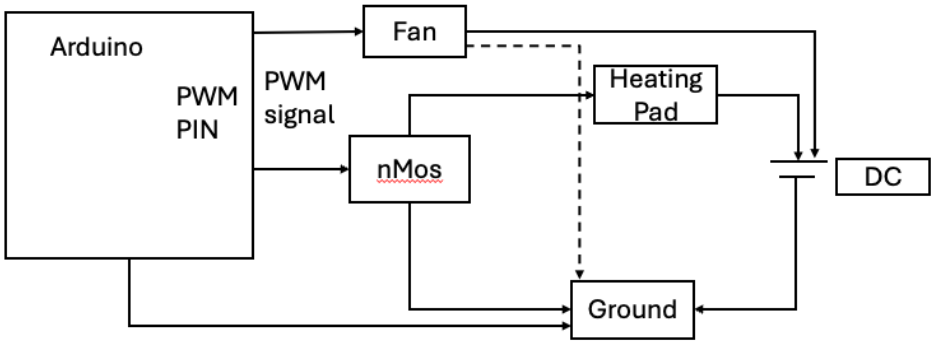


Figure 56. Block diagram of Control Logic in Temperature and Fan Speed Control System

The Control Logic Block Diagram extends the application of PWM control to both the heating pad and the fan, managed by an Arduino. The PWM signals were crucial for modulating the power delivered to these components, enabling variable but precise control over their operations. By adjusting the duty cycle of the PWM signals, the Arduino effectively managed the speed of the fan and the heat output of the heating pad in tandem. This coordinated

control mechanism allowed for a balanced thermal environment, where the fan speed increased with rising temperature, promoting efficient heat distribution and dissipation.

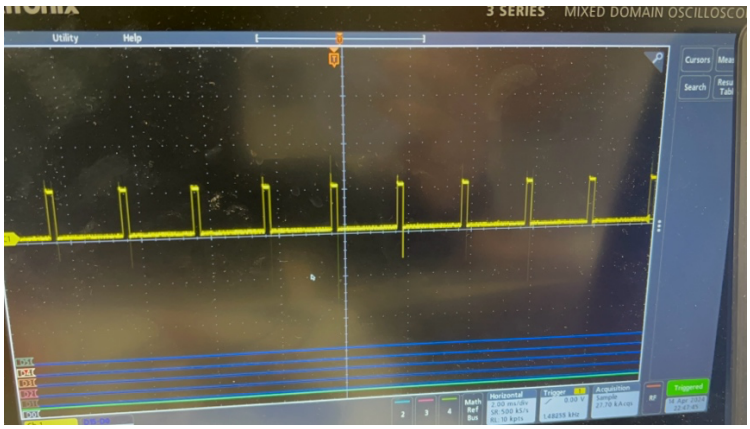


Figure 57. Oscilloscope Trace of Arduino-generated PWM signal

The attached oscilloscope screenshot provides a visual confirmation of the PWM signal generated by the Arduino. This signal was critical for controlling the power delivery to the heating pad and fan in our prototype circuit. The oscilloscope displayed a series of voltage pulses, which represented the digital 'on' and 'off' states used to modulate power. The duration or duty cycle of each pulse directly influenced the average voltage and current supplied to the circuit's load, thus controlling the temperature of the heating pad and the speed of the fan.

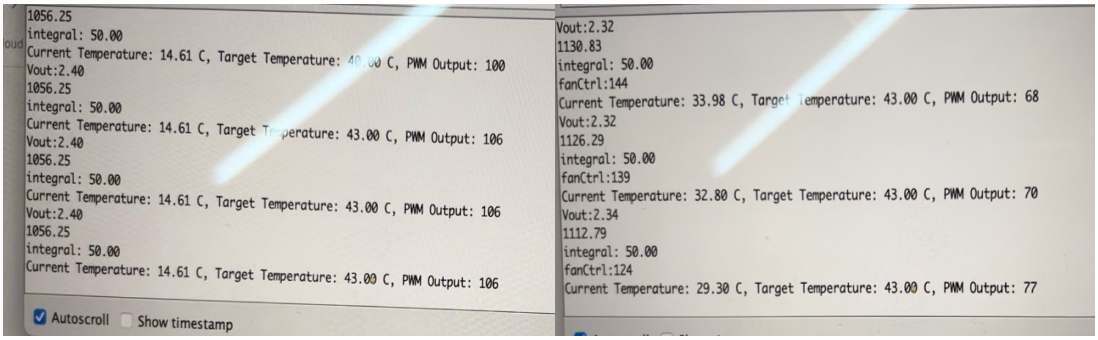


Figure 58. Arduino Output Monitoring for Temperature Control

Arduino's serial output during the operation of the temperature control system can be seen. This monitoring window displayed real-time data, including the current temperature, target temperature, integral value, and the PWM output. From the image, it is evident that the circuit was operating according to the control logic, actively managing temperature by rapidly heating up the heating pad when the current temperature was below the target temperature until it reached the set point. When the temperature reached 20 degrees Celsius, the fan began to operate, with its speed gradually increasing as the temperature

rose, thus achieving automatic control of the fan speed. The specific parameters for these operations are detailed in the code.

sketch_mar29b

```
// Define pin connections
const int sensorPin = A0; // PT1000 sensor pin
const int potPin = A1; // Potentiometer pin for setting the target temperature
const int pwmPin = 9; // PWM pin connected to the MOSFET gate
const int fanPin = 3; // control open / close of the fanf
// PI controller parameters
const float Kp = 2.0; // Proportional coefficient
const float Ki = 0.1; // Integral coefficient
float integral = 0.0; // Initial integral value
float lastError = 0.0; // Last error value
uint8_t fanCtrl = 0;

// Parameters for the PT1000 and voltage divider resistor
const float referenceResistor = 975.0; // Resistance value of the voltage divider resistor
const float R0 = 1000.0; // Resistance of PT1000 at 0°C
const float T0 = 0.0; // Reference temperature 0°C
const float alpha = 0.00385; // Temperature coefficient of PT1000

void setup() {
  pinMode(sensorPin, INPUT);
  pinMode(pwmPin, OUTPUT); // Set the PWM pin as output
  pinMode(fanPin, OUTPUT);
  pinMode(potPin, INPUT);
  Serial.begin(9600); // Initialize serial communication
}

void loop() {
  // Read and calculate the temperature
  float Vout = analogRead(sensorPin) * (5.0 / 1000.0);
  Serial.print("Vout:");
  Serial.println(Vout);
  // float Rt = (Vout / (5.0 - Vout)) * referenceResistor;
  float Rt = ((5*referenceResistor)/Vout) - referenceResistor;
Serial.println(Rt);
  float temperature = (Rt / R0 - 1.0) / alpha + T0;
  // Serial.println(temperature);
  // Read the potentiometer value and convert to target temperature (e.g., 0-100°C)
  float targetTemperature = map(analogRead(potPin), 0, 1023, 0, 60);
  // Serial.print("tar")
  // Calculate temperature error
  float error = targetTemperature - temperature;
  // Update integral term
  integral += error * Ki;

  if(integral > 50) integral = 50;
  if(integral < -50) integral = -50;
  Serial.print("integral: ");
  Serial.println(integral);
  // Calculate PWM output
  float pwmOutput = (Kp * error) + integral;

  // Constrain PWM output to valid range (0-255)
  int pwmValue = constrain((int)pwmOutput, 0, 255);
  if(temperature > 20){
    fanCtrl = 255*(temperature / 60);
    Serial.print("fanCtrl:");
    Serial.println(fanCtrl);
    analogWrite(fanPin, fanCtrl);
  }
  else{
    fanCtrl = 0;
    analogWrite(fanPin,fanCtrl);
    Serial.print("fanCtrl:");
    Serial.println(fanCtrl);
  }
  // pwmValue = 100;
  // Output PWM signal
  analogWrite(pwmPin, pwmValue);

  // Print current temperature and target temperature to serial
  Serial.print("Current Temperature: ");
  Serial.print(temperature);
  Serial.print(" C, Target Temperature: ");
  Serial.print(targetTemperature);
  Serial.print(" C, PWM Output: ");
  Serial.println(pwmValue);

  // Short delay
  delay(1000);
}
```

Figure 59. Arduino Code

The source code that underpinned the temperature control system implemented on the Arduino is shown above. This code snippet illustrates the setup and loop functions where the temperature sensor inputs were read, and control actions were determined based on the PI control algorithm. Key sections of the code included the calculation of the error between the target and current temperatures, adjustment of the integral term, and computation of the PWM output for controlling the heating pad. This code was essential for understanding how the control parameters were implemented and adjusted to maintain the desired system performance.

10.2.1.4 Finished Product

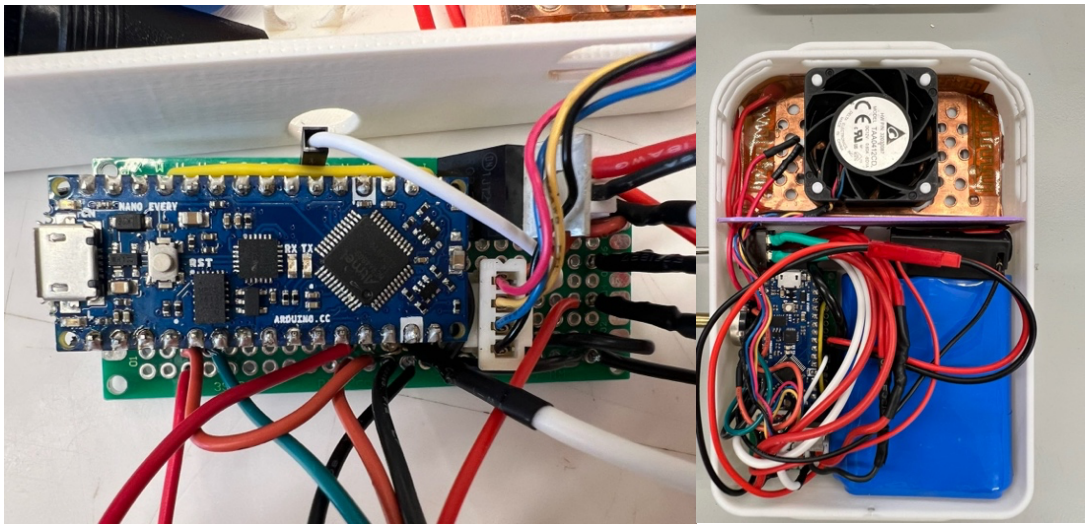


Figure 60. Finished Prototype

Following successful hardware prototyping and code debugging on a breadboard-based prototype, the components were soldered onto a custom PCB to assemble the final product. The finished product consists of two main parts: the Arduino board and the control components housed in a compact casing.

This assembly encapsulates the Arduino board with all necessary connections to sensors and actuators, ensuring robust and reliable operation. The image on the right shows the control box, which includes a neatly arranged PCB housing the circuitry and components like the fan and heating pad controller. This enclosed setup provides a practical and professional appearance, significantly enhancing the durability and functionality of the device in real-world applications.

10.2.2 Part Selection

10.2.2.1 Mesh

During the previous semester, a unique issue arose - an unpleasant smell from the heated mesh. It was suspected that the heat melted the coating on the aluminum mesh, producing a plastic-like odor. Recognizing the need to address this problem, the team embarked on a search for an alternative mesh material, one that not only lacked any coating but also possessed superior thermal conductivity compared to aluminum.

To facilitate an informed decision, a comprehensive comparison of different materials was conducted, with the findings summarized in the table below.

Table 3. Mesh Material Selection

Material	Thermal Conductivity (W/m K)
Silver	428
Copper	401
Aluminum Bronze (95% Cu, 5% Al)	83
Bronze (75% Cu, 25% Sn)	26
Brass (Yellow Brass) (70% Cu, 30% Zn)	111
Cartridge brass (UNS C26000)	120
Gold	327
Aluminum	236
Duralumin (94-96% Al, 3-5% Cu, trace Mg)	164
Iron	83.5
Nickel	94
Tungsten	182
Zinc	122
Steel (composition not specified)	45

Three factors were considered when choosing the most suitable material - price, availability, and thermal conductivity. There are obvious choices that are out of our budget, such as silver and gold. In addition, materials such as zinc and tungsten are not commonly made into sheet or mesh form and are also difficult to source. Therefore, copper was chosen as the best material.

One issue we faced was that the available copper mesh were extremely fine, with thin wires and small openings that do not retain heat well.

Figure 61. Mesh 1

Our solution to this problem was to purchase a thin sheet of copper and drill holes into it to mimic a mesh. The sizing and distribution of the holes are customizable, so we are able to control how much heat can be retained and how much air can flow through.

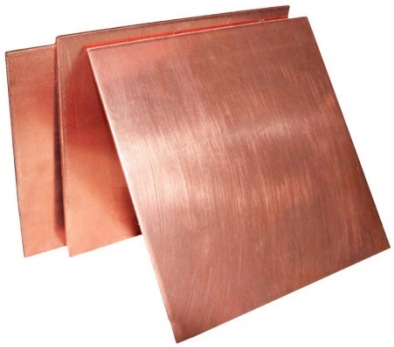


Figure 62. Mesh 2

10.2.2.2 Fan

There were two types of fans to choose from - axial and centrifugal. For the design, a fan that blows air radially instead of axially was required, necessitating the use of a centrifugal fan. However, finding a centrifugal fan that matched the exact specifications (12V DC, dimensions under 80mm x 80mm x 20mm, and CFM of at least 20) proved difficult. Most centrifugal fans either had sufficient CFM but were too large or operated at the wrong voltage. Consequently, axial fans were purchased instead, and the design of the outer shell was modified to accommodate the different air flow direction of the axial fans. This change in fan type prompted adjustments to the overall design to ensure proper air circulation and heating efficiency within the product.

Figure 63. Fan

10.2.2.3 Battery

The battery selection presented a significant challenge because we specifically required a 12V rechargeable battery. Initially, we sourced a non-rechargeable 12V battery with a lower amperage, but it could not sustain running both the fan and the heater for an extended period. As a result, we sourced a larger rechargeable battery that provided sufficient power, but this led to space constraints within the design. Ultimately, we needed to balance power requirements with portability and functionality while ensuring the HotPod remained compact and user-friendly.

Figure 64. Previous Battery

Figure 65. New Battery

10.2.3 Layout

The rectangular form factor was chosen for the product design to optimally accommodate the main components - fan, battery, mesh, and PCB. This shape offers several advantages over the previously considered hexagonal design. Firstly, the rectangular layout saves more

internal space compared to the hexagonal shape. Secondly, it allows better physical separation between the heating element and the battery. In the hexagonal design, the battery and heating element were stacked directly on top of each other, posing a potential overheating risk. The rectangular shape minimizes direct surface contact between these two components.

By adopting the rectangular shape, the design achieves a more space-efficient layout while prioritizing component segregation and implementing additional safety measures to mitigate the risk of battery overheating. These improvements contribute to an overall safer and more optimized product design.

10.2.4 Design Iterations

10.2.4.1 Design Iteration 3

The initial shell design had dimensions of 160 x 90 x 25 mm. This size was chosen to accommodate a 60 x 60 x 20 mm standard fan, an A23 battery, and the PCB. Approximately half of the internal space was allocated for the fan/mesh assembly, while the other half was reserved for the electronics and battery.

The mesh was designed to fit the top portion of the shell, matching the fan's dimensions. The heating element would be attached to the sides of the mesh to allow heat dissipation throughout. The fan placement was intended to draw air from the bottom and expel it through the sides, flowing over the heated mesh.

However, this was only a preliminary design, as the exact dimensions of the battery and PCB were still unknown at that stage. Further iterations were necessary to refine the design based on the actual component sizes.

Figure 66. Iteration 3 CAD Model

Figure 67. Iteration 3 Prototype

10.2.4.2 Design Iteration 4

The battery received was larger (68 x 55 x 19 mm) than initially anticipated. To accommodate this without increasing the product's overall dimensions, the fan size had to be reduced. Downsizing the PCB was also necessary to create space for wiring. It became evident that two batteries would be required—one to power the Arduino and another for the fan. The mesh size was reduced to match the smaller fan.

Since a centrifugal fan was unavailable, placing the mesh on top of the fan instead of underneath was considered, as directing the air upwards through the heated mesh could potentially retain more heat. However, after testing, it was found that positioning the mesh underneath resulted in warmer air temperatures. As the fan drew air from the bottom and expelled it upwards and sideways, more openings were added to the bottom and sides of the shell to facilitate better airflow.

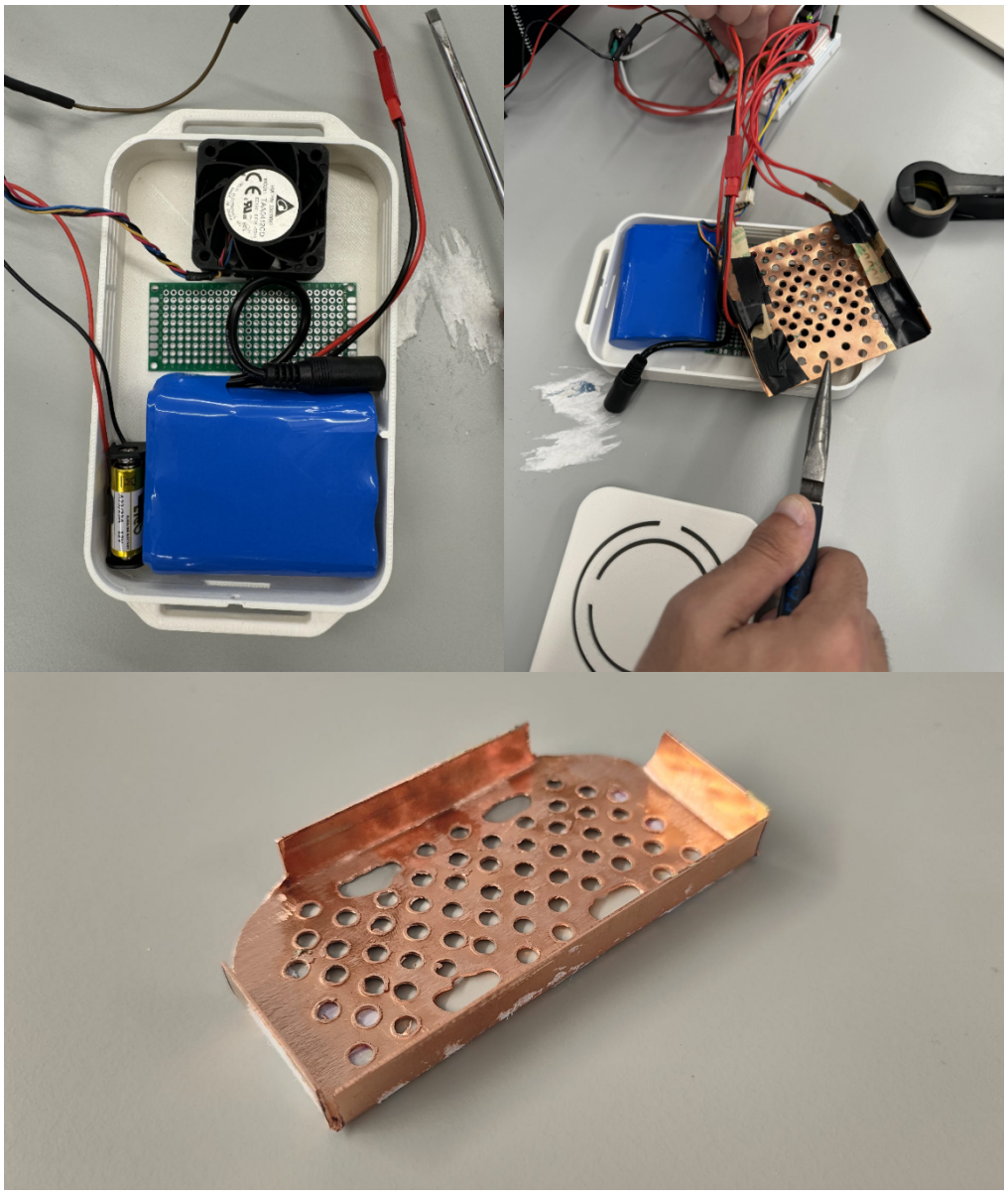


Figure 68. Iteration 4 Prototype

Concurrently, the idea of using magnets as an attachment mechanism was explored, temporarily renaming the product "MagnaHeat." However, this concept was ultimately abandoned due to safety concerns regarding the strength of the magnets posing a risk for users with pacemakers, as well as potential weight issues.

Figure 69. Iteration 4 CAD Model

10.2.4.3 Design Iteration 5

The preliminary layout was established. The power switch and temperature dial were positioned on the right side, while the charging port was located on the left. The temperature sensor was integrated with the mesh panel. The PCB was placed on top of the battery, with a divider separating the heated mesh area from the electronics. Accommodating the cluster of wires within the case proved challenging.

To address the wiring issue, the following potential solutions were explored:

- The wires were rerouted more efficiently to minimize clutter and improve cable management.
- Shorter wire lengths or slimmer wiring replaced thick cable bundles where possible.
- The internal space allocation for wiring was increased by slightly modifying the case dimensions or reshaping certain components.
- Wireless alternatives for specific connections were explored to reduce the number of physical wires.

By implementing a combination of these measures, a more organized and streamlined internal layout was created, ensuring a tidy fit within the case while maintaining proper functionality and accessibility for future maintenance or modifications.

Figure 70. Iteration 5 CAD Model

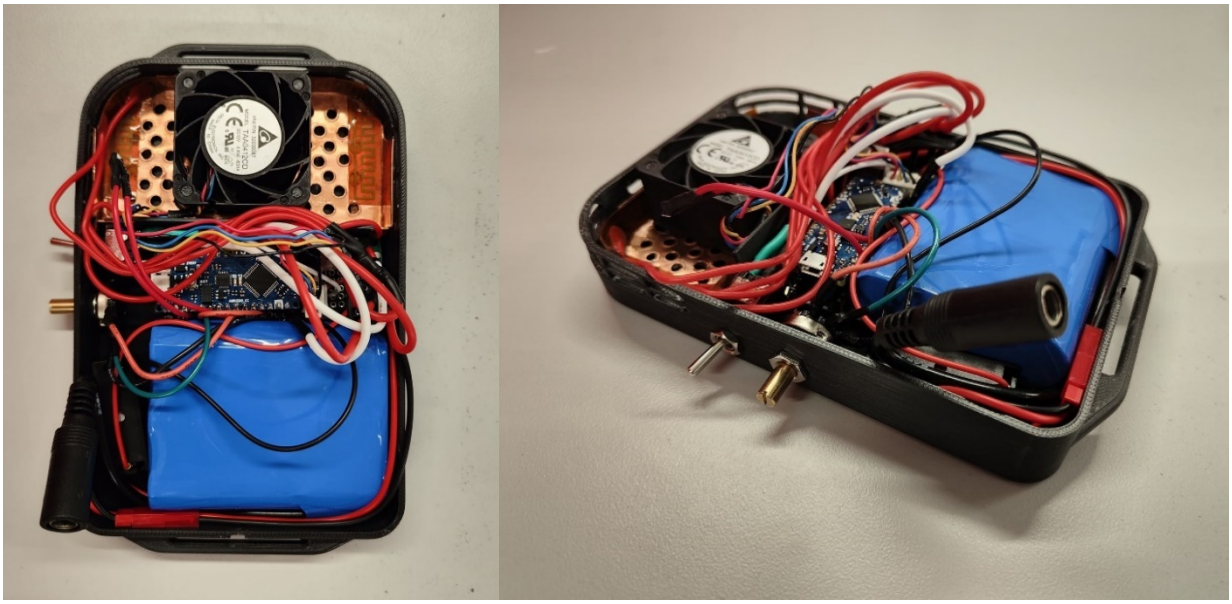


Figure 71. Iteration 5 Prototype

10.2.4.4 Design Iteration 6

After extensive testing, we discovered that having only one mesh panel underneath the fan caused the hot air being expelled to mix with the cold air entering from the side vents, compromising the cooling efficiency. To address this, we added a second mesh panel on top of the fan to capture heat from the heating elements while preventing cold air from mixing before being directed upwards. Initially, the divider panel was fixed, but it broke easily when installing the mesh panels. Therefore, we redesigned it to be adjustable, allowing it to slide into different slots on the cover to change its position as needed.

To accommodate the wiring, we elevated the switches, enabling the PCB to slide underneath, and relocated the battery to the side. This change also facilitated the correct placement of the power port. Furthermore, we split the cover into two separate pieces to allow for easier testing and to offer users the option of customizable cover attachments.

Figure 72. Iteration 6 CAD Model

Figure 73. Iteration 6 Prototype

11. Business

11.1 Branding

Our brand name is derived from the words "Hot" and "Bubble," reflecting our product's purpose to envelop the human body in a warm bubble, providing comfort during winter. Originally, we named our product MagnaHeat, inspired by its unique magnetic connection feature. However, due to technical challenges, this feature was not implemented. Nevertheless, we retained the name MagnaHeat as it aligns with our company's tagline, "Magnify Your Warmth," emphasizing our commitment to enhancing warmth.

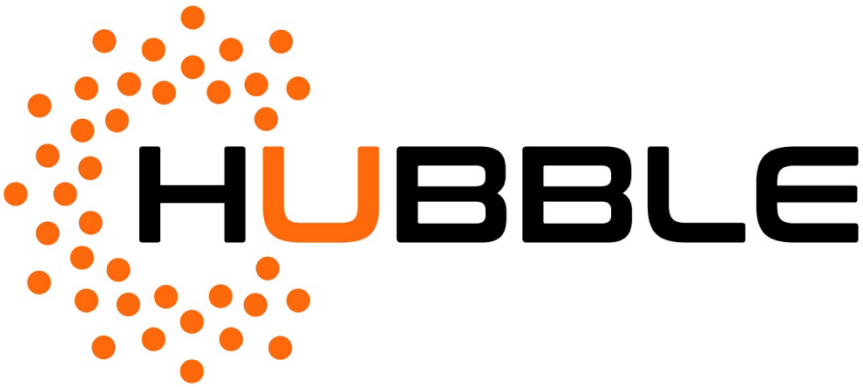


Figure 74. Branding and Logo

11.2 Business Model Canvas

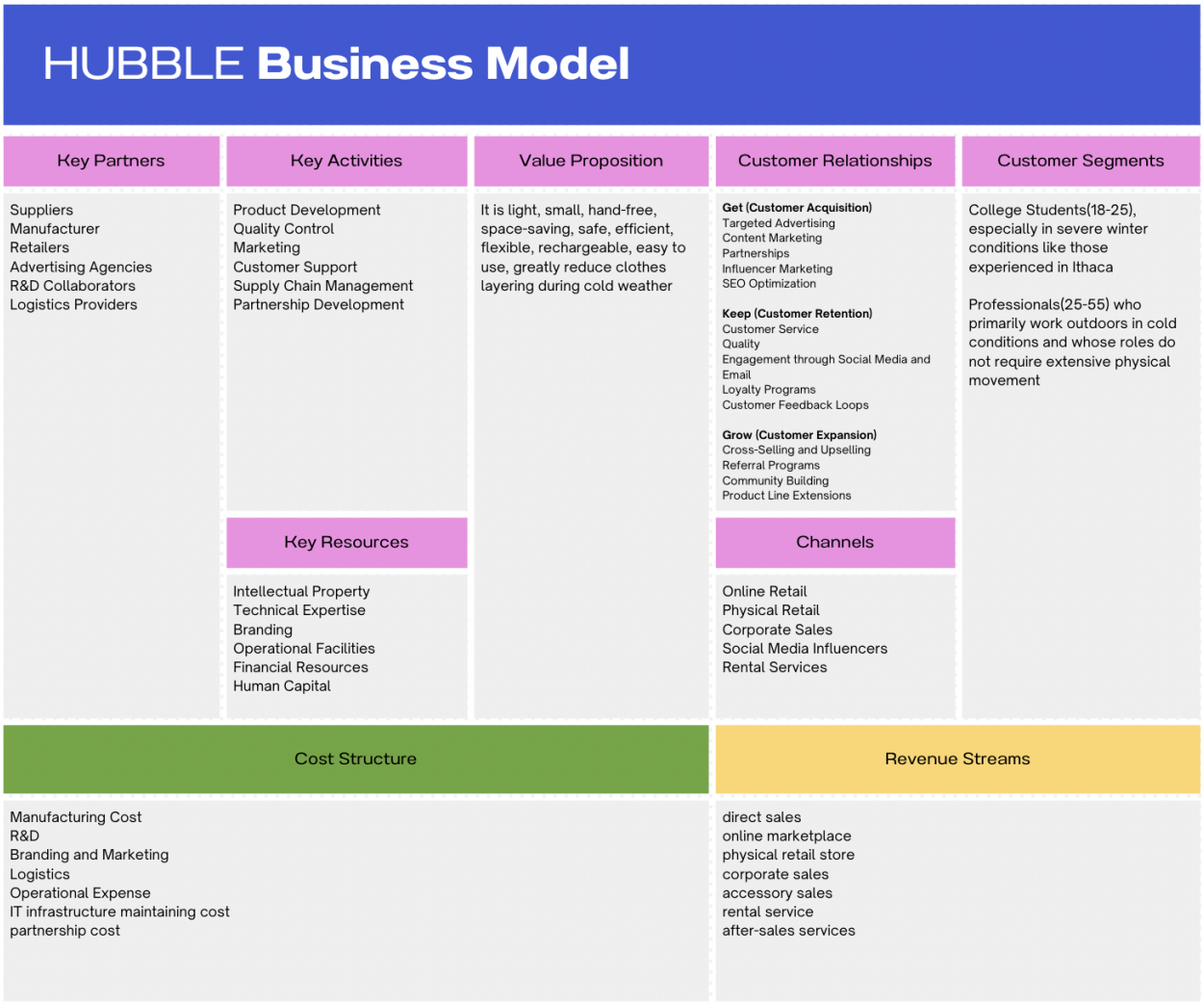


Figure 75. Business Model Canvas

Who?

Customer Segments:

-College Students (18-25): This segment includes students living in cold climates, who face daily challenges due to severe winter conditions. Our product is designed to offer these students a convenient and portable solution to stay warm without the bulkiness of traditional winter wear.

-Professionals (25-60): These are individuals working outdoors in professions such as construction, landscaping, or outdoor event management. They need cold weather gear that does not restrict mobility.

Customer Relationships:

Get-Keep-Grow was used in our customer relationship management to keep our target market and ourselves in a dynamic relationship.

We use targeted advertising, through digital channels like LinkedIn and Instagram, in the Get stage of customer acquisition that is designed to attract both professionals and younger audiences. Our other emphasis is content marketing, and we create blog entries, product usage videos, and winter survival guides that highlight the benefits of our product in harsh environments. While influencer marketing enables us to use well-known personalities in the outdoor and adventure lifestyle industries to increase product credibility and expand our reach, partnerships with outdoor gear stores and winter sports facilities enable us to showcase the advantages of our product in a live setting.

Last but not the least, SEO optimization, which optimizes the product website for search engines to attract organic traffic from potential customers searching for winter gear.

Our strategy in the Keep stage of customer retention is to provide multi-channel help via phone, email, and live chat to promptly fix any problems, increasing user satisfaction and loyalty. Frequent quality inspections reduce returns and preserve consumer confidence, and to keep users engaged with our brand, we use personalized email newsletters and interactive social media content. With loyalty programs, we further encourage repeat business and social sharing, and we always incorporate consumer input to enhance and hone our product offers.

For the Grow stage, we promote upselling and cross-selling of coordinating accessories like extra batteries or weatherproof covers. We emphasize creating a community through online forums and social media groups, which promotes peer-to-peer interactions and brand advocacy, and our referral programs reward users for recommending our product to others. We are also always creating new product lines to meet related needs of our clients, which expands our market reach and keeps them coming back.

Sales channels:

Hubble offers thorough product information and customer service on its official website, where direct sales are handled. Popular e-commerce sites like Etsy and Amazon also have our products listed. For those that would rather make a physical purchase, we work with physical retailers that focus on winter and outdoor gear. In addition, we offer bulk purchases and customized deals to businesses whose employees work in colder climates, and we market our product as a valuable corporate gift for clients or staff in those areas. Lastly, we offer our product for rent during outdoor events.

What?

Value Propositions

“It is light, small, hand-free, space-saving, safe, efficient, flexible, long-lasting, easy to use, greatly reduce clothes layering during cold weather”

The portability and convenience of our product—its lightweight and small design make it a great substitute for heavy winter gear—are among its value propositions. The device has a sophisticated feedback mechanism to avoid overheating and adjustable heat settings for user comfort in different outdoor conditions. Its unusual design that makes use of convective heat transfer distinguishes it from other heating systems and offers a practical and original way to distribute heat.

How?

Key Partners:

Our Key Partners are, operationally, suppliers of premium materials, manufacturers who can increase production without sacrificing quality, strategic retail partners, R&D partners for ongoing product innovation, and logistics companies for effective product distribution.

Key Activity:

Our key activities include product development with an emphasis on design, functionality, and safety; strict quality control; strategic marketing and sales initiatives; all-encompassing customer service; and effective supply chain management.

How much?

Cost Structure:

Major expenditures in manufacturing, R&D, marketing, logistics, operating costs, IT upkeep, and partnership management

Revenue Streams:

Direct Sales, Corporate Sales, Accessory Sales(Product Case, Attachment System Replacement), Rental Services, and After-sales services

11.3 SWOT Analysis

STRENGTHS +	WEAKNESSES –
- **Innovation**: The use of magnetic technology for easy attachment and hot air circulation is innovative. - **User Control**: Allows users to adjust the temperature, providing a customizable experience. - **Convenience**: Offers warmth under 5 minutes, which is convenient in cold conditions. - **Safety Features**: Likely includes auto-shutoff and other safety mechanisms to prevent overheating.	- **Cost**: Innovative tech can be more expensive, potentially limiting its market. - **Battery Life**: As a battery-powered device, its operational time may be limited before needing a recharge. - **Market Penetration**: Being a new product, it may struggle to gain market share from established alternatives.
- **Market Expansion**: Potential to tap into outdoor and sports markets, as well as everyday consumers. - **Partnerships**: Opportunities to collaborate with clothing brands for integrated solutions. - **Technological Advancements**: Provide external power sources to increases the battery capacity. - **Seasonal Promotions**: Targeted marketing during colder seasons can boost sales.	- **Competition**: Established warming products pose a threat. - **Safety Regulations**: Stricter safety regulations may increase production costs or limit the product's features. - **Economic Downturns**: Non-essential items often see reduced sales in economic downturns.
OPPORTUNITIES +	THREATS –

Figure 76. SWOT Analysis

12. Systems Engineering Tool (Hubble)

12.1 Use Cases

In this table, we have listed the different user cases for the product along with their priority levels. The table categorizes user scenarios into three priorities: High (H), Medium (M), and Low (L), indicating the importance of each scenario. These user scenarios cover a range of purposes from basic operations to specific application scenarios such as outdoor activities, healthcare tasks, etc., ensuring that the device can meet a wide range of needs and environments. Additionally, the table emphasizes the importance of safety features, environmental impacts, and user interactions. This classification helps our team understand and prioritize functionalities that have the greatest impact on the user experience.

	User Cases	Priority
1	User attaches MagnaHeat to the inner lining of a jacket	H
2	Device detects ambient temperature and adjusts heat output accordingly	H
3	User manually adjusts the temperature setting though machine or app	M
4	Automatic shutdown after a predefined period to ensure safety	H
5	User uses the MagnaHeat through magnetic attachment	L
6	User connects the MagnaHeat through a belt	L
7	Battery low notification to user via device indicator	H
8	Safety cutoff in case of device malfunction or excessive temperature	H
9	Magnetic strength optimization to ensure the device stays in place during activities	H
10	Compatibility check with different fabrics and clothing materials	M
11	Low temperature operation mode for mild climates	L
12	Usage tutorials and tips provided	L
13	Device diagnostics and self-test on startup	H
14	Tourist Uses MagnaHeat for Warmth While Visiting Cold Climates	M
15	Outdoor Enthusiast Uses MagnaHeat during Hiking	H
16	Adventurer Uses MagnaHeat's Water-resistant Feature in Snowy Conditions	H
17	Hiker Relies on Battery Low Notification for Timely Recharging	H
18	Skier Adjusts MagnaHeat Through Gloves Using Simplified Controls	H
19	Student Uses MagnaHeat for Early Morning Campus Commutes	M
20	Packaging designed for minimal environmental impact	M
21	User Shares Feedback on Heating Efficiency for Continuous Improvement	M
22	Healthcare Worker Uses MagnaHeat for Warmth During Long Shifts Outdoors	H
23	Device should be ready to use within 5 minutes from turning on	H
24	Device should be able to last for at least 2 hours	H
25	In-app Notifications for Weather Forecast and Suggested Settings	M
26	User Accesses Battery Health Monitoring to Maximize Device Lifespan	M
27	Daily usage statistics available to the user for monitoring battery life and heating patterns	L
28	Automatic reconnection to mobile app after being out of range	M
29	The app alerts user of optimal attachment points for efficient heating	M
30	Emergency stop feature accessible through the device and mobile app	H
	Note: H - High Priority, M - Medium Priority, L - Low Priority	

Figure 77. Use Cases

12.2 Revised SysML Use Case Diagram

In this diagram, we showcase various Use Cases for the "MagnaHeat" system using SysML standards, primarily focusing on the interaction between the system and users. It covers a range of functionalities from basic switch control to more advanced features like device control via mobile phone and usage in specific contexts such as skiing or other winter sports. This helps software developers and system engineers understand user requirements, ensuring that the designed and developed solutions can meet these needs.

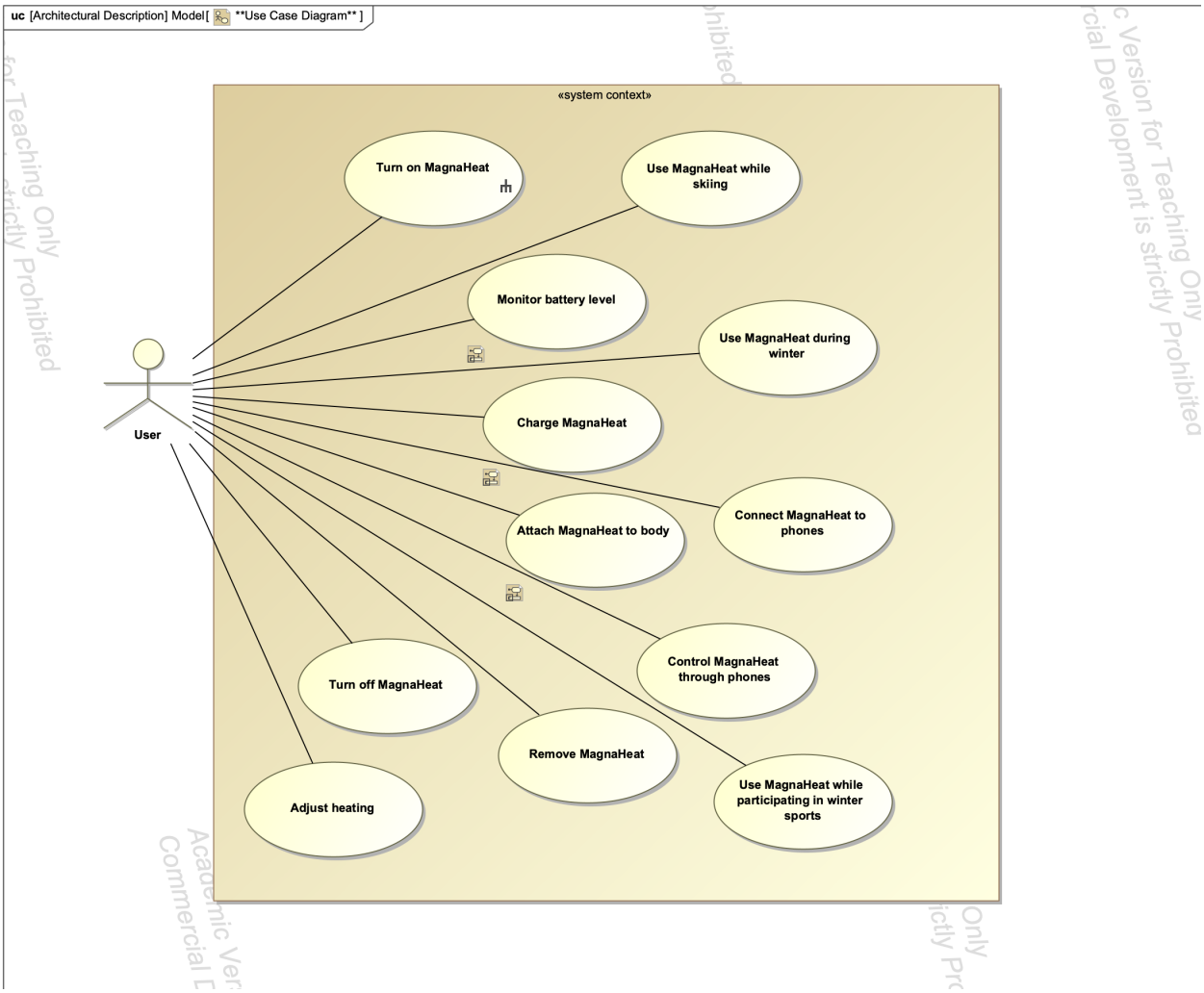


Figure 78. Revised SysML Use Case Diagram

12.3 Revised SysML Block Definition Diagram

The Block Definition Diagram provides a detailed depiction of the various components and their interrelationships within the "Hubble Domain" system. Each block is directly linked to "Hubble Domain," indicating that these components are integral parts of the system.

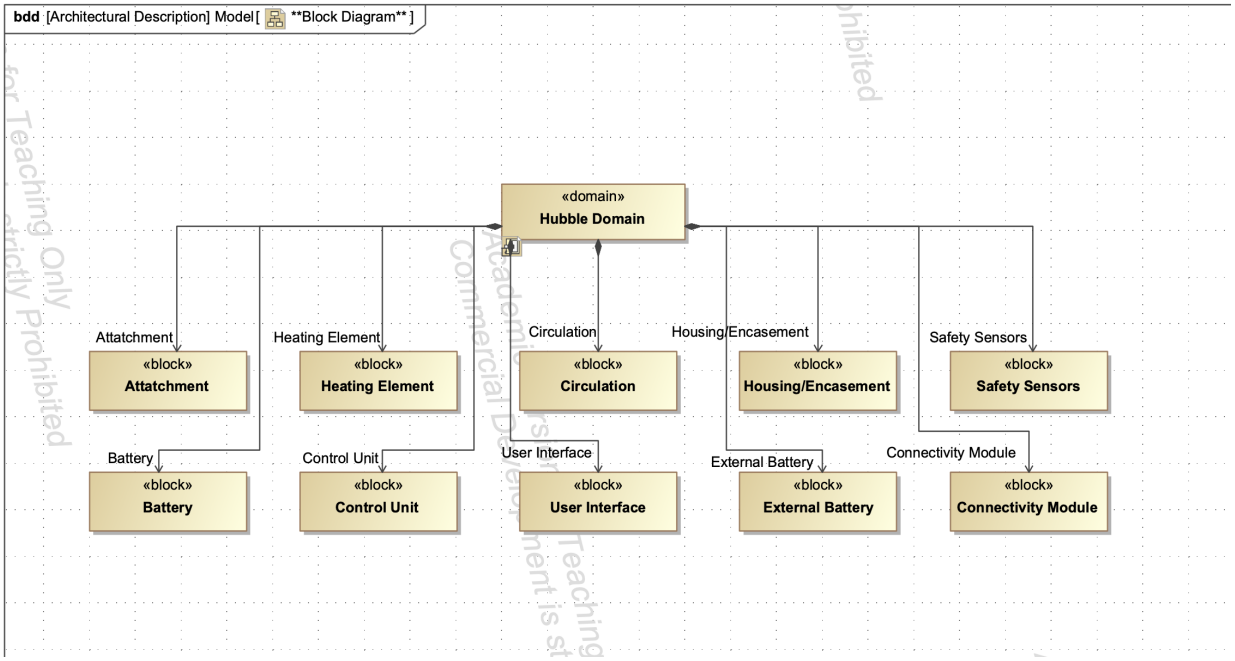


Figure 79. Revised SysML Block Definition Diagram

12.4 Revised SysML Internal Flow Diagram

The Internal Flow Diagram provides a detailed description of how components interact and connect within the "Hubble Domain" system, showcasing the interaction flow between users and the system. This ensures that the design meets user requirements and safety standards.

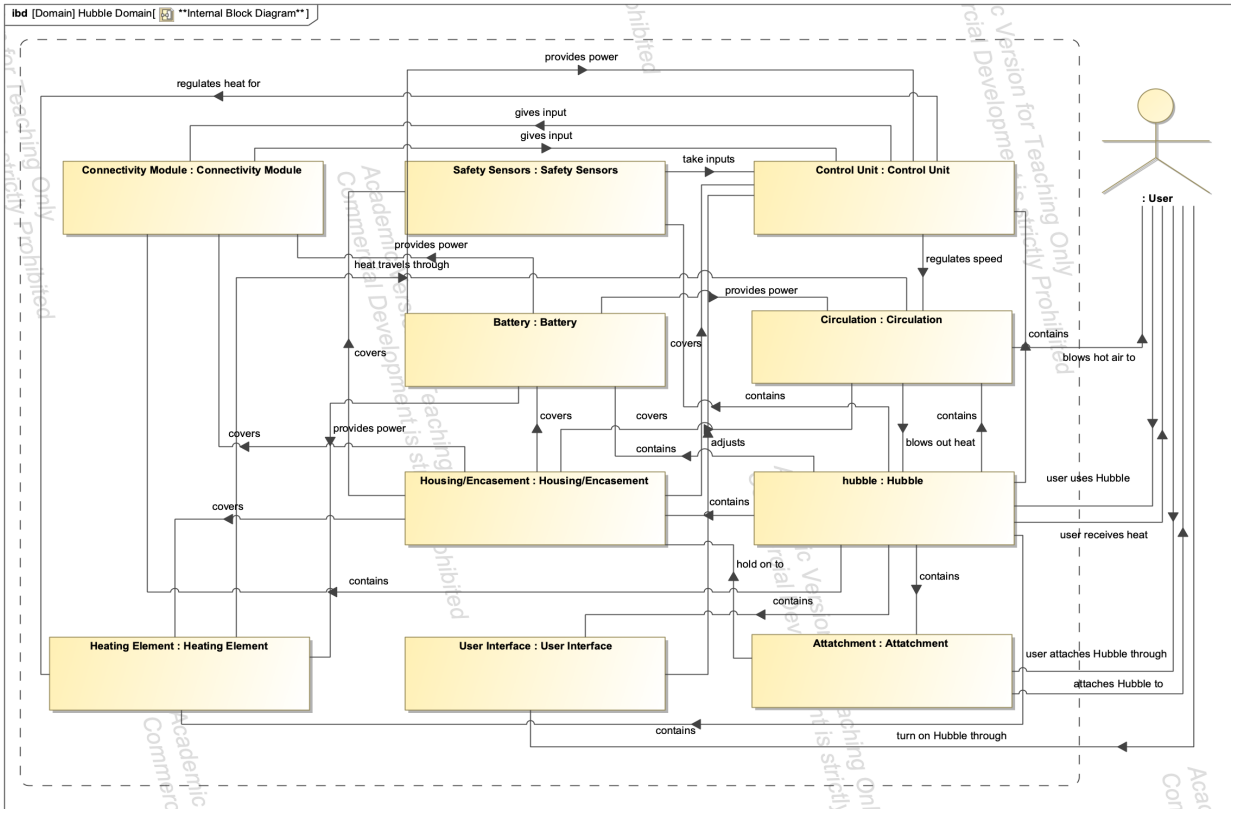


Figure 80. Revised SysML Internal Flow Diagram

12.5 Decision Matrix

This decision matrix is used to compare and evaluate the performance of six different heating products across multiple key attributes. Each attribute is assigned a weight based on its importance, and each product is rated for its performance on each attribute. The matrix displays the weighted total score for each product across all attributes on the right side, reflecting the overall performance of the product considering all important attributes. This matrix design helps decision-makers choose the product that best meets their needs based on a multidimensional assessment.

Decision Matrix														
	Normalized Score						User Dependencies		Final Score					
	A	B	C	D	E	F	Min Scored	Weight	A	B	C	D	E	F
Portability	8	10	3	10	10	7	3	7	56	70	21	70	70	49
Ease of Use	9	10	7	10	9	8	7	7	63	70	49	70	63	56
Able to Adjust Temperatur	9	2	8	1	1	3	1	8	72	16	64	8	8	24
Life Span of Product	7	1	6	1	9	8	1	6	42	6	36	6	54	48
Weight	7	10	4	10	10	6	4	6	42	60	24	60	60	36
Design	9	5	6	4	7	8	4	5	45	25	30	20	35	40
Safety	8	7	5	6	10	9	5	9	72	63	45	54	90	81
								Total:	392	310	269	288	380	334

A - Hubble MagnaHeat
B - Traditional Hand Warmers
C - Electric Blankets
D - Chemical Warmers
E - Thermal Layers
F - Insulated Bottles with Warm Liquids

Figure 81. Decision Matrix

12.6 Goal / Question / Metric Chart

This chart is designed for systematically evaluating and ensuring that a product meets the specific needs of its target user group. The information is organized based on different objectives of product development. Under each objective, a series of related questions is listed, each accompanied by ideal metrics and data collection methods. This design helps the team clarify the specific problems they need to address, choose appropriate metrics, and adopt suitable methods for collecting the necessary data, thus ensuring that the product's design and features can meet user expectations and needs.

