Study Bearbot

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***Abstract*— Studying can be overwhelming, especially for individuals prone to stress or short attention spans. To enhance focus and well-being, we introduce Study Bearbot, an interactive desktop companion designed to reduce stress while maintaining productivity. Study Bearbot integrates fidget-friendly components, a soft squeezable exterior, optional soothing music, and a built-in scent diffuser. Research indicates that music listening for relaxation is related to lower subjective stress levels [1], and tactile stimulation has been shown to effectively moderate stress and relax users [2]. By providing a multisensory experience, Study Bearbot aims to create a calming environment that enhances study efficiency and promotes well-being.**

***Index Terms*—Aromatherapy, BearBot, design, fidget, human-robot interaction, robot, sensor, study companion, stress reduction, user interface**

I. Introduction

College students today face unprecedented levels of stress and pressure. Research indicates that nearly half of American college students report experiencing "more than average stress," with an additional third reporting "average stress" levels [