Goal	Question	Ideal Metric	Approximate Metric	Data Collection Method
Ensure MagnaHeat is tailored to meet the needs of its target customers	What is the lowest temperature peole experienced where they live?	Obtain temperature readings in degrees Celsius or Fahrenheit	(No Substitute)	Survey
	What is the highest temperature people experienced where they live?	Obtain temperature readings in degrees Celsius or Fahrenheit	(No Substitute)	Survey
	What is the desired age group?	Collect age data in numerical form	(No Substitute)	Survey
Ensure that MagnaHeat is compatible with all types and layers of clothing.	How many layers of clothing do people typically wear on their upper body during the winter season?	Collect age data in numerical form	(No Substitute)	Survey
	What type of clothing do people wear in the innermost layer during winter?	Categorical Data (T-shirt, Sweater, Tank-top etc.)	(No Substitute)	Survey
	What type of clothing do people wear in the outermost layer during winter?	Categorical Data (Puffer Jacket, Sweater, etc.)	(No Substitute)	Survey
Ensure that MagnaHeat meets the needs of our target customers.	Which features of MagnaHeat are most appealing to our target customers?	Categorical Data (Portability, Ease-of-Use, etc.)	(No Substitute)	Survey
	In which situations would our customers use our product?	Categorical Data (Outdoor Sports, At Work, Commute, etc.)	(No Substitute)	Survey
Ensure that MagnaHeat is priced appropriately	What is the most acceptable price point at which our customers are willing to purchase MagnaHeat?	Categorical Data (Under $50, $50-$100, $100-$150, etc.)	(No Substitute)	Survey
Ensure that the magnet's strength is sufficient to support the entire device	How strong does the magnet need to be to support the device without adding excessive weight?	Attach a magnet to a weight block that matches the approximate weight of MagnaHeat and run around to see if the magnet remains attached.	(No Substitute)	Experiment
Ensure that the temperature output matches the target temperature	What is the comfortable body temperature for humans when heated during cold winter conditions?	Using a thermometer to test the most comfortable temperature while heated inside the jacket	(No Substitute)	Experiment

Figure 82. Goal-Question-Metric Chart

12.7 Revised Originating Requirements

This table outlines the initial requirements for the product, providing specific abstract functional names, related questions, and solutions for each requirement. It is a crucial tool to ensure that the design and functionality meet expected standards. By detailing the specific problems and solutions for each requirement, the design team can systematically address potential design challenges.

Index	Originating Requirements	Abstract Function Name	Issues	Resolution
OR.1	The MagnaHeat shall be capable of rapidly heating to achieve the desired temperature quickly	Rapid Heating	Issue: What kind of materials should we use to ensure the heat transfers rapidly?	Utilize materials with high thermal conductivity for the heating element, such as copper.
OR.2	The MagnaHeat shall be compatible with a range of clothing types.	Versatility	Issue: What should be the ideal temperature ouput ro ensure MagnaHeat is suitable for all types of clothings?	Conduct experiments to find a temperature range that is comfortable for various clothing materials and thicknesses.
OR.3	The MagnaHeat shall be designed for lightweight portability.	Heat Resistant	Issue: MagnaHeat contains many heavy components, such as the battery and magnet.	Opt for lightweight materials like neodymium magnets, balancing weight and performance.
OR.4	The MagnaHeat shall be durably constructed to withstand regular use.	Durable	Issue: Which material should be used for the outer casing, plastic or metal?	Compare the durability, weight, and cost of plastics like ABS or polycarbonate versus metals like aluminum for the casing.
OR.5	The MagnaHeat shall include overheat protection and safety features.	Safety	Issue: What is the optimal placement for sensors, and is it necessary to include an additional sensor as a backup?	Place sensors near heating element for accuracy, and a secondary sensor for redundancy in critical safety systems.
OR.6	The MagnaHeat shall ensure even heat distribution.	Heat Distribution	Issue: How to ensure that the heat will be evenly distributed within the case?	Design the heating element layout to provide uniform heat across the entire device.
OR.7	The MagnaHeat shall have adjustable temperature settings.	Adjustable Temperature	Issue: What should be the lowest output temperature and what should be the highest output temperature?	Establish a safe temperature range based on user comfort studies and material limits.
OR.8	The Magnaheat shall offer extended battery life for prolonged use.	Battery Life	Issue: A larger battery increases the weight of MagnaHeat. Should we explore the option of an external battery?	Investigate alternative power solutions such as dual batteries or an optional external battery pack for extended use scenarios.
OR.9	The MagnaHeat shall operate effectively at temperatures as low as −20°C.	Operate at Low Temperatures	Issue: To make sure that the MagnaHeat operates normally under −20°C, we should test it under harsher environments.	Develop clear standards and certifications for water and sweat resistance levels.
OR.10	The MagnaHeat shall be both sweatproof and waterproof.	Waterproof	Issue: How are 'waterproof' and 'sweatproof' defined? Does it mean resistant to splashes of water or complete submersion?	Define IP ratings for the device that meet industry standards for waterproof and sweatproof claims.

Figure 83. Revised Originating Requirements

12.8 Revised Behavioral Test Plans

This table provides a detailed outline of the product's behavioral testing plan, aiming to validate whether MagnaHeat meets specific performance standards and user requirements. These tests ensure that the product meets expected standards from various aspects, including performance, safety, and durability. Each test is rigorously designed to verify key performance metrics and the overall reliability of the device.

Req. #	Requirement	Abstract Name	Test #	Test Method	Test Facilities	Entry Condition	Exit Condition
OR.1	The MagnaHeat shall be capable of rapidly heating to achieve the desired temperature quickly	Rapid Heating	**TP.1**	Test Procedure: Turning on a fully charged MagnaHeat and calculate the time it takes to reach its full operation.	MagnaHeat Prototype	Turn on the fully charged Magna Heat	MagnaHeat operates at its full capacity in under 5 minutes.
OR.2	The MagnaHeat shall be compatible with a range of clothing types.	Versatility	**TP.2**	Test Procedure: Attach MagnaHeat to different types of fabric and observe if it stays in place and heats effectively.	MagnaHeat Prototype	MagnaHeat attached to different fabrics	MagnaHeat remains attached and effective across all fabric types.
OR.3	The MagnaHeat shall be designed for lightweight portability.	Heat Resistant	**TP.3**	Test Procedure: Measure the weight of MagnaHeat and compare it with industry standards for portable devices.	MagnaHeat Prototype	Device ready for weight measurement	MagnaHeat is within the top quartile for lightweight design in its category.
OR.4	The MagnaHeat shall be durably constructed to withstand regular use.	Durable	**TP.4**	Test Procedure: Perform durability testing through repeated use cycles and environmental stress tests.	MagnaHeat Prototype	Device is new and functional	MagnaHeat functions effectively after durability test cycles.
OR.5	The MagnaHeat shall include overheat protection and safety features.	Safety	**TP.5**	Test Procedure: Run device until overheat protection feature triggers a shutdown. Verify safety features activate appropriately.	MagnaHeat Prototype	MagnaHeat operational and safety features reset	Safety features trigger at the correct temperature thresholds without fail.
OR.6	The MagnaHeat shall ensure even heat distribution.	Heat Distribution	**TP.6**	Test Procedure: Use a thermometer to test temperatures at different parts of the upper body device when in operation.	MagnaHeat Prototype Thermometer	MagnaHeat charged and operational	Temperature readings confirms even distribution of heat.
OR.7	The MagnaHeat shall have adjustable temperature settings.	Adjustable Temperature	**TP.7**	Test Procedure: Verify the temperature adjustment mechanism over the full range of settings.	MagnaHeat Prototype	MagnaHeat charged and operational	MagnaHeat reaches both lowest and highest settings as specified.
OR.8	The Magnaheat shall offer extended battery life for prolonged use.	Battery Life	**TP.8**	Test Procedure: Operate MagnaHeat until the battery is depleted to measure battery life.	MagnaHeat Prototype	Fully charged MagnaHeat	Battery life meets or exceeds the specified duration.
OR.9	The MagnaHeat shall operate effectively at temperatures as low as −20°C.	Operate at Low Temperatures	**TP.9**	Test Procedure: Place MagnaHeat in a controlled environment at −20°C to observe its operation.	MagnaHeat Prototype	MagnaHeat at room ten	MagnaHeat operates effectively at −20°C.
OR.10	The MagnaHeat shall be both sweatproof and waterproof.	Waterproof	**TP.10**	Test Procedure: Subject MagnaHeat to water and perspiration simulation tests to assess ingress protection.	MagnaHeat Prototype Water Sink	Device unexposed to water or sweat	No ingress of water or simulated sweat in the device.

Figure 84. Revised Behavioral Test Plans

12.9 Subsystem Matrix

The Subsystem Matrix showcases the various subsystems of the device along with their key components and functionalities. This aids in understanding how each part collaborates to support the overall operation of the device. The subsystem matrix is a critical tool in ensuring that all parts of the product work as intended. It helps the team clarify the functions and responsibilities of each component, ensuring the integration and functionality of the entire system. In this way, the design team can systematically review each component and subsystem to meet the device's performance and safety standards.

Subsystem Matrix								
Battery	Heating Element	Control Unit	Attatchment	User Interface	Circulation (Fan)	Housing/Encasement	Safety Sensors	Connectivity Module*
The system shall store sufficient electrical energy to power the MagnaHeat device for a predetermined amount of time.	The system shall generate controlled heat when activated by the user.	he system shall regulate the power flow and temperature settings according to user input.	The system shall enable the device to be attached to the clothing through magnets.	The system shall enable the user to adjust the temperature and turn the device on/off.	The system shall circulate air to distribute heat evenly within the clothing.	The system shall protect internal components from environmental exposure and user handling.	The system shall shut down the device if the temperature exceeds the maximum danger temperature threshold.	The system shall provide wireless communication capabilities for the device to interface with mobile phones.
Rechargeable Work Power Supply	Heating Pad *4	Arduino Nano Board	Strap	Switch	DC Centrifugal Fan	Plastic Case	Temperature Sensor	Bluetooth Module
Control Circuit Battery		N-Mosfet		Potentiometer				Wi-Fi module
Note: *Not present in the protptype								

Figure 85. Subsystem Matrix

12.10 Interface Matrix

The Interface Matrix is used to showcase the different attributes of product design and their associations with various subsystems. The information in the table helps understand the key parameters of product design and their impact on the overall system. The layout of the table helps clarify how each design parameter corresponds to specific subsystems and indicates whether these parameters are estimated. Such a matrix is highly useful for product design and development teams in evaluating, optimizing, and confirming product specifications, ensuring design consistency and feasibility.

Interface Matrix						
Design	MagnaHeat		Value	Units	Estimate?	Energy StorageSubsystem
	Provided to	Battery Capacity	22000	mAh		Battery Pack
	Provided to	Heat Settings	3	#	X	Temperature Control
	Provided to	Charge Time	4	Hours		Charging System
	Provided to	Cable Type	1	#	X	Built-in USB-C
Provided to		Unit Cost	100	$	X	System Cost
Provided to		Size Dimensions	15105	cm	X	Device Size
Provided to		Weight	500	g	X	Device Weight
Provided to		User Manual	1	#		User Instructions

Figure 86. Interface Matrix

12.11 Analytical Hierarchy Process

This table illustrates the process of prioritizing different characteristics of a product using the Analytic Hierarchy Process (AHP). It helps us identify and focus on those attributes that are most critical for the end-user experience and market competitiveness, including safety, battery life, effectiveness, size or weight, and other factors. By quantitatively comparing the importance of different features, the team can more effectively allocate resources and priorities to achieve the optimal balance in product design.

Analytical Hierarchy Process										
Safety			Battery Life		Effectiveness			Size or Weight	Other	
0.3			0.15		0.3			0.1	0.15	
									Design	Price
									0.2	0.8
MagnaHeat shall integrate with smart devices for temperature control	MagnaHeat shall be waterproof and heat-resistant	MagnaHeat shall include overheat protection	MagnaHeat shall have a long battery life	Magnageat shall be rechargeable	Magna Heat shall heat up within 5 minutes	MagnaHeat shall have adjustable heat settings	MagnaHeat shall provide even heat distribution	MagnaHeat shall be lightweight for easy portability	MagnaHeat shall have a sleek, modern design	MagnaHeat shall be affordable and offer good value
0.1	0.1	0.1	0.075	0.075	0.1	0.1	0.1	0.1	0.03	0.12

Figure 87. Analytical Hierarchy Process

12.12 House of Quality (QFD)

The table is used to systematically translate customer requirements into design specifications and ensure that the product meets these needs. By analyzing and comparing the relationships between different customer attributes and design requirements, the table helps determine which design aspects need to be prioritized. This ensures that the design team understands and meets customer needs while making reasonable trade-offs in every aspect of product design.

		Engineering Relationships		Maximize the duration of effective operation									
				Minimize the weight									
					Maximize the effectiveness								
						Maximize the product's lifespan							
							Maximize the adjustable temperature range						
								Minimize the warm-up time					
									Minimize the price of the product				
										Maximize safety			
											Minumize the size		
												Maximize user experience	
		Engineering Characteristics	Maximize the duration of effective operation	Minimize the weight	Maximize the effectiveness	Maximize the product's lifespan	Maximize the adjustable temperature range	Mininize the time it takes to get warm	Minimize the price of the product	Maximize safety	Minimize the size	Maximize user experience	Customer Perception
		Direction of Change	↑	↓	↑	↑	↑	↓	↓	↑	↓	↑	
	Customer Attributes	Relative Importances											1 2 3 4 5
Versatile	MagnaHeat should work on all types of fabrics	0.1			✓✓		✓	✓					D A
Durability	MagnaHeat should have a long lasting battery life	0.15	✓✓	X	✓				XX		XX	✓	B A
Easy	MagnaHeat can be easily stored	0.1		✓		X					✓✓		E C B D A
Fast	MagnaHeat can heat up quickly	0.2	✓		✓✓			✓✓	X			✓✓	C E A B
Weight	MagnaHeat should be light	0.1		✓✓							✓✓		B D E A C
Reliable	MagnaHeat should be relieable	0.1	✓					✓		✓✓		✓✓	D A
Safe	MagnaHeat should be safe	0.15		X			X			✓✓	X		D A
Conectivity	MagnaHeat can be controlled through phones	0.1							XX			✓✓	B A
Object Measures	Measurement Units		minutes	g	s	yr	°C	s	$	# of sensors	N/A	N/A	
	HUBBLE MagnaHeat		120	250	30	3	35-45	5	119	1	N/A	N/A	
	Chemical Heating Pads		60	50	55	N/A	35-50	10	49	0	N/A	N/A	
	ThermaGear Heated Clothing		360	453	60	3	N/A	30	130	0	N/A	N/A	
	Portable Hand Warmers		480	350	10	4	39-63	3	39.99	0	N/A	N/A	
	Thermal Insulation Layers		N/A	270	100	3	40-55	20	90	0	N/A	N/A	
Technical Difficulty (1-Low, 5-High)			4	3	5	4	5	4	4	5	5	2	
Imputed Importance (%)			90%	60%	85%	85%	55%	46%	100%	100%	70%	100%	
Estimated Cost (1-Low, 5-High)			3	3	5	4	2	2	5	5	3	4	
Targets			200	250		3	45-55	30	100	N/A	N/A	N/A	

Relationships	
✓✓	Strong Positive
✓	Medium Positive
X	Medium Negative
XX	Strong Negative
↑	Increase
↓	Decrease

Competitors	
A	MagnaHeat
B	Chemical Heating Pads
C	ThermaGear Heated Clothing
D	Portable Hand Warmers
E	Thermal Insulation Layers

Figure 88. Revised House of Quality Diagram

12.13 Revised FMEA

The FMEA table is used to evaluate possible failure modes in the MagnaHeat product, including potential impacts, causes, likelihood of occurrence, and preventive measures to mitigate risks. Each failure mode is assigned a Risk Priority Number (RPN), which is calculated based on the severity of failure impact, likelihood of occurrence, and ease of detection.

Failure Mode #	Subsystem	Failure Mode	Failure Effect	Possible Cause	Failure Effects Severity	Occurrence Likelihood	Risk Priority Number (RPN)	Risk Criticality (Corrective Action Difficulty)	Corrective Action
F.1	Internal Battery	Battery Depletion / Short-Circuit	Reduced operational time / Unexpected power loss / Fire Hazard	Degradation over time; Defective battery cells / Improper Handling	5	1	15	HIGH	Integrate Battery Management System (BMS); Better and more insulating circuit connections; More insulation around battery housing to prevent fires/burns
F.2	Heating Element	Overheating	Burns to user / Damage to product	Fan defect / Temperature control system malfunction	5	2	15	HIGH	Use an extra temperature sensor; Implement thermal cutoff switch of thermal and better material to prevent burns in case of failure
F.3	Control Unit	Component Failure	Device stops functioning	Electrical surge; Manufacturing defect	3	2	10	MEDIUM	Surge protection and redundant design implementation
F.4	Attatchment	Magnet Detatched	Unable to attact product	Strong Impact	3	1	6	LOW	Introduce various connection methods as backups and ensure the magnets are easily replaceable.
F.5	User Interface	Bottons Unresponsive /Port Failure	User cannot operate the device effectively	Electrical failure / Wear and tear /Poor connection quality	4	3	10	MEDIUM	Reinforce port structure / Implement magnetic connectors / Waterproof buttons and include tactile feedback
F.6	Circulation (Fan)	Fan Failure	Overheat / Product not functioning	Motor burnout; Electrical overload	5	2	15	LOW	Introduce brushless motors and debris sensors
F.7	Housing/Encasement	Cracking or Warping	Exposure of internal components / User injury	Impact / Excessive heat / Material defect	3	1	10	LOW	Use impact-resistant materials and conduct stress testing; Increase wall thickness
F.8	Safety Sensors	Sensor malfunction	Inaccurate temperature reading leading to overheating or underheating	Faulty sensor / Software error / Calibration error	4	2	10	HIGH	Install dual sensor system for redundancy
F.10	Connectivity Module*	Connection Loss	Inability to interface with network or remote controls	Software bug / Hardware failure	1	2	6	HIGH	Implement redundant communication pathways / Update firmware to address software bugs / Enhance hardware reliability with improved components.
F.11	External Battery*	Battery Depletion	Reduced operational time / Unexpected power loss / Fire Hazard	Degradation over time / Defective battery cells	1	1	6	LOW	Integrate Battery Management System (BMS); Better and more insulating circuit connections; More insulation around battery housing to prevent fires/burns

Likelihood	Current # of Risks Shown Stoplight Graph				
5	0	0	0	0	0
4	0	0	0	0	0
3	0	0	0	1	0
2	1	0	1	1	2
1	1	0	2	0	1
	1	2	3	4	5

Figure 89. Revised FMEA Table

12.14 Revised Activity Diagram

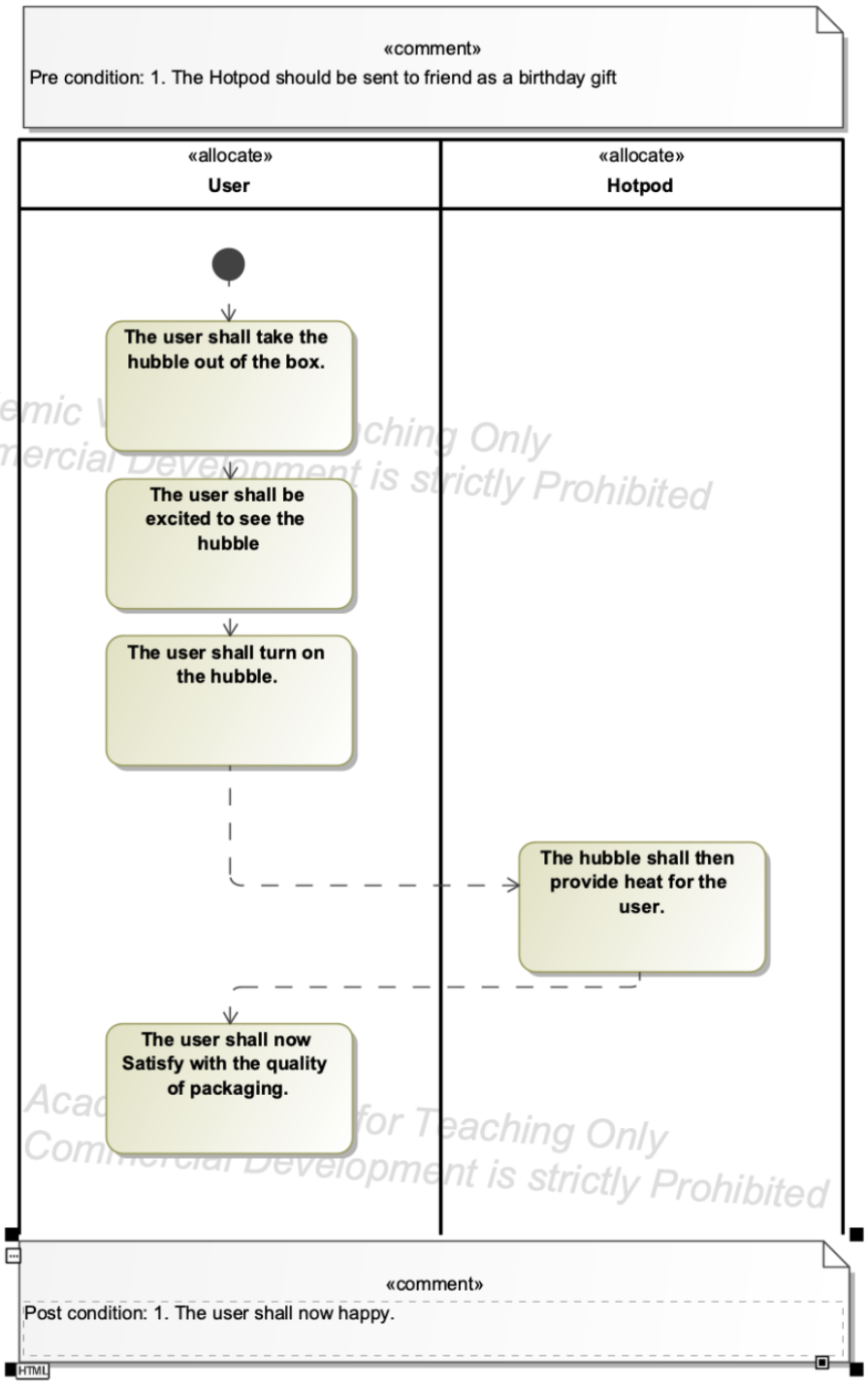


Figure 90. Revised Activity Diagram 1

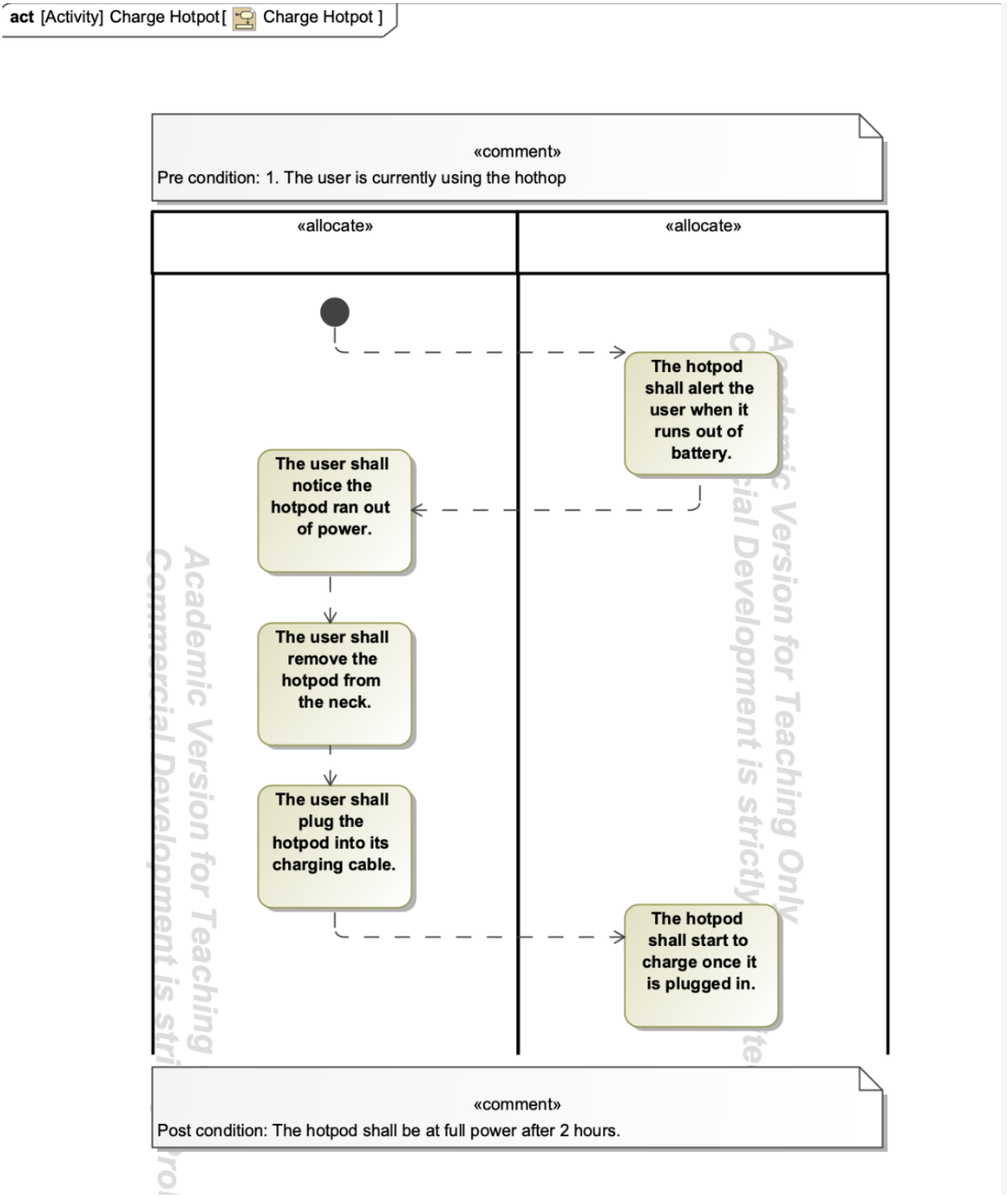


Figure 91. Revised Activity Diagram 2

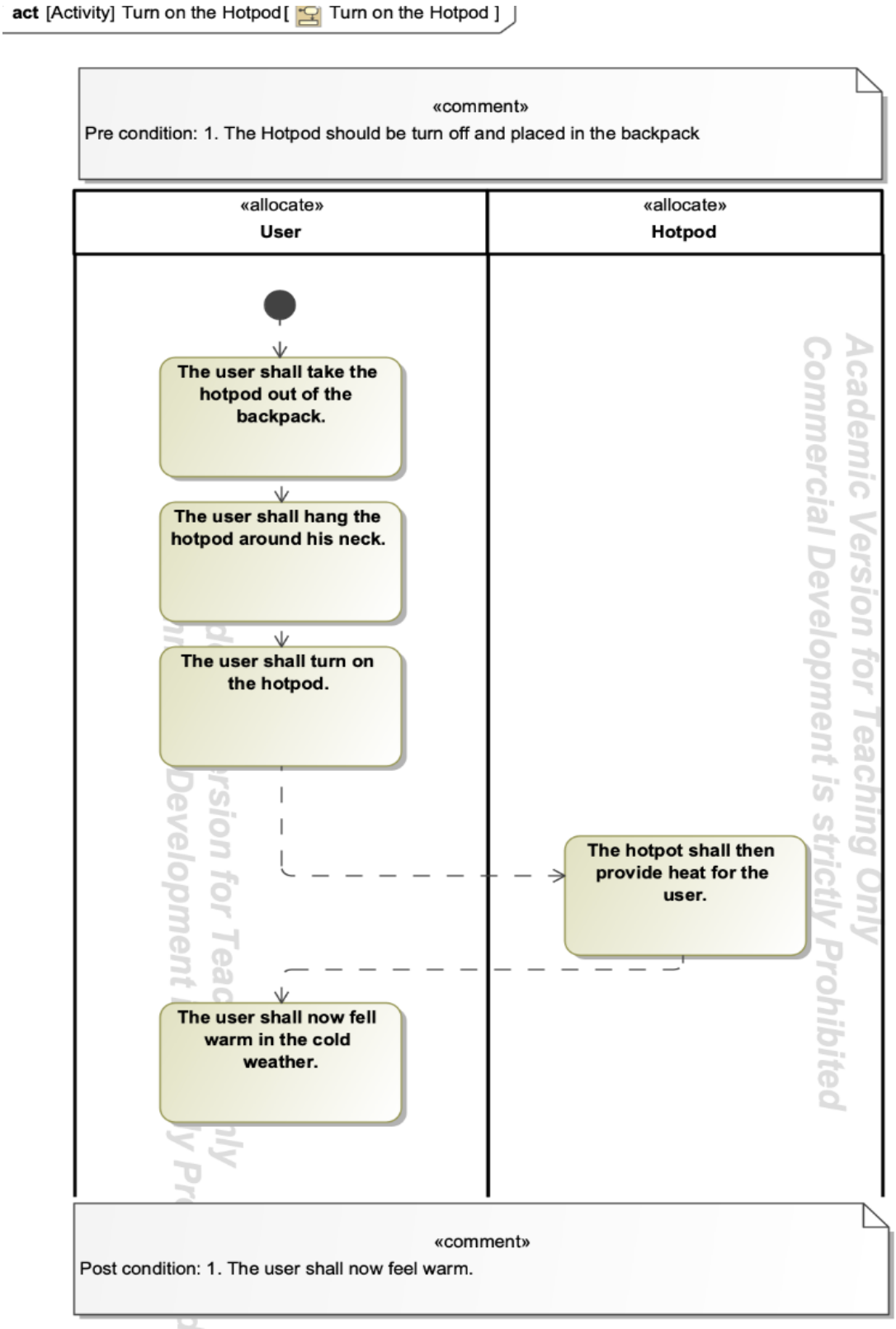


Figure 92. Revised Activity Diagram 3

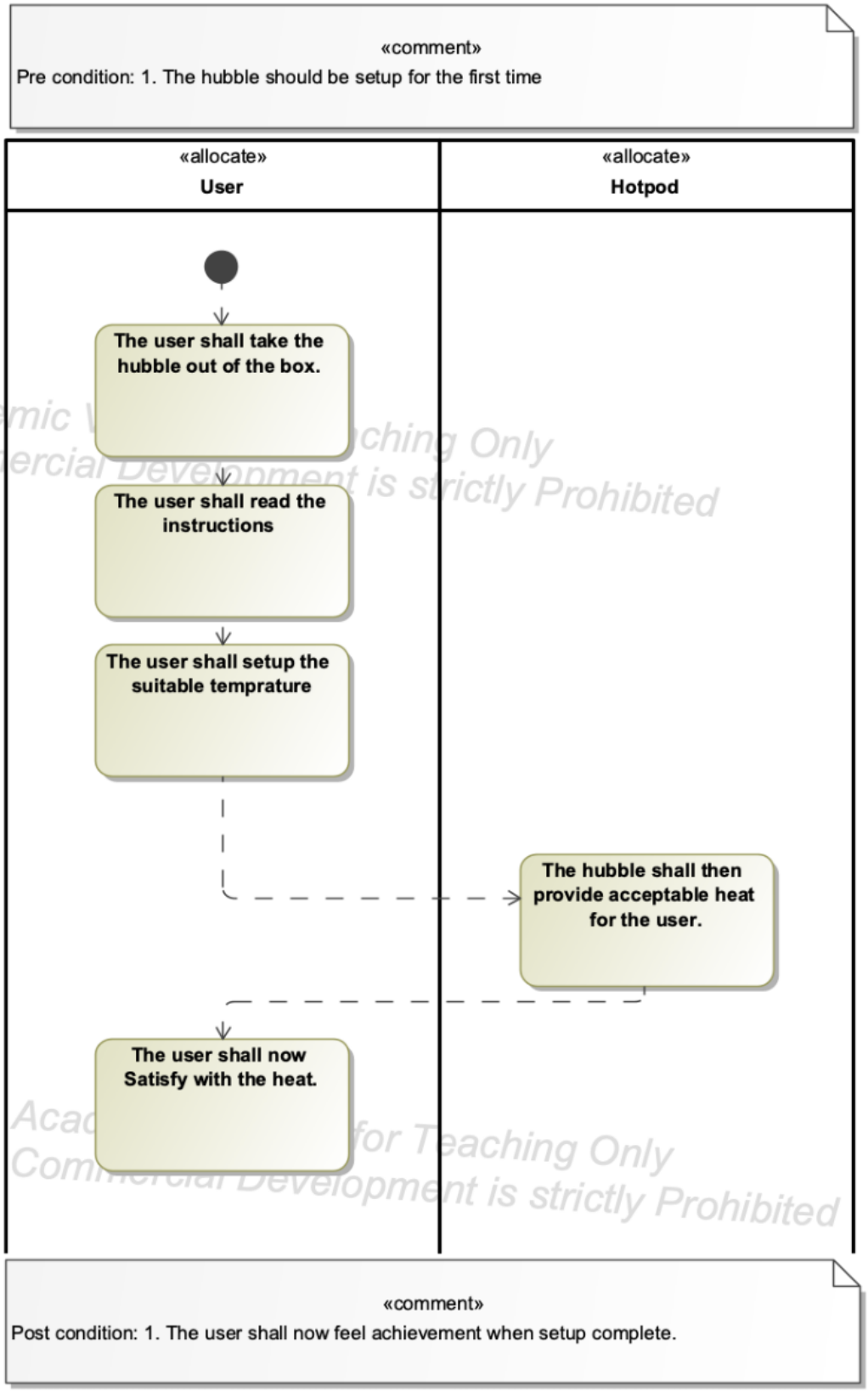


Figure 93. Revised Activity Diagram 4

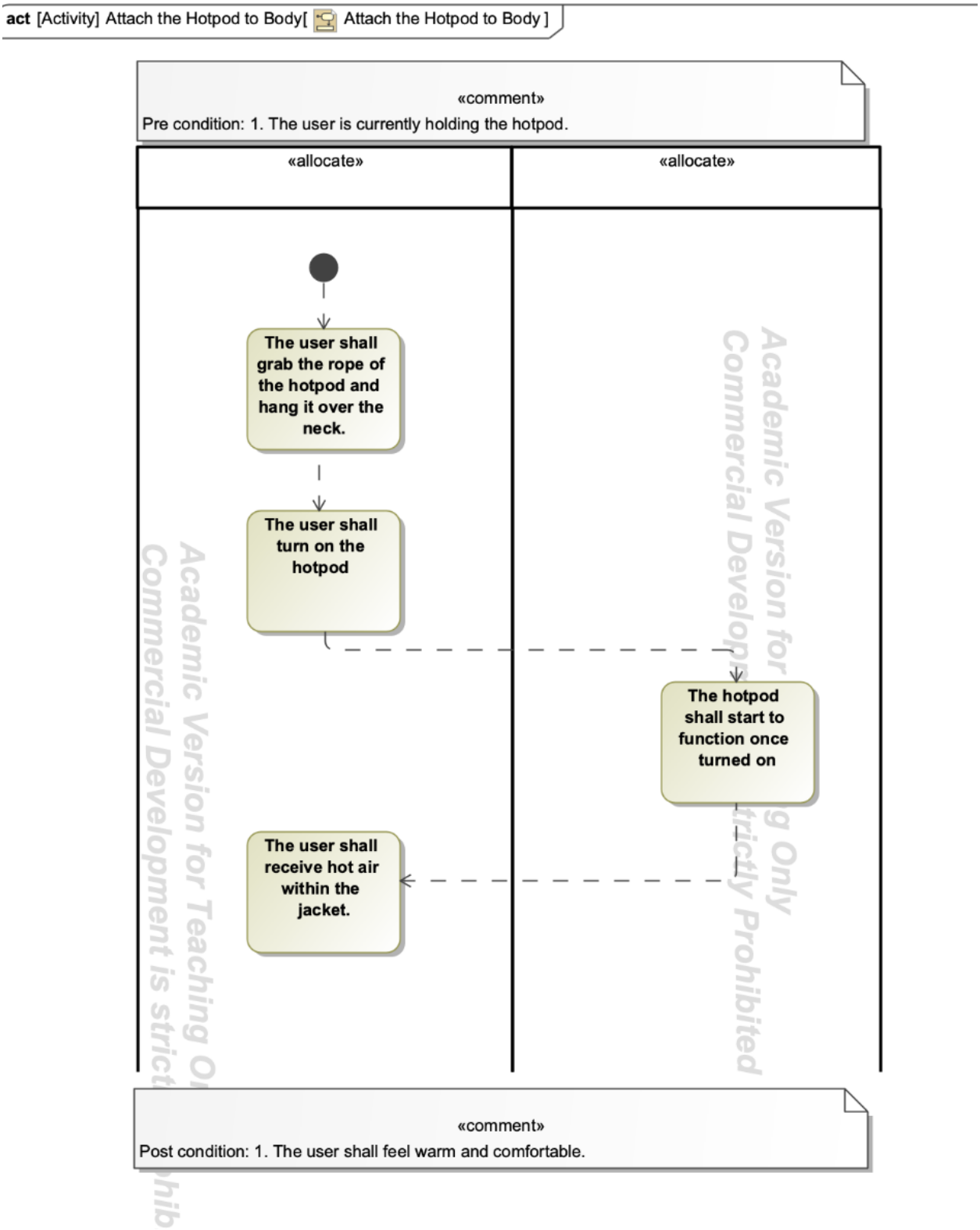


Figure 94. Revised Activity Diagram 5

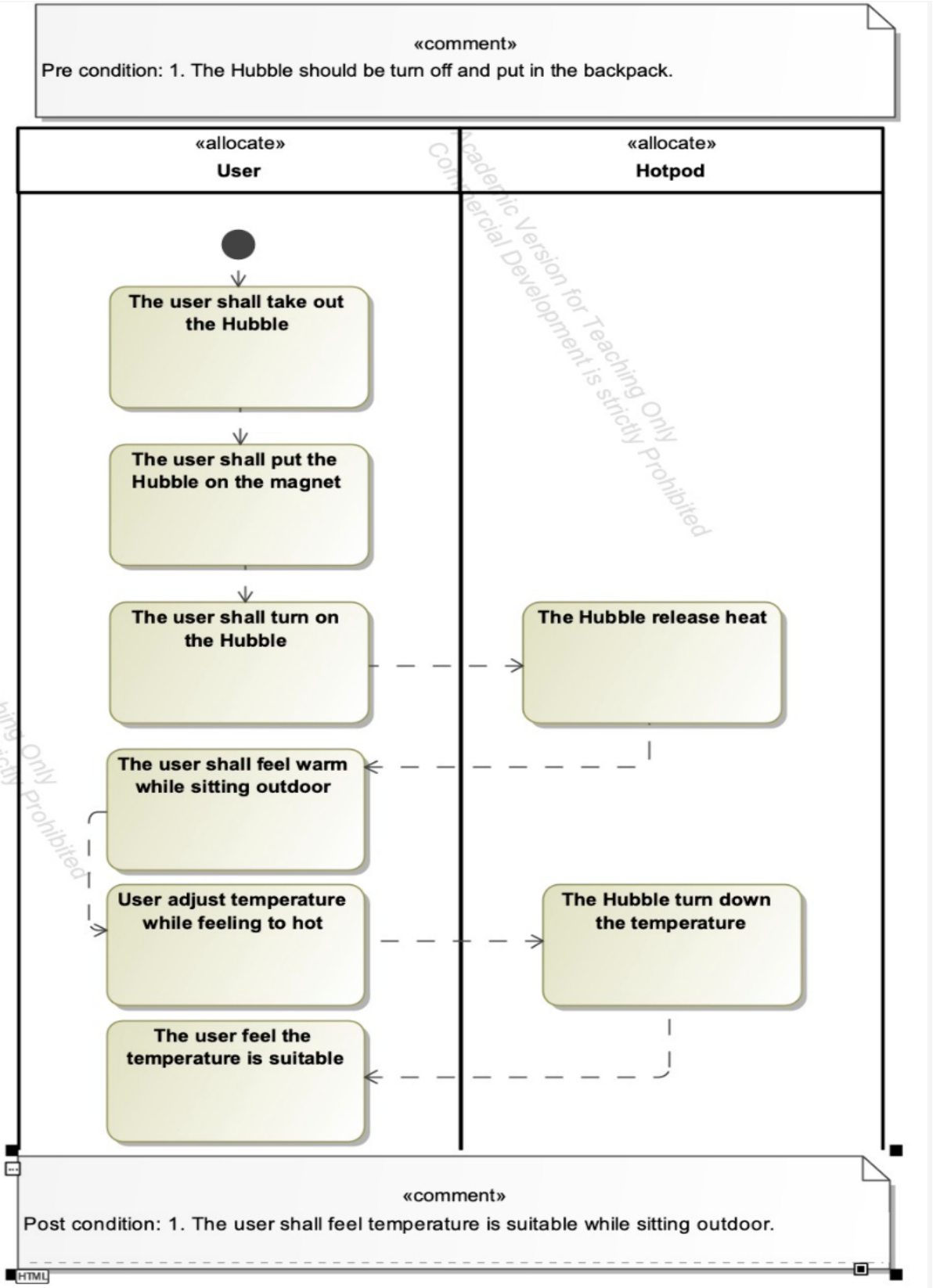


Figure 95. Revised Activity Diagram 6

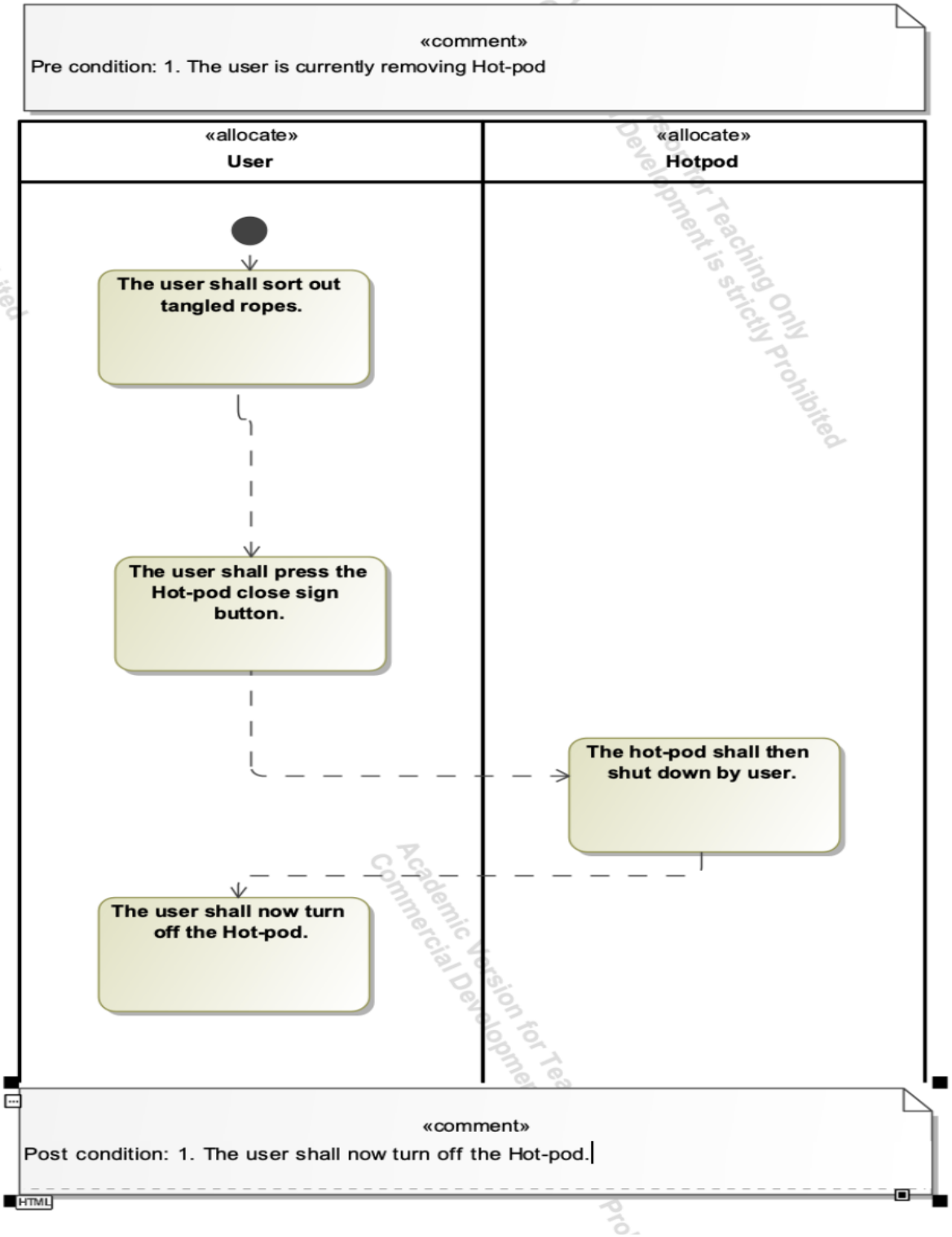


Figure 96. Revised Activity Diagram 7

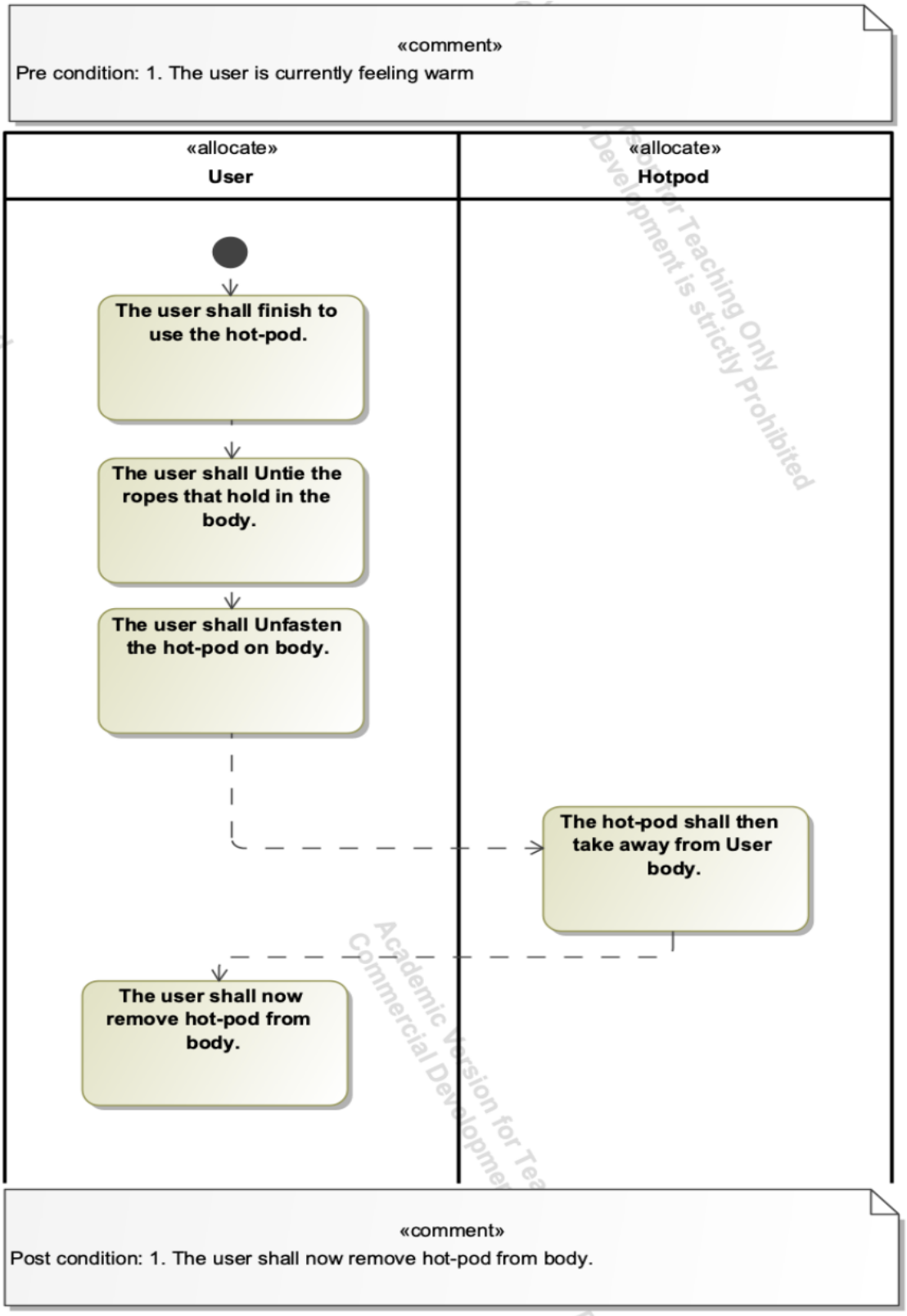


Figure 97. Revised Activity Diagram 8

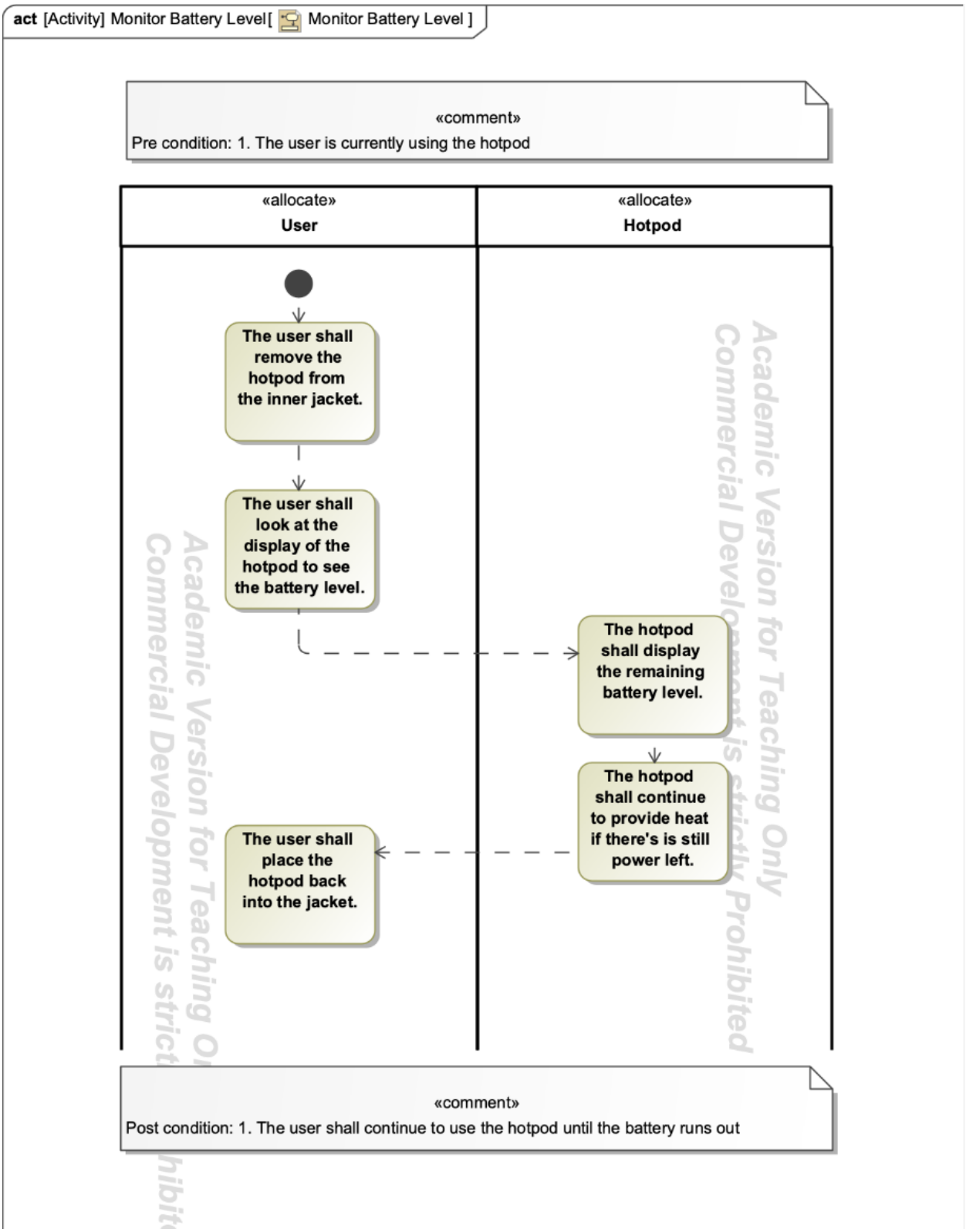


Figure 98. Revised Activity Diagram 9

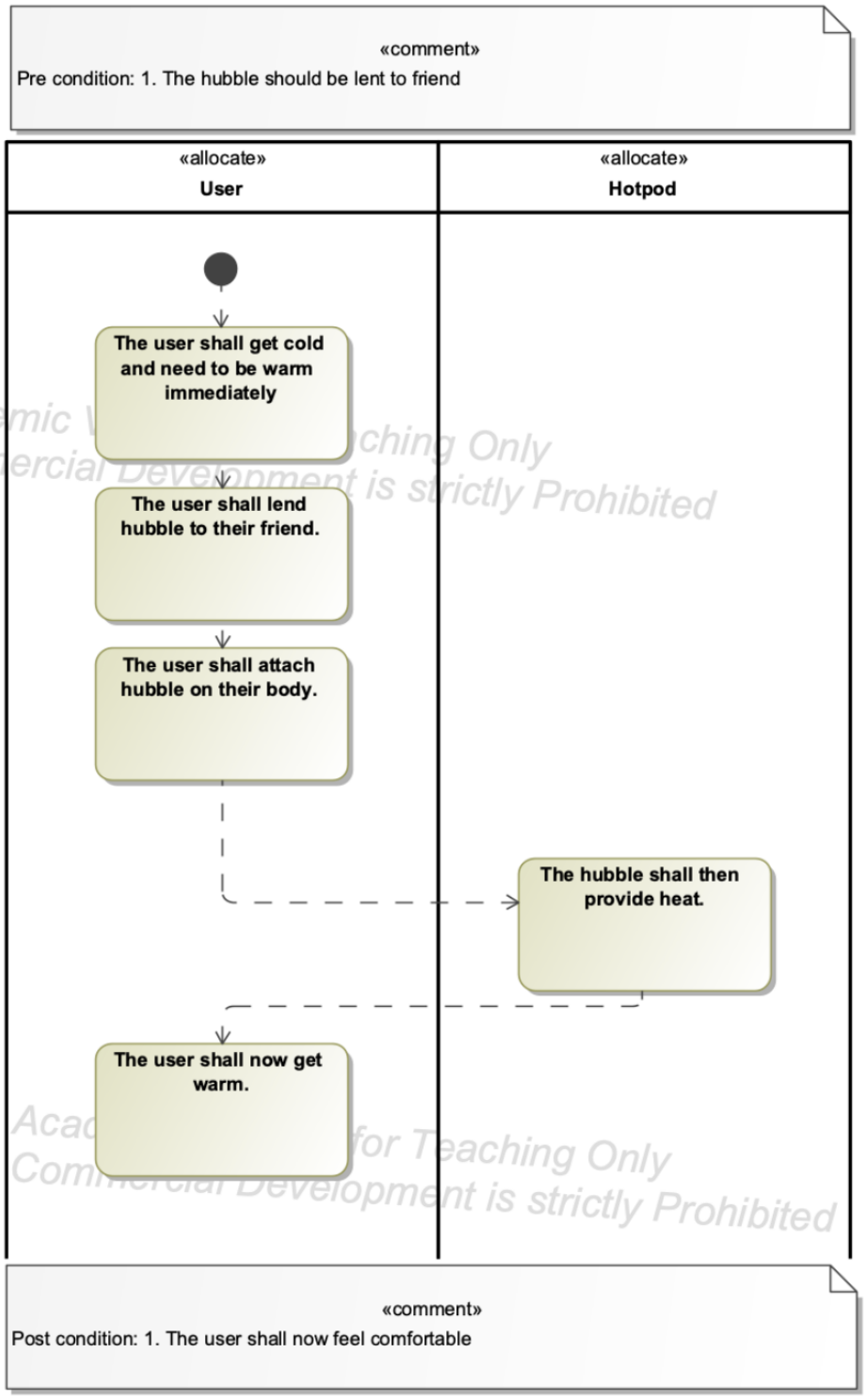


Figure 99. Revised Activity Diagram 10

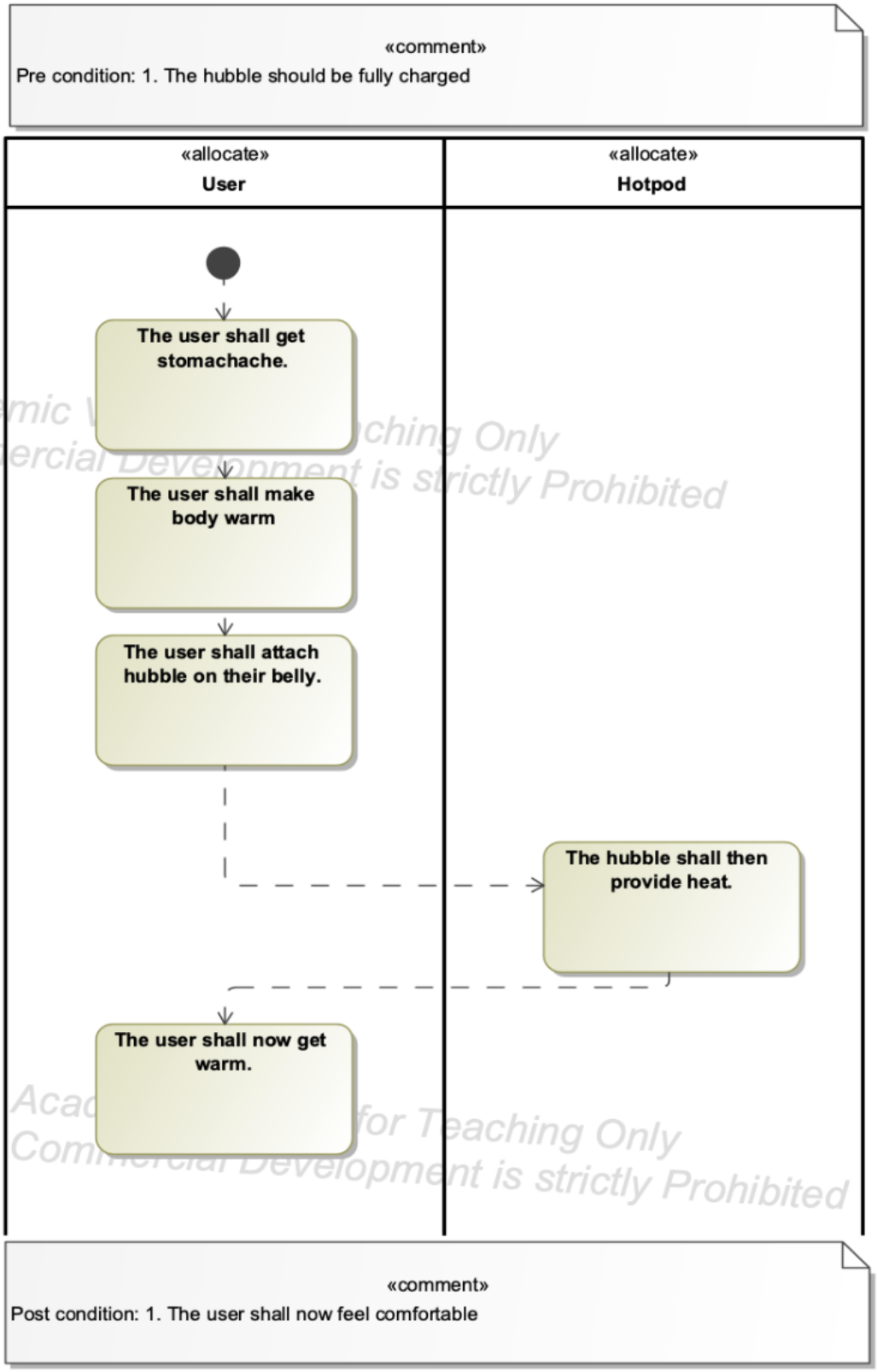


Figure 100. Revised Activity Diagram 11

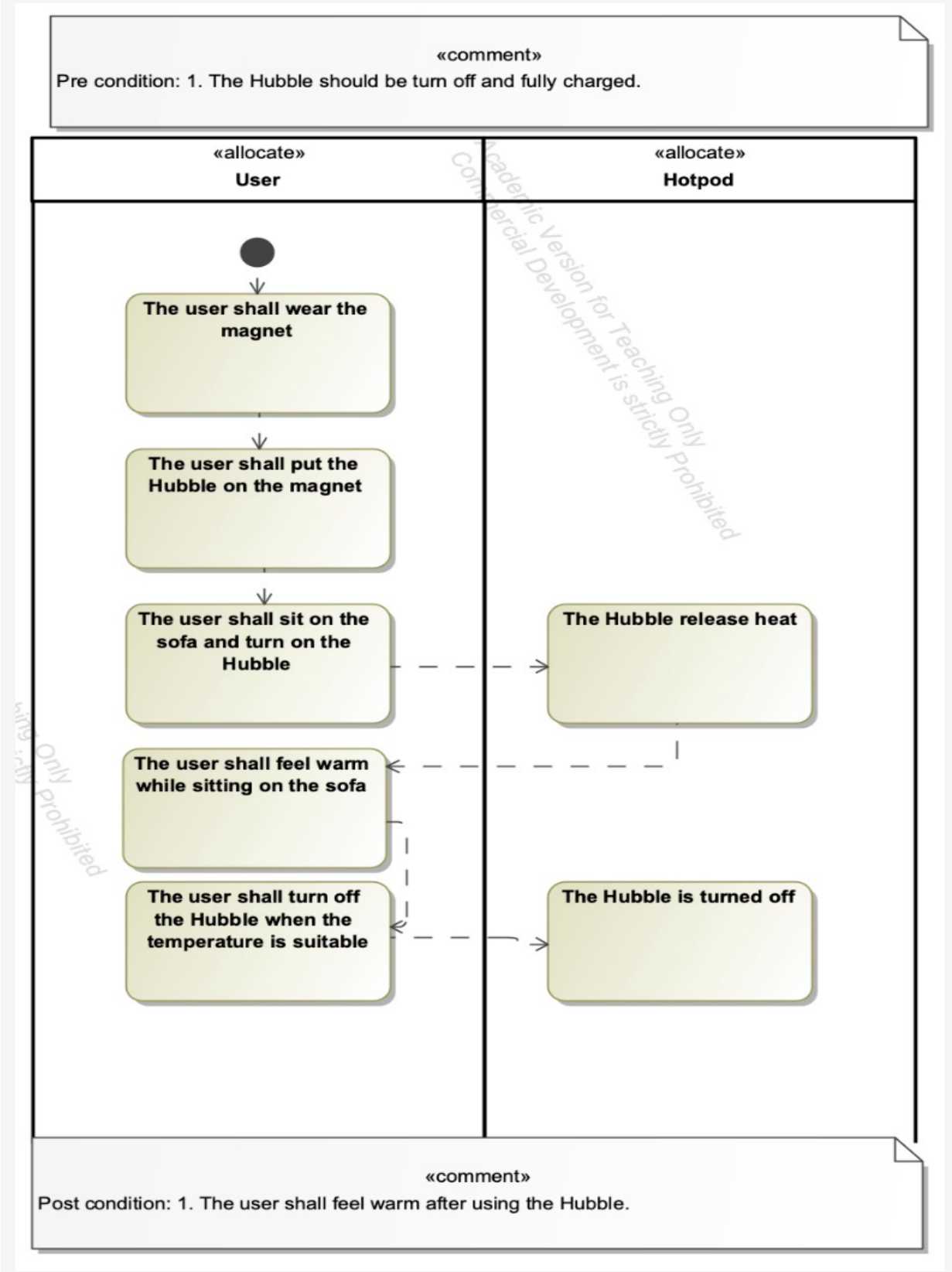


Figure 101. Revised Activity Diagram 12

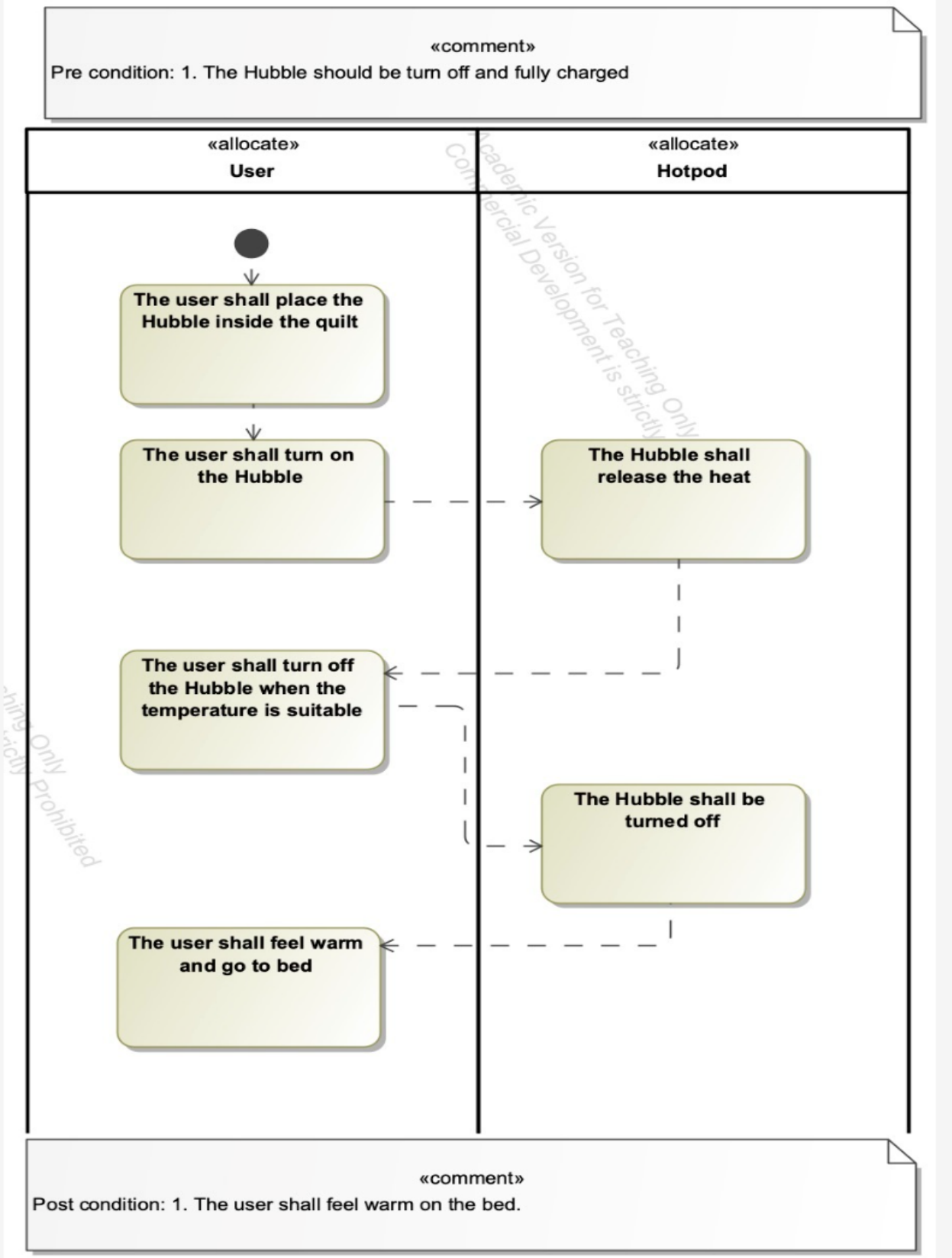


Figure 102. Revised Activity Diagram 13

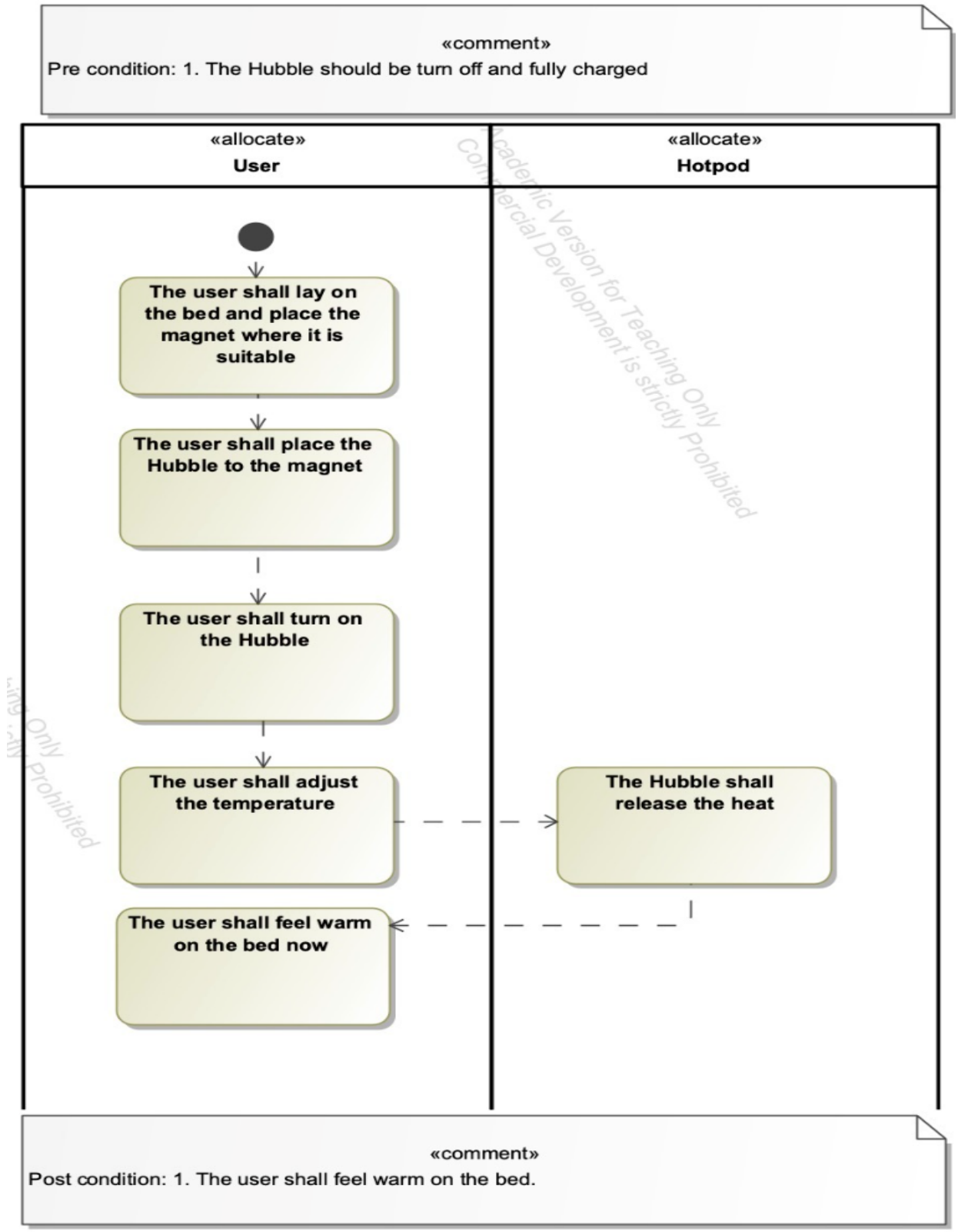


Figure 103. Revised Activity Diagram 14

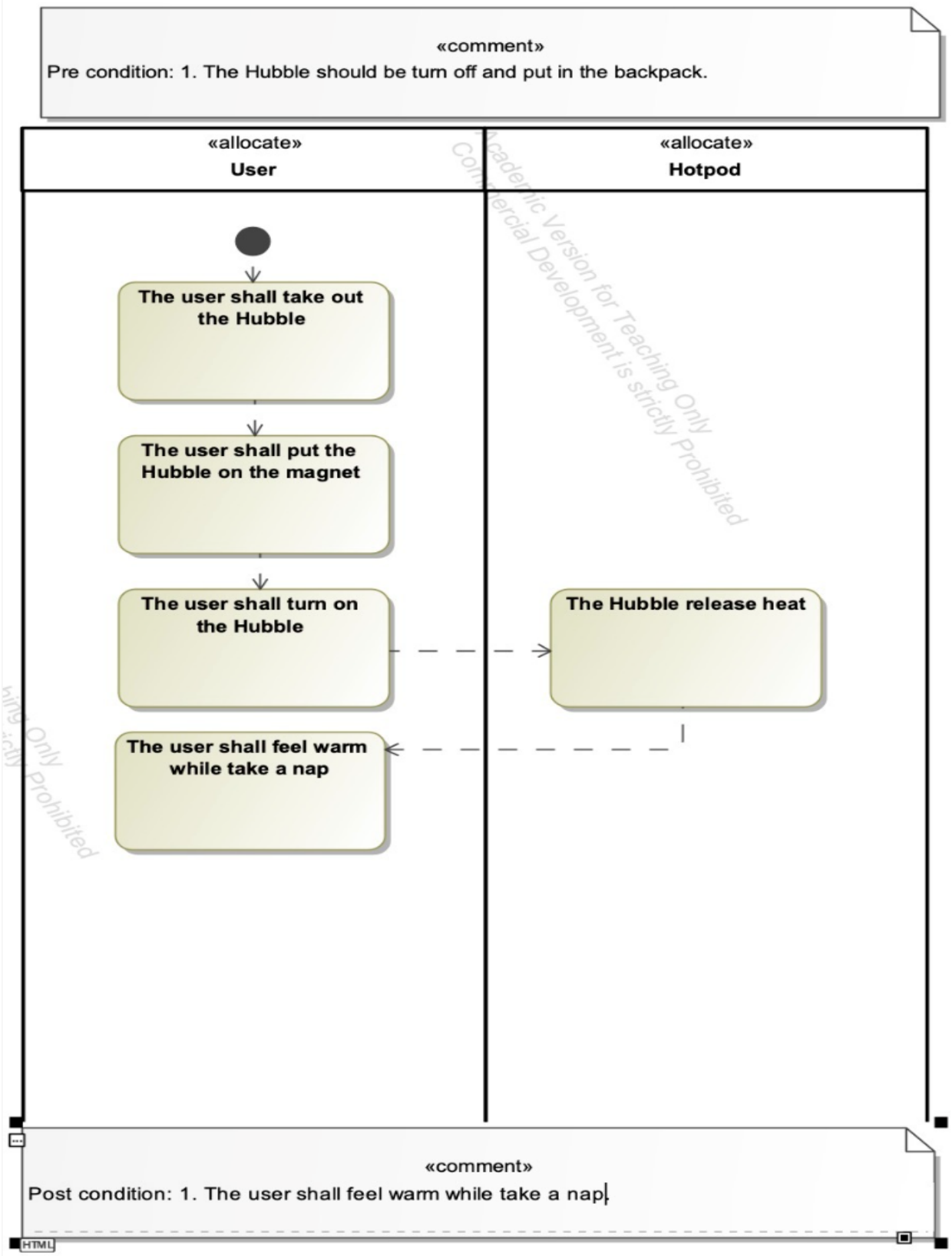


Figure 104. Revised Activity Diagram 15

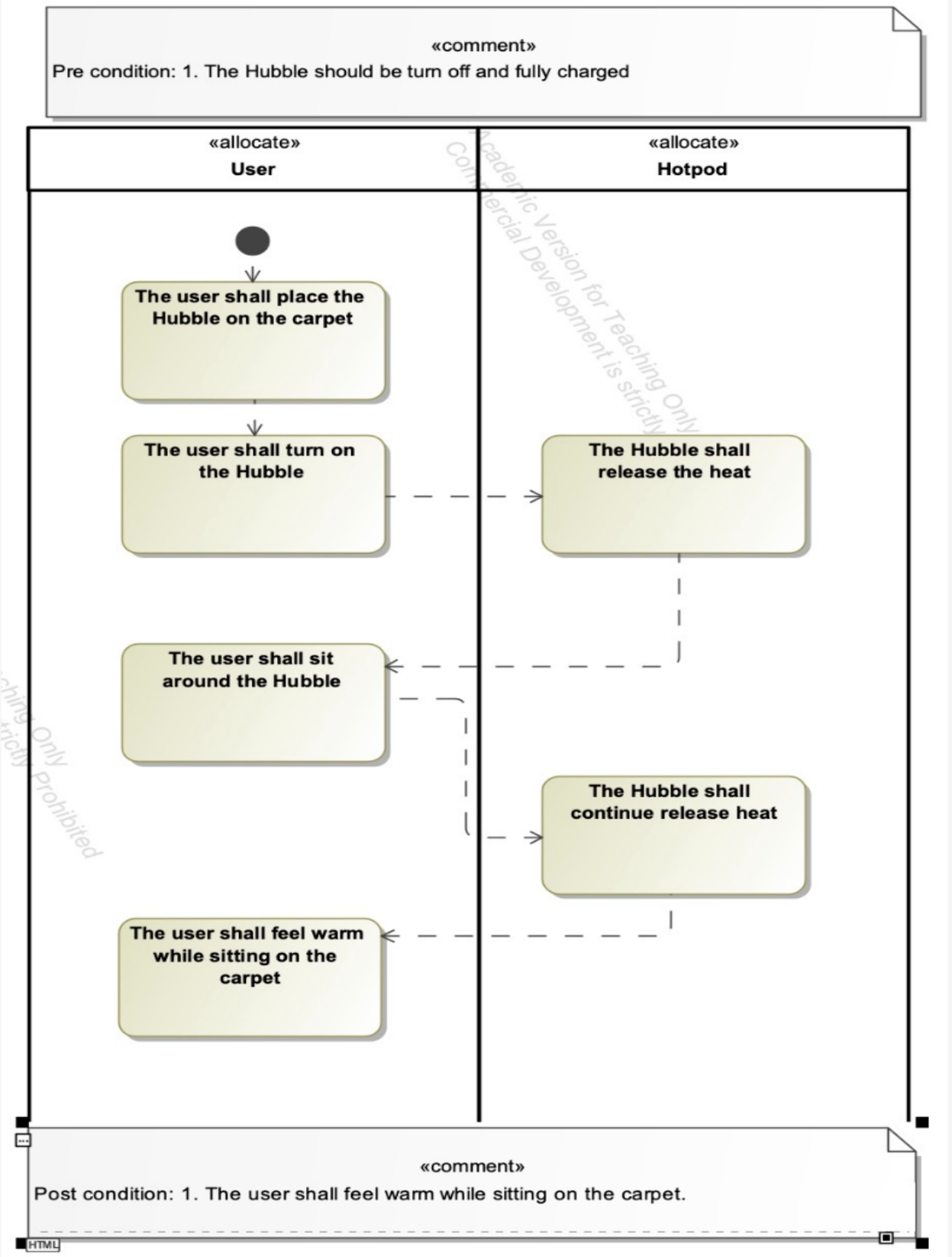


Figure 105. Revised Activity Diagram 16

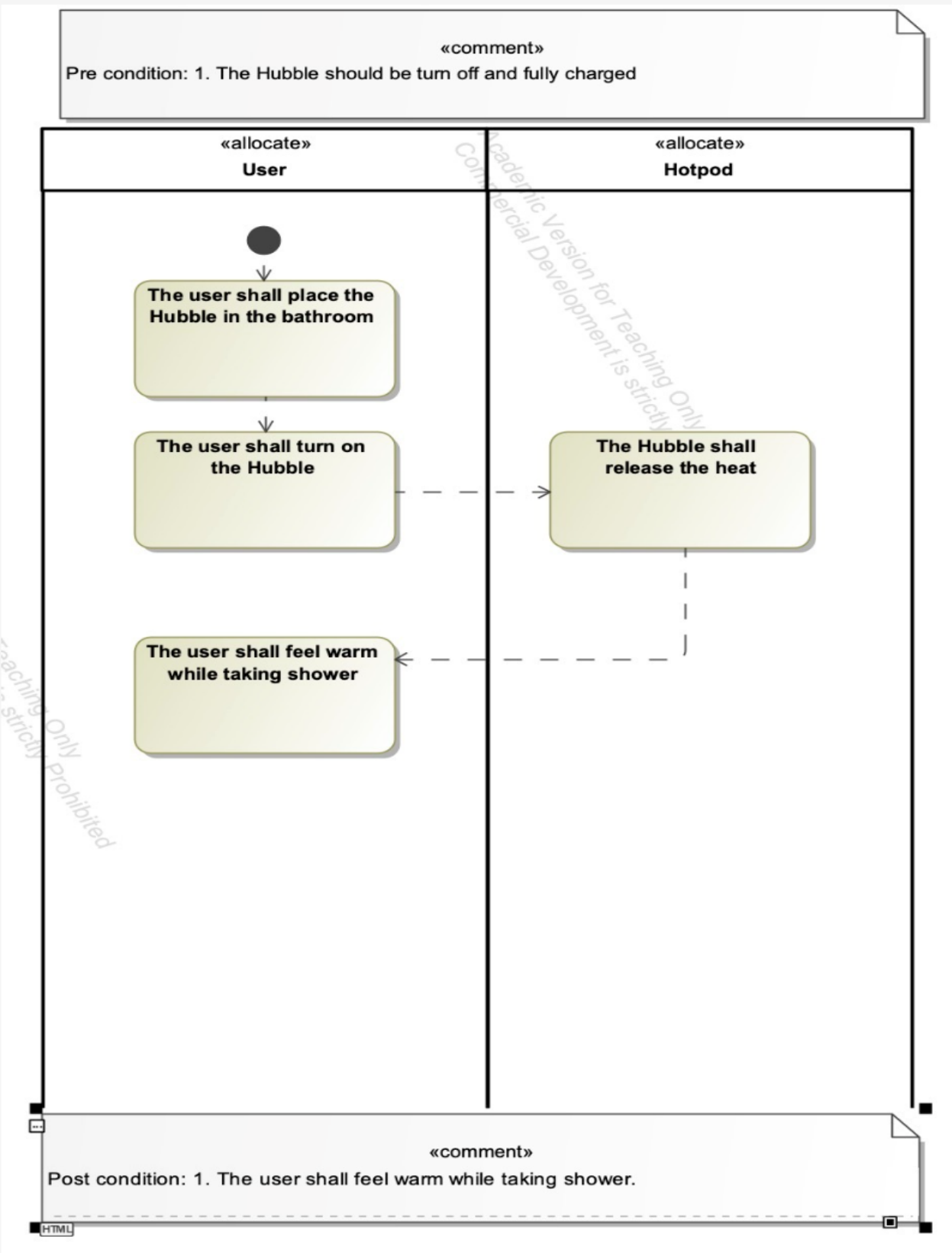


Figure 106. Revised Activity Diagram 17

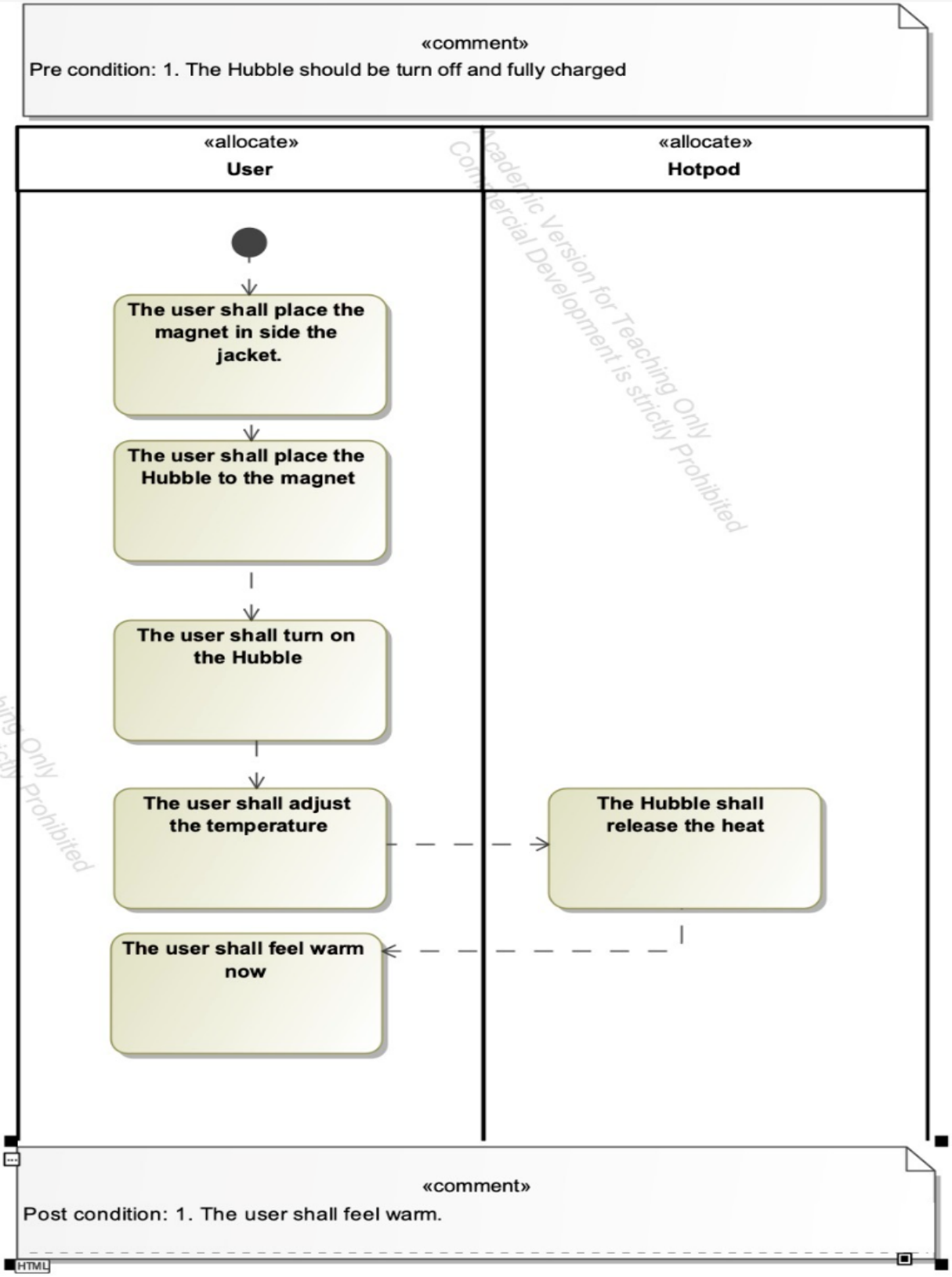


Figure 107. Revised Activity Diagram 18

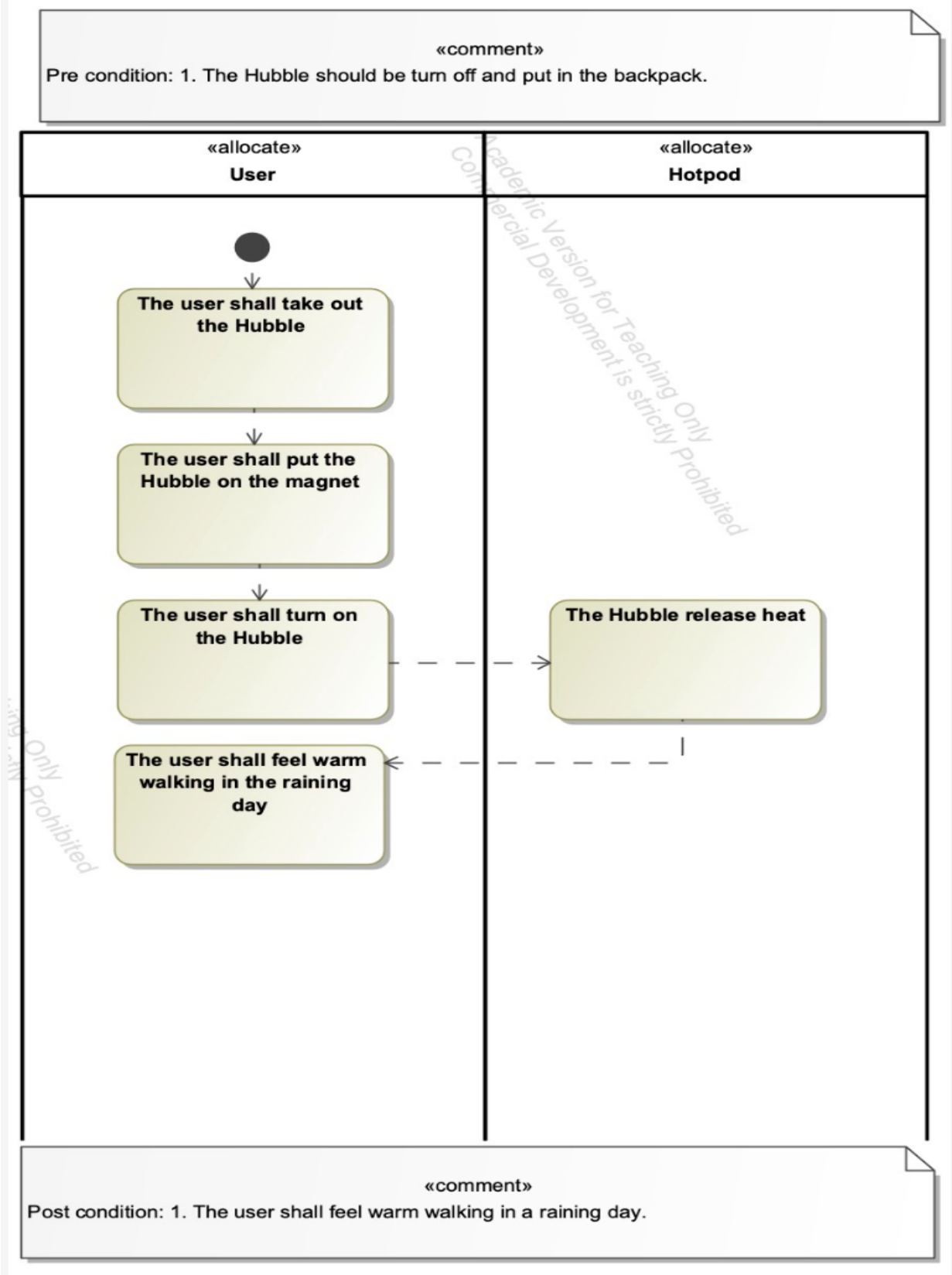


Figure 108. Revised Activity Diagram 19

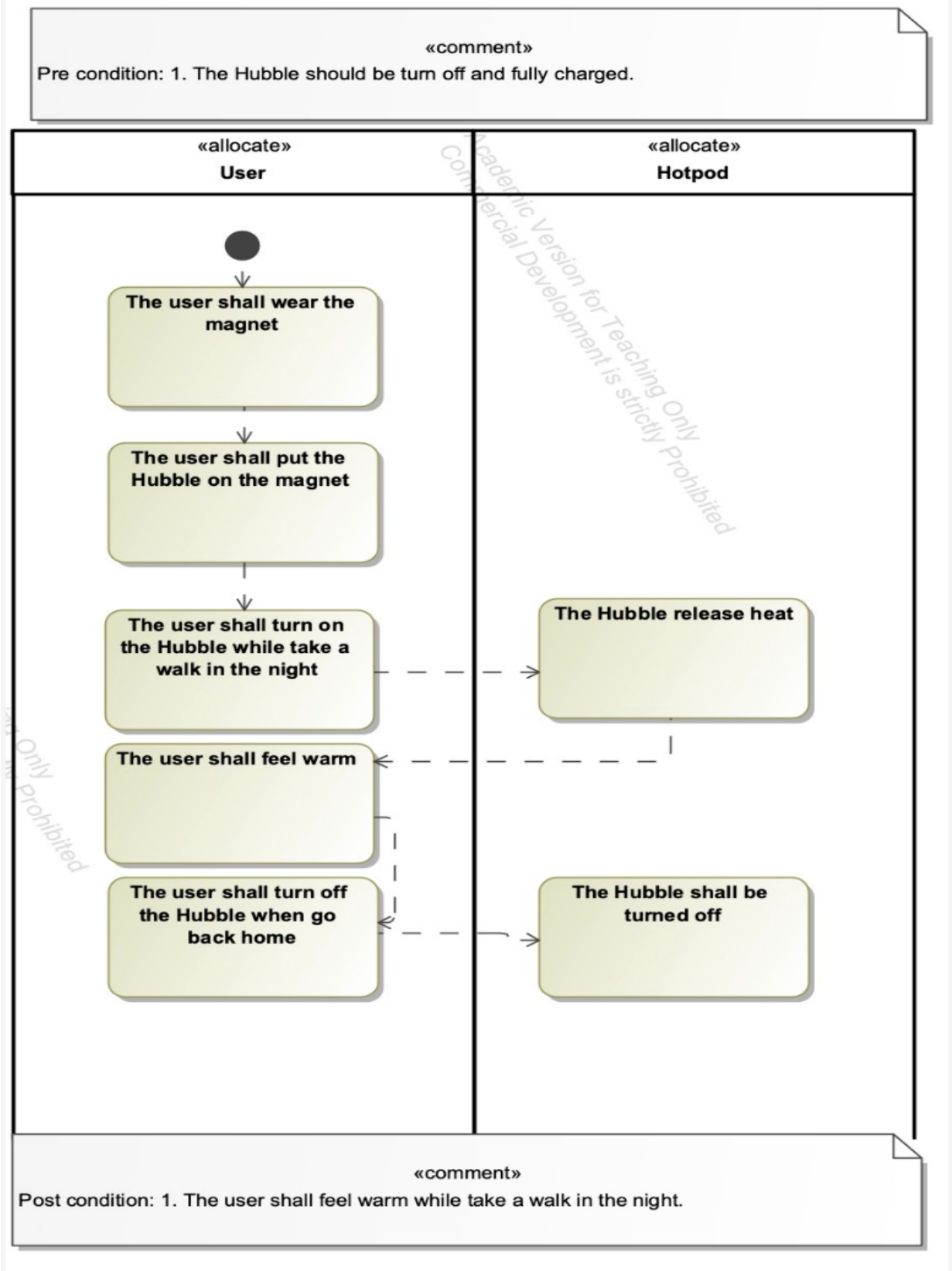


Figure 109. Revised Activity Diagram 20

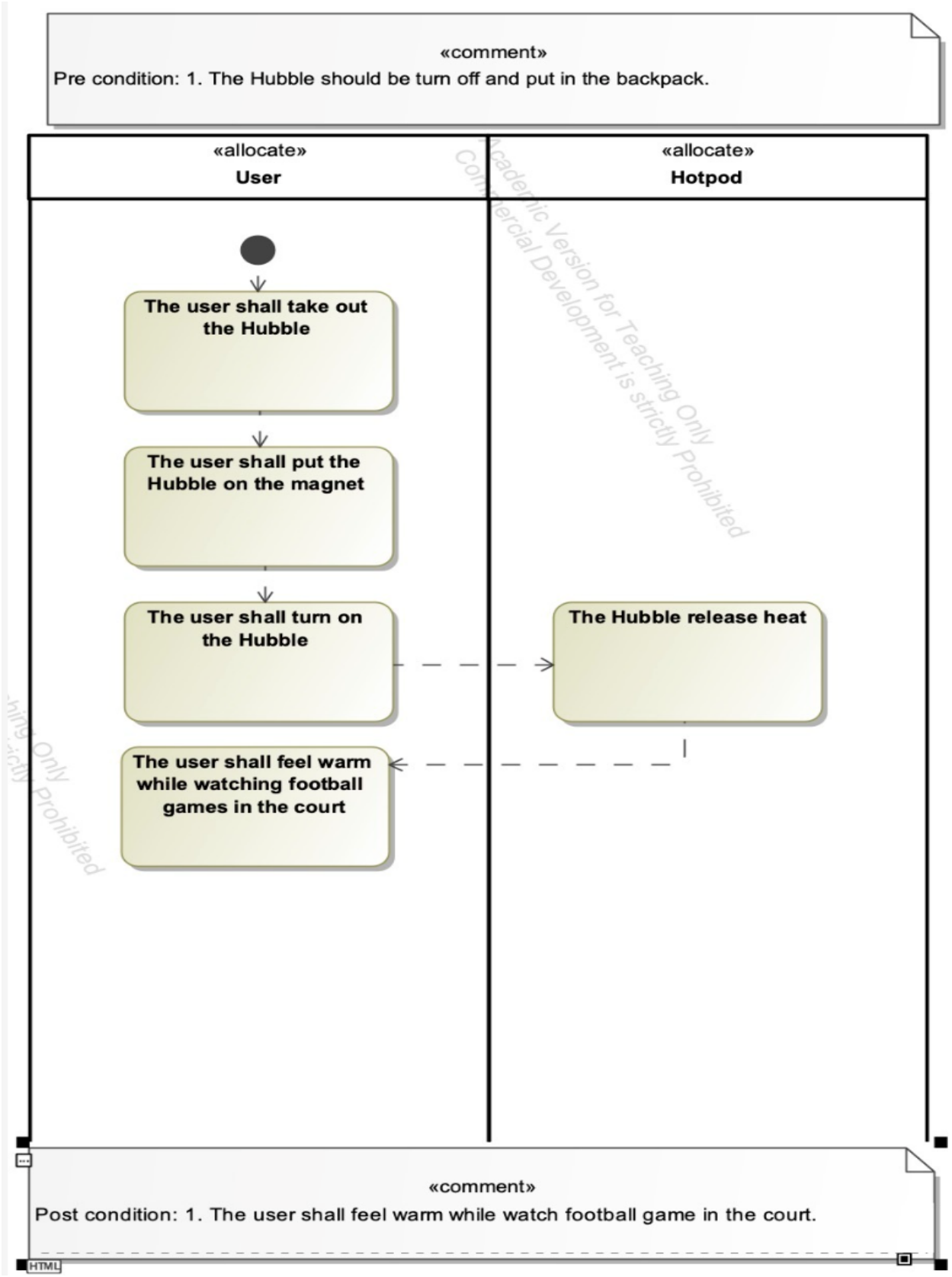


Figure 110. Revised Activity Diagram 21

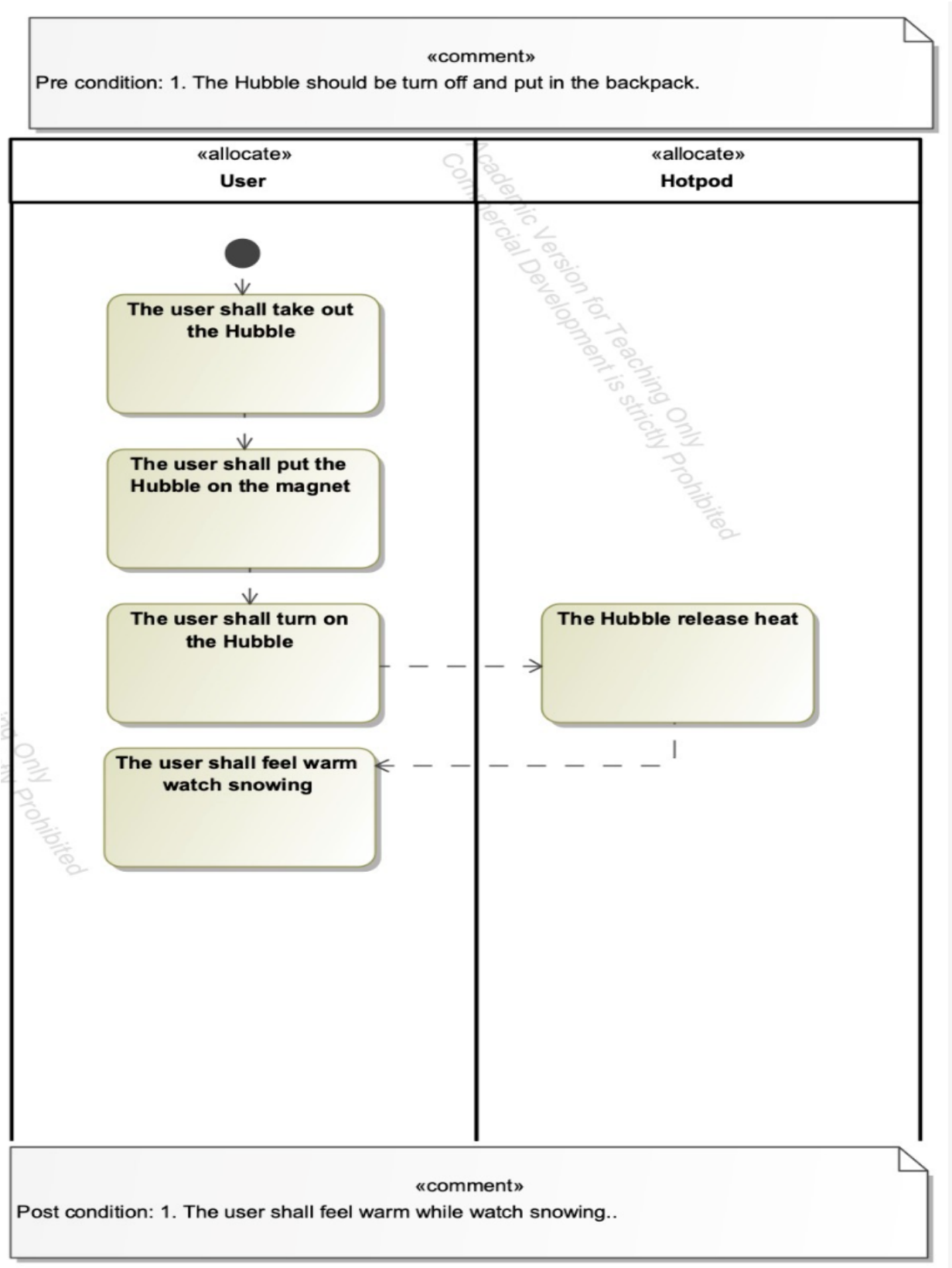


Figure 111. Revised Activity Diagram 22

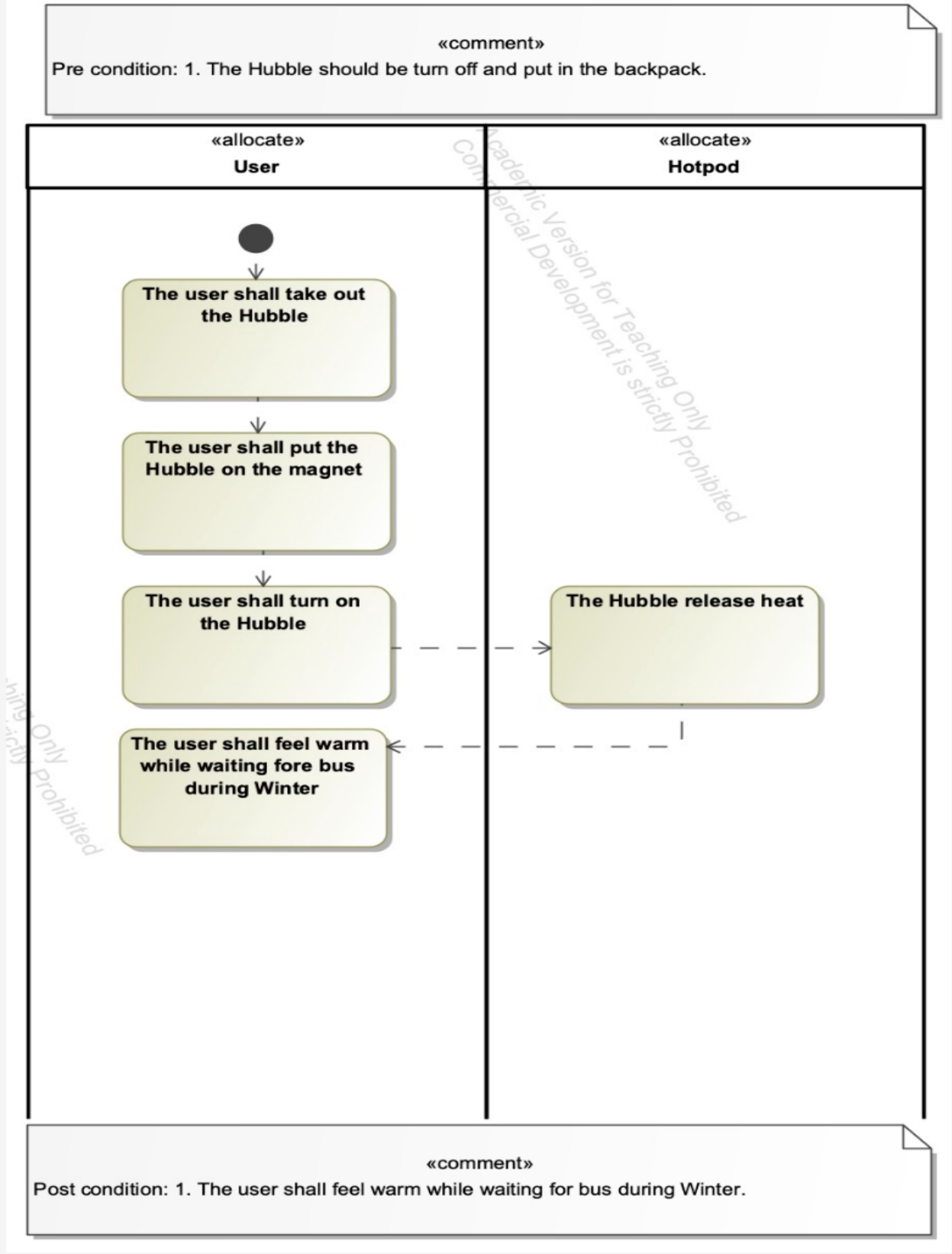


Figure 112. Revised Activity Diagram 23

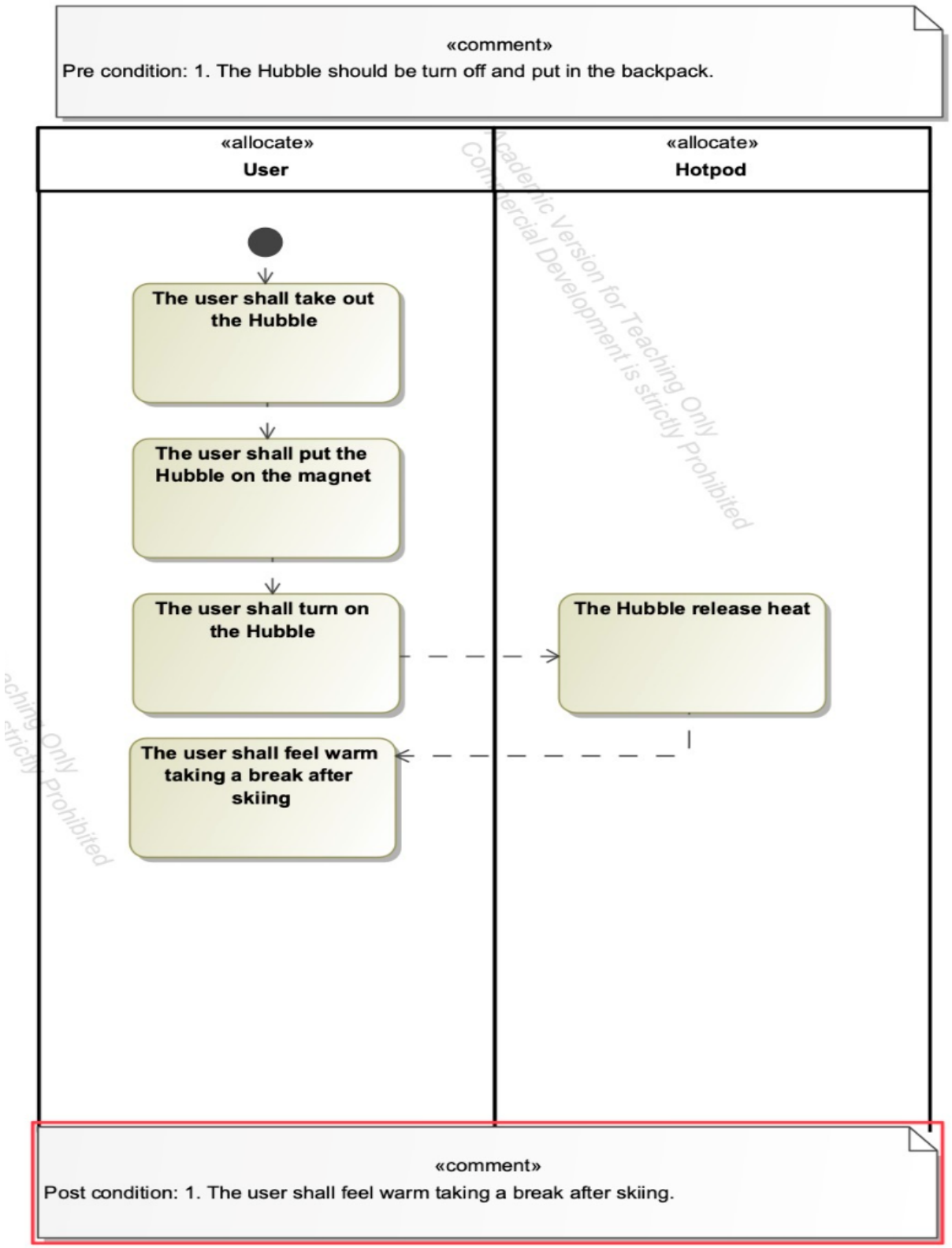


Figure 113. Revised Activity Diagram 24

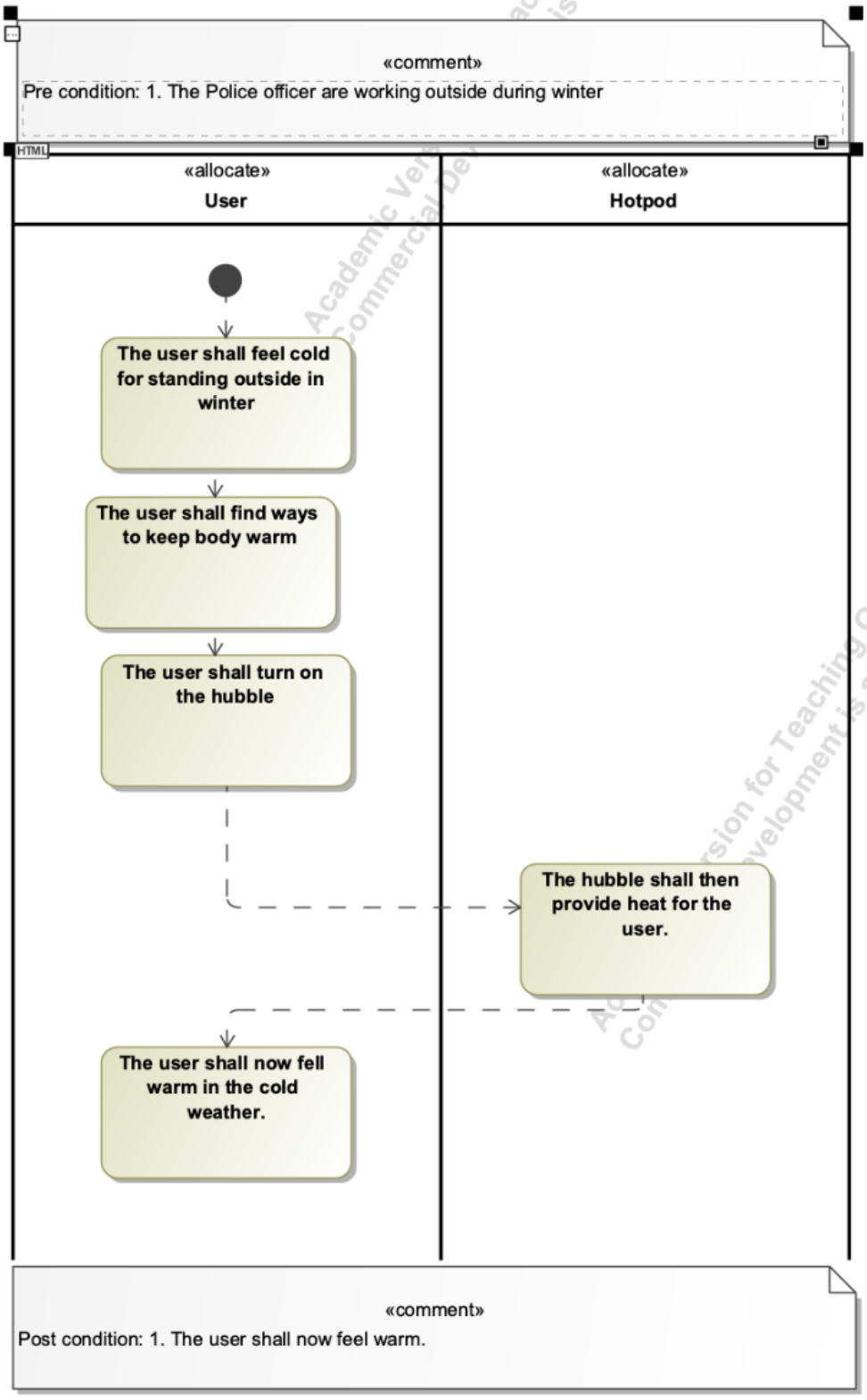


Figure 114. Revised Activity Diagram 25

The 25 emotional activity diagrams detail the user interaction process with our HotPod and Using for different scenarios like inside and outside. The diagrams give us a clear picture of how the users interact with HotPod under different aspects: Turning on the HotPod; Monitoring Battery Level; Charging the HotPod; Attaching the HotPod to Body. Using inside and outside. Overall, the diagrams convey a clear sequence of interactions that align with the product's key performance targets of quick heating, portability, durability, safety, even heat distribution, adjustable temperature, and long battery life.

Here are the detail analysis of these diagrams:

1. Initial Setup and Use:
    - This diagram highlights the unboxing experience and the immediate functionality test of the HotPod, focusing on user satisfaction from the product's presentation and performance.
    - The emotional response of the user ("excited", "happy") is highlighted, showing the product's impact on user sentiment.
2. Charging the HotPod:
    - The user is alerted by the device, which is an essential feature for convenience and safety.
    - The user then removes the HotPod and connects it to a charging cable, indicating a straightforward recharging process.
    - The post-condition states that the HotPod should be at full power after 2 hours, setting an expectation for charging duration.
3. Turning on the HotPod:
    - The user initiates the process by taking the HotPod out of the backpack, indicating that the product is stored in a non-operational state for safety and preservation of battery life.
    - The HotPod is then hung around the user's neck, suggesting a wearable design for hands-free operation.
    - The user turns on the HotPod, which then provides heat, fulfilling its primary function.
    - The desired outcome is the user feeling warm in cold weather, showcasing the product's effectiveness.
4. First time use the Hubble:
    - This diagram focuses on the first-time setup of the Hubble, emphasizing the importance of understanding the instructions and adjusting settings to user preference.
    - The process appears straightforward and user-friendly, likely designed to ensure ease of use right from the start.

- Satisfaction with the device's performance is highlighted, suggesting that initial user interaction is crucial for long-term acceptance.

5. Attach the Hubble to Body:
    - The user places the Hubble around the neck and turns it on, which is a repeated sequence from the first diagram, emphasizing the simplicity and consistency of the operation.
    - The Hubble begins to function and provides heat within the jacket, ensuring the user feels warm and comfortable, which is the final goal of the user interaction.
6. Use the Hubble Outdoor:
    - This scenario shows how the Hubble can be conveniently carried and used outdoors, reflecting its portable design.
    - Includes user interaction with the device's temperature controls, indicating that the Hubble has adjustable settings to cater to different comfort levels.
7. Turn off the Hubble:
    - This diagram emphasizes the importance of user interaction in safely shutting down the Hubble, highlighting steps like untangling ropes and pressing specific shutdown buttons.
    - The sequence ensures that the device is turned off properly to prevent accidental operation or battery drain.
8. Remove the Hubble from body:
    - This diagram details the process of detaching the Hubble once the user feels sufficiently warm, focusing on the physical steps needed to safely remove the device.
    - Ensures user comfort and device safety by illustrating the proper method to remove the device.
9. Monitoring Battery Level:
    - The user is expected to remove the Hubble from the jacket to check the battery level, suggesting that the display is not visible during normal use, which could be a point of consideration for design improvement.
    - After observing the battery level, the user places the Hubble back into the jacket, indicating that the product's design requires physical interaction to monitor power levels.
    - The Hubble continues to provide heat if there's still power left, which aligns with the product's aim to deliver continuous warmth.
10. Lend Hubble to friend:
    - This scenario illustrates a social use of the Hubble, where it is shared between friends, reflecting its ease of use and adaptability in social settings.

- The process from feeling cold to achieving comfort through the Hubble is highlighted, showcasing the device's quick response and effectiveness in providing warmth.

11. Use for stomachache:
    - The user begins in a state of physical discomfort due to a stomachache, feeling uneasy and possibly anxious.
    - The preparation to warm their body indicates a proactive step towards self-care, fostering a slight uplift in mood through action.
    - Attaching the Hubble and feeling the warmth directly on the belly brings immediate relief, reducing discomfort and promoting a sense of well-being.
    - As the warmth alleviates the pain, the user transitions into a state of comfort, feeling grateful and relaxed.
12. Use for sitting on the sofa:
    - The user prepares the setup by wearing the magnet, possibly feeling a bit of curiosity or mild frustration if adjusting the magnet is cumbersome.
    - As the user places the Hubble on the magnet and sits down, there's a sense of engagement and anticipation for the forthcoming warmth.
    - The warmth released by the Hubble provides a relaxing effect as the user sits on the sofa, enhancing their comfort while engaged in passive activities like reading or watching TV.
13. Use for sleeping:
    - The user feels anticipatory and hopeful as they prepare the Hubble for use, expecting it to provide comfort.
    - As the Hubble begins to release heat, the user experiences relief from the cold, feeling the gradual increase in warmth.
    - When turning off the Hubble after reaching the desired temperature, the user feels satisfied with the control and effectiveness of the device.
    - The ultimate comfort from the warmth allows the user to feel cozy, leading to a peaceful transition to sleep.
14. Use for lying on the bed:
    - The user prepares the bed with the Hubble, anticipating a cozy sleep environment.
    - As the Hubble releases heat, the user experiences physical comfort that enhances emotional relaxation.
    - Turning off the Hubble once the desired temperature is achieved leads to a feeling of control and satisfaction with the environment.

- The warm bed provides a nurturing setting, ideal for a peaceful sleep, fostering a deep sense of tranquility.

15. Use for taking a nap:
    - The user sets up the Hubble for a nap, which can induce a calm and prepared mental state.
    - The warmth emitted by the Hubble during the nap helps in reducing physical tension and mental stress.
    - The warmth supports a restorative nap, leading to feelings of rejuvenation and well-being.
16. Use on the carpet:
    - Placing the Hubble and sitting around it can create a moment of gathering, either with self or others, enhancing feelings of togetherness.
    - The warmth enriches the user's leisure time, making activities more enjoyable and relaxing.
    - Continuous warmth delivery while sitting adds to sustained comfort and satisfaction, deepening relaxation and enjoyment of the moment.
17. Use for showering:
    - Introducing warmth into a typically cold setting (bathroom) immediately alleviates discomfort, promoting a sense of relief.
    - Warm conditions while showering can transform the experience, making it pleasurable and luxurious.
    - Concluding a warm shower leaves the user feeling refreshed and cared for, enhancing overall mood and readiness for subsequent activities.
18. Use in jacket:
    - The user begins by inserting a magnet inside their jacket, setting the stage for the Hubble's use.
    - They then attach the Hubble to the magnet and activate it, an act that combines both anticipation of warmth and the satisfaction of taking proactive steps against the cold.
    - Adjusting the temperature allows the user to customize the warmth to their preference, likely leading to a feeling of control and comfort.
    - The sequence ends with the user feeling warm, an immediate, tangible reward that confirms the effectiveness of their actions and the Hubble's functionality.
19. Use on the rainy day:
    - Starting with the Hubble in the backpack indicates preparedness for adverse weather.

- Activating the Hubble once outdoors and feeling its warmth combats the discomfort of the rain, likely bringing a sense of relief and protection from the harsh elements.
- The emotional journey here peaks with the satisfaction of remaining warm even in less ideal conditions, enhancing the user's overall resilience and mood during what might otherwise be a dreary situation.

20. Use for night walk:
    - The activity starts with gearing up for a night walk, which might be mixed with apprehension due to the cold.
    - Activating the Hubble brings warmth, transforming the night walk from potentially uncomfortable to pleasantly warm.
    - The resulting warmth not only comforts but also likely enhances the enjoyment and peacefulness of a night walk, making it a more inviting and enjoyable experience.
21. Use for watching matches:
    - Preparing the Hubble for use at a game sets up anticipation not just for the sport but for staying comfortably warm.
    - Feeling warm while watching the game allows the user to focus more on the enjoyment of the game rather than the distraction of the cold.
    - The emotional peak here is a blend of social enjoyment (watching the game) and personal comfort (from the warmth), leading to a fulfilling experience.
22. Use for watching snow:
    - Similar to the other scenarios, the preparation phase involves anticipating the need for warmth.
    - Observing snow is often associated with a sense of wonder, and experiencing this natural beauty without the discomfort of cold greatly enhances the emotional experience.
    - The warm sensation against the cold visual tableau of snow offers a deeply satisfying, almost picturesque experience.
23. Use for waiting for bus on winter:
    - Comfort and relief.
    - Waiting for a bus in the cold can be an uncomfortable experience. The warmth from the Hubble provides immediate physical comfort, translating into emotional relief and a sense of well-being.
24. Use for skiing:
    - Rejuvenation.

- After the exertion and chill of skiing, the warmth provided by the Hubble can be rejuvenating, helping the user recover physically and emotionally, enhancing the overall skiing experience.

25. Use for Police Officer during winter duty:
    - Assurance and sustained focus.
    - For a police officer, staying warm is crucial not just for comfort but for maintaining alertness and effectiveness. The Hubble ensures they can stay focused and feel assured that the cold won't hinder their duties.

13. Product Market Fit

Our primary target market includes outdoor professionals such as construction workers and event planners. Given that 63.9% of the users foresee using our product during outdoor activities and 34.7% during commuting in the questionnaires we have conducted, we also see great potential among college students who live in areas with severe winter climates and need a portable heat source for their daily commuting and outdoor social activities.

From our market research and questionnaires, 53% of participants prefer a device that is easy to carry, and 71.7% of them are concerned about safety. It's clear that the top two features our customers are looking for are ease of use and safety, following these are portability, customizable heating and long battery life. Additionally, we plan to set up channels to gather customer feedback through online surveys and direct interactions post-launch.

Our market analysis projects a strong demand with an anticipated first-year sales growth of 35%. We aim to capture a 20% market share among outdoor professionals in cold regions within two years.

Our marketing strategy, which includes pre-launch campaigns via social media and email, is designed to create buzz and measure customer interest. Additionally, we expect a significant amount of organic growth through word-of-mouth, thanks to preliminary product reviews.

Initial feedback from focus groups has been very encouraging. Our early indicators from website interest also suggest sustained market demand. Based on this positive beta feedback, we recommend ramping up marketing efforts targeted at outdoor professionals in cold regions. We also plan to incorporate feedback from beta testing to refine the product further. In the future, we're looking to expand our market research to include additional segments like senior citizens or individuals with health conditions that benefit from regulated warm devices.

14. Company Differentiation

Hubble's differentiation lies in our ability to blend innovative technology with user-friendly designs and sustainable materials.

Hubble's HotPod employs advanced convective heat transfer technology, this not only ensures a more even distribution of heat but also enhances energy efficiency, which sets it apart from traditional heating solutions that rely on conduction or radiation.

Hubble focuses on the user experience. The HotPod is engineered to be ultra-lightweight and ergonomically designed to fit seamlessly as an accessory just like the necklace you wear every day. It offers multiple heat settings which can be adjusted through a simple and intuitive interface.

Additionally, The HotPod is equipped with a sophisticated feedback mechanism that prevents overheating by shutting down the system temporarily if necessary.

All Hubble's products are constructed from recycled materials and are designed to be fully recyclable at the end of their lifecycle.

15. Closure

15.1 Observations and Future Improvements

Through the development of the HotPod, we learned several valuable lessons:

- Due to battery requirements and the convective heat transfer mechanism, the HotPod will inevitably remain relatively large. The fan will also be slightly loud and audible, which cannot be easily controlled.
- Given the size and noise factors, the HotPod appears to be more suitable for industrial settings rather than for students.

Future Improvements

Upgrade to a PCB:

Now that the circuit is finalized, upgrading to a custom PCB would streamline the electronics and reduce wiring complexity.

Design Improvements:

The design could be further improved to facilitate better airflow. We intend to perform Computational Fluid Dynamics (CFD) analysis to optimize the airflow.

Peltier System Integration:

Future iterations could employ a Peltier system to provide both cooling and heating capabilities, making the device useful throughout the year.

15.2 Conclusion

The Hubble HotPod project has been an insightful journey in developing a portable heating solution tailored to enhance the lives of college students. Beginning with empathy fieldwork and ideation sessions, we identified key challenges faced by students and translated them into a practical design through multiple prototyping iterations.

Design 0 laid the groundwork with a basic functional prototype, while subsequent iterations focused on refining the HotPod's form factor, airflow efficiency, and overall usability. The transition to a hexagonal shape in Design 2 significantly reduced the product's size while but lead to lesser heat distribution and lack of functionality due to heavy emphasis on aesthetics. Further iterations (Designs 3, 4, and 5) continued to optimize the device based on user feedback while keeping functionality as the primary goal, enhancing battery life, reducing weight, and incorporating a custom PCB for streamlined electronics.

Despite challenges like size and noise, which suggest that the HotPod might be more suitable for industrial settings than for students, the project demonstrated the value of iterative design and rigorous user testing. Future improvements include integrating a Peltier system for both heating and cooling, upgrading to a PCB, and improving airflow through CFD analysis.

The Hubble HotPod project reflects a user-centered design approach utilizing the systems design thinking and standard engineering principles that successfully addressed the identified challenges and lays the groundwork for further innovation.

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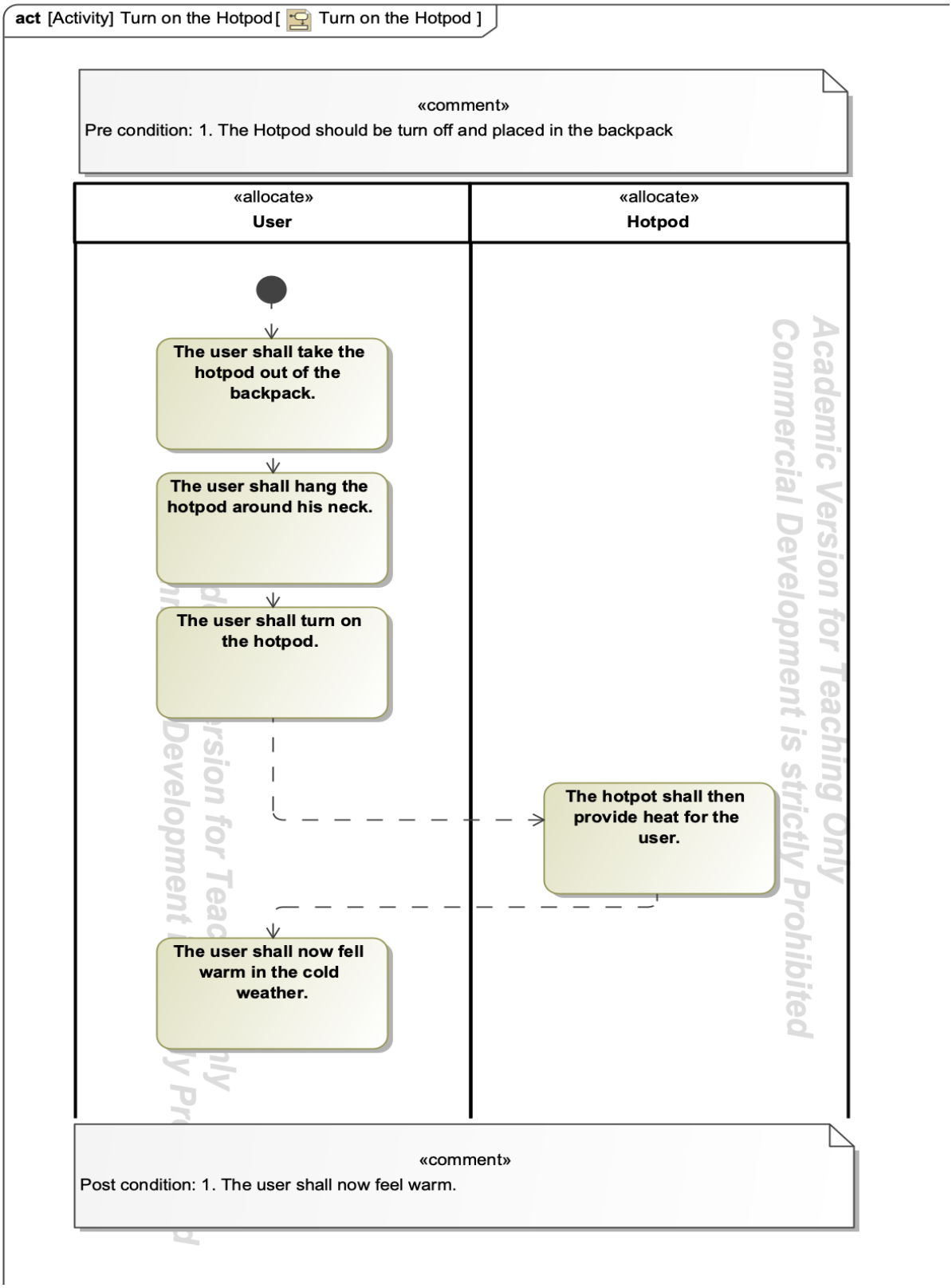
17. Appendix

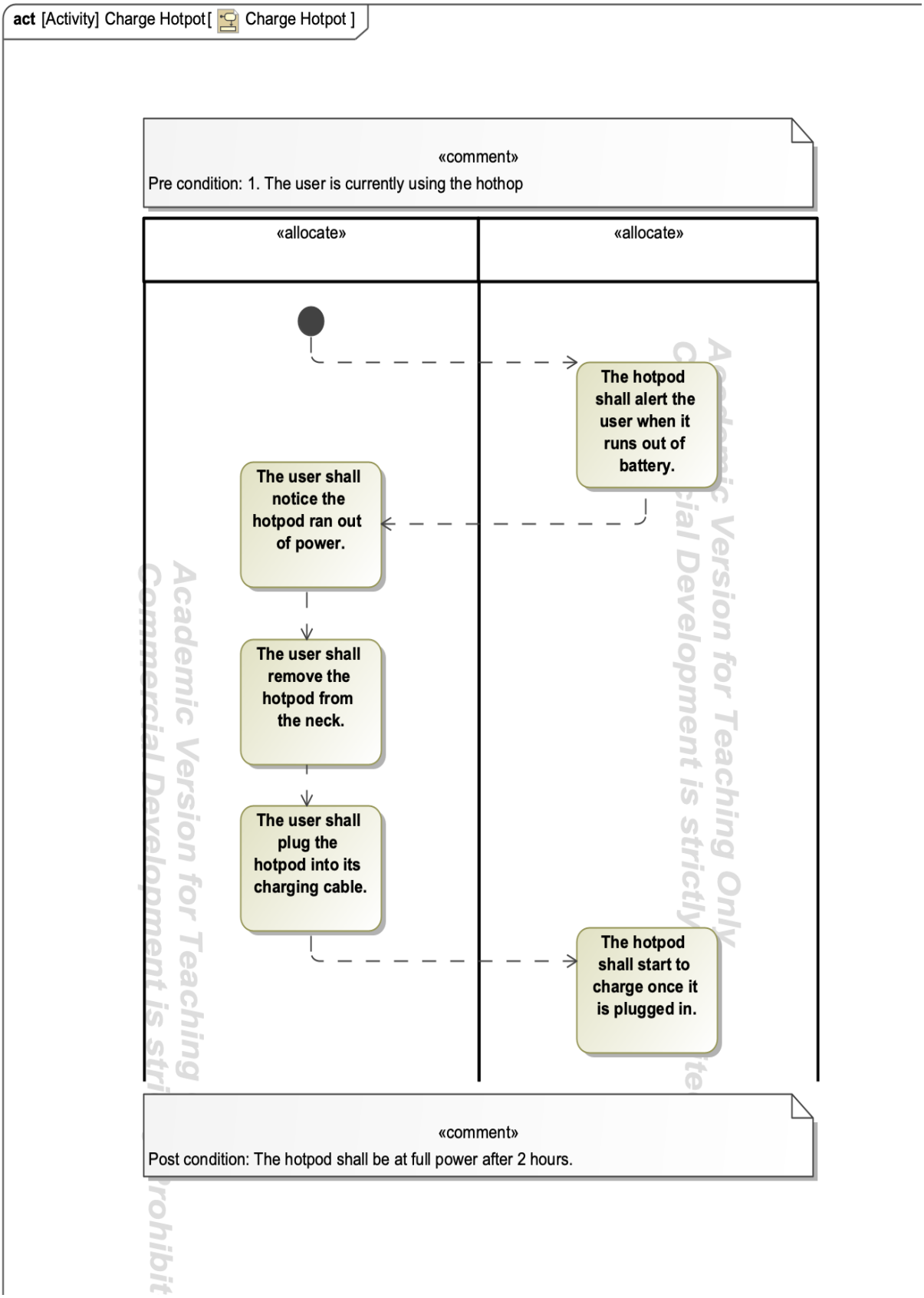
17.1 Design Competitions

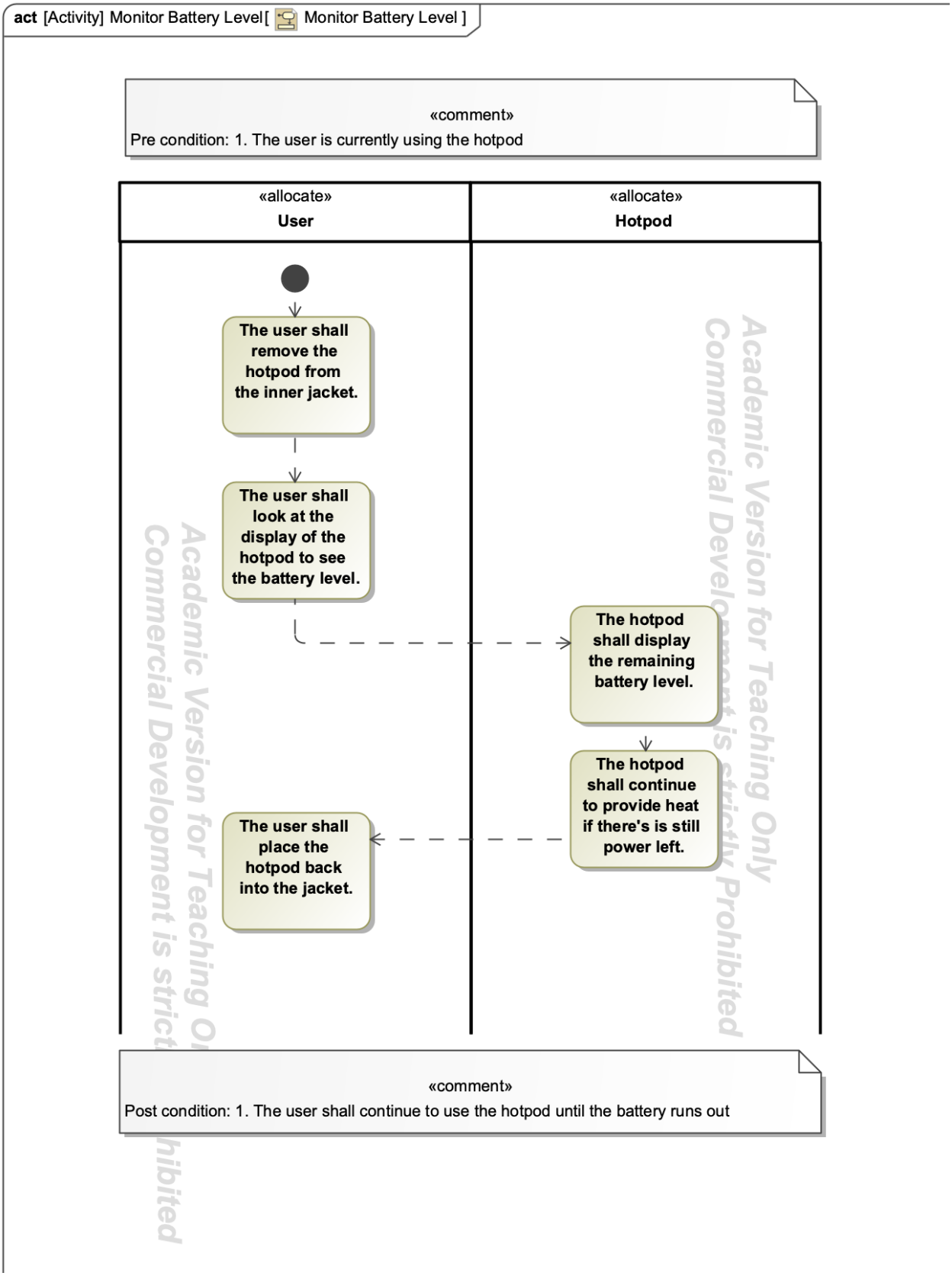
#	Competition	Target Audience	Focus	Website
1	James Dyson Award	Design engineering students	Designs that solve a problem	jamesdysonaward.org
2	Red Dot Design Award	Designers and companies	High-quality design innovations	red-dot.org

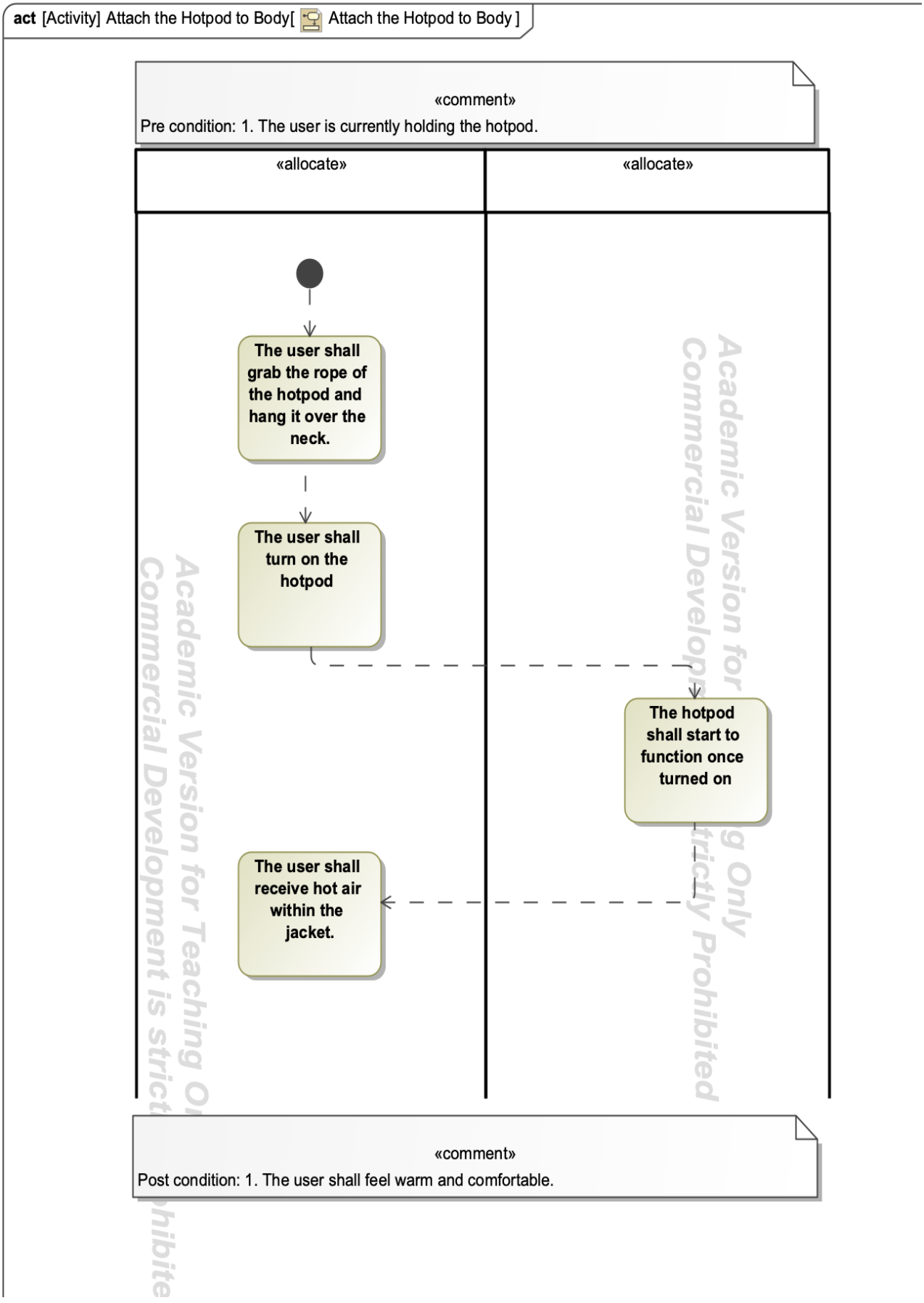
3	International Design Excellence Awards (IDEA)	Designers	Design excellence in various categories	idsa.org/awards/idea
4	Core77 Design Awards	Designers	Excellence in all areas of design	designawards.core77.com
5	Innovation by Design Awards	Innovators	Innovative and disruptive design	fastcompany.com/apply/innovation-by-design
6	Student Design Competition by the Design Society	Student designers	Engineering and product design	designsociety.org
7	The R&D 100 Awards	Innovators in technology	Top technology products	rd100awards.com

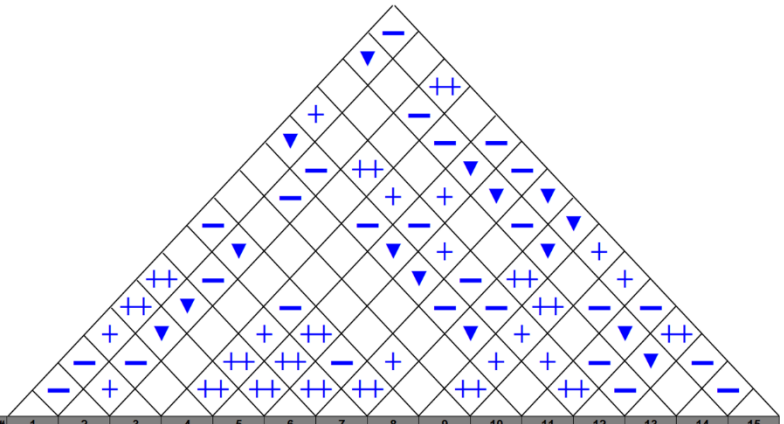
17.2 System Engineering Diagrams (BeeEZ)






act [Activity] Monitor Battery Level[Monitor Battery Level]
«comment»
Pre condition: 1. The user is currently using the hotpod
«allocate»
User
«allocate»
Hotpod
The user shall remove the hotpod from the inner jacket.
The user shall look at the display of the hotpod to see the battery level.
The hotpod shall display the remaining battery level.
The hotpod shall continue to provide heat if there's is still power left.
The user shall place the hotpod back into the jacket.
«comment»
Post condition: 1. The user shall continue to use the hotpod until the battery runs out
Academic Version for Teaching Only
Commercial Development is strictly Prohibited





Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Heating Element and Sink	Product Weight	Material Quality	Temperature Sensor	Electronics	Fan	Fan Speed Control Knob	Battery Capacity	User Friendly Interface	Attachment Method	Product Dimensions	Product Design and Finish	Battey Replacement/Charging Method	Cost Effective Materials	Thermal Insulation and Ingress Protection
				Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	x	▼	x	x	x	▲	x	▲	x	x	▼	▲	x	▲	▲
				Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	Heating Element and Sink	Product Weight	Material Quality	Temperature Sensor	Electronics	Fan	Fan Speed Control Knob	Battery Capacity	User Friendly Interface	Attachment Method	Product Dimensions	Product Design and Finish	Battey Replacement/Charging Method	Cost Effective Materials	Thermal Insulation and Ingress Protection
1	9	11.6	5.0	Rapid Heating	Θ					O	▲	▲							
2	9	11.6	5.0	Low Weight	▲	Θ	O	▲	▲	▲		O		▲					
3	9	9.3	4.0	Durable Construction		▲	Θ							O		▲			O
4	9	11.6	5.0	Overheat Protection and Safety	▲		▲	Θ	O					▲			▲		Θ
5	9	11.6	5.0	Uniform Heat Distribution	O			▲		Θ						O			
6	9	7.0	3.0	Variable Temperature Control							Θ		▲						
7	9	9.3	4.0	Extended Battery Life	▲			▲	▲	▲		Θ					▲		
8	9	11.6	5.0	Competitive Pricing			▲				▲		▲			▲		Θ	▲
9	9	9.3	4.0	Ease of Use		▲					O	▲	Θ	Θ	▲		O		▲
10	9	7.0	3.0	Attractive Design		▲	▲				▲	▲	▲		O	Θ			▲
				Target or Limit Value	< 5 W, 90 s	400 grams	High Quality	-30 to 50 deg C	Minimal	20 CFM	Multi-Setting	6 hours	Intuitive	Intuitive and Firmly Attached	8.50 mm x 8.50 mm x 2.50 mm	Elegant	Type - C Charging	$120	IP Rating & Thermal Insulation Rating
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	9	7	3	9	6	6	4	9	8	8	10	7	6	9	10
				Max Relationship Value in Column	9	9	9	9	3	9	9	9	9	9	3	9	3	9	9
				Weight / Importance	172.1	130.2	148.8	137.2	55.8	160.5	120.9	146.5	109.3	134.9	30.2	118.6	48.8	104.7	160.5
				Relative Weight	9.7	7.3	8.4	7.7	3.1	9.0	6.8	8.2	6.1	7.6	1.7	6.7	2.7	5.9	9.0

17.3 System Engineering Diagrams (Hubble)

	User Cases	Priority
1	User attaches MagnaHeat to the inner lining of a jacket	H
2	Device detects ambient temperature and adjusts heat output accordingly	H
3	User manually adjusts the temperature setting though machine or app	M
4	Automatic shutdown after a predefined period to ensure safety	H
5	User uses the MagnaHeat through magnetic attachment	L
6	User connects the MagnaHeat through a belt	L
7	Battery low notification to user via device indicator	H
8	Safety cutoff in case of device malfunction or excessive temperature	H
9	Magnetic strength optimization to ensure the device stays in place during activities	H
10	Compatibility check with different fabrics and clothing materials	M
11	Low temperature operation mode for mild climates	L
12	Usage tutorials and tips provided	L
13	Device diagnostics and self-test on startup	H
14	Tourist Uses MagnaHeat for Warmth While Visiting Cold Climates	M
15	Outdoor Enthusiast Uses MagnaHeat during Hiking	H
16	Adventurer Uses MagnaHeat's Water-resistant Feature in Snowy Conditions	H
17	Hiker Relies on Battery Low Notification for Timely Recharging	H
18	Skier Adjusts MagnaHeat Through Gloves Using Simplified Controls	H
19	Student Uses MagnaHeat for Early Morning Campus Commutes	M
20	Packaging designed for minimal environmental impact	M
21	User Shares Feedback on Heating Efficiency for Continuous Improvement	M
22	Healthcare Worker Uses MagnaHeat for Warmth During Long Shifts Outdoors	H
23	Device should be ready to use within 5 minutes from turning on	H
24	Device should be able to last for at least 2 hours	H
25	In-app Notifications for Weather Forecast and Suggested Settings	M
26	User Accesses Battery Health Monitoring to Maximize Device Lifespan	M
27	Daily usage statistics available to the user for monitoring battery life and heating patterns	L
28	Automatic reconnection to mobile app after being out of range	M
29	The app alerts user of optimal attachment points for efficient heating	M
30	Emergency stop feature accessible through the device and mobile app	H
	Note: H - High Priority, M - Medium Priority, L - Low Priority	

Failure Mode #	Subsystem	Failure Mode	Failure Effect	Possible Cause	Failure Effects Severity	Occurrence Likelihood	Risk Priority Number (RPN)	Risk Criticality (Corrective Action Difficulty)	Corrective Action
F.1	Internal Battery	Battery Depletion / Short-Circuit	Reduced operational time / Unexpected power loss / Fire Hazard	Degradation over time; Defective battery cells / Improper Handling	5	1	15	HIGH	Integrate Battery Management System (BMS); Better and more insulating circuit connections; More insulation around battery housing to prevent fires/burns
F.2	Heating Element	Overheating	Burns to user / Damage to product	Fan defect / Temperature control system malfunction	5	2	15	HIGH	Use an extra temperature sensor; Implement thermal cutoff switch of thermal and better material to prevent burns in case of failure
F.3	Control Unit	Component Failure	Device stops functioning	Electrical surge; Manufacturing defect	3	2	10	MEDIUM	Surge protection and redundant design implementation
F.4	Attatchment	Magnet Detatched	Unable to attact product	Strong Impact	3	1	6	LOW	Introduce various connection methods as backups and ensure the magnets are easily replaceable.
F.5	User Interface	Bottons Unresponsive /Port Failure	User cannot operate the device effectively	Electrical failure / Wear and tear /Poor connection quality	4	3	10	MEDIUM	Reinforce port structure / Implement magnetic connectors / Waterproof buttons and include tactile feedback
F.6	Circulation (Fan)	Fan Failure	Overheat / Product not functioning	Motor burnout; Electrical overload	5	2	15	LOW	Introduce brushless motors and debris sensors
F.7	Housing/Encasement	Cracking or Warping	Exposure of internal components / User injury	Impact / Excessive heat / Material defect	3	1	10	LOW	Use impact-resistant materials and conduct stress testing; Increase wall thickness
F.8	Safety Sensors	Sensor malfunction	Inaccurate temperature reading leading to overheating or underheating	Faulty sensor / Software error / Calibration error	4	2	10	HIGH	Install dual sensor system for redundancy
F.10	Connectivity Module*	Connection Loss	Inability to interface with network or remote controls	Software bug / Hardware failure	1	2	6	HIGH	Implement redundant communication pathways / Update firmware to address software bugs / Enhance hardware reliability with improved components.
F.11	External Battery*	Battery Depletion	Reduced operational time / Unexpected power loss / Fire Hazard	Degradation over time / Defective battery cells	1	1	6	LOW	Integrate Battery Management System (BMS); Better and more insulating circuit connections; More insulation around battery housing to prevent fires/burns

Likelihood	Current # of Risks Shown Stoplight Graph				
5	0	0	0	0	0
4	0	0	0	0	0
3	0	0	0	1	0
2	1	0	1	1	2
1	1	0	2	0	1
	1	2	3	4	5

Decision Matrix														
	Normalized Score						User Dependencies		Final Score					
	A	B	C	D	E	F	Min Scored	Weight	A	B	C	D	E	F
Portability	8	10	3	10	10	7	3	7	56	70	21	70	70	49
Ease of Use	9	10	7	10	9	8	7	7	63	70	49	70	63	56
Able to Adjust Temperatur	9	2	8	1	1	3	1	8	72	16	64	8	8	24
Life Span of Product	7	1	6	1	9	8	1	6	42	6	36	6	54	48
Weight	7	10	4	10	10	6	4	6	42	60	24	60	60	36
Design	9	5	6	4	7	8	4	5	45	25	30	20	35	40
Safety	8	7	5	6	10	9	5	9	72	63	45	54	90	81
								Total:	392	310	269	288	380	334

A - Hubble MagnaHeat
B - Traditional Hand Warmers
C - Electric Blankets
D - Chemical Warmers
E - Thermal Layers
F - Insulated Bottles with Warm Liquids

Interface Matrix						
Design	MagnaHeat		Value	Units	Estimate?	Energy StorageSubsystem
	Provided to	Battery Capacity	22000	mAh		Battery Pack
	Provided to	Heat Settings	3	#	X	Temperature Control
	Provided to	Charge Time	4	Hours		Charging System
	Provided to	Cable Type	1	#	X	Built-in USB-C
Provided to		Unit Cost	100	$	X	System Cost
Provided to		Size Dimensions	15105	cm	X	Device Size
Provided to		Weight	500	g	X	Device Weight
Provided to		User Manual	1	#		User Instructions

Goal	Question	Ideal Metric	Approximate Metric	Data Collection Method
Ensure MagnaHeat is tailored to meet the needs of its target customers	What is the lowest temperature peole experienced where they live?	Obtain temperature readings in degrees Celsius or Fahrenheit	(No Substitute)	Survey
	What is the highest temperature people experienced where they live?	Obtain temperature readings in degrees Celsius or Fahrenheit	(No Substitute)	Survey
	What is the desired age group?	Collect age data in numerical form	(No Substitute)	Survey
Ensure that MagnaHeat is compatible with all types and layers of clothing.	How many layers of clothing do people typically wear on their upper body during the winter season?	Collect age data in numerical form	(No Substitute)	Survey
	What type of clothing do people wear in the innermost layer during winter?	Categorical Data (T-shirt, Sweater, Tank-top etc.)	(No Substitute)	Survey
	What type of clothing do people wear in the outermost layer during winter?	Categorical Data (Puffer Jacket, Sweater, etc.)	(No Substitute)	Survey
Ensure that MagnaHeat meets the needs of our target customers.	Which features of MagnaHeat are most appealing to our target customers?	Categorical Data (Portability, Ease-of-Use, etc.)	(No Substitute)	Survey
	In which situations would our customers use our product?	Categorical Data (Outdoor Sports, At Work, Commute, etc.)	(No Substitute)	Survey
Ensure that MagnaHeat is priced appropriately	What is the most acceptable price point at which our customers are willing to purchase MagnaHeat?	Categorical Data (Under $50, $50-$100, $100-$150, etc.)	(No Substitute)	Survey
Ensure that the magnet's strength is sufficient to support the entire device	How strong does the magnet need to be to support the device without adding excessive weight?	Attach a magnet to a weight block that matches the approximate weight of MagnaHeat and run around to see if the magnet remains attached.	(No Substitute)	Experiment
Ensure that the temperature output matches the target temperature	What is the comfortable body temperature for humans when heated during cold winter conditions?	Using a thermometer to test the most comfortable temperature while heated inside the jacket	(No Substitute)	Experiment

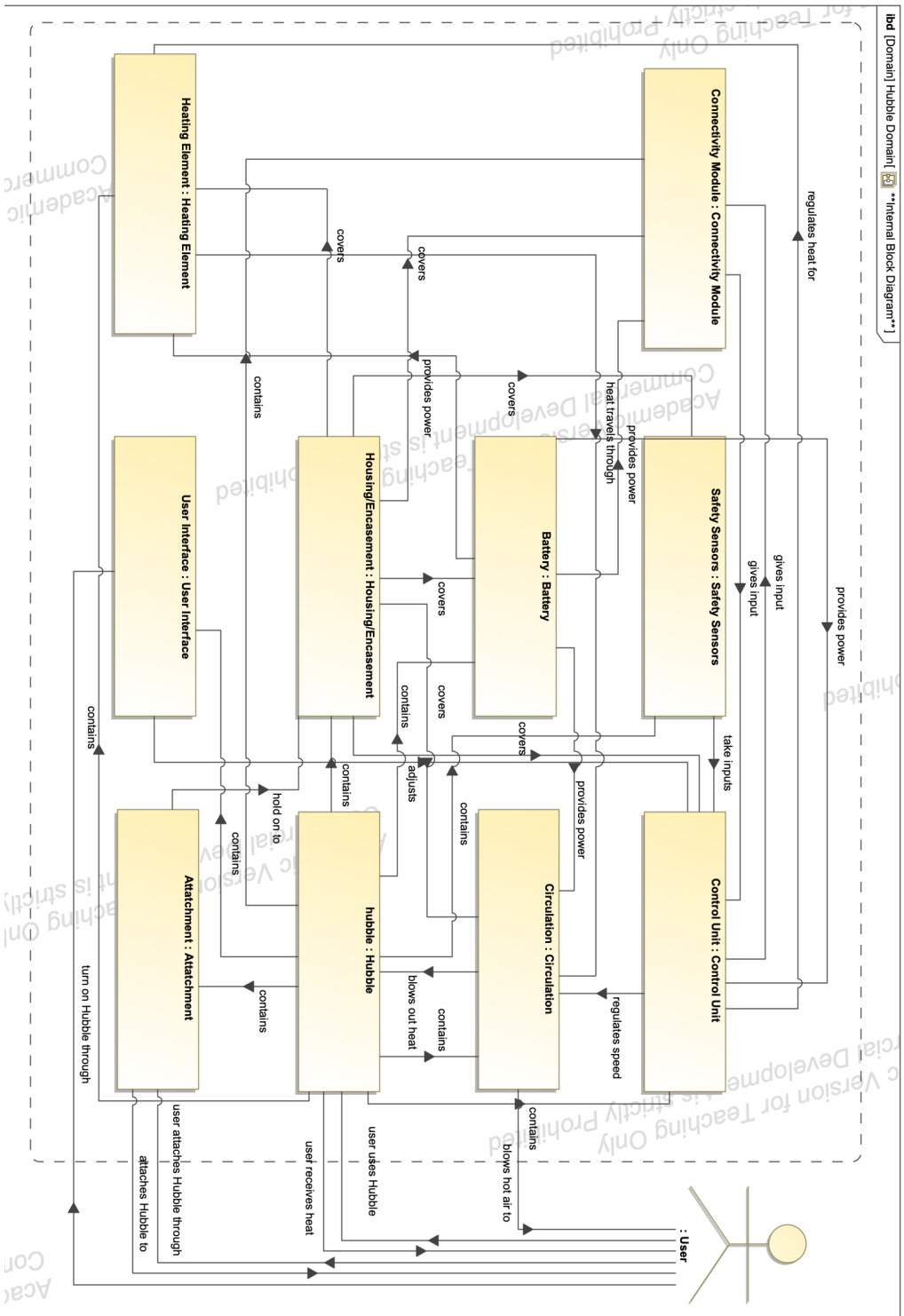
Index	Originating Requirements	Abstract Function Name	Issues	Resolution
OR.1	The MagnaHeat shall be capable of rapidly heating to achieve the desired temperature quickly	Rapid Heating	Issue: What kind of materials should we use to ensure the heat transfers rapidly?	Utilize materials with high thermal conductivity for the heating element, such as copper.
OR.2	The MagnaHeat shall be compatible with a range of clothing types.	Versatility	Issue: What should be the ideal temperature ouput ro ensure MagnaHeat is suitable for all types of clothings?	Conduct experiments to find a temperature range that is comfortable for various clothing materials and thicknesses.
OR.3	The MagnaHeat shall be designed for lightweight portability.	Heat Resistant	Issue: MagnaHeat contains many heavy components, such as the battery and magnet.	Opt for lightweight materials like neodymium magnets, balancing weight and performance.
OR.4	The MagnaHeat shall be durably constructed to withstand regular use.	Durable	Issue: Which material should be used for the outer casing, plastic or metal?	Compare the durability, weight, and cost of plastics like ABS or polycarbonate versus metals like aluminum for the casing.
OR.5	The MagnaHeat shall include overheat protection and safety features.	Safety	Issue: What is the optimal placement for sensors, and is it necessary to include an additional sensor as a backup?	Place sensors near heating element for accuracy, and a secondary sensor for redundancy in critical safety systems.
OR.6	The MagnaHeat shall ensure even heat distribution.	Heat Distribution	Issue: How to ensure that the heat will be evenly distributed within the case?	Design the heating element layout to provide uniform heat across the entire device.
OR.7	The MagnaHeat shall have adjustable temperature settings.	Adjustable Temperature	Issue: What should be the lowest output temperature and what should be the highest output temperature?	Establish a safe temperature range based on user comfort studies and material limits.
OR.8	The Magnaheat shall offer extended battery life for prolonged use.	Battery Life	Issue: A larger battery increases the weight of MagnaHeat. Should we explore the option of an external battery?	Investigate alternative power solutions such as dual batteries or an optional external battery pack for extended use scenarios.
OR.9	The MagnaHeat shall operate effectively at temperatures as low as −20°C.	Operate at Low Temperatures	Issue: To make sure that the MagnaHeat operates normally under −20°C, we should test it under harsher environments.	Develop clear standards and certifications for water and sweat resistance levels.
OR.10	The MagnaHeat shall be both sweatproof and waterproof.	Waterproof	Issue: How are 'waterproof' and 'sweatproof' defined? Does it mean resistant to splashes of water or complete submersion?	Define IP ratings for the device that meet industry standards for waterproof and sweatproof claims.

Req. #	Requirement	Abstract Name	Test #	Test Method	Test Facilities	Entry Condition	Exit Condition
OR.1	The MagnaHeat shall be capable of rapidly heating to achieve the desired temperature quickly	Rapid Heating	**TP.1**	Test Procedure: Turning on a fully charged MagnaHeat and calculate the time it takes to reach its full operation.	MagnaHeat Prototype	Turn on the fully charged Magna Heat	MagnaHeat operates at its full capacity in under 5 minutes.
OR.2	The MagnaHeat shall be compatible with a range of clothing types.	Versatility	**TP.2**	Test Procedure: Attach MagnaHeat to different types of fabric and observe if it stays in place and heats effectively.	MagnaHeat Prototype	MagnaHeat attached to different fabrics	MagnaHeat remains attached and effective across all fabric types.
OR.3	The MagnaHeat shall be designed for lightweight portability.	Heat Resistant	**TP.3**	Test Procedure: Measure the weight of MagnaHeat and compare it with industry standards for portable devices.	MagnaHeat Prototype	Device ready for weight measurement	MagnaHeat is within the top quartile for lightweight design in its category.
OR.4	The MagnaHeat shall be durably constructed to withstand regular use.	Durable	**TP.4**	Test Procedure: Perform durability testing through repeated use cycles and environmental stress tests.	MagnaHeat Prototype	Device is new and functional	MagnaHeat functions effectively after durability test cycles.
OR.5	The MagnaHeat shall include overheat protection and safety features.	Safety	**TP.5**	Test Procedure: Run device until overheat protection feature triggers a shutdown. Verify safety features activate appropriately.	MagnaHeat Prototype	MagnaHeat operational and safety features reset	Safety features trigger at the correct temperature thresholds without fail.
OR.6	The MagnaHeat shall ensure even heat distribution.	Heat Distribution	**TP.6**	Test Procedure: Use a thermometer to test temperatures at different parts of the upper body device when in operation.	MagnaHeat Prototype Thermometer	MagnaHeat charged and operational	Temperature readings confirms even distribution of heat.
OR.7	The MagnaHeat shall have adjustable temperature settings.	Adjustable Temperature	**TP.7**	Test Procedure: Verify the temperature adjustment mechanism over the full range of settings.	MagnaHeat Prototype	MagnaHeat charged and operational	MagnaHeat reaches both lowest and highest settings as specified.
OR.8	The Magnaheat shall offer extended battery life for prolonged use.	Battery Life	**TP.8**	Test Procedure: Operate MagnaHeat until the battery is depleted to measure battery life.	MagnaHeat Prototype	Fully charged MagnaHeat	Battery life meets or exceeds the specified duration.
OR.9	The MagnaHeat shall operate effectively at temperatures as low as −20°C.	Operate at Low Temperatures	**TP.9**	Test Procedure: Place MagnaHeat in a controlled environment at −20°C to observe its operation.	MagnaHeat Prototype	MagnaHeat at room tem	MagnaHeat operates effectively at −20°C.
OR.10	The MagnaHeat shall be both sweatproof and waterproof.	Waterproof	**TP.10**	Test Procedure: Subject MagnaHeat to water and perspiration simulation tests to assess ingress protection.	MagnaHeat Prototype Water Sink	Device unexposed to water or sweat	No ingress of water or simulated sweat in the device.

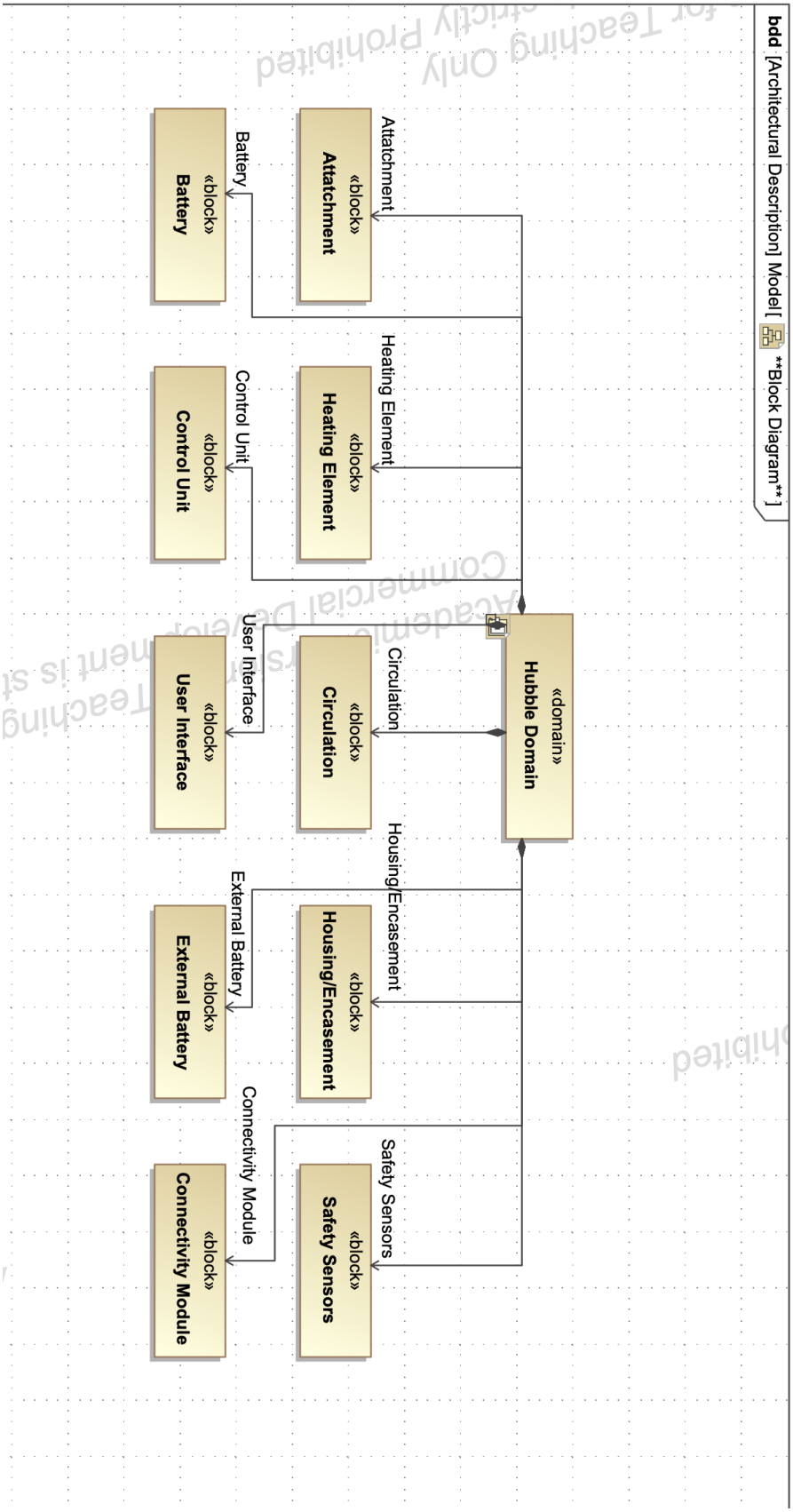
		Engineering Relationships															
				Maximize the duration of effective operation													
					Minimize the weight												
						Maximize the effectiveness											
							Maximize the product's lifespan										
								Maximize the adjustable temperature range									
									Minimize the warm-up time								
										Minimize the price of the product							
											Maximize safety						
												Minumize the size					
													Maximize user experience				
		Engineering Characteristics		Maximize the duration of effective operation	Minimize the weight	Maximize the effectiveness	Maximize the product's lifespan	Maximize the adjustable temperature range	Minimize the time it takes to get warm	Minimize the price of the product	Maximize safety	Minimize the size	Maximize user experience	Customer Perception			
		Direction of Change		↑	↓	↑	↑	↑	↓	↓	↑	↓	↑				
Customer Attributes		Relative Importances												1	2	3	4	5
Versatile	MagnaHeat should work on all types of fabrics	0.1				✓✓		✓	✓								D	A
Durability	MagnaHeat should have a long lasting battery life	0.15		✓✓	X	✓				XX		XX	✓			B		A
Easy	MagnaHeat can be easily stored	0.1			✓		X					✓✓		E	C	B	D	A
Fast	MagnaHeat can heat up quickly	0.2		✓		✓✓			✓✓	X			✓✓	C		E	A	B
Weight	MagnaHeat should be light	0.1			✓✓							✓✓		B	D	E	A	C
Reliable	MagnaHeat should be relieable	0.1		✓					✓		✓✓		✓✓			D		A
Safe	MagnaHeat should be safe	0.15			X			X			✓✓	X			D		A	
Conectivity	MagnaHeat can be controlled through phones	0.1								XX			✓✓				B	A
Object Measures	Measurement Units			minutes	g	s	yr	°C	s	$	# of sensors	N/A	N/A					
	HUBBLE MagnaHeat			120	250	30	3	35-45	5	119	1	N/A	N/A					
	Chemical Heating Pads			60	50	55	N/A	35-50	10	49	0	N/A	N/A					
	ThermaGear Heated Clothing			360	453	60	3	N/A	30	130	0	N/A	N/A					
	Portable Hand Warmers			480	350	10	4	39-63	3	39.99	0	N/A	N/A					
	Thermal Insulation Layers			N/A	270	100	3	40-55	20	90	0	N/A	N/A					
Technical Difficulty (1-Low, 5-High)				4	3	5	4	5	4	4	5	5	2					
Imputed Importance (%)				90%	60%	85%	85%	55%	46%	100%	100%	70%	100%					
Estimated Cost (1-Low, 5-High)				3	3	5	4	2	2	5	5	3	4					
Targets				200	250		3	45-55	30	100	N/A	N/A	N/A					

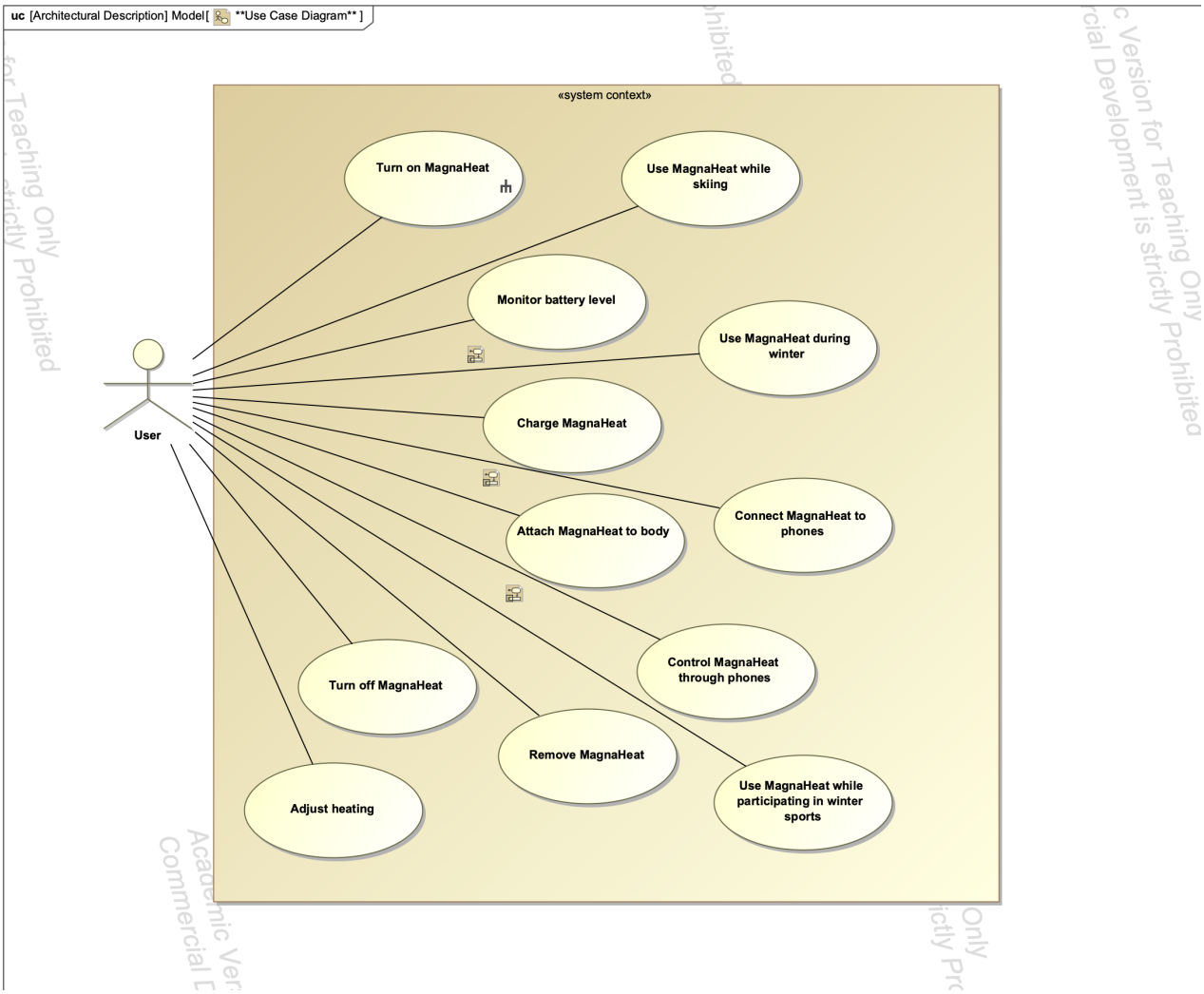
Relationships	
✓✓	Strong Positive
✓	Medium Positive
X	Medium Negative
XX	Strong Negative
↑	Increase
↓	Decrease

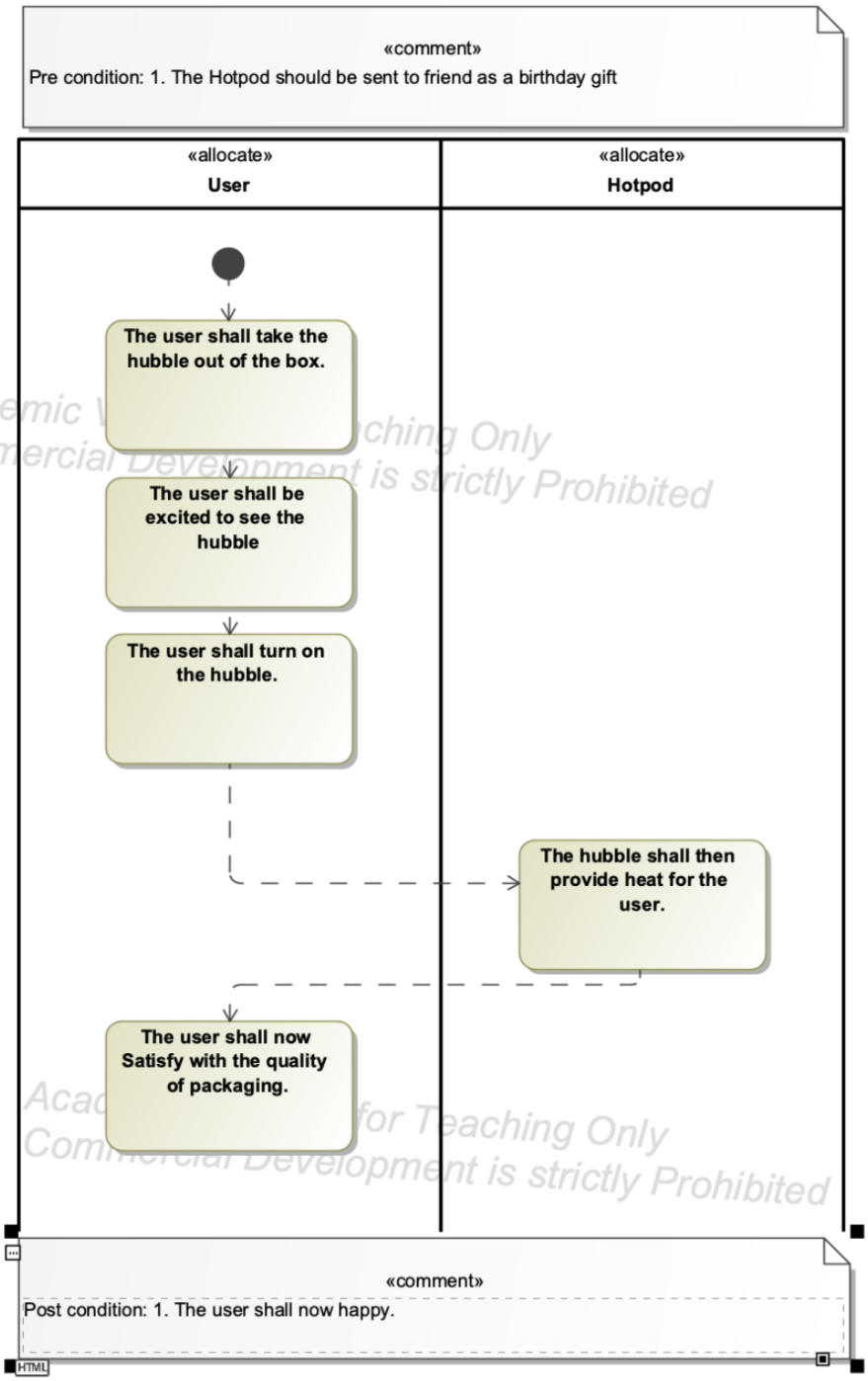
Competitors	
A	MagnaHeat
B	Chemical Heating Pads
C	ThermaGear Heated Clothing
D	Portable Hand Warmers
E	Thermal Insulation Layers

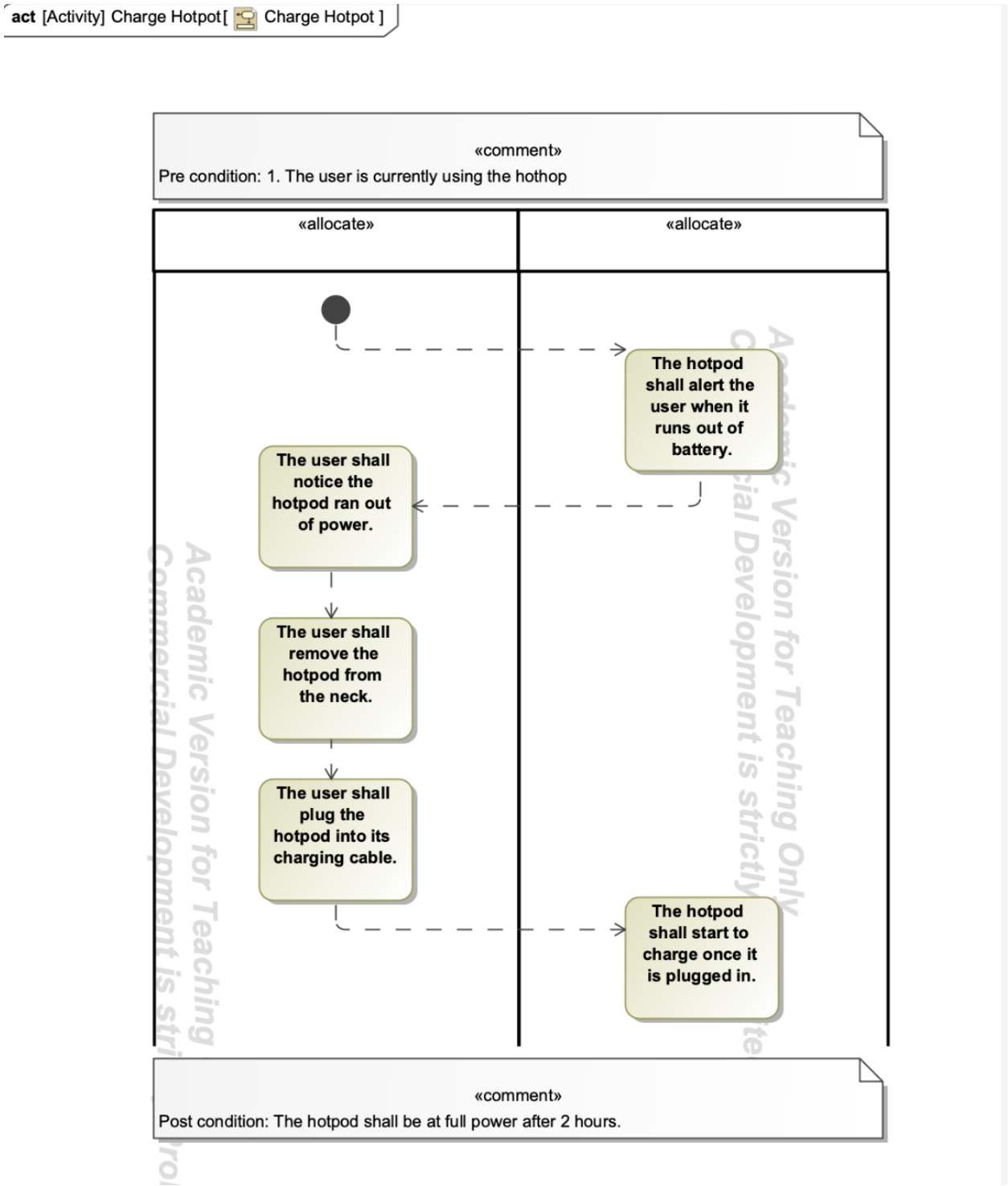


Connectivity Module*
The system shall provide wireless communication capabilities for the device to interface with mobile phones.
Bluetooth Module
Wi-Fi module
present in the protptype

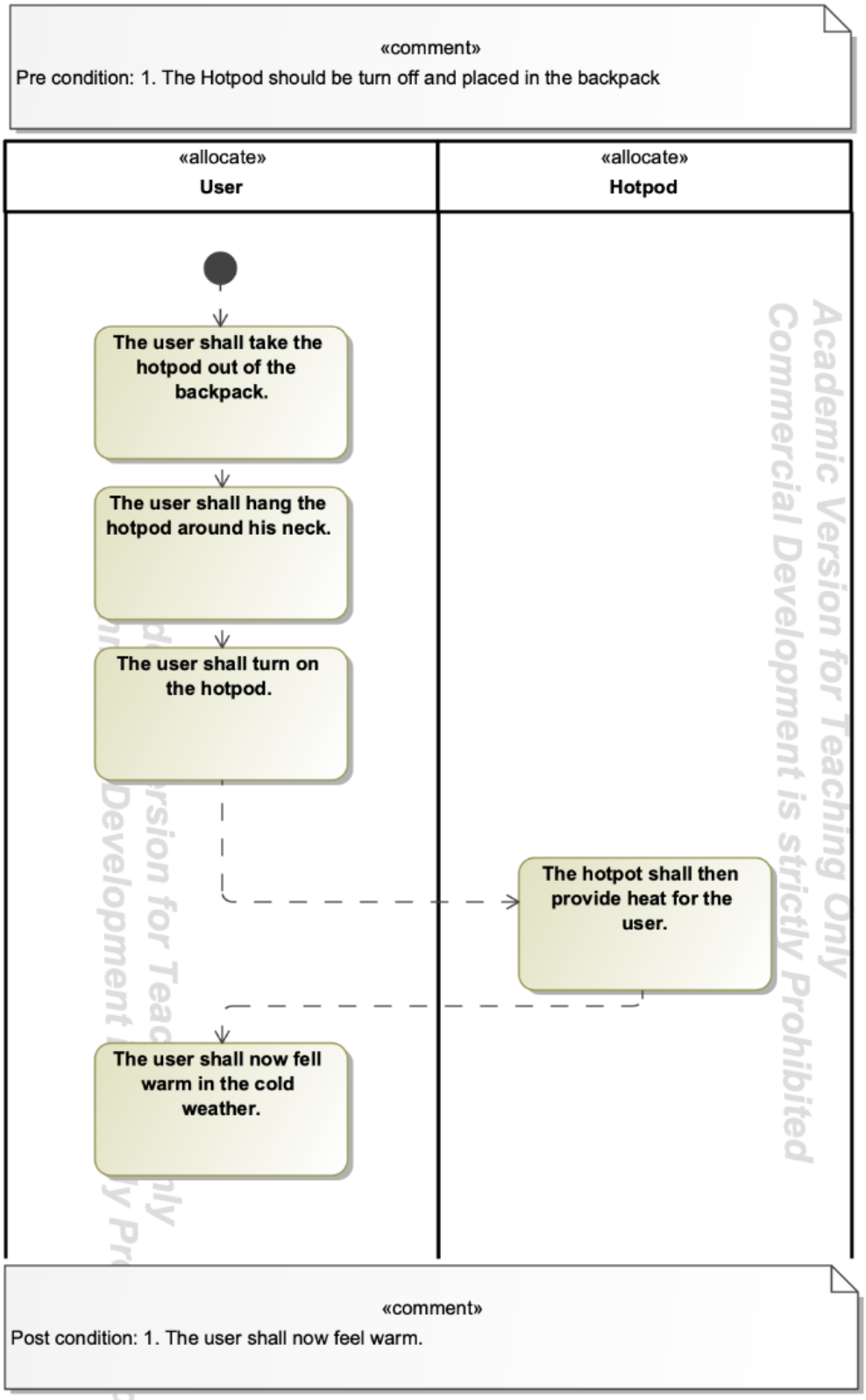

bdd [Architectural Description] Model [**Block Diagram**]
«domain»
Hubble Domain
Attatchment
«block»
Attatchment
Battery
«block»
Battery
Heating Element
«block»
Heating Element
Control Unit
«block»
Control Unit
Circulation
«block»
Circulation
User Interface
«block»
User Interface
Housing/Encasement
«block»
Housing/Encasement
External Battery
«block»
External Battery
Safety Sensors
«block»
Safety Sensors
Connectivity Module
«block»
Connectivity Module

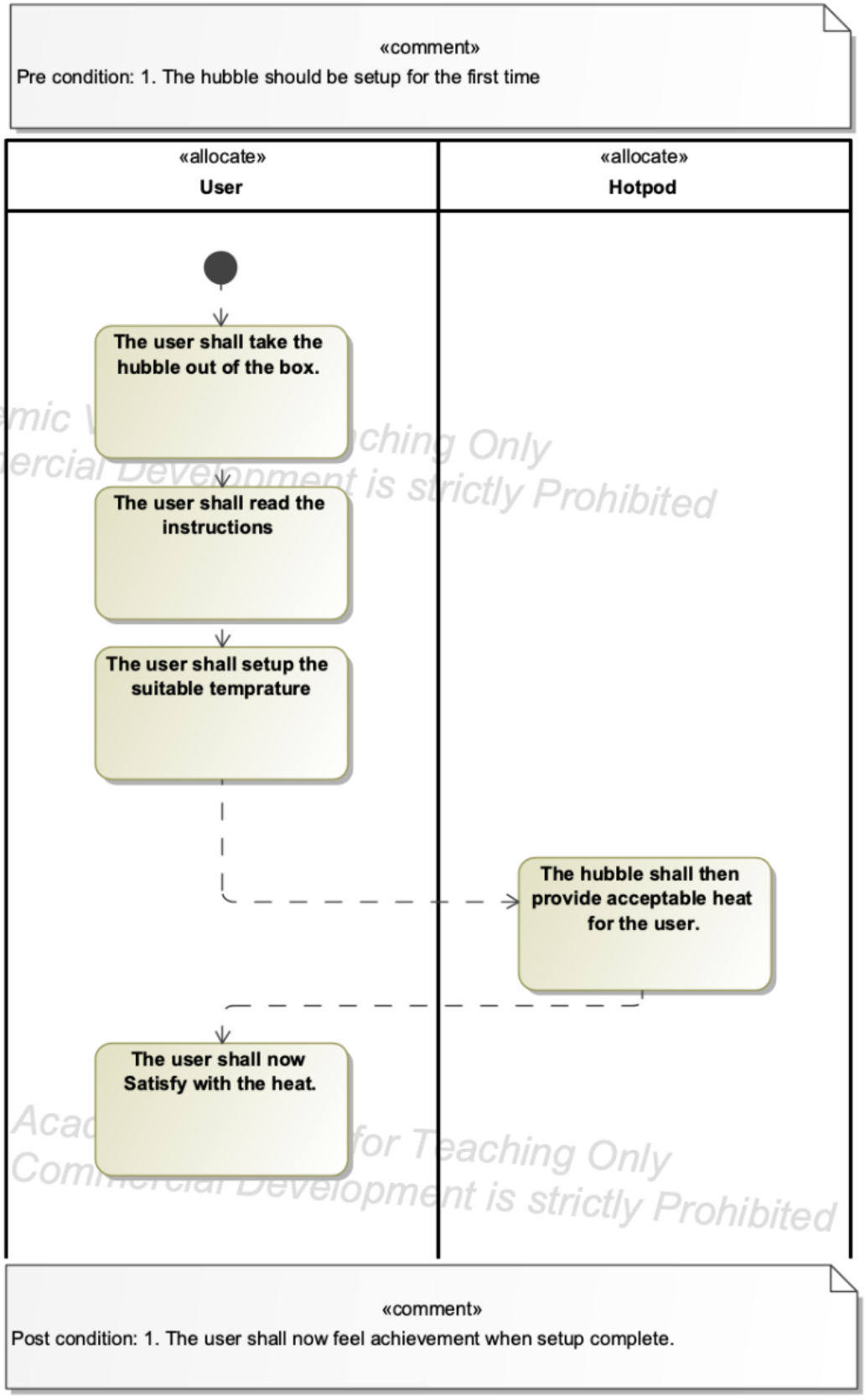


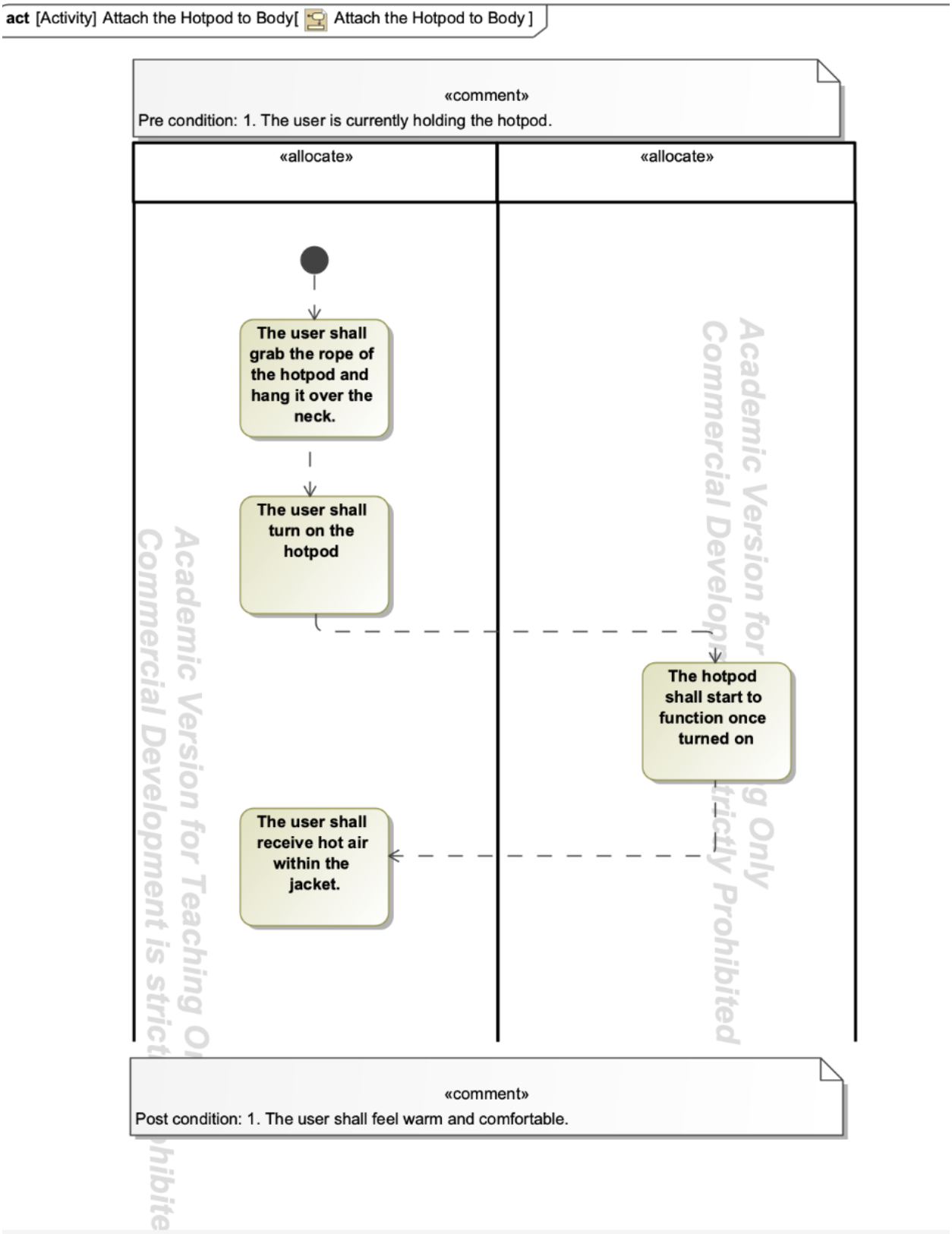


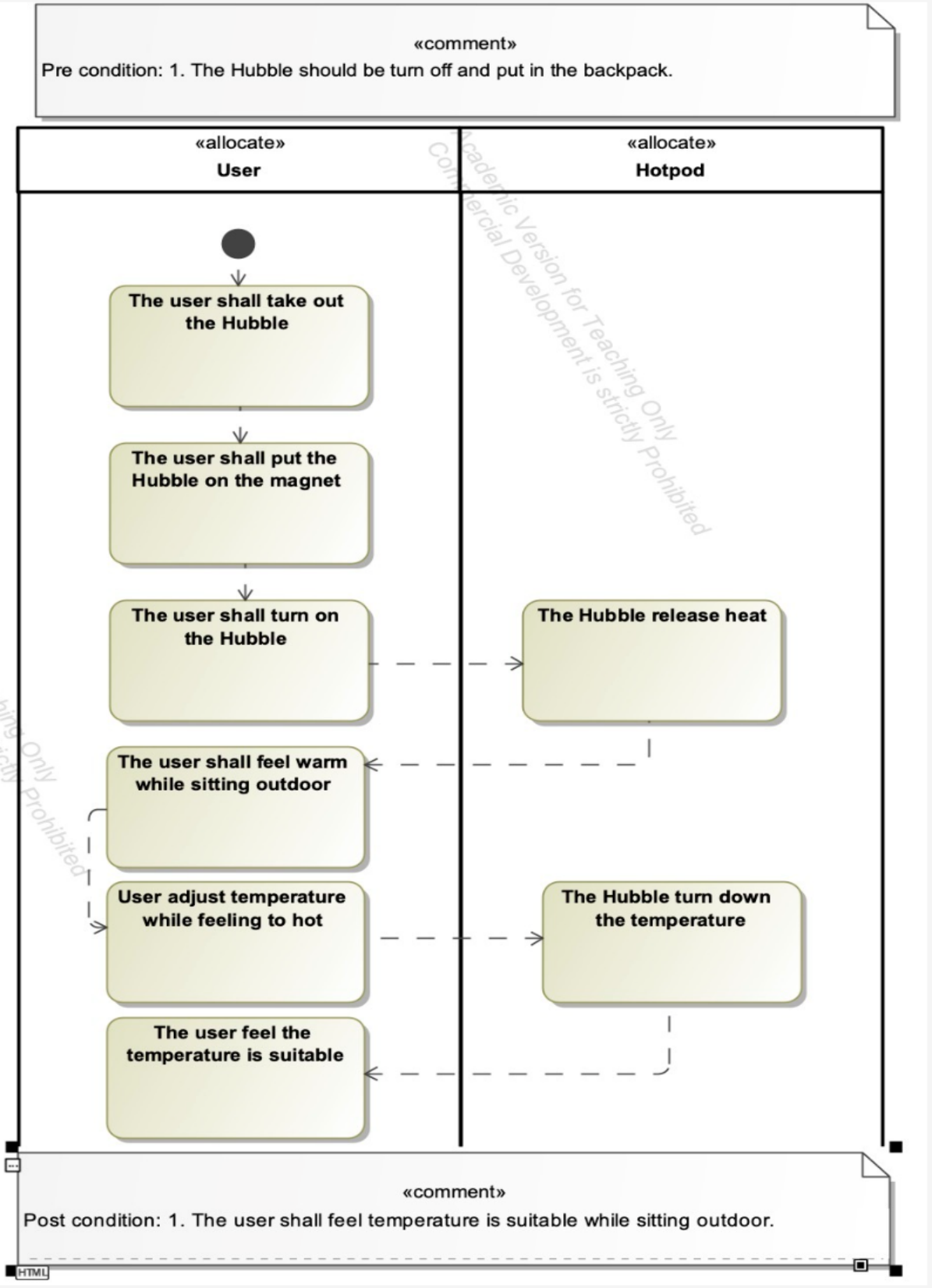


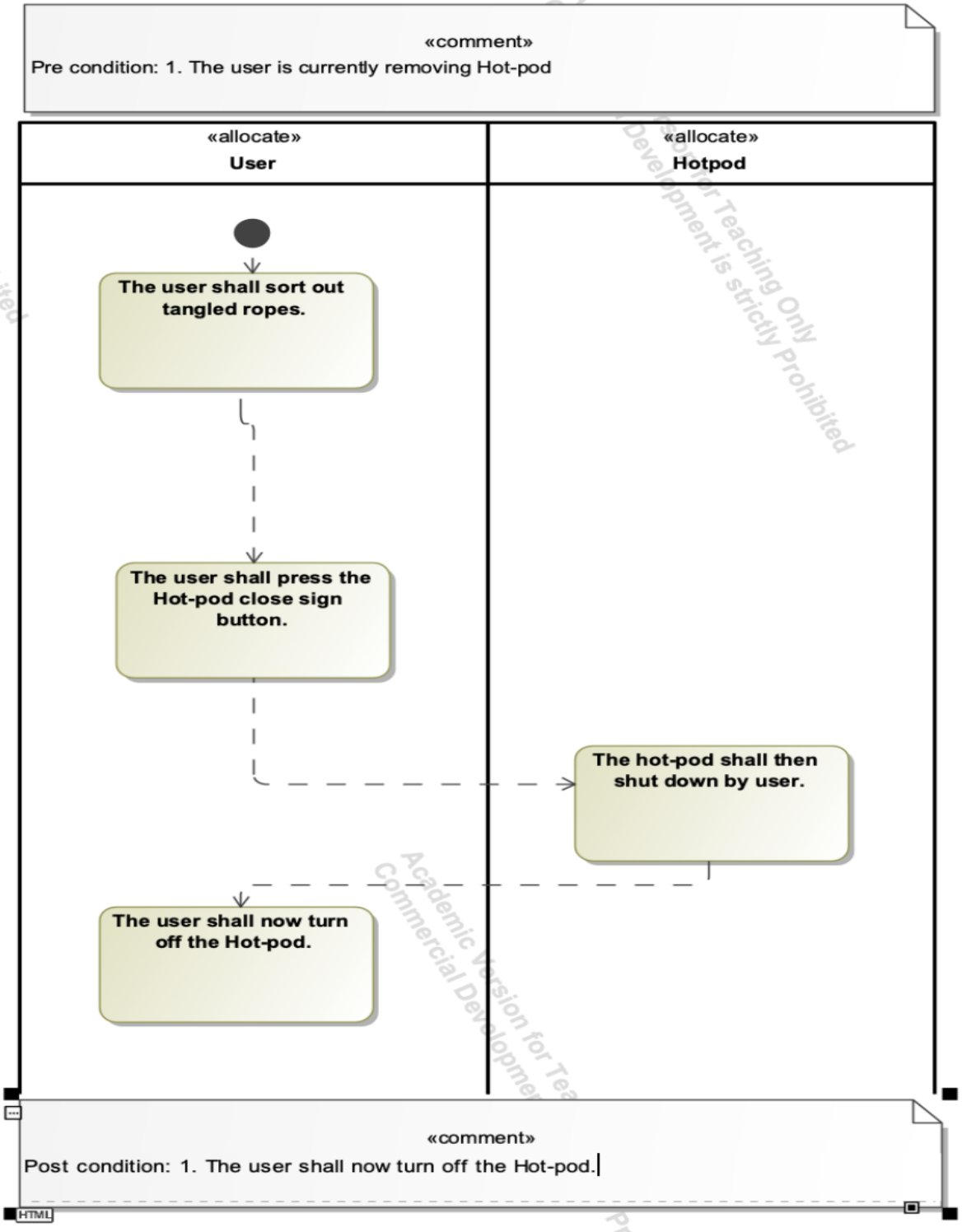
act [Activity] Turn on the Hotpod[Turn on the Hotpod]

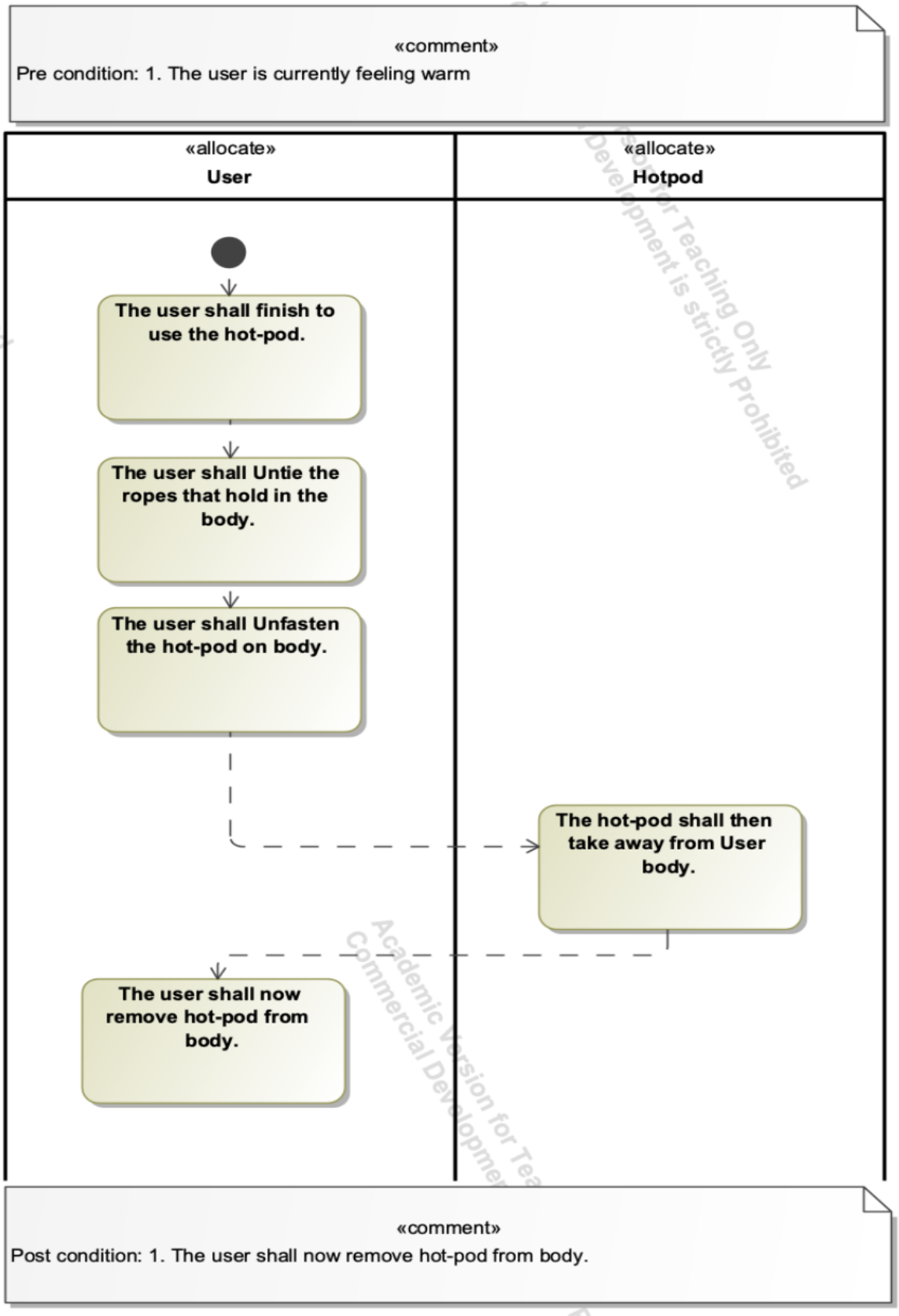


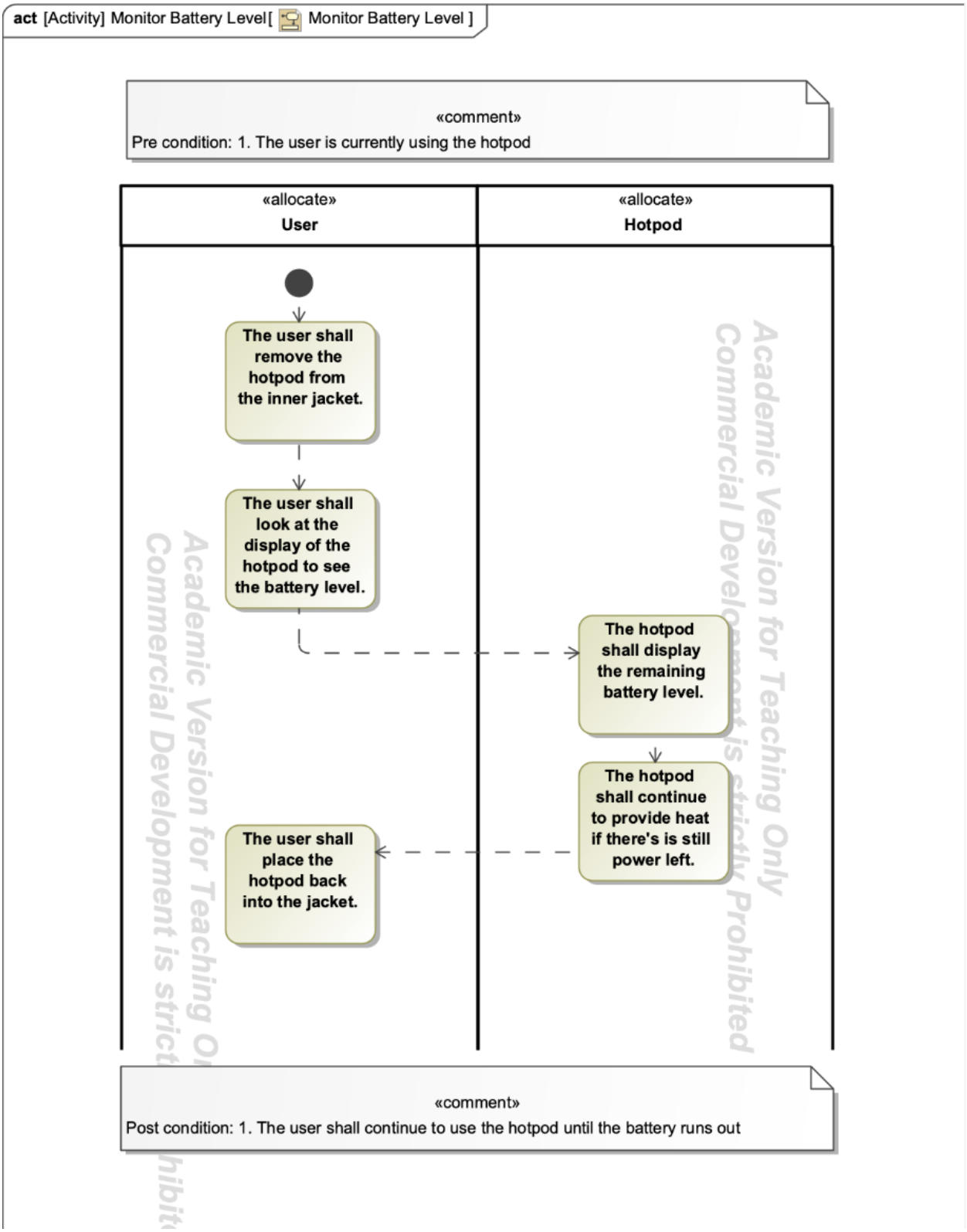


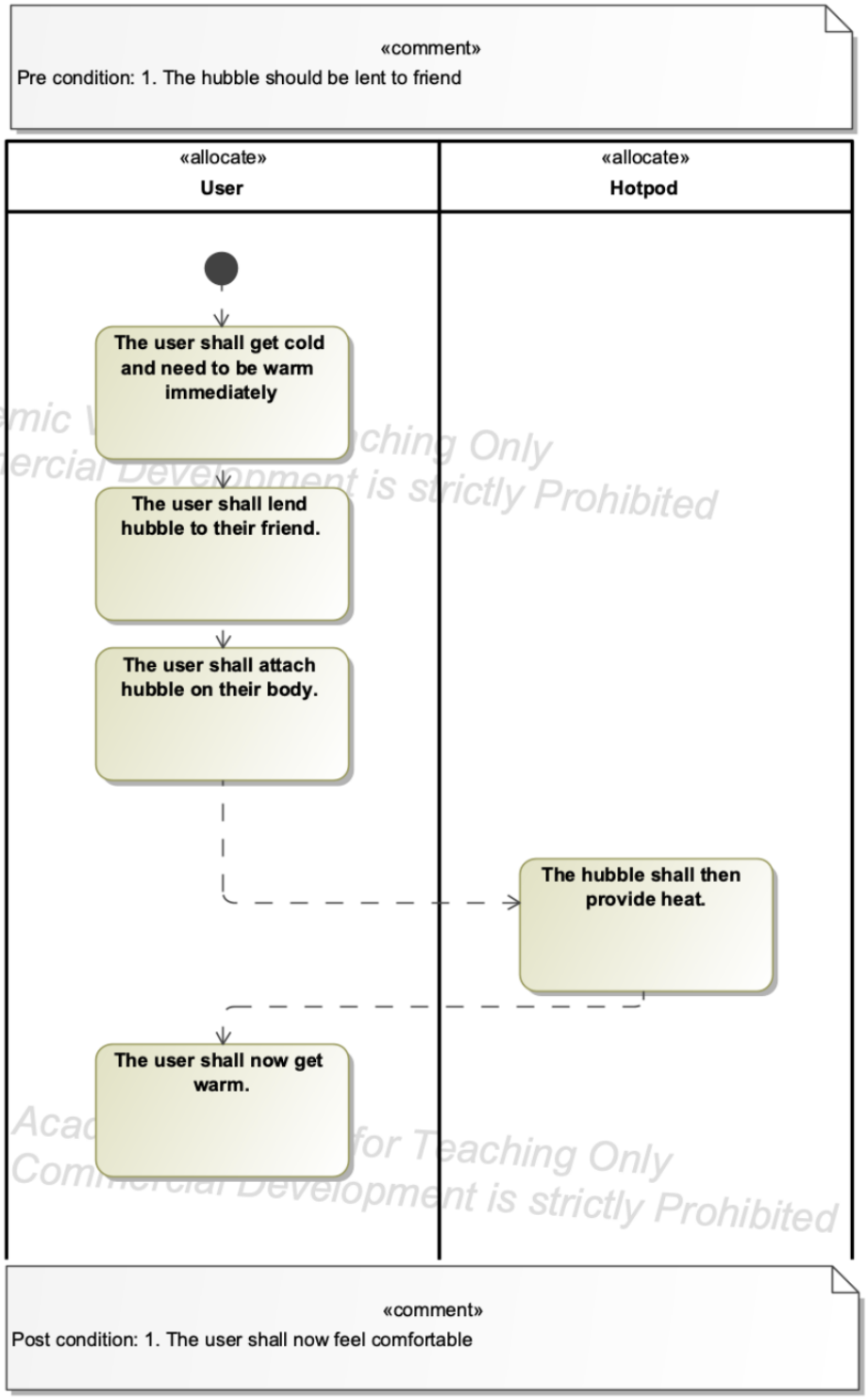

act [Activity] Attach the Hotpod to Body[Attach the Hotpod to Body]
«comment»
Pre condition: 1. The user is currently holding the hotpod.
«allocate»
«allocate»
The user shall grab the rope of the hotpod and hang it over the neck.
The user shall turn on the hotpod
The hotpod shall start to function once turned on
The user shall receive hot air within the jacket.
«comment»
Post condition: 1. The user shall feel warm and comfortable.
Academic Version for Teaching Only
Commercial Development is strictly Prohibited

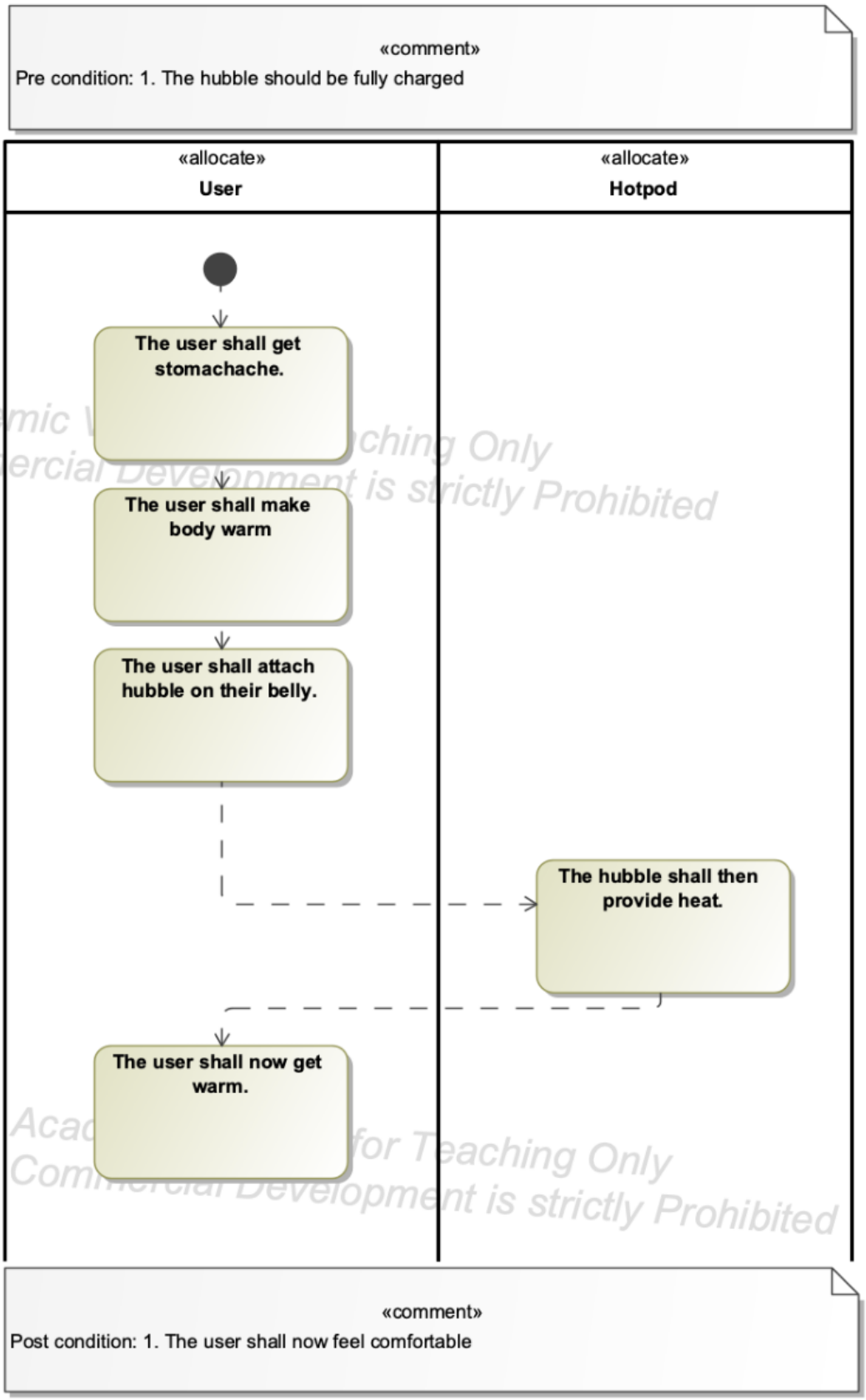

«comment»
Pre condition: 1. The Hubble should be turn off and put in the backpack.
«allocate»
User
«allocate»
Hotpod
The user shall take out the Hubble
The user shall put the Hubble on the magnet
The user shall turn on the Hubble
The Hubble release heat
The user shall feel warm while sitting outdoor
User adjust temperature while feeling to hot
The Hubble turn down the temperature
The user feel the temperature is suitable
«comment»
Post condition: 1. The user shall feel temperature is suitable while sitting outdoor.
HTML

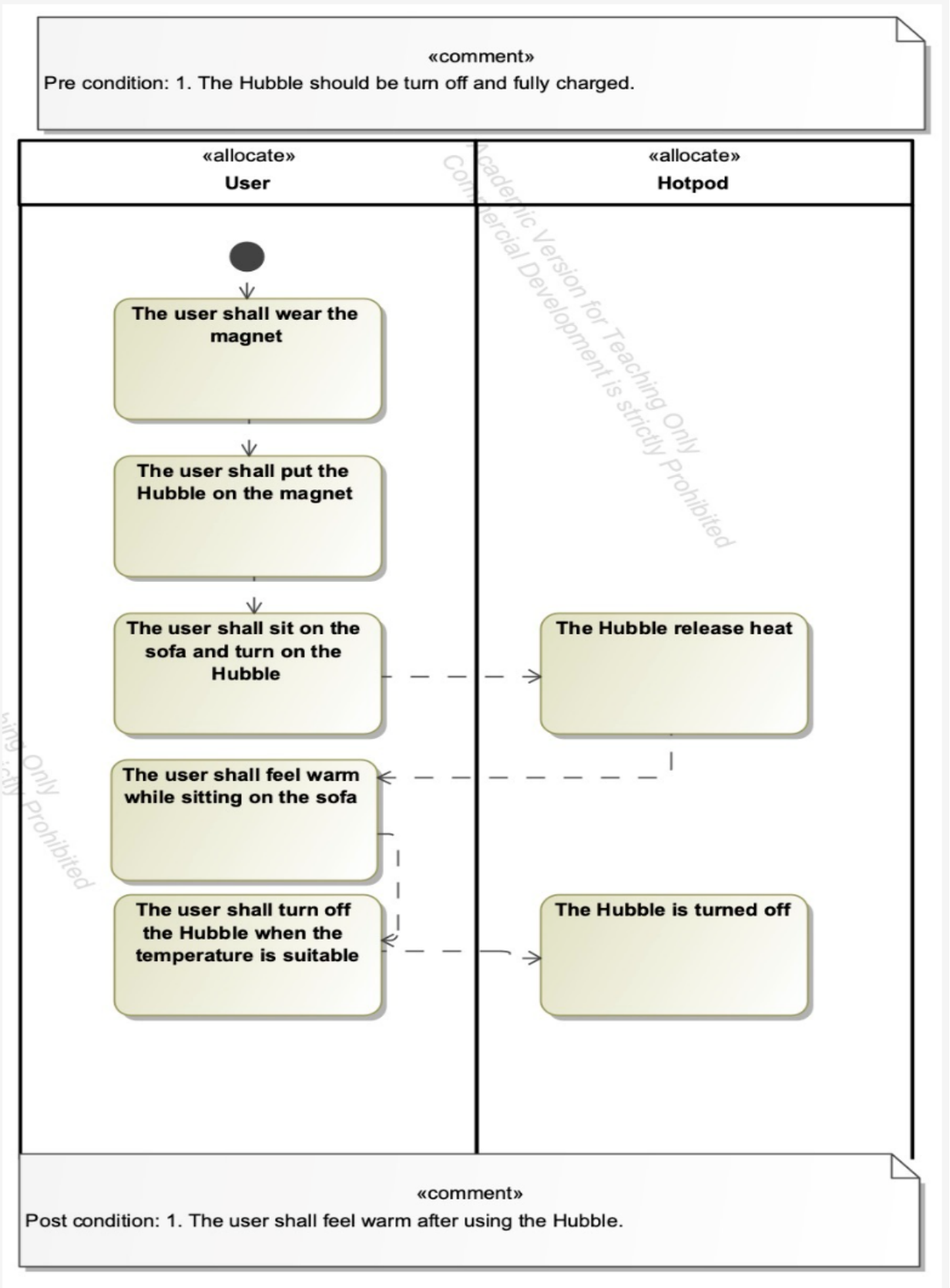

«comment»
Pre condition: 1. The user is currently removing Hot-pod
«allocate»
User
«allocate»
Hotpod
The user shall sort out tangled ropes.
The user shall press the Hot-pod close sign button.
The hot-pod shall then shut down by user.
The user shall now turn off the Hot-pod.
«comment»
Post condition: 1. The user shall now turn off the Hot-pod.
HTML

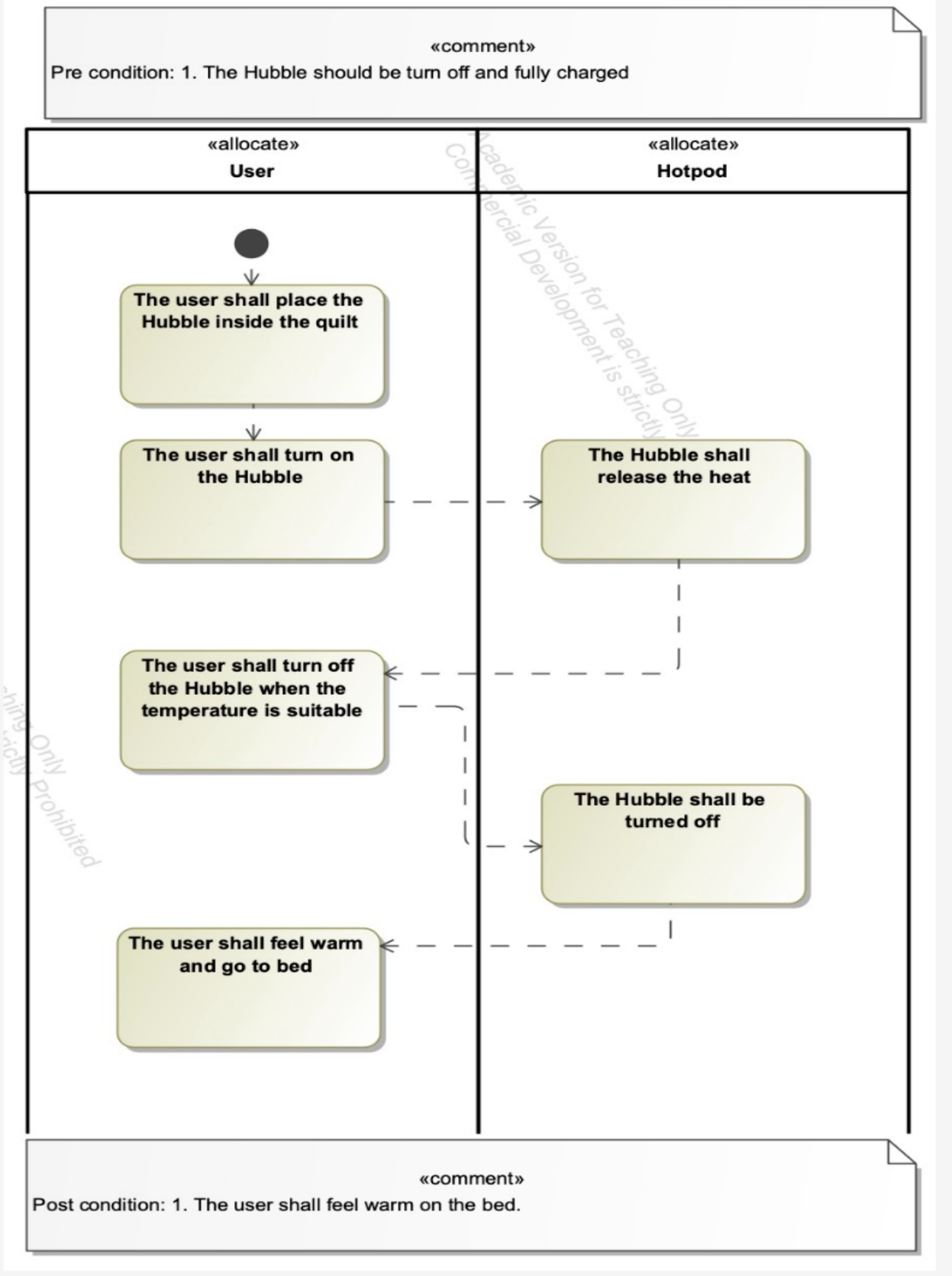


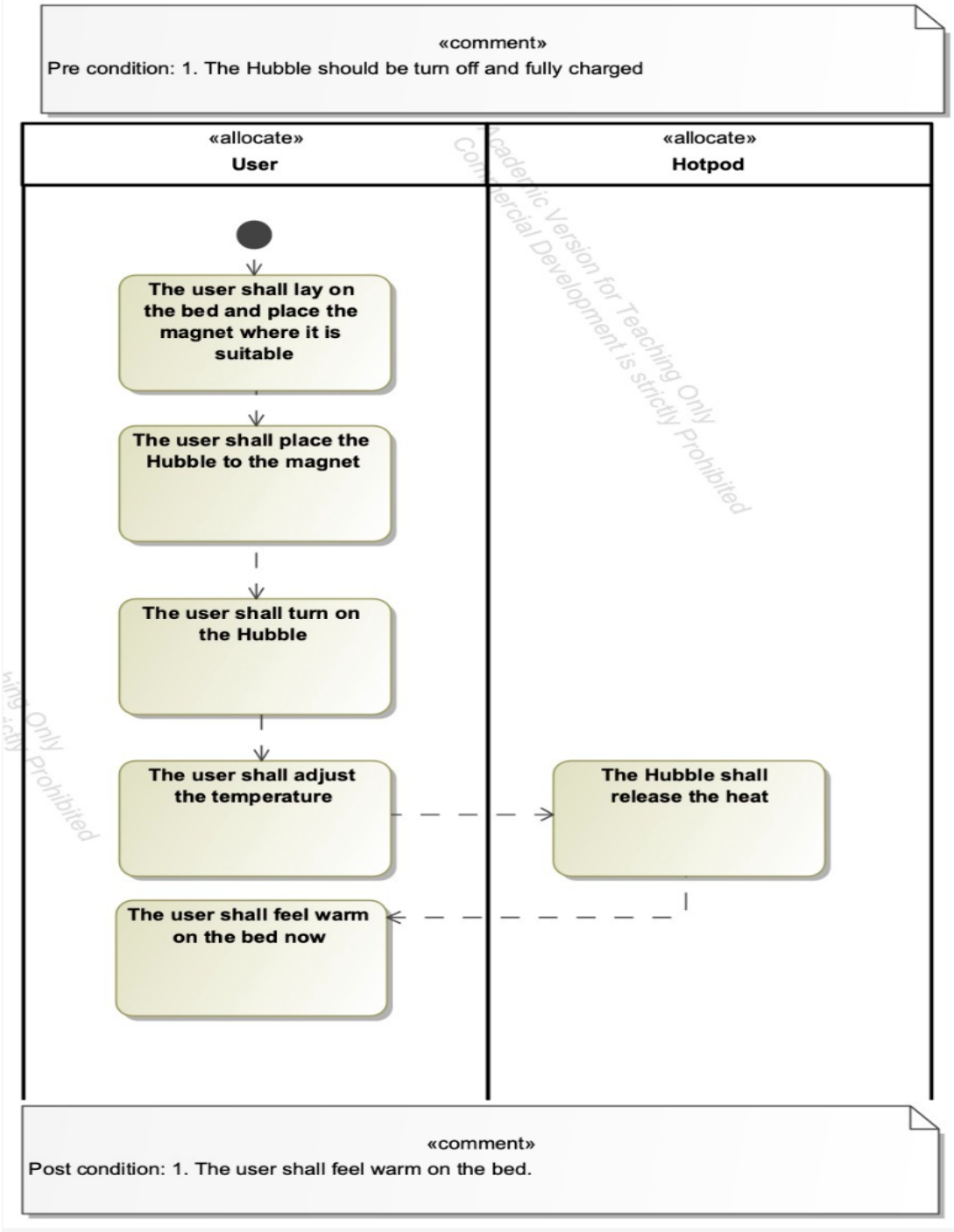

act [Activity] Monitor Battery Level[Monitor Battery Level]
«comment»
Pre condition: 1. The user is currently using the hotpod
«allocate»
User
«allocate»
Hotpod
The user shall remove the hotpod from the inner jacket.
The user shall look at the display of the hotpod to see the battery level.
The hotpod shall display the remaining battery level.
The hotpod shall continue to provide heat if there's is still power left.
The user shall place the hotpod back into the jacket.
«comment»
Post condition: 1. The user shall continue to use the hotpod until the battery runs out
Academic Version for Teaching Only
Commercial Development is strictly Prohibited

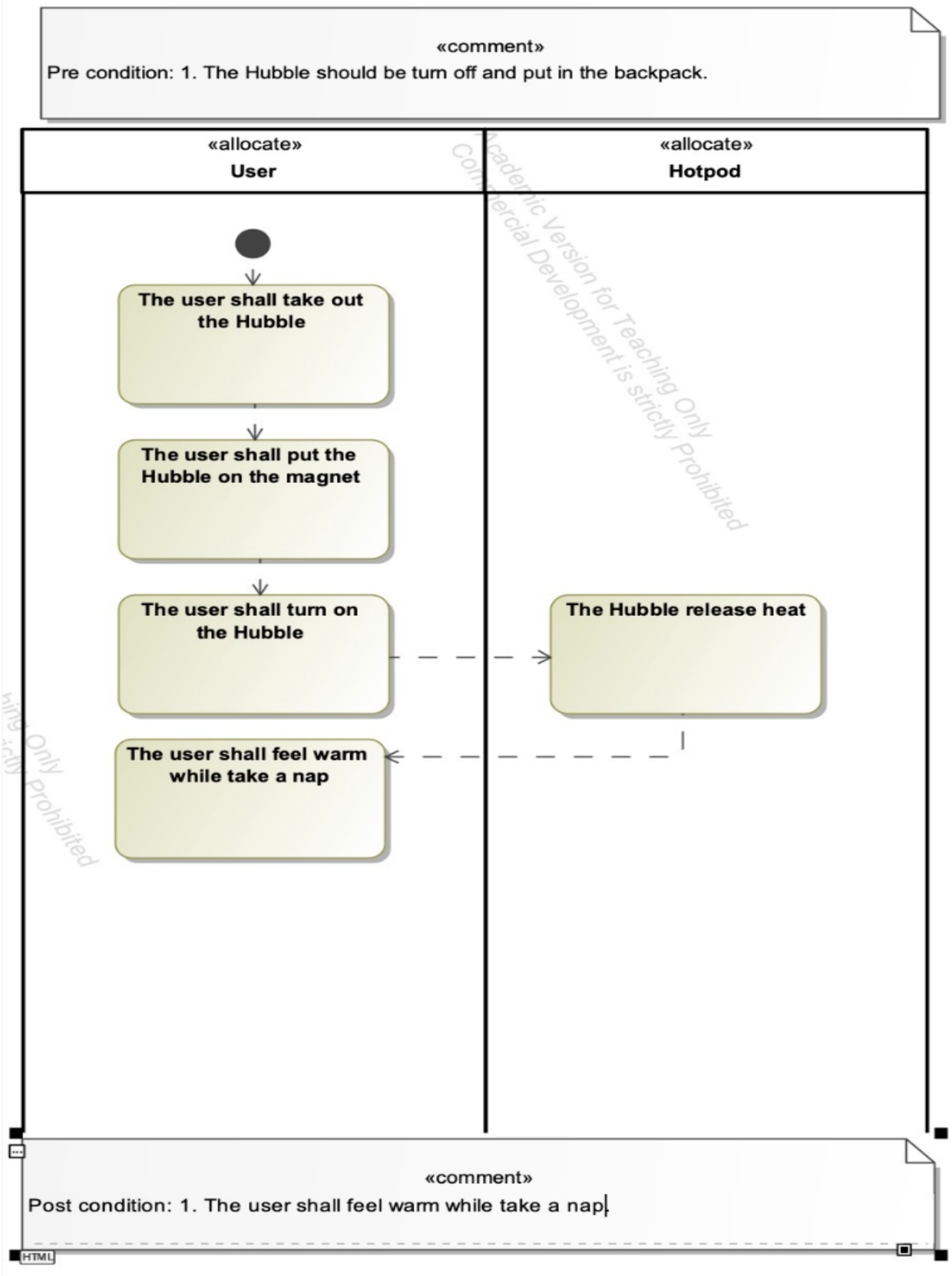


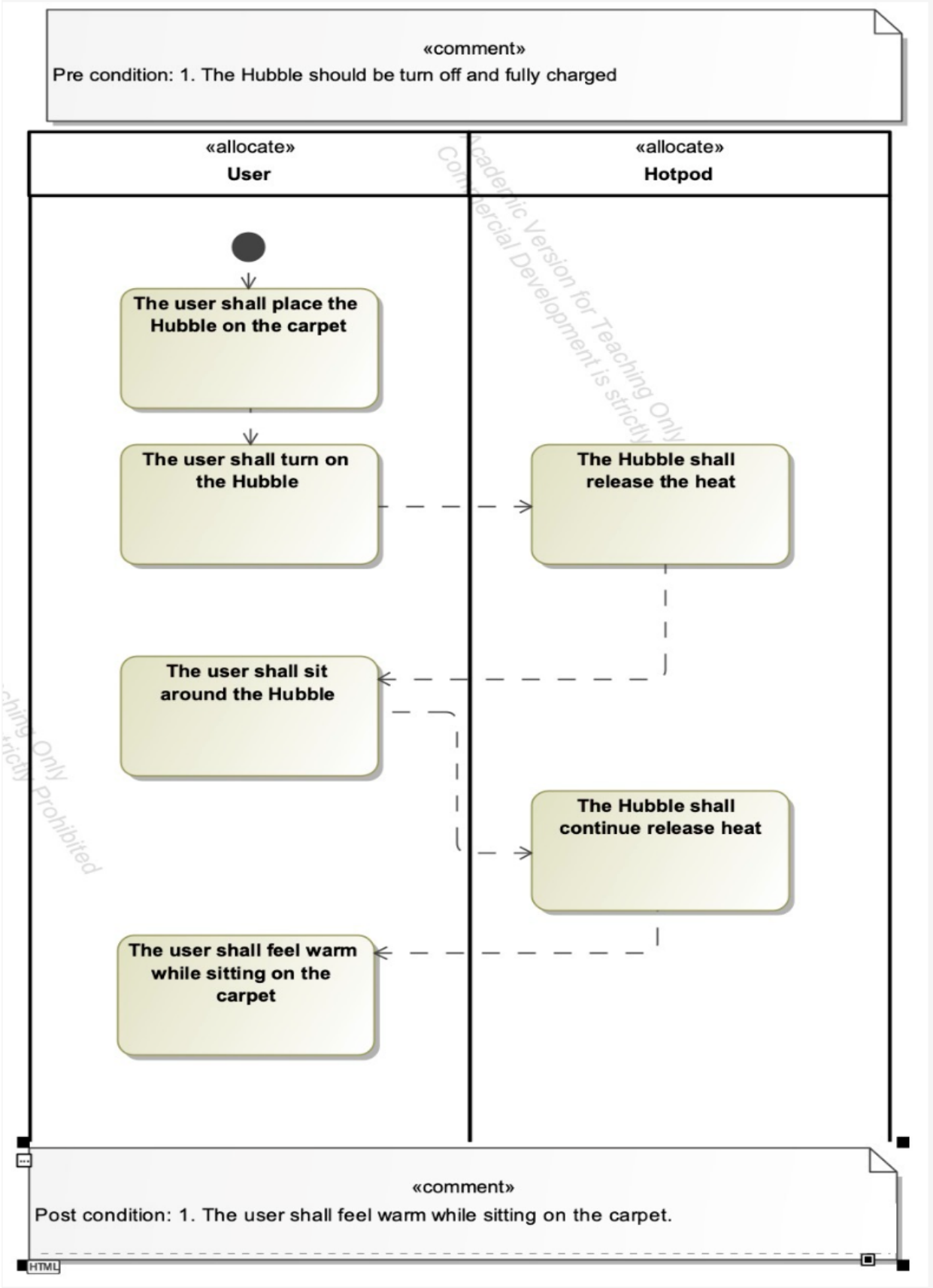


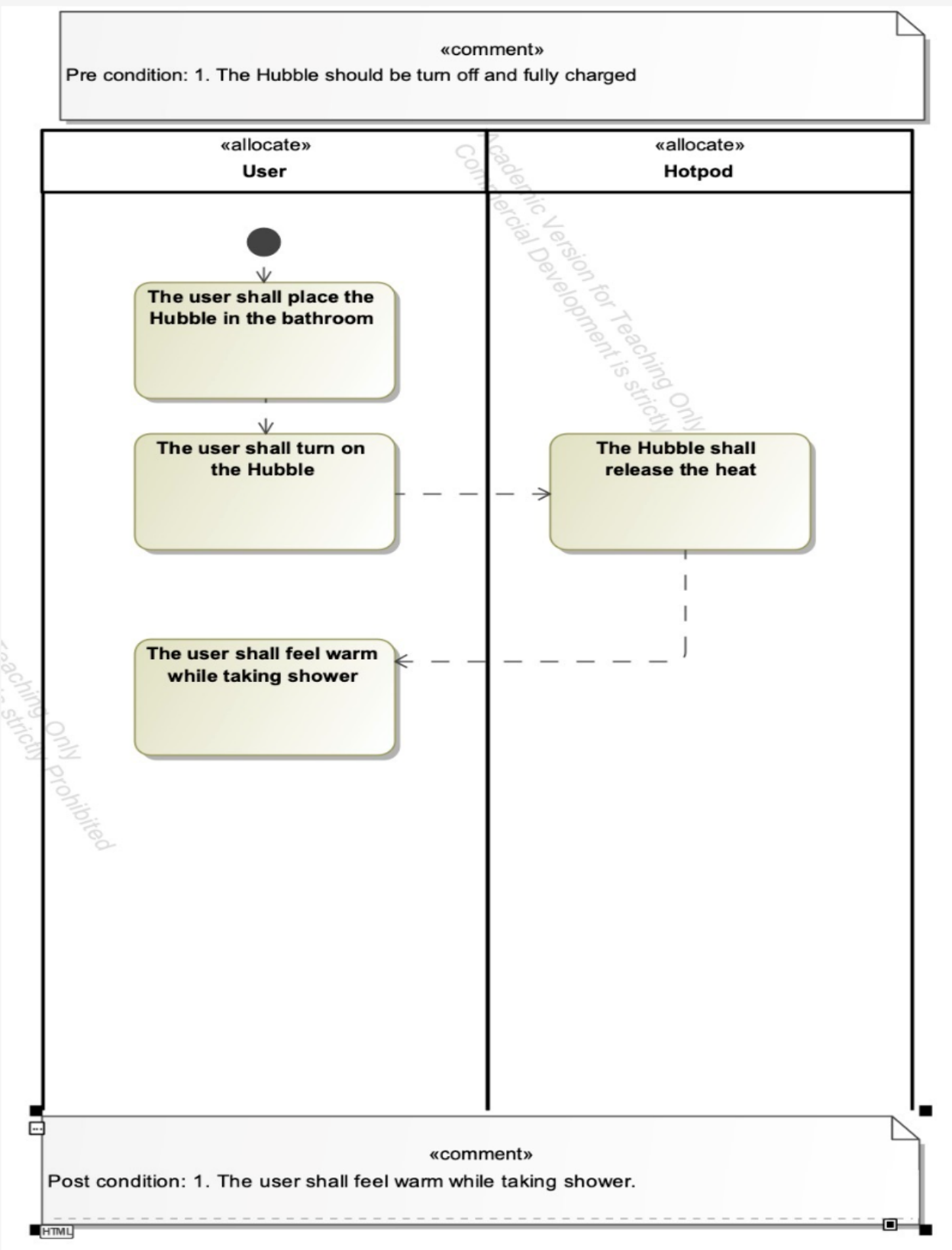

«comment»
Pre condition: 1. The Hubble should be turn off and fully charged.
«allocate»
User
«allocate»
Hotpod
The user shall wear the magnet
The user shall put the Hubble on the magnet
The user shall sit on the sofa and turn on the Hubble
The Hubble release heat
The user shall feel warm while sitting on the sofa
The user shall turn off the Hubble when the temperature is suitable
The Hubble is turned off
«comment»
Post condition: 1. The user shall feel warm after using the Hubble.

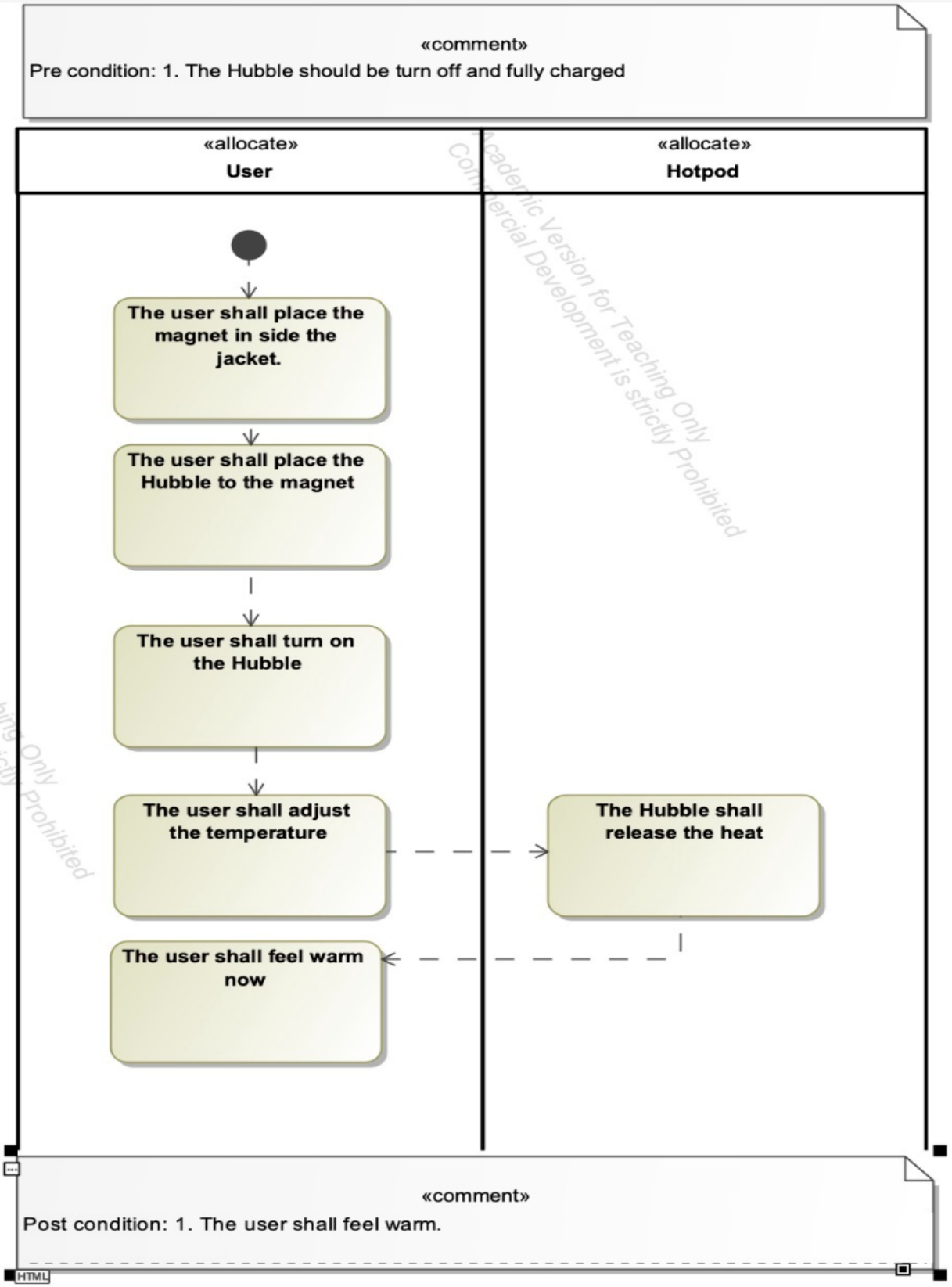

«comment»
Pre condition: 1. The Hubble should be turn off and fully charged
«allocate»
User
«allocate»
Hotpod
The user shall place the Hubble inside the quilt
The user shall turn on the Hubble
The Hubble shall release the heat
The user shall turn off the Hubble when the temperature is suitable
The Hubble shall be turned off
The user shall feel warm and go to bed
«comment»
Post condition: 1. The user shall feel warm on the bed.

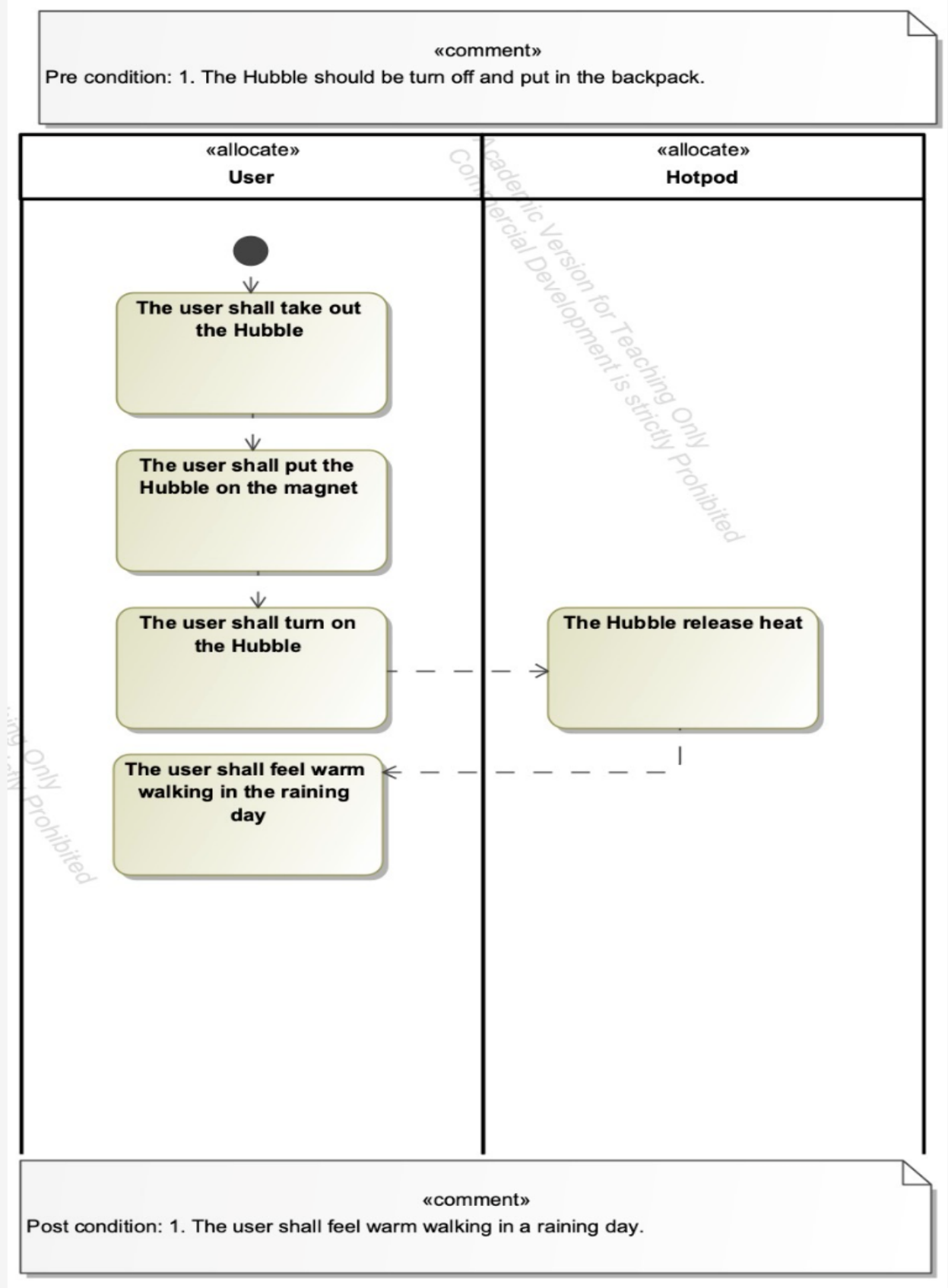

«comment»
Pre condition: 1. The Hubble should be turn off and fully charged
«allocate»
User
«allocate»
Hotpod
The user shall lay on the bed and place the magnet where it is suitable
The user shall place the Hubble to the magnet
The user shall turn on the Hubble
The user shall adjust the temperature
The Hubble shall release the heat
The user shall feel warm on the bed now
«comment»
Post condition: 1. The user shall feel warm on the bed.

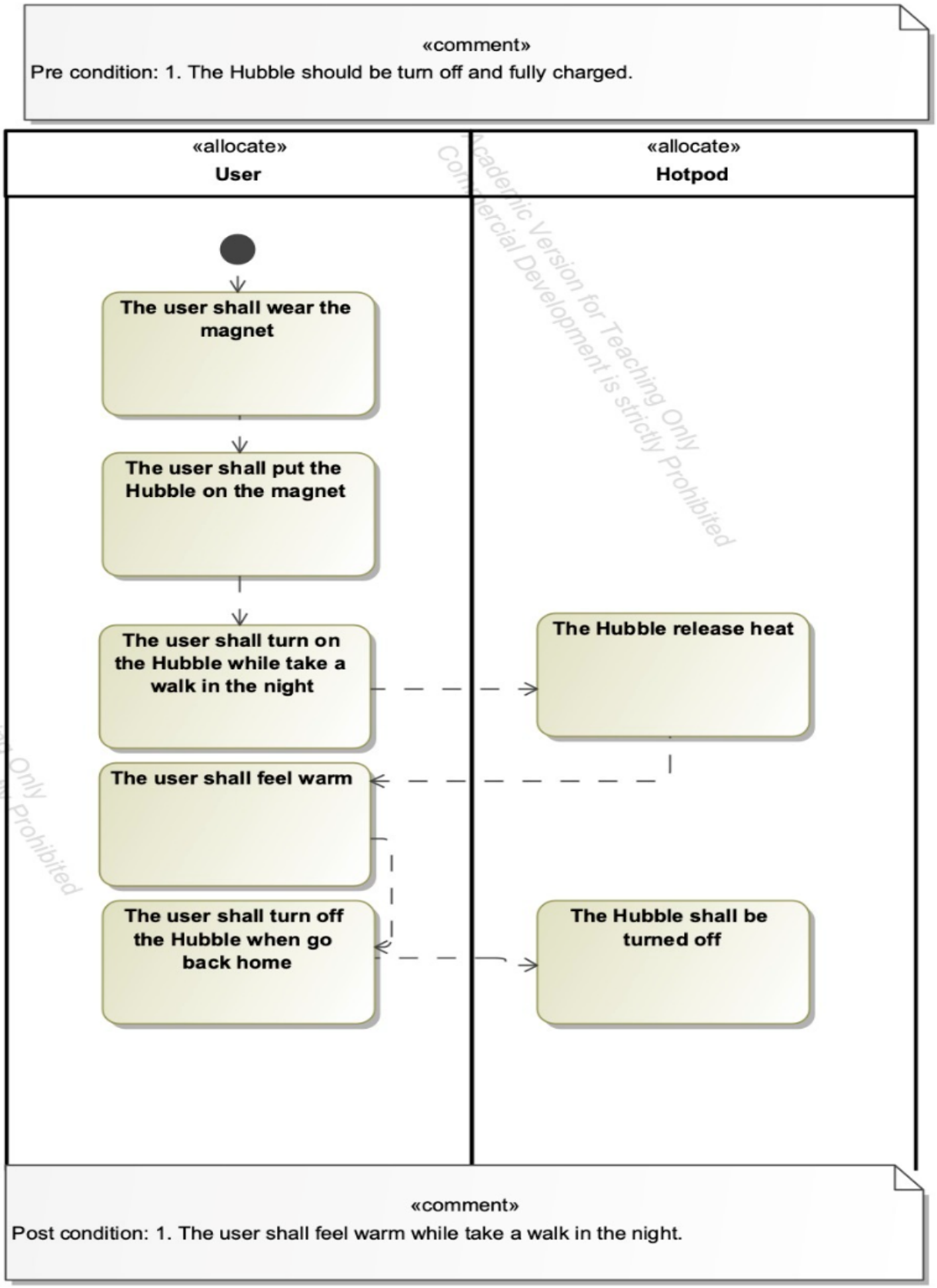


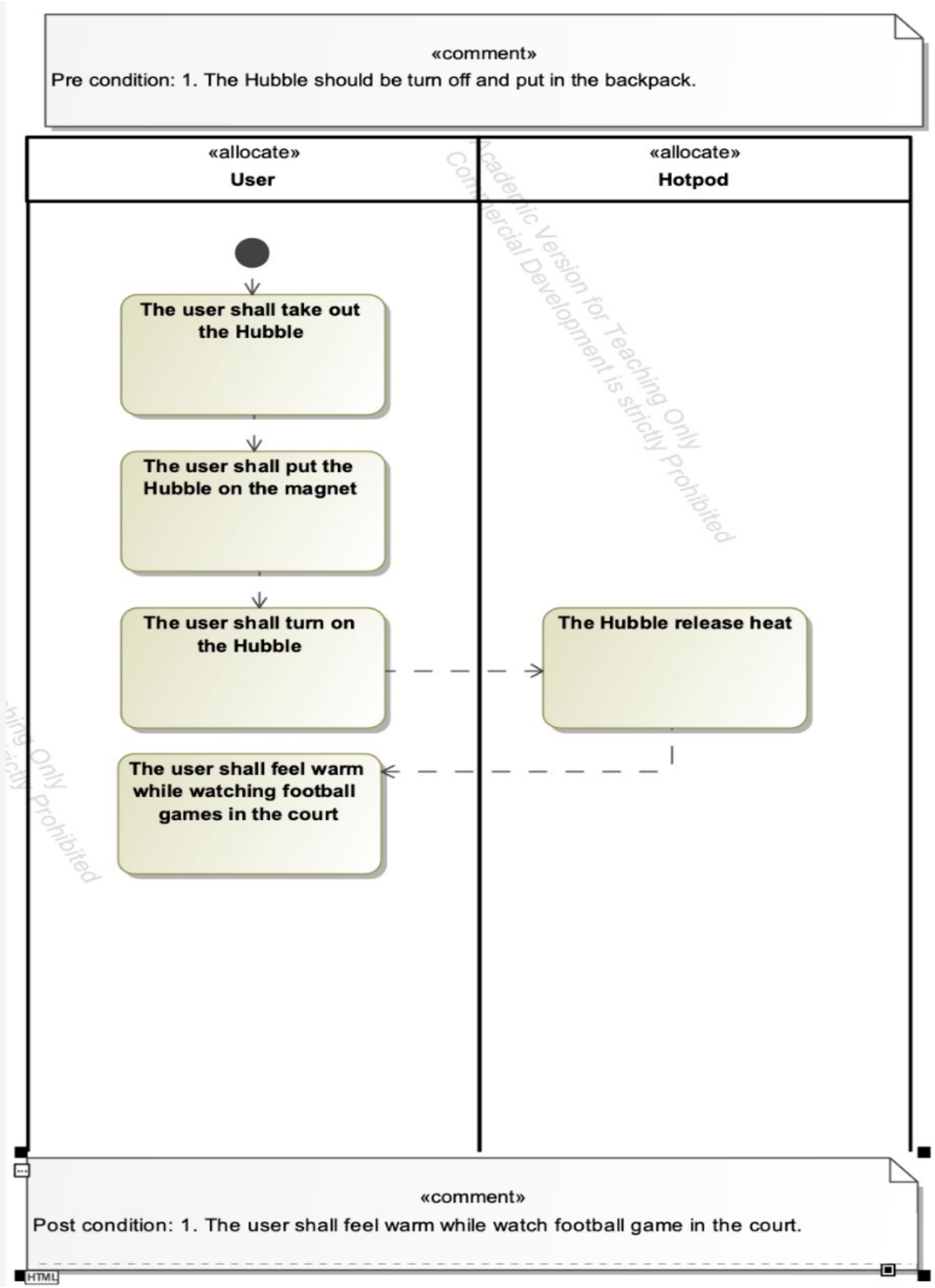

«comment»
Pre condition: 1. The Hubble should be turn off and fully charged
«allocate»
User
«allocate»
Hotpod
The user shall place the Hubble on the carpet
The user shall turn on the Hubble
The Hubble shall release the heat
The user shall sit around the Hubble
The Hubble shall continue release heat
The user shall feel warm while sitting on the carpet
«comment»
Post condition: 1. The user shall feel warm while sitting on the carpet.
HTML

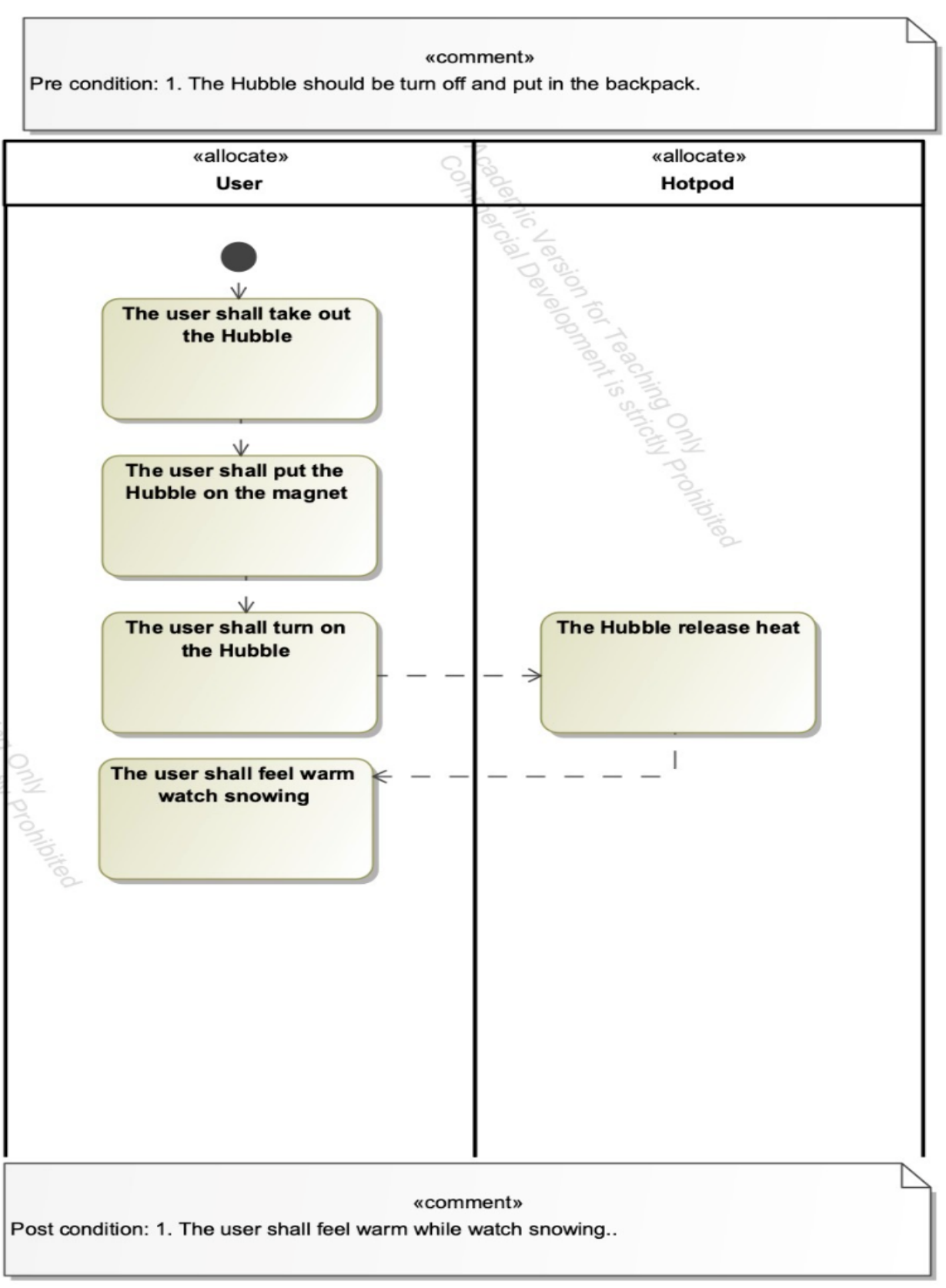

«comment»
Pre condition: 1. The Hubble should be turn off and fully charged
«allocate»
User
«allocate»
Hotpod
The user shall place the Hubble in the bathroom
The user shall turn on the Hubble
The Hubble shall release the heat
The user shall feel warm while taking shower
«comment»
Post condition: 1. The user shall feel warm while taking shower.
HTML

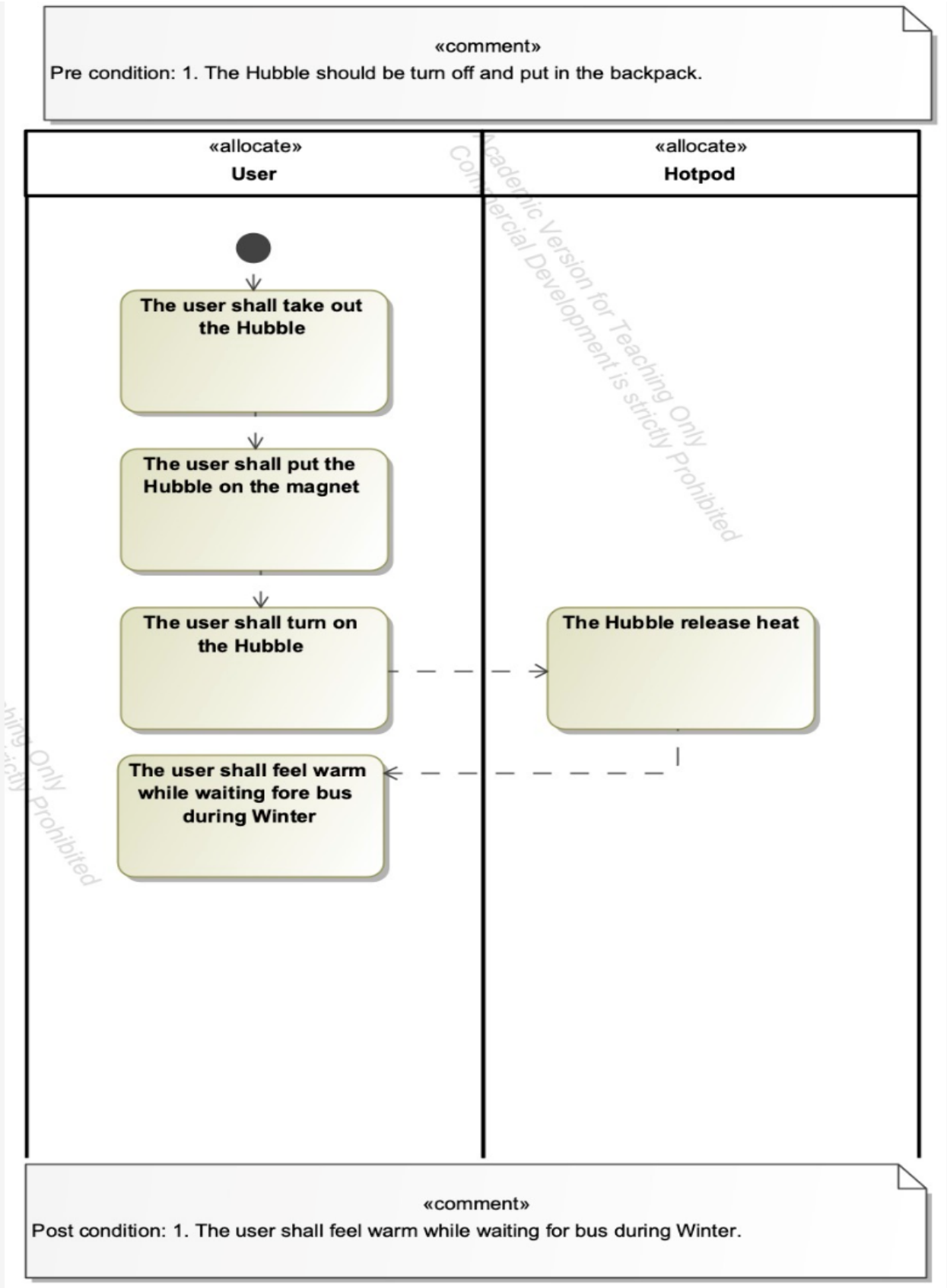


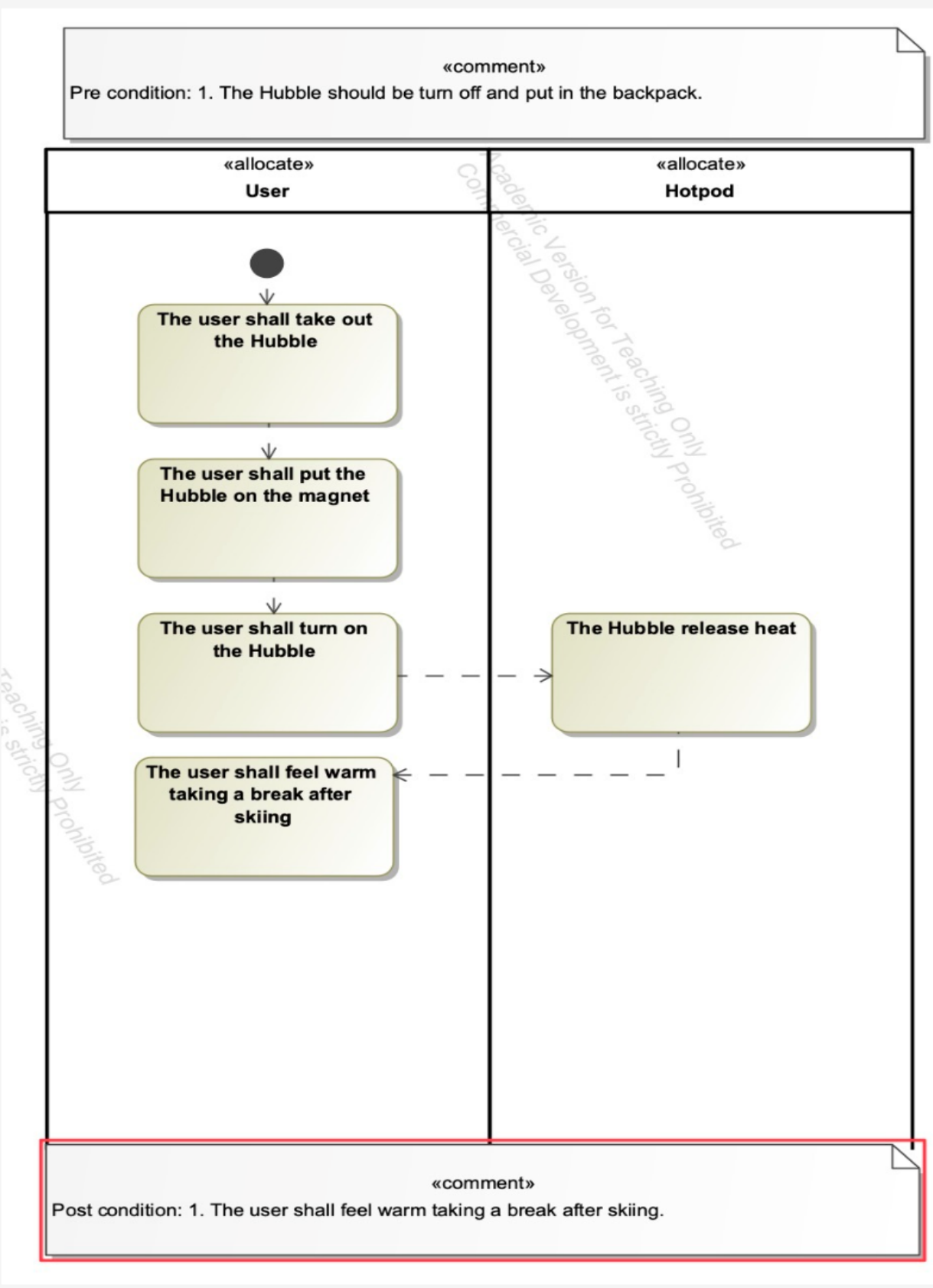



«comment»
Pre condition: 1. The Hubble should be turn off and fully charged.
«allocate»
User
«allocate»
Hotpod
The user shall wear the magnet
The user shall put the Hubble on the magnet
The user shall turn on the Hubble while take a walk in the night
The Hubble release heat
The user shall feel warm
The user shall turn off the Hubble when go back home
The Hubble shall be turned off
«comment»
Post condition: 1. The user shall feel warm while take a walk in the night.




«comment»
Pre condition: 1. The Hubble should be turn off and put in the backpack.
«allocate»
User
«allocate»
Hotpod
The user shall take out the Hubble
The user shall put the Hubble on the magnet
The user shall turn on the Hubble
The Hubble release heat
The user shall feel warm watch snowing
«comment»
Post condition: 1. The user shall feel warm while watch snowing..

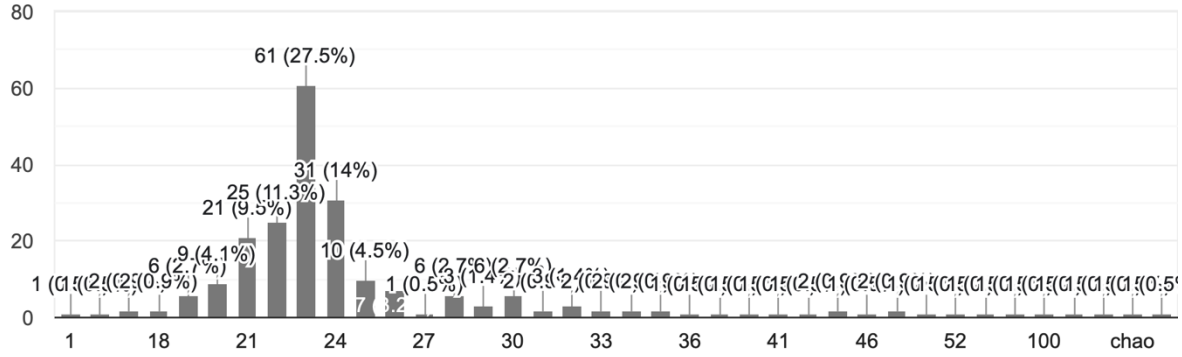

«comment»
Pre condition: 1. The Hubble should be turn off and put in the backpack.
«allocate»
User
«allocate»
Hotpod
The user shall take out the Hubble
The user shall put the Hubble on the magnet
The user shall turn on the Hubble
The Hubble release heat
The user shall feel warm while waiting fore bus during Winter
«comment»
Post condition: 1. The user shall feel warm while waiting for bus during Winter.


«comment»
Pre condition: 1. The Hubble should be turn off and put in the backpack.
«allocate»
User
«allocate»
Hotpod
The user shall take out the Hubble
The user shall put the Hubble on the magnet
The user shall turn on the Hubble
The Hubble release heat
The user shall feel warm taking a break after skiing
«comment»
Post condition: 1. The user shall feel warm taking a break after skiing.

17.4 Product Questionnaire

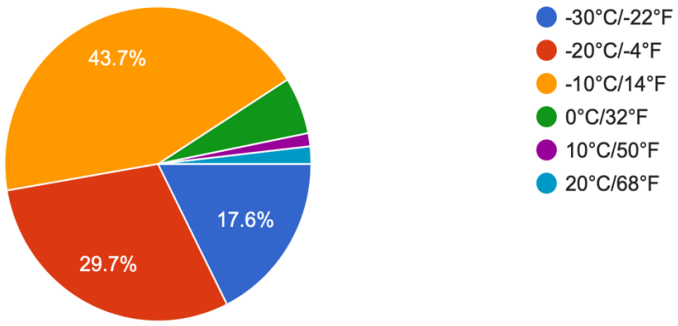
Please indicate your age:

222 responses



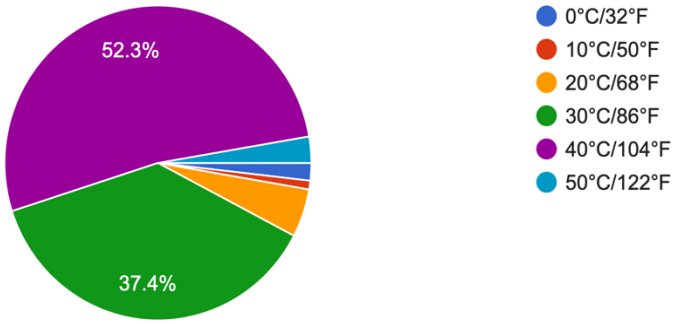
What is the lowest temperature you've experienced where you live?

222 responses



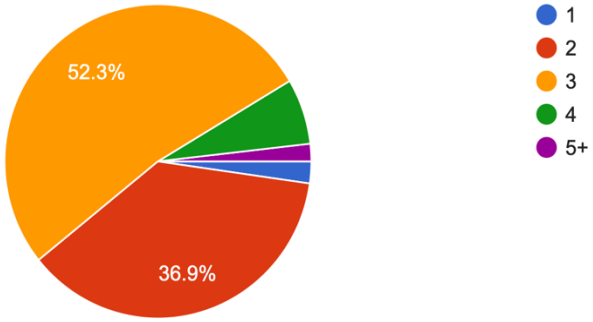
What is the highest temperature you've experienced where you live?

222 responses



How many layers of clothing do you typically wear on your upper body during the winter season?

222 responses

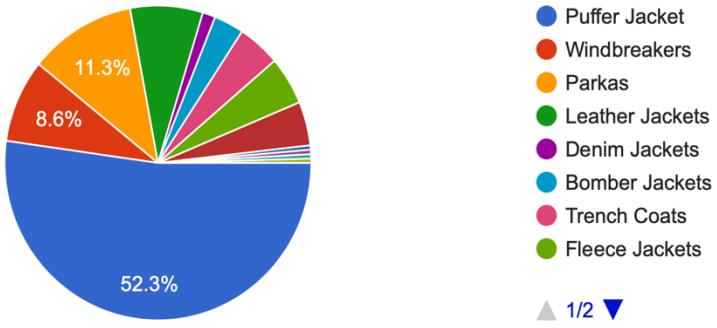


What type of clothing are you wearing in the innermost layer during winter?

222 responses

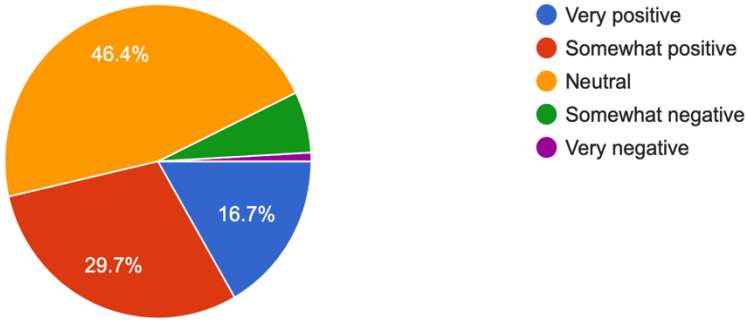
What type of clothing are you wearing in the outermost layer during winter?

222 responses



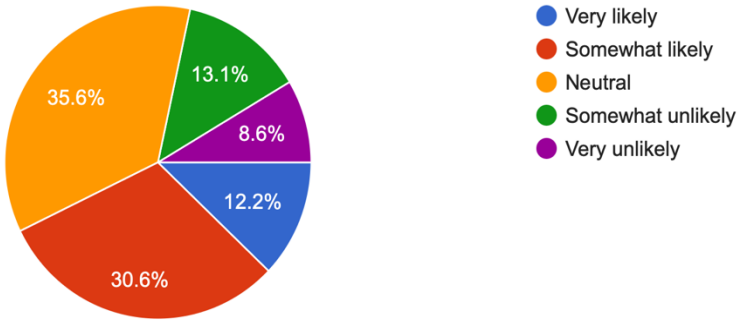
What is your initial impression of MagnaHeat?

222 responses



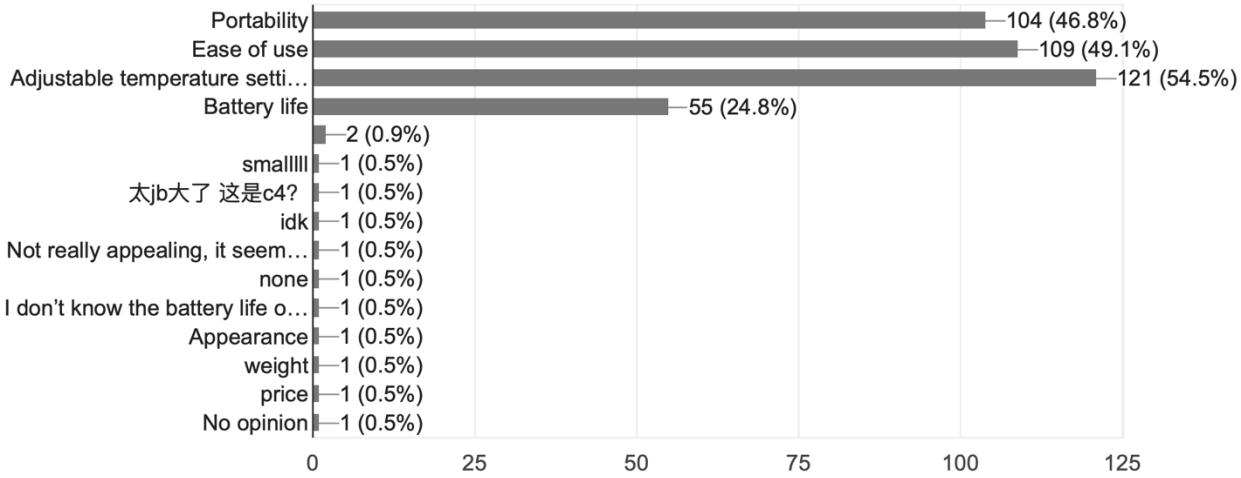
How likely are you to use a product like MagnaHeat during winter?

222 responses



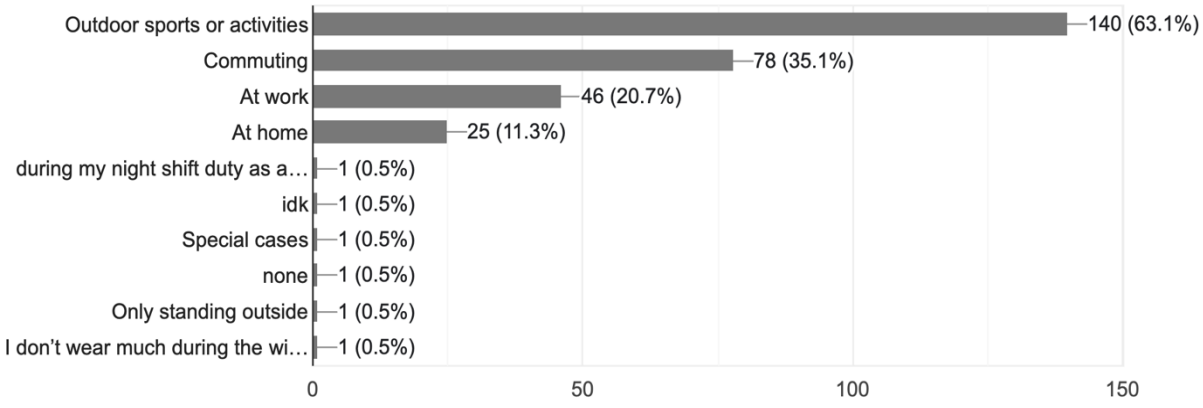
Which following features of MagnaHeat are most appealing to you? (Select all that apply)

222 responses



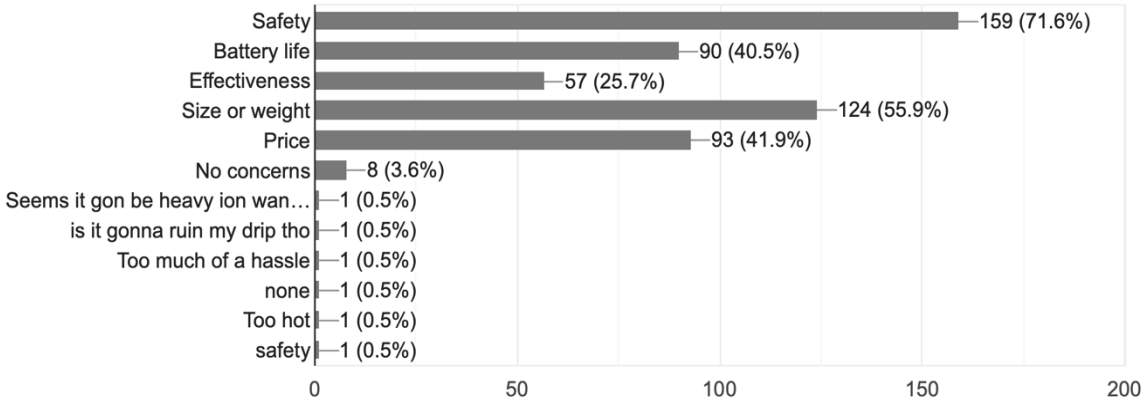
In which situations would you see yourself using MagnaHeat? (Select all that apply)

222 responses



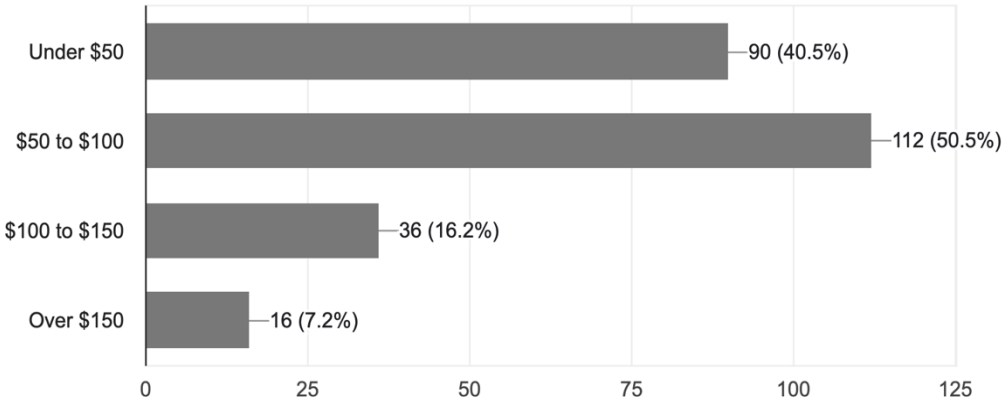
Do you have any concerns about using MagnaHeat?

222 responses



How much would you be willing to pay for MagnaHeat?

222 responses

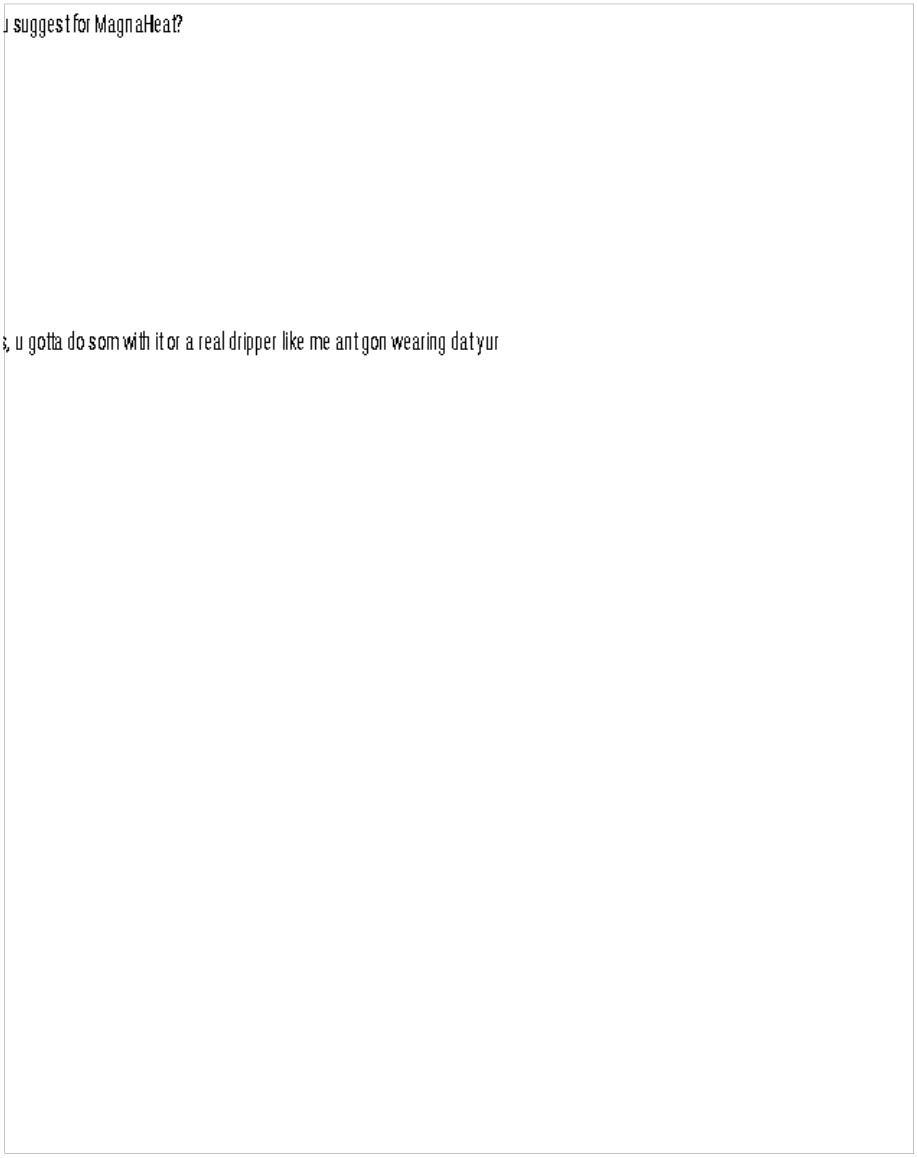


17.5 Questionnaire Original Data

Timestamp	Please indicate your age:	What is the lowest temper	What is the highest tempe	How many layers of clothi
3/12/2024 20:01:04	24	-10°C/14°F	30°C/86°F	3
3/20/2024 9:16:04	23	-10°C/14°F	40°C/104°F	2
3/20/2024 9:22:06	24	-20°C/-4°F	30°C/86°F	2
3/20/2024 9:24:30	17	-20°C/-4°F	40°C/104°F	3
3/21/2024 10:28:20	23	-20°C/-4°F	50°C/122°F	2
3/21/2024 11:01:34	25	-20°C/-4°F	50°C/122°F	2
3/21/2024 11:21:06	23	-10°C/14°F	30°C/86°F	3
3/21/2024 11:57:09	23	-10°C/14°F	30°C/86°F	3
3/21/2024 12:10:36	47	-30°C/-22°F	0°C/32°F	5+
3/22/2024 10:07:23	21	-20°C/-4°F	40°C/104°F	4
3/22/2024 10:07:53	22	-10°C/14°F	20°C/68°F	2
3/22/2024 10:13:05	45	-20°C/-4°F	40°C/104°F	2
3/22/2024 10:13:23	26	-20°C/-4°F	40°C/104°F	2
3/22/2024 10:15:25	28	-30°C/-22°F	30°C/86°F	2
3/22/2024 10:23:14	21	-20°C/-4°F	40°C/104°F	3
3/22/2024 10:25:11	26	-30°C/-22°F	40°C/104°F	2
3/22/2024 10:36:26	22	-10°C/14°F	30°C/86°F	3
3/22/2024 10:58:51	25	20°C/68°F	40°C/104°F	3
3/22/2024 11:11:55	19	-20°C/-4°F	40°C/104°F	2
3/22/2024 11:25:59	25	-10°C/14°F	40°C/104°F	4
3/22/2024 11:31:31	26	-10°C/14°F	30°C/86°F	2
3/22/2024 11:43:09	30	-10°C/14°F	20°C/68°F	2
3/22/2024 11:49:06	32	-20°C/-4°F	30°C/86°F	3
3/22/2024 11:55:23	18	-20°C/-4°F	30°C/86°F	2
3/22/2024 12:07:20	24	-10°C/14°F	30°C/86°F	2
3/22/2024 12:07:21	22	-20°C/-4°F	30°C/86°F	3
3/22/2024 12:08:26	26	-30°C/-22°F	40°C/104°F	3
3/22/2024 12:09:36	23	-20°C/-4°F	40°C/104°F	3

What type of clothing are	What type of clothing are	What is your initial impres	How likely are you to use	Which following features c
Shirt	Puffer Jacket	Somewhat positive	Somewhat likely	Adjustable temperature se
T-Shirt/Polo Shirt	Puffer Jacket	Somewhat positive	Somewhat likely	Battery life
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Neutral	Portability, Ease of use
Sweater	Puffer Jacket	Very positive	Somewhat likely	Portability, Ease of use, A
Hoodies	Puffer Jacket	Very positive	Very likely	Portability, Ease of use, A
T-Shirt/Polo Shirt	Puffer Jacket	Somewhat positive	Somewhat likely	Portability, Ease of use
T-Shirt/Polo Shirt	Windbreakers	Somewhat positive	Very likely	Portability, Ease of use
em Rick Owens drips hea	Parkas	Neutral	Somewhat likely	Ease of use, Adjustable te
armor	metal armor	Very positive	Very likely	Portability, Ease of use, A
Shirt	Puffer Jacket	Neutral	Somewhat unlikely	Ease of use, Adjustable te
T-Shirt/Polo Shirt	Denim Jackets	Somewhat negative	Very unlikely	Ease of use, Battery life
Sweater	Puffer Jacket	Neutral	Somewhat unlikely	Ease of use, Battery life
T-Shirt/Polo Shirt	Puffer Jacket	Somewhat positive	Neutral	Portability
T-Shirt/Polo Shirt	Parkas	Neutral	Neutral	Portability, Ease of use, B
Sweater	Windbreakers	Somewhat positive	Somewhat likely	Ease of use
Sweater	Puffer Jacket	Neutral	Somewhat unlikely	Adjustable temperature se
T-Shirt/Polo Shirt	Trench Coats	Neutral	Somewhat likely	Ease of use, Adjustable te
Hoodies	Puffer Jacket	Neutral	Neutral	Adjustable temperature se
Hoodies	Windbreakers	Somewhat positive	Somewhat likely	Adjustable temperature se
Sweater	Puffer Jacket	Somewhat positive	Somewhat likely	Portability, Ease of use
Shirt	Parkas	Very positive	Somewhat likely	Adjustable temperature se
Shirt	Puffer Jacket	Neutral	Neutral	Adjustable temperature se
T-Shirt/Polo Shirt	Puffer Jacket	Somewhat positive	Neutral	Portability, Ease of use, A
Sweater	Hoodies	Somewhat positive	Neutral	Ease of use
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Neutral	Adjustable temperature se
Hoodies	Fleece Jackets	Neutral	Somewhat likely	Adjustable temperature se
T-Shirt/Polo Shirt	Leather Jackets	Very positive	Very likely	Portability, Ease of use
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Somewhat likely	Ease of use

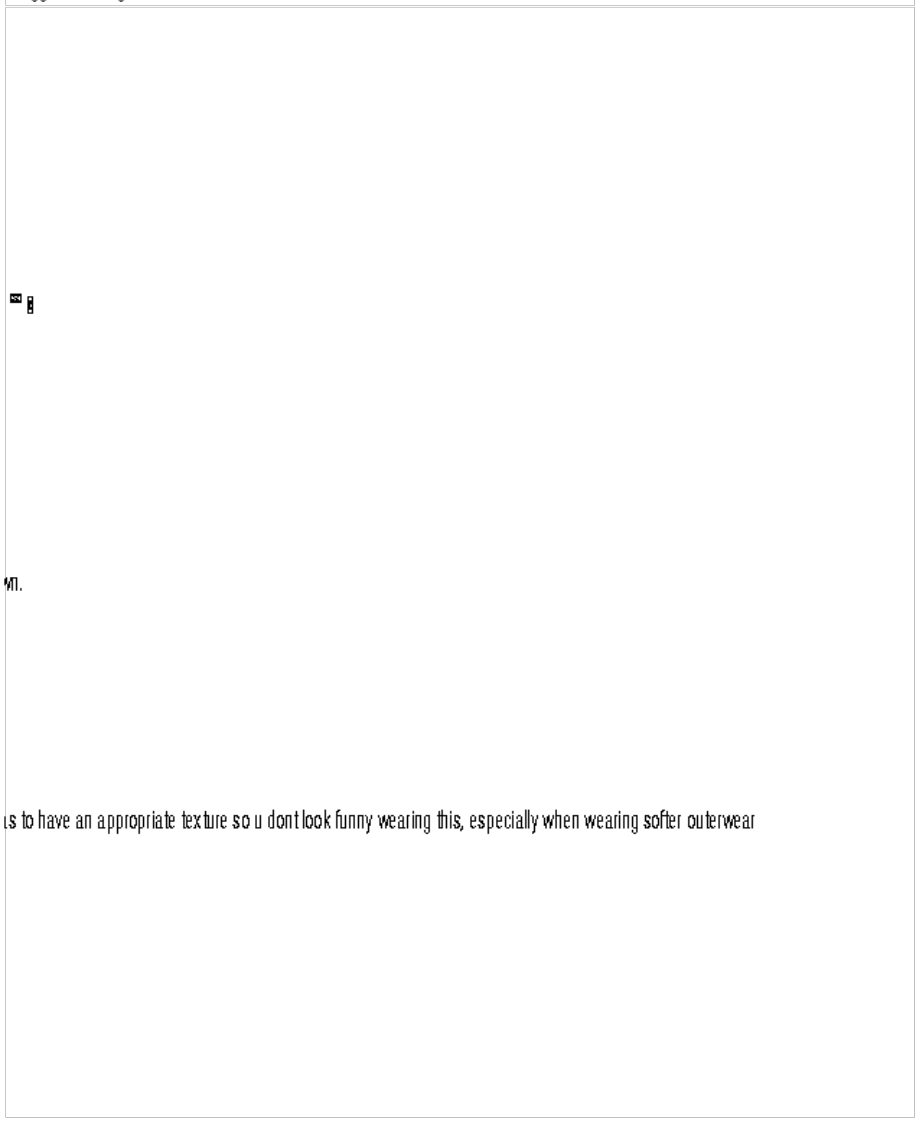
In which situations would	Do you have any concern	How much would you be v	What improvements or additional features would you
Outdoor sports or activitie	Safety, Battery life, Size o	$50 to $100	thinner
Outdoor sports or activitie	Safety, Battery life, Effecti	$50 to $100, $100 to $150	
Commuting	Effectiveness	Under $50, $50 to $100	
Outdoor sports or activitie	Safety, Effectiveness, Sizi	$50 to $100	
Outdoor sports or activitie	Safety, Battery life	$50 to $100	
Outdoor sports or activitie	Battery life, Effectiveness	Under $50	
Commuting, At work	Safety, Size or weight	$50 to $100	
Commuting	Seems it gon be heavy io	Under $50	Again the weight gon be messing with ma Rick drips
Outdoor sports or activitie	Safety, Battery life, Effecti	Over $150	
Outdoor sports or activitie	Battery life, Price	$50 to $100	
At home	Safety, Size or weight, Pri	Under $50	
Outdoor sports or activitie	Battery life, Size or weigh	Under $50	
Outdoor sports or activitie	Safety, Size or weight	Under $50, $50 to $100	
At work	Battery life, Effectiveness,	$50 to $100, $100 to $15	none
Commuting	Safety	$50 to $100	
Outdoor sports or activitie	Safety, Size or weight, Pri	$50 to $100	
At work	Safety, Battery life	$50 to $100	
At work	Safety, Size or weight	$50 to $100, $100 to $150	
Commuting, At work	Safety, Battery life, Size o	$50 to $100, $100 to $150	
Outdoor sports or activitie	Safety, Battery life, Price	$50 to $100	weight shouldn't be high
Outdoor sports or activitie	Safety	Under $50	
Outdoor sports or activitie	Safety, Battery life, Size o	Under $50	
Outdoor sports or activitie	Safety, Battery life, Effecti	Under $50	
Outdoor sports or activitie	No concerns	$50 to $100	
At work	Safety, Effectiveness, Sizi	Under $50	
Outdoor sports or activitie	Safety, Size or weight, Pri	Over $150	
Outdoor sports or activitie	Price	$100 to $150	
Commuting, At work, Ath	Safety, Battery life, Size o	$50 to $100	Easy carry and hid


u suggest for MagnaHeat?
s, u gotta do som with it or a real dripper like me ant gon wearing dat yur

Timestamp	Please indicate your age:	What is the lowest temper	What is the highest tempe	How many layers of clothi
3/22/2024 12:10:31	23	-30°C/-22°F	30°C/86°F	3
3/22/2024 12:15:30	21	-30°C/-22°F	40°C/104°F	2
3/22/2024 12:16:51	21	-20°C/-4°F	40°C/104°F	3
3/22/2024 12:17:07	24	-10°C/14°F	30°C/86°F	2
3/22/2024 12:18:49	22	-10°C/14°F	40°C/104°F	3
3/22/2024 12:24:57	22	-30°C/-22°F	0°C/32°F	2
3/22/2024 12:26:24	20	-10°C/14°F	40°C/104°F	3
3/22/2024 12:26:45	23	-10°C/14°F	40°C/104°F	3
3/22/2024 12:27:20	26	0°C/32°F	40°C/104°F	2
3/22/2024 12:32:26	32	-20°C/-4°F	40°C/104°F	3
3/22/2024 12:35:51	22	-10°C/14°F	40°C/104°F	4
3/22/2024 12:38:19	22	-20°C/-4°F	40°C/104°F	3
3/22/2024 12:38:39	23	-20°C/-4°F	40°C/104°F	5+
3/22/2024 12:40:56	24	-10°C/14°F	30°C/86°F	3
3/22/2024 12:41:51	24	-10°C/14°F	40°C/104°F	3
3/22/2024 12:47:56	22	-10°C/14°F	10°C/50°F	2
3/22/2024 12:53:37	23	-30°C/-22°F	30°C/86°F	2
3/22/2024 13:16:41	24	-10°C/14°F	40°C/104°F	3
3/22/2024 13:23:49	23	-10°C/14°F	40°C/104°F	2
3/22/2024 13:25:37	20	-10°C/14°F	40°C/104°F	3
3/22/2024 13:27:34	24	-20°C/-4°F	40°C/104°F	3
3/22/2024 13:31:29	23	-10°C/14°F	40°C/104°F	3
3/22/2024 13:41:00	21	-20°C/-4°F	40°C/104°F	3
3/22/2024 14:04:39	20	-10°C/14°F	40°C/104°F	3
3/22/2024 14:12:14	20	-10°C/14°F	30°C/86°F	4
3/22/2024 14:20:06	19	-10°C/14°F	30°C/86°F	1
3/22/2024 15:01:17	23	0°C/32°F	30°C/86°F	2
3/22/2024 15:21:04	100	-30°C/-22°F	50°C/122°F	1

What type of clothing are	What type of clothing are	What is your initial impres	How likely are you to use	Which following features c
Tank Tops	Trench Coats	Very positive	Somewhat likely	Adjustable temperature se
Shirt	Parkas	Neutral	Neutral	Portability
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Neutral	Portability, Adjustable tem
Sweater	Parkas	Somewhat positive	Somewhat likely	Portability, Battery life
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Very likely	Ease of use
T-Shirt/Polo Shirt	Puffer Jacket	Very positive	Somewhat likely	Ease of use
T-Shirt/Polo Shirt	Leather Jackets	Somewhat positive	Somewhat unlikely	Portability, Ease of use
Base Layer	Parkas	Somewhat negative	Somewhat unlikely	[illegible]
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Neutral	Portability, Ease of use, A
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Neutral	Adjustable temperature se
Tank Tops	Puffer Jacket	Neutral	Somewhat likely	Portability, Ease of use, A
Sweater	Trench Coats	Very positive	Somewhat likely	Portability, Ease of use, A
Shirt	Puffer Jacket	Neutral	Neutral	Adjustable temperature se
T-Shirt/Polo Shirt	Bomber Jackets	Somewhat positive	Somewhat likely	Ease of use, Adjustable te
Sweater	Puffer Jacket	Somewhat negative	Somewhat unlikely	Portability, Ease of use, A
T-Shirt/Polo Shirt	Puffer Jacket	Somewhat negative	Very unlikely	idk
T-Shirt/Polo Shirt	Puffer Jacket	Somewhat positive	Somewhat likely	Ease of use
T-Shirt/Polo Shirt	Parkas	Somewhat positive	Neutral	Portability, Adjustable tem
Hoodies	Puffer Jacket	Somewhat positive	Neutral	Ease of use, Adjustable te
T-Shirt/Polo Shirt	Puffer Jacket	Somewhat negative	Very unlikely	Adjustable temperature se
T-Shirt/Polo Shirt	Puffer Jacket	Somewhat positive	Somewhat likely	Portability, Ease of use
Shirt	Parkas	Very positive	Very likely	Portability, Battery life
Hoodies	Leather Jackets	Very positive	Neutral	Portability
Hoodies	Puffer Jacket	Somewhat positive	Neutral	Portability
Sweater	Leather Jackets	Very positive	Very likely	Portability
T-Shirt/Polo Shirt	Fleece Jackets	Neutral	Very likely	Not really appealing, it se
Sweater	Puffer Jacket	Neutral	Somewhat likely	Adjustable temperature se
Hoodies	Hoodies	Very negative	Very likely	Battery life

In which situations would	Do you have any concern	How much would you be v	What improvements or additional features would you
Outdoor sports or activitie	Safety, Effectiveness, Pric	$50 to $100	
Outdoor sports or activitie	Safety, Effectiveness	$100 to $150	
Outdoor sports or activitie	No concerns	Under $50	
Outdoor sports or activitie	Effectiveness, Size or wei	$50 to $100	
Outdoor sports or activitie	Safety, Size or weight	Under $50, $50 to $100	
Commuting	Safety	Under $50	ww
Outdoor sports or activitie	Safety, Effectiveness	Under $50	
Commuting	Effectiveness, Size or wei	Under $50, $50 to $100	[illegible]
Commuting	Safety, Battery life, Effecti	Under $50	
Outdoor sports or activitie	Safety, Battery life	$100 to $150	
Commuting, At work	Safety, Battery life, Price	$50 to $100, $100 to $150	
Outdoor sports or activitie	Safety, Price	Under $50	Good enough
Outdoor sports or activitie	Size or weight, Price	Under $50	Adjust size&weight
Commuting	Safety, Battery life, Size o	$50 to $100	
At home	Safety, Size or weight	Under $50	My feets and legs are cold and how the air goes dov
idk	Too much of a hassle	Under $50	
Outdoor sports or activitie	Safety	$50 to $100	A little bit smaller
Outdoor sports or activitie	Safety, Battery life, Size o	$50 to $100	
Outdoor sports or activitie	Safety, Battery life, Effecti	$50 to $100	
Commuting, At work	Safety, Battery life	Under $50	
Commuting	Size or weight	Under $50	Size and weight really matters to me and I think it ha
Commuting	Safety, Battery life, Effecti	Under $50, $50 to $100	
Outdoor sports or activitie	Safety	Under $50	
Outdoor sports or activitie	Safety, Battery life, Effecti	$50 to $100	
Outdoor sports or activitie	Size or weight	Under $50	
Outdoor sports or activitie	Safety, Battery life, Effecti	Under $50	
Outdoor sports or activitie	Safety, Battery life, Size o	$50 to $100	
Commuting	Size or weight	Under $50, $50 to $100, $100 to $150, Over $150	

u suggest for MagnaHeat?


Timestamp	Please indicate your age:	What is the lowest temper	What is the highest tempe	How many layers of clothi
3/22/2024 15:21:40	29	-20°C/-4°F	30°C/86°F	2
3/22/2024 15:37:50	41	-30°C/-22°F	40°C/104°F	4
3/22/2024 15:57:05	23	-10°C/14°F	30°C/86°F	3
3/22/2024 17:26:40	21	-10°C/14°F	40°C/104°F	3
3/22/2024 17:51:43	23	-20°C/-4°F	30°C/86°F	2
3/22/2024 20:15:41	24	-10°C/14°F	40°C/104°F	3
3/22/2024 20:23:08	24	-30°C/-22°F	40°C/104°F	2
3/22/2024 20:23:37	chao	-10°C/14°F	40°C/104°F	3
3/22/2024 20:23:58	23	-10°C/14°F	40°C/104°F	3
3/22/2024 20:26:25	20	-30°C/-22°F	40°C/104°F	2
3/22/2024 20:27:39	38	-10°C/14°F	30°C/86°F	3
3/22/2024 20:28:34	24	-20°C/-4°F	30°C/86°F	3
3/22/2024 20:28:41	23	-10°C/14°F	30°C/86°F	3
3/22/2024 20:29:00	22	-10°C/14°F	40°C/104°F	2
3/22/2024 20:29:22	23	-20°C/-4°F	40°C/104°F	4
3/22/2024 20:31:01	24	-30°C/-22°F	30°C/86°F	2
3/22/2024 20:31:24	22	-20°C/-4°F	30°C/86°F	2
3/22/2024 20:37:04	21	-10°C/14°F	40°C/104°F	2
3/22/2024 20:37:47	30	-10°C/14°F	30°C/86°F	2
3/22/2024 20:38:39	24	-20°C/-4°F	40°C/104°F	2
3/22/2024 20:39:17	23	-30°C/-22°F	30°C/86°F	3
3/22/2024 20:47:01	44	-10°C/14°F	30°C/86°F	3
3/22/2024 20:52:44	21	-20°C/-4°F	40°C/104°F	2
3/22/2024 20:55:20	23	0°C/32°F	30°C/86°F	2
3/22/2024 20:55:25	21	-20°C/-4°F	50°C/122°F	3
3/22/2024 21:00:04	28	-10°C/14°F	40°C/104°F	2
3/22/2024 21:01:03	23	-20°C/-4°F	30°C/86°F	2
3/22/2024 21:02:16	21	-10°C/14°F	20°C/68°F	3

What type of clothing are	What type of clothing are	What is your initial impres	How likely are you to use	Which following features c
Sweater	Parkas	Somewhat negative	Very unlikely	Portability, Ease of use, A
Crop Tops	Windbreakers	Neutral	Very unlikely	Battery life,
Shirt	Puffer Jacket	Somewhat positive	Very likely	Portability, Ease of use, A
Shirt	Puffer Jacket	Somewhat positive	Somewhat likely	Adjustable temperature se
Tank Tops	Parkas	Very positive	Somewhat likely	Portability
Tank Tops	Puffer Jacket	Neutral	Neutral	Adjustable temperature se
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Neutral	Ease of use
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Neutral	Adjustable temperature se
Tank Tops	Leather Jackets	Neutral	Very unlikely	Adjustable temperature se
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Somewhat likely	Portability, Ease of use, A
Shirt	Puffer Jacket	Somewhat positive	Somewhat likely	Portability, Ease of use
Hoodies	Puffer Jacket	Neutral	Neutral	Adjustable temperature se
Hoodies	Fleece Jackets	Somewhat positive	Neutral	Adjustable temperature se
Shirt	Parkas	Very positive	Very likely	Adjustable temperature se
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Neutral	Ease of use, Adjustable te
T-Shirt/Polo Shirt	Puffer Jacket	Somewhat positive	Neutral	Portability, Ease of use, A
Sweater	Leather Jackets	Somewhat positive	Somewhat likely	Ease of use
Shirt	Windbreakers	Somewhat positive	Somewhat unlikely	Adjustable temperature se
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Neutral	Portability
Hoodies	Hoodies	Neutral	Somewhat likely	Portability, Ease of use
T-Shirt/Polo Shirt	Puffer Jacket	Somewhat negative	Very unlikely	Adjustable temperature se
T-Shirt/Polo Shirt	Windbreakers	Neutral	Neutral	Adjustable temperature se
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Somewhat unlikely	Ease of use
dress	Leather Jackets	Somewhat positive	Somewhat likely	Adjustable temperature se
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Neutral	Portability
Hoodies	Hoodies	Very positive	Neutral	Portability, Ease of use, A
Sweater	Puffer Jacket	Somewhat positive	Very likely	Ease of use, Adjustable te
Shirt	Puffer Jacket	Very positive	Somewhat likely	Portability, Ease of use, A

In which situations would	Do you have any concern	How much would you be v	What improvements or additional features would you
Commuting	Safety	Under $50	
Outdoor sports or activitie	Safety	Under $50	
Outdoor sports or activitie	Safety, Size or weight, Pri	Under $50	thinner size
At work	Safety, Battery life, Price	$50 to $100	
Outdoor sports or activitie	Safety	Under $50	
Outdoor sports or activitie	Safety	Under $50	
Outdoor sports or activitie	Safety, Battery life, Size o	Under $50	
At work	Safety	Under $50	
Commuting	Safety	Under $50	no
Outdoor sports or activitie	Safety, Battery life, Size o	$100 to $150	
Commuting	Safety, Size or weight, Pri	$50 to $100	Easy to charge
At home	Size or weight	Under $50	
Outdoor sports or activitie	Safety, Battery life, Effecti	$50 to $100	Better design of appearance
Commuting	Price	$100 to $150	
Outdoor sports or activitie	Safety, Size or weight, Pri	$50 to $100, $100 to $150	
Commuting	Battery life, Price	$50 to $100	
Outdoor sports or activitie	Battery life	$50 to $100	
At home	Safety, Effectiveness, Size	$50 to $100	
At work	No concerns	$50 to $100	
Outdoor sports or activitie	Safety, Price	Under $50	
At work	Battery life, Size or weigh	Under $50	It would be better to make it as thin as possible in te
Outdoor sports or activitie	Size or weight	$100 to $150	
Outdoor sports or activitie	Size or weight	$50 to $100	No
At work, At home	Safety, Battery life	Over $150	
Outdoor sports or activitie	Safety	$50 to $100	
Outdoor sports or activitie	Safety, Effectiveness, Size	Under $50, $50 to $100	
Commuting, At work	Safety, Battery life	Under $50	
Outdoor sports or activitie	Safety, Effectiveness, Size	$50 to $100	

u suggest for MagnaHeat?
rms of thickness

Timestamp	Please indicate your age:	What is the lowest temper	What is the highest tempe	How many layers of clothi
3/22/2024 21:03:25	23	-20°C/-4°F	40°C/104°F	3
3/22/2024 21:04:17	23	-10°C/14°F	30°C/86°F	3
3/22/2024 21:05:27	23	-30°C/-22°F	30°C/86°F	3
3/22/2024 21:09:42	30	0°C/32°F	30°C/86°F	3
3/22/2024 21:09:54	22	-10°C/14°F	30°C/86°F	3
3/22/2024 21:10:26	20	-20°C/-4°F	40°C/104°F	3
3/22/2024 21:13:51	21	-10°C/14°F	30°C/86°F	4
3/22/2024 21:19:31	23	-20°C/-4°F	30°C/86°F	2
3/22/2024 21:21:01	23	-10°C/14°F	30°C/86°F	3
3/22/2024 21:21:48	23	-30°C/-22°F	40°C/104°F	2
3/22/2024 21:22:45	25	-20°C/-4°F	20°C/68°F	2
3/22/2024 21:22:51	23	-10°C/14°F	30°C/86°F	3
3/22/2024 21:23:20	21	-30°C/-22°F	40°C/104°F	3
3/22/2024 21:26:45	22	-10°C/14°F	40°C/104°F	3
3/22/2024 21:27:13	28	0°C/32°F	30°C/86°F	3
3/22/2024 21:29:21	61	-10°C/14°F	30°C/86°F	3
3/22/2024 21:29:59	28	0°C/32°F	30°C/86°F	4
3/22/2024 21:30:11	22	-30°C/-22°F	30°C/86°F	3
3/22/2024 21:32:55	24	-30°C/-22°F	40°C/104°F	3
3/22/2024 21:33:49	24	-30°C/-22°F	40°C/104°F	3
3/22/2024 21:34:46	20	20°C/68°F	20°C/68°F	3
3/22/2024 21:35:41	23	-30°C/-22°F	30°C/86°F	3
3/22/2024 21:36:37	23	-10°C/14°F	30°C/86°F	3
3/22/2024 21:37:00	21	-30°C/-22°F	40°C/104°F	2
3/22/2024 21:37:08	24	-10°C/14°F	40°C/104°F	2
3/22/2024 21:37:27	23	-20°C/-4°F	40°C/104°F	3
3/22/2024 21:37:42	31	-10°C/14°F	30°C/86°F	3
3/22/2024 21:39:50	23	-30°C/-22°F	40°C/104°F	3

What type of clothing are	What type of clothing are	What is your initial impres	How likely are you to use	Which following features c
T-Shirt/Polo Shirt	Puffer Jacket	Somewhat positive	Neutral	Portability
T-Shirt/Polo Shirt	Parkas	Very positive	Very likely	Battery life
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Very unlikely	Portability, Battery life
Sweater	Leather Jackets	Neutral	Neutral	Battery life
Shirt	Puffer Jacket	Neutral	Neutral	Adjustable temperature se
T-Shirt/Polo Shirt	Puffer Jacket	Somewhat positive	Somewhat likely	Ease of use
T-Shirt/Polo Shirt	Puffer Jacket	Very negative	Very unlikely	none
Hoodies	Windbreakers	Neutral	Somewhat likely	Portability
Shirt	Trench Coats	Neutral	Neutral	Adjustable temperature se
T-Shirt/Polo Shirt	Windbreakers	Neutral	Somewhat unlikely	Adjustable temperature se
Hoodies	Puffer Jacket	Neutral	Somewhat likely	Ease of use, Adjustable te
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Very unlikely	Adjustable temperature se
T-Shirt/Polo Shirt	Hoodies	Very positive	Very likely	Ease of use, Adjustable te
Shirt	Puffer Jacket	Neutral	Neutral	Portability
T-Shirt/Polo Shirt	Bomber Jackets	Neutral	Somewhat likely	Portability, Battery life
T-Shirt/Polo Shirt	Puffer Jacket	Very positive	Somewhat likely	Portability
Tank Tops	Leather Jackets	Somewhat positive	Somewhat likely	Adjustable temperature se
T-Shirt/Polo Shirt	Fleece Jackets	Neutral	Neutral	Portability, Ease of use, A
Crop Tops	Puffer Jacket	Neutral	Somewhat likely	Adjustable temperature se
T-Shirt/Polo Shirt	Bomber Jackets	Somewhat positive	Somewhat likely	Adjustable temperature se
Hoodies	Parkas	Neutral	Neutral	Portability, Ease of use, A
Sweater	Puffer Jacket	Neutral	Somewhat unlikely	Portability, Ease of use, A
Tank Tops	Puffer Jacket	Somewhat positive	Somewhat likely	Portability, Ease of use, A
T-Shirt/Polo Shirt	Windbreakers	Neutral	Neutral	Portability
T-Shirt/Polo Shirt	Windbreakers	Neutral	Somewhat unlikely	Portability, Ease of use, w
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Neutral	Adjustable temperature se
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Neutral	Portability, Ease of use, A
Crop Tops	Trench Coats	Neutral	Neutral	Portability

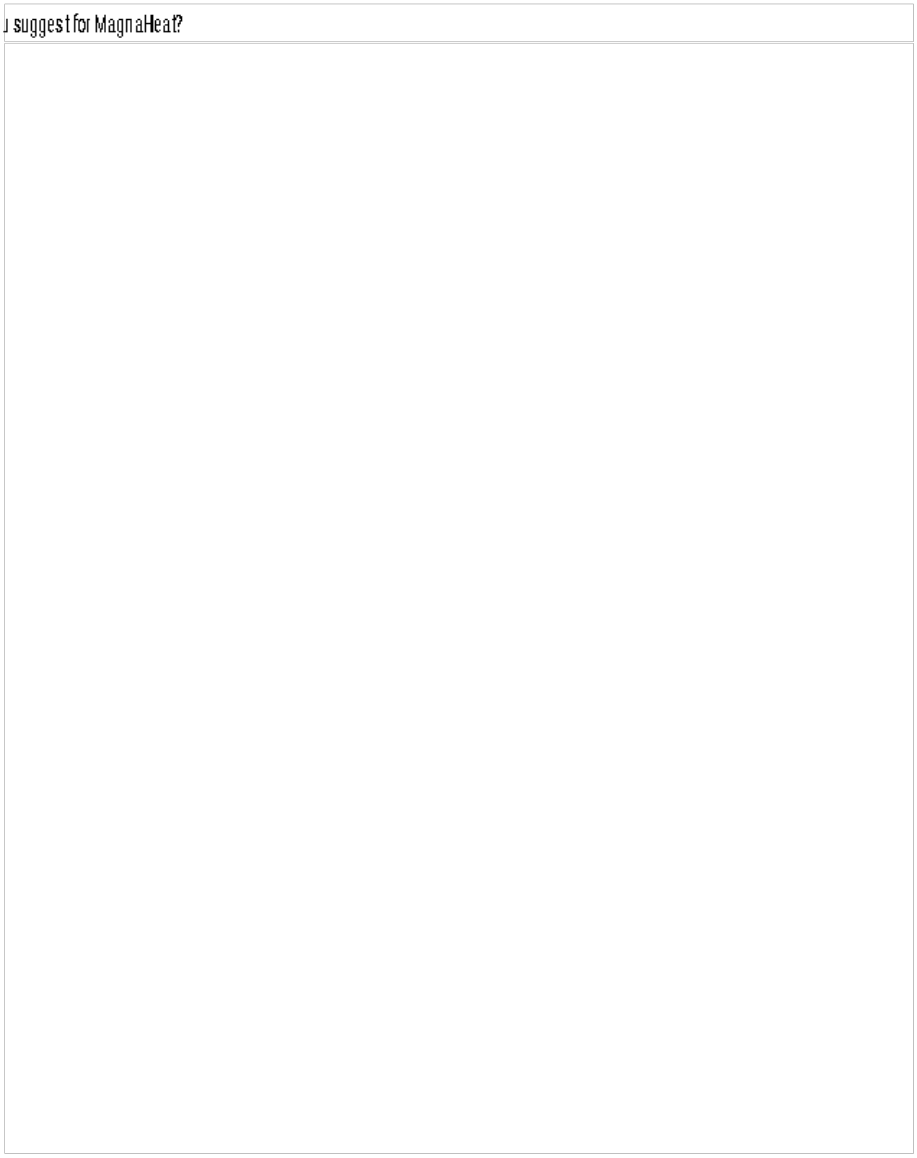
In which situations would	Do you have any concern	How much would you be v	What improvements or additional features would you
Special cases	Safety, Effectiveness, Size	$50 to $100	It might be better if it come along with a jacket
At work	Safety	Over $150	Make it portable to carry and also outside appearanc
Outdoor sports or activitie	Safety, Battery life, Effecti	$100 to $150	
Outdoor sports or activitie	Size or weight, Price	$50 to $100	
At home	Safety, Size or weight	Under $50	
Outdoor sports or activitie	Safety, Battery life, Size o	$100 to $150	
none	none	Under $50	
Outdoor sports or activitie	Safety	$50 to $100	
At work	Price	Under $50	
Outdoor sports or activitie	Safety, Battery life	$50 to $100, $100 to $150	
Outdoor sports or activitie	Safety, Size or weight, Pri	$50 to $100	
Outdoor sports or activitie	Safety	$50 to $100	
At home	Safety, Size or weight, Pri	$100 to $150	
At work	Safety, Size or weight, Pri	Under $50	Bluetooth
Commuting	Safety, Battery life, Effecti	$50 to $100	Replaceable battery
Outdoor sports or activitie	Safety	Under $50	No idea yet
Commuting, At work	Safety, Effectiveness, Pric	$50 to $100	It would be best if in some way this product could be
Outdoor sports or activitie	Safety, Battery life, Price	$50 to $100	Can be controlled on the phone
At work	Size or weight, Price	$50 to $100	size looks too big and so the weight
Outdoor sports or activitie	Safety	$100 to $150	
Outdoor sports or activitie	Safety, Battery life, Effecti	Under $50	
Outdoor sports or activitie	Safety, Battery life, Effecti	$50 to $100	
Commuting	Safety, Battery life, Effecti	Under $50	
Outdoor sports or activitie	Size or weight	$50 to $100	
Outdoor sports or activitie	Safety, Size or weight	$50 to $100	
Outdoor sports or activitie	Battery life	$50 to $100	Could have different colors and shapes, such as Dis
Outdoor sports or activitie	Safety	Under $50	
Outdoor sports or activitie	Safety, Battery life, Size o	Over $150	

u suggest for MagnaHeat?
ce after wearing it.
split into two pieces so that I could have it perfectly balanced on my body, or even carry one in a pocket or share it with my friends
ney characters, if possible.

Timestamp	Please indicate your age:	What is the lowest temper	What is the highest tempe	How many layers of clothi
3/22/2024 21:40:25	24	-20°C/-4°F	40°C/104°F	2
3/22/2024 21:40:51	22	20°C/68°F	30°C/86°F	2
3/22/2024 21:41:27	23	-10°C/14°F	40°C/104°F	3
3/22/2024 21:45:51	23	-20°C/-4°F	40°C/104°F	2
3/22/2024 21:47:17	21	-10°C/14°F	30°C/86°F	2
3/22/2024 21:47:34	21	-10°C/14°F	40°C/104°F	2
3/22/2024 21:49:41	23	-20°C/-4°F	40°C/104°F	3
3/22/2024 21:50:12	24	-30°C/-22°F	20°C/68°F	3
3/22/2024 21:50:39	23	-10°C/14°F	30°C/86°F	3
3/22/2024 21:51:45	40	10°C/50°F	40°C/104°F	2
3/22/2024 21:52:21	23	-20°C/-4°F	30°C/86°F	3
3/22/2024 21:52:36	23	-10°C/14°F	40°C/104°F	2
3/22/2024 21:53:27	35	-10°C/14°F	30°C/86°F	2
3/22/2024 21:55:13	21	-30°C/-22°F	40°C/104°F	2
3/22/2024 21:56:12	23	-20°C/-4°F	40°C/104°F	3
3/22/2024 21:56:40	23	0°C/32°F	30°C/86°F	3
3/22/2024 21:57:19	10	20°C/68°F	0°C/32°F	1
3/22/2024 22:03:15	23	-30°C/-22°F	40°C/104°F	3
3/22/2024 22:03:35	17	-20°C/-4°F	40°C/104°F	3
3/22/2024 22:03:38	23	-10°C/14°F	40°C/104°F	2
3/22/2024 22:03:52	19	-10°C/14°F	40°C/104°F	3
3/22/2024 22:05:13	29	-10°C/14°F	30°C/86°F	2
3/22/2024 22:05:31	23	-20°C/-4°F	40°C/104°F	3
3/22/2024 22:05:42	18	-10°C/14°F	10°C/50°F	2
3/22/2024 22:07:04	MEng	-20°C/-4°F	40°C/104°F	3
3/22/2024 22:08:01	24	-30°C/-22°F	0°C/32°F	1
3/22/2024 22:08:23	28	-10°C/14°F	30°C/86°F	3
3/22/2024 22:08:43	29	-10°C/14°F	40°C/104°F	2

What type of clothing are	What type of clothing are	What is your initial impres	How likely are you to use	Which following features c
Shirt	Hoodies	Neutral	Somewhat unlikely	Ease of use
Shirt	Puffer Jacket	Somewhat positive	Neutral	Ease of use
Shirt	Parkas	Somewhat negative	Neutral	Portability, Ease of use, A
Sweater	Puffer Jacket	Somewhat positive	Somewhat likely	Portability, Ease of use
Sweater	Leather Jackets	Neutral	Neutral	Portability
Shirt	Bomber Jackets	Neutral	Neutral	Portability, Adjustable tem
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Somewhat likely	Ease of use
T-Shirt/Polo Shirt	Leather Jackets	Somewhat positive	Neutral	Portability
Shirt	Puffer Jacket	Somewhat positive	Very likely	Portability, Ease of use, A
T-Shirt/Polo Shirt	Puffer Jacket	Somewhat negative	Somewhat unlikely	Portability, Adjustable tem
T-Shirt/Polo Shirt	Parkas	Neutral	Neutral	Portability, Ease of use, A
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Somewhat likely	Adjustable temperature se
T-Shirt/Polo Shirt	Puffer Jacket	Somewhat positive	Neutral	Portability
T-Shirt/Polo Shirt	Parkas	Somewhat positive	Somewhat likely	Portability
T-Shirt/Polo Shirt	Windbreakers	Somewhat positive	Somewhat likely	Portability
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Somewhat unlikely	Portability, Ease of use
Crop Tops	Bomber Jackets	Neutral	Very unlikely	Battery life
T-Shirt/Polo Shirt	Puffer Jacket	Somewhat positive	Somewhat unlikely	Ease of use, Battery life
Sweater	Puffer Jacket	Somewhat positive	Somewhat likely	Portability, Ease of use
Hoodies	Fleece Jackets	Neutral	Very unlikely	Portability
T-Shirt/Polo Shirt	Puffer Jacket	Somewhat positive	Somewhat unlikely	Adjustable temperature se
Shirt	Parkas	Neutral	Somewhat likely	Portability, Ease of use, A
Hoodies	Fleece Jackets	Somewhat positive	Neutral	Adjustable temperature se
T-Shirt/Polo Shirt	Parkas	Neutral	Somewhat likely	Battery life
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Somewhat likely	Ease of use, Adjustable te
T-Shirt/Polo Shirt	Puffer Jacket	Very positive	Very likely	Portability
Hoodies	Leather Jackets	Somewhat positive	Somewhat likely	Ease of use
Tank Tops	Puffer Jacket	Very positive	Neutral	Ease of use

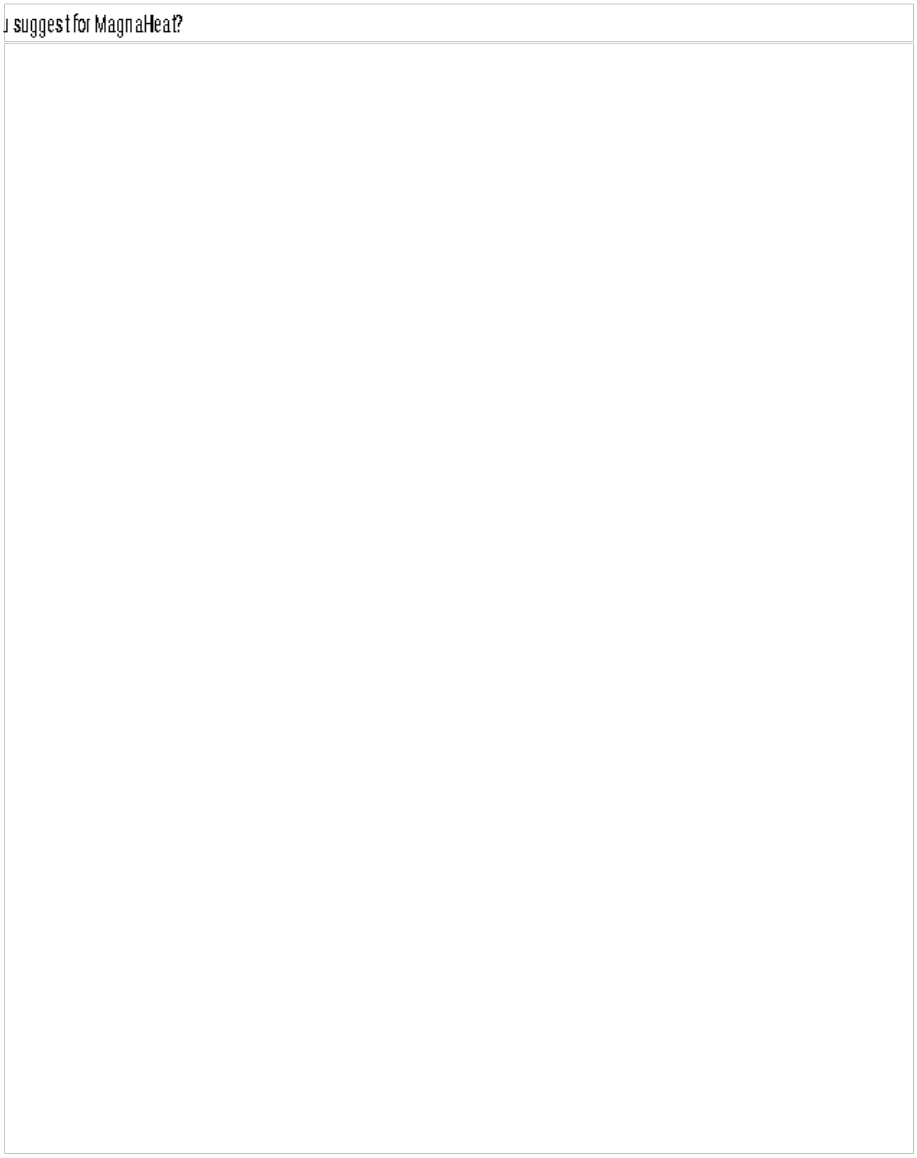
In which situations would	Do you have any concern	How much would you be v	What improvements or additional features would you
At work	Safety, Size or weight, Pri	$50 to $100	
Outdoor sports or activitie	Safety, Size or weight	$50 to $100, $100 to $150	
Commuting	Safety, Battery life, Size o	$50 to $100	
Commuting, At home	Safety, Battery life, Effecti	$50 to $100	
Outdoor sports or activitie	Battery life	$100 to $150	longer life
Outdoor sports or activitie	Safety, Battery life, Effecti	$50 to $100	
Outdoor sports or activitie	Safety, Battery life, Size o	Under $50, $50 to $100	
Outdoor sports or activitie	Safety	Under $50	
Outdoor sports or activitie	Safety, Battery life, Size o	$50 to $100	better to be light.
Outdoor sports or activitie	No concerns	Under $50	In china they have nuanbaobao and it is cheaper.
Outdoor sports or activitie	Price	$50 to $100	
Commuting	Safety, Battery life, Size o	$100 to $150	
Outdoor sports or activitie	Safety	Over $150	
Outdoor sports or activitie	Safety, Battery life, Price	$50 to $100	
At work	Safety	Under $50	
Outdoor sports or activitie	Safety, Battery life	$50 to $100	
At home	No concerns	Over $150	
Outdoor sports or activitie	Safety, Size or weight	$50 to $100	
Outdoor sports or activitie	Safety, Effectiveness, Size	$50 to $100	
Outdoor sports or activitie	Safety	$50 to $100	
Outdoor sports or activitie	Battery life, Size or weigh	$50 to $100	
Outdoor sports or activitie	Safety, Effectiveness, Size	Under $50, $50 to $100	
Commuting, At work	Battery life, Size or weigh	$100 to $150	
Outdoor sports or activitie	Battery life	Under $50	
Outdoor sports or activitie	Safety, Effectiveness	$50 to $100	
Outdoor sports or activitie	Safety	Under $50	
Outdoor sports or activitie	Battery life, Size or weigh	$50 to $100	no
Outdoor sports or activitie	Safety, Effectiveness, Size	Under $50	


suggest for MagnaHeat?

Timestamp	Please indicate your age:	What is the lowest temper	What is the highest tempe	How many layers of clothi
3/22/2024 22:08:45	24	-10°C/14°F	40°C/104°F	2
3/22/2024 22:08:50	21	-20°C/-4°F	30°C/86°F	2
3/22/2024 22:09:28	23	-10°C/14°F	40°C/104°F	4
3/22/2024 22:10:23	46	-30°C/-22°F	30°C/86°F	3
3/22/2024 22:11:21	23	-10°C/14°F	40°C/104°F	3
3/22/2024 22:12:43	22	-10°C/14°F	40°C/104°F	3
3/22/2024 22:13:29	25	-20°C/-4°F	40°C/104°F	3
3/22/2024 22:14:18	23	-20°C/-4°F	30°C/86°F	3
3/22/2024 22:16:22	34	-10°C/14°F	40°C/104°F	3
3/22/2024 22:17:34	22	-20°C/-4°F	20°C/68°F	2
3/22/2024 22:17:40	24	-20°C/-4°F	40°C/104°F	3
3/22/2024 22:20:08	zhaoyafen0423@gmail.cc	-20°C/-4°F	40°C/104°F	2
3/22/2024 22:20:13	23	-10°C/14°F	40°C/104°F	2
3/22/2024 22:20:40	47	-20°C/-4°F	30°C/86°F	1
3/22/2024 22:21:21	23	-30°C/-22°F	50°C/122°F	2
3/22/2024 22:21:32	25	-20°C/-4°F	40°C/104°F	3
3/22/2024 22:22:33	32	0°C/32°F	40°C/104°F	2
3/22/2024 22:24:15	19	-10°C/14°F	40°C/104°F	3
3/22/2024 22:28:07	21	-10°C/14°F	30°C/86°F	3
3/22/2024 22:28:34	24	-10°C/14°F	30°C/86°F	2
3/22/2024 22:31:41	36	-20°C/-4°F	40°C/104°F	2
3/22/2024 22:34:21	27	-10°C/14°F	30°C/86°F	2
3/22/2024 22:37:50	24	-10°C/14°F	30°C/86°F	2
3/22/2024 22:37:55	26	-10°C/14°F	40°C/104°F	2
3/22/2024 22:39:47	22	-10°C/14°F	40°C/104°F	4
3/22/2024 22:40:56	30	-10°C/14°F	30°C/86°F	3
3/22/2024 22:41:15	30	-10°C/14°F	40°C/104°F	3
3/22/2024 22:41:52	25	-10°C/14°F	40°C/104°F	3

What type of clothing are	What type of clothing are	What is your initial impres	How likely are you to use	Which following features c
Hoodies	Puffer Jacket	Somewhat positive	Neutral	Portability, Ease of use, A
Sweater	Bomber Jackets	Somewhat positive	Somewhat likely	Ease of use
Sweater	Puffer Jacket	Neutral	Neutral	Battery life
Sweater	Puffer Jacket	Neutral	Neutral	Ease of use
Sweater	Leather Jackets	Somewhat positive	Somewhat likely	Ease of use
Sweater	Puffer Jacket	Somewhat positive	Neutral	Ease of use, Battery life
T-Shirt/Polo Shirt	Windbreakers	Neutral	Somewhat unlikely	Adjustable temperature se
T-Shirt/Polo Shirt	Parkas	Neutral	Very unlikely	Portability, Adjustable ter
T-Shirt/Polo Shirt	Puffer Jacket	Very positive	Very likely	Portability
Hoodies	Puffer Jacket	Neutral	Somewhat likely	Portability, Ease of use, A
Tank Tops	Puffer Jacket	Neutral	Very unlikely	Portability, Ease of use, A
Hoodies	Puffer Jacket	Neutral	Somewhat unlikely	Portability
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Very unlikely	Adjustable temperature se
Hoodies	Puffer Jacket	Neutral	Neutral	Ease of use
T-Shirt/Polo Shirt	Puffer Jacket	Very positive	Very likely	Adjustable temperature se
Tank Tops	Puffer Jacket	Neutral	Somewhat unlikely	Ease of use, Adjustable te
T-Shirt/Polo Shirt	Trench Coats	Neutral	Somewhat likely	Portability, Ease of use, A
T-Shirt/Polo Shirt	Puffer Jacket	Very positive	Somewhat likely	Ease of use
Sweater	Puffer Jacket	Somewhat negative	Somewhat unlikely	Adjustable temperature se
Sweater	Fleece Jackets	Neutral	Neutral	Portability, Ease of use, A
Shirt	Puffer Jacket	Neutral	Neutral	Portability, Ease of use, A
T-Shirt/Polo Shirt	Windbreakers	Neutral	Neutral	Portability
Hoodies	Windbreakers	Neutral	Very unlikely	Adjustable temperature se
Hoodies	Windbreakers	Somewhat positive	Very likely	Portability, Ease of use, A
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Somewhat unlikely	Adjustable temperature se
Hoodies	Parkas	Very positive	Neutral	Ease of use
Hoodies	Puffer Jacket	Neutral	Neutral	Portability, Ease of use, A
Shirt	Trench Coats	Somewhat positive	Somewhat unlikely	Portability

In which situations would	Do you have any concern	How much would you be v	What improvements or additional features would you
Outdoor sports or activitie	Safety, Battery life, Size o	Under $50	
Outdoor sports or activitie	Size or weight	Under $50	
Outdoor sports or activitie	Battery life, Size or weigh	$50 to $100, $100 to $15	NA
Commuting	Safety, Battery life	Under $50	
Outdoor sports or activitie	Safety, Size or weight, Pri	Under $50	
Outdoor sports or activitie	Safety, Battery life, Size o	$50 to $100	
Outdoor sports or activitie	Battery life	Under $50	
Outdoor sports or activitie	Safety, Battery life, Size o	Under $50	
Outdoor sports or activitie	Safety, Battery life, Size o	Under $50	
Outdoor sports or activitie	Effectiveness, Size or wei	$50 to $100, $100 to $150	
Outdoor sports or activitie	Safety, Effectiveness, Size	Under $50	
Outdoor sports or activitie	Safety	Under $50	
Outdoor sports or activitie	Safety, Size or weight	$50 to $100, $100 to $150	
Commuting	Size or weight	Under $50	
Outdoor sports or activitie	Safety	Over $150	
Outdoor sports or activitie	Safety, Size or weight, Pri	Under $50	
Outdoor sports or activitie	Price	Over $150	
Commuting	Safety	Under $50, Over $150	
Commuting	Safety, Effectiveness	$50 to $100	
Outdoor sports or activitie	Safety, Size or weight	$50 to $100	
Outdoor sports or activitie	Safety, Battery life, Effecti	$50 to $100	
Outdoor sports or activitie	Safety	Under $50	
At home	Safety	Under $50	
Outdoor sports or activitie	Safety, Battery life, Size o	Under $50	
At work	Safety, Effectiveness	Over $150	
Outdoor sports or activitie	Effectiveness	Under $50	
Commuting	Safety, Size or weight, Pri	Under $50	Weight, easy to put on and take off
Commuting	Safety	Under $50	


suggest for MagnaHeat?

Timestamp	Please indicate your age:	What is the lowest temper	What is the highest tempe	How many layers of clothi
3/22/2024 22:42:19	19	-10°C/14°F	30°C/86°F	2
3/22/2024 22:42:38	35	-30°C/-22°F	40°C/104°F	3
3/22/2024 22:43:44	21	-10°C/14°F	30°C/86°F	2
3/22/2024 22:46:12	23	-20°C/-4°F	40°C/104°F	3
3/22/2024 22:47:57	26	0°C/32°F	40°C/104°F	3
3/22/2024 22:49:04	23	-20°C/-4°F	30°C/86°F	2
3/22/2024 22:52:35	22	-20°C/-4°F	40°C/104°F	3
3/22/2024 23:06:13	23	-10°C/14°F	40°C/104°F	4
3/22/2024 23:06:40	22	0°C/32°F	20°C/68°F	2
3/22/2024 23:08:39	23	-20°C/-4°F	40°C/104°F	3
3/22/2024 23:15:59	50	-10°C/14°F	30°C/86°F	3
3/22/2024 23:16:39	Stan Tang	-10°C/14°F	30°C/86°F	3
3/22/2024 23:22:07	31	-30°C/-22°F	40°C/104°F	4
3/22/2024 23:28:36	24	-10°C/14°F	30°C/86°F	3
3/22/2024 23:33:04	25	-20°C/-4°F	40°C/104°F	3
3/22/2024 23:33:45	22	10°C/50°F	40°C/104°F	2
3/22/2024 23:36:49	1	-20°C/-4°F	40°C/104°F	3
3/22/2024 23:41:25	24	-10°C/14°F	40°C/104°F	3
3/23/2024 0:01:55	23	0°C/32°F	30°C/86°F	3
3/23/2024 0:07:28	33	-10°C/14°F	30°C/86°F	2
3/23/2024 0:11:34	23	-10°C/14°F	30°C/86°F	3
3/23/2024 0:17:19	23	-20°C/-4°F	30°C/86°F	3
3/23/2024 0:26:13	25	-20°C/-4°F	40°C/104°F	2
3/23/2024 0:30:29	30	-10°C/14°F	30°C/86°F	2
3/23/2024 0:49:47	23	-10°C/14°F	40°C/104°F	2
3/23/2024 1:37:41	24	-10°C/14°F	30°C/86°F	3
3/23/2024 1:56:02	21	-20°C/-4°F	40°C/104°F	3
3/23/2024 2:05:41	34	-10°C/14°F	30°C/86°F	2

What type of clothing are	What type of clothing are	What is your initial impres	How likely are you to use	Which following features c
Sweater	Puffer Jacket	Somewhat positive	Somewhat likely	Portability, Adjustable tem
Sweater	Wool coat	Neutral	Somewhat unlikely	Portability, Ease of use, A
T-Shirt/Polo Shirt	Trench Coats	Neutral	Somewhat unlikely	Ease of use
Hoodies	Puffer Jacket	Neutral	Neutral	Ease of use
T-Shirt/Polo Shirt	Parkas	Neutral	Neutral	Adjustable temperature se
Hoodies	Denim Jackets	Very positive	Neutral	Portability, Ease of use
Shirt	Puffer Jacket	Neutral	Somewhat likely	Adjustable temperature se
Tank Tops	Puffer Jacket	Very positive	Very likely	Portability
sweatershirt	Parkas	Neutral	Very likely	Adjustable temperature se
Shirt	Parkas	Somewhat positive	Neutral	Adjustable temperature se
Sweater	Fleece Jackets	Neutral	Somewhat likely	Adjustable temperature se
Sweater	Trench Coats	Neutral	Neutral	Ease of use
T-Shirt/Polo Shirt	Puffer Jacket	Somewhat negative	Somewhat unlikely	Adjustable temperature se
T-Shirt/Polo Shirt	Leather Jackets	Very positive	Neutral	Portability, Ease of use, A
Shirt	Puffer Jacket	Neutral	Somewhat unlikely	Adjustable temperature se
T-Shirt/Polo Shirt	Hoodies	Neutral	Neutral	Portability, Ease of use, A
Hoodies	Puffer Jacket	Somewhat negative	Somewhat unlikely	Portability
T-Shirt/Polo Shirt	Parkas	Neutral	Neutral	Portability, Ease of use, A
Crop Tops	Down Jacket	Somewhat positive	Somewhat likely	Ease of use, Adjustable te
Sweater	Fleece Jackets	Somewhat positive	Somewhat likely	Portability, Ease of use, A
Tank Tops	Puffer Jacket	Somewhat positive	Neutral	Adjustable temperature se
T-Shirt/Polo Shirt	Windbreakers	Somewhat positive	Neutral	Ease of use, Adjustable te
Hoodies	Puffer Jacket	Somewhat positive	Neutral	Portability, Battery life
T-Shirt/Polo Shirt	Puffer Jacket	Very positive	Neutral	Portability,
Hoodies	Puffer Jacket	Neutral	Neutral	Adjustable temperature se
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Somewhat likely	Portability, Ease of use
T-Shirt/Polo Shirt	Bomber Jackets	Very positive	Somewhat likely	Portability, Ease of use
Hoodies	Puffer Jacket	Somewhat positive	Very unlikely	Portability, Ease of use

In which situations would	Do you have any concern	How much would you be v	What improvements or additional features would you
Outdoor sports or activitie	Safety, Battery life, Size o	$50 to $100	none
Outdoor sports or activitie	Size or weight, Price	Under $50, $50 to $100	The size of the product looks too big
At work	Size or weight	$50 to $100	
Commuting	Safety	$50 to $100, $100 to $150	
Only standing outside	Too hot	$100 to $150	
Outdoor sports or activitie	Safety, Effectiveness, Pric	$50 to $100, $100 to $150	
Outdoor sports or activitie	Battery life, Effectiveness	$50 to $100	
Outdoor sports or activitie	Size or weight	Under $50	no
Outdoor sports or activitie	Battery life, Size or weigh	Under $50, $50 to $100	
Outdoor sports or activitie	Safety, Battery life, Effecti	Under $50	Under most circumstances my body won't feel cold.
Outdoor sports or activitie	Safety	Under $50	
Commuting	Safety	$50 to $100	
Outdoor sports or activitie	Safety, Effectiveness, Size	$100 to $150	
Outdoor sports or activitie	Safety, Battery life, Size o	$50 to $100	
Outdoor sports or activitie	Safety, Battery life, Effecti	$50 to $100	
Outdoor sports or activitie	No concerns	Under $50	
Outdoor sports or activitie	Safety, Battery life	$100 to $150	
At work	Safety, Price	$50 to $100	
Outdoor sports or activitie	Safety, Size or weight	$100 to $150, Over $150	
Outdoor sports or activitie	Safety, Battery life, Size o	$50 to $100	
Commuting	Safety, Battery life, Size o	$50 to $100	
Outdoor sports or activitie	Safety, Size or weight	$50 to $100	
Outdoor sports or activitie	Safety, Size or weight	$100 to $150	
Outdoor sports or activitie	Safety	$50 to $100	
At home	Safety, Battery life	$50 to $100	
Outdoor sports or activitie	Price	$50 to $100	
Outdoor sports or activitie	Safety, Battery life, Size o	$50 to $100, $100 to $150, Over $150	
Outdoor sports or activitie	Safety, Effectiveness, Size	$50 to $100	

ı suggest for MagnaHeat?
But my legs and hands will.

Timestamp	Please indicate your age:	What is the lowest temper	What is the highest tempe	How many layers of clothi
3/23/2024 2:06:44	23	-20°C/-4°F	40°C/104°F	3
3/23/2024 2:16:41	24	-30°C/-22°F	30°C/86°F	2
3/23/2024 2:22:04	22	-10°C/14°F	40°C/104°F	2
3/23/2024 2:54:36	20	-20°C/-4°F	20°C/68°F	4
3/23/2024 3:28:04	23	-20°C/-4°F	40°C/104°F	3
3/23/2024 3:42:04	33	-30°C/-22°F	40°C/104°F	5+
3/23/2024 3:57:55	22	-20°C/-4°F	40°C/104°F	3
3/23/2024 7:09:43	23	10°C/50°F	30°C/86°F	3
3/23/2024 9:50:47	22	-30°C/-22°F	30°C/86°F	3
3/23/2024 10:07:56	45	0°C/32°F	40°C/104°F	2
3/23/2024 10:10:43	22	-20°C/-4°F	50°C/122°F	3
3/23/2024 11:58:15	23	-10°C/14°F	40°C/104°F	3
3/23/2024 13:54:13	23	-10°C/14°F	30°C/86°F	2
3/23/2024 14:05:56	52	-30°C/-22°F	40°C/104°F	3
3/23/2024 14:23:58	28	-10°C/14°F	40°C/104°F	3
3/23/2024 14:40:29	53	-30°C/-22°F	40°C/104°F	3
3/23/2024 14:45:27	24	-20°C/-4°F	30°C/86°F	3
3/23/2024 16:10:18	24	-30°C/-22°F	40°C/104°F	3
3/23/2024 19:14:15	24	-10°C/14°F	30°C/86°F	3
3/23/2024 22:04:31	24	-20°C/-4°F	40°C/104°F	3
3/24/2024 0:23:05	22	-10°C/14°F	20°C/68°F	3
3/24/2024 21:15:01	20	0°C/32°F	40°C/104°F	5+
3/24/2024 22:25:54	23	-10°C/14°F	40°C/104°F	2
3/25/2024 14:19:12	19	-30°C/-22°F	40°C/104°F	2
3/26/2024 17:45:35	25	-30°C/-22°F	20°C/68°F	4
3/27/2024 0:02:33	21	-10°C/14°F	30°C/86°F	4

What type of clothing are	What type of clothing are	What is your initial impres	How likely are you to use	Which following features
Crop Tops	Puffer Jacket	Very positive	Neutral	Adjustable temperature se
T-Shirt/Polo Shirt	Hunting Jacket	Somewhat negative	Very unlikely	Adjustable temperature se
T-Shirt/Polo Shirt	Hoodies	Neutral	Somewhat unlikely	No opinion
Shirt	Leather Jackets	Neutral	Neutral	Adjustable temperature se
T-Shirt/Polo Shirt	Fleece Jackets	Somewhat positive	Somewhat likely	Portability, Adjustable tem
Sweater	Hoodies	Very positive	Very likely	Portability, Ease of use, A
T-Shirt/Polo Shirt	Puffer Jacket	Somewhat positive	Somewhat likely	Ease of use
Sweater	Puffer Jacket	Very positive	Very likely	Portability, Ease of use, A
Shirt	Leather Jackets	Somewhat positive	Somewhat likely	Portability, Adjustable tem
T-Shirt/Polo Shirt	Windbreakers	Neutral	Neutral	Portability
Sweater	Puffer Jacket	Somewhat positive	Somewhat likely	Ease of use
Shirt	Puffer Jacket	Very positive	Very likely	Portability
T-Shirt/Polo Shirt	Leather Jackets	Neutral	Neutral	Portability, Battery life
Tank Tops	Puffer Jacket	Very positive	Very likely	Ease of use, Adjustable te
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Somewhat likely	Adjustable temperature se
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Neutral	Ease of use, Adjustable te
T-Shirt/Polo Shirt	Puffer Jacket	Neutral	Somewhat unlikely	Portability, Adjustable tem
T-Shirt/Polo Shirt	Trench Coats	Somewhat positive	Somewhat likely	Ease of use
T-Shirt/Polo Shirt	Hoodies	Somewhat negative	Somewhat likely	Ease of use, Adjustable te
Sweater	Puffer Jacket	Somewhat positive	Neutral	Portability, Battery life
Shirt	Puffer Jacket	Very positive	Very likely	Portability, Ease of use, A
Tank Tops	Windbreakers	Very positive	Very likely	Ease of use, Adjustable te
Hoodies	Windbreakers	Neutral	Very unlikely	Ease of use, Adjustable te
Sweater	Denim Jackets	Somewhat positive	Neutral	Ease of use
Hoodies	Fleece Jackets	Very positive	Neutral	Ease of use, Adjustable te
Crop Tops	Parkas	Somewhat positive	Somewhat likely	Portability, Ease of use, B

In which situations would	Do you have any concern	How much would you be v	What improvements or additional features would you
Outdoor sports or activitie	Safety, Battery life, Effecti	Under $50, $50 to $100	The box might make people feel uncomfortable while
At work	Safety, Battery life, Effecti	Under $50	Nothing beats a hunting jacket even in extreme wea
I don't wear much during	No concerns	Under $50	
At work	Size or weight	$100 to $150	
Commuting	Safety, Effectiveness, Sizı	$50 to $100	It's important to me that it would not look bulky and a
Outdoor sports or activitie	Safety, Battery life, Effecti	Over $150	
Outdoor sports or activitie	Battery life, Size or weigh	Over $150	
Outdoor sports or activitie	Battery life, Price	$50 to $100	
Outdoor sports or activitie	Safety, Effectiveness, Sizı	$100 to $150	
Commuting, At work, At h	No concerns	$50 to $100	
Commuting	Effectiveness, Size or wei	Under $50	
Outdoor sports or activitie	Safety, Battery life, Size o	Under $50	
Outdoor sports or activitie	Safety, Price	Under $50	
Commuting, At home	Safety, Battery life, Effecti	$50 to $100	
Outdoor sports or activitie	Safety	$100 to $150	
Commuting, At home	Safety, Battery life, Effecti	Under $50	
Commuting	Safety, Battery life, Size o	$50 to $100	
Outdoor sports or activitie	Battery life	$50 to $100	
Outdoor sports or activitie	Safety, Battery life, Effecti	$50 to $100	
Outdoor sports or activitie	Size or weight	Under $50	
Commuting	Safety, Size or weight, Pri	$50 to $100	
Commuting	Battery life, Effectiveness,	Under $50	None, but when advertising it would be more impres
Outdoor sports or activitie	Safety, Size or weight, Pri	$50 to $100	
At home	Safety, Battery life, Price	$50 to $100	rapid temperature control
Commuting, At work	Safety, Price	$50 to $100	
Commuting	Size or weight, Price	Under $50, $50 to $100	Less noise

u suggest for MagnaHeat?

e wearing it. what about the legs and feet when they get cold. I feel poeple would not like the mix feeling of warm top body and cold
thers. It's what they're designed for, wind proof and waterproof and sustain heat. This device is just unnecessary for any weather. I w

wkward. If it works well and fast, and is sleek but not too heavy then that's great!

sive to see some experiment result!

17.6 LOGO Options

HUBBLE


hubble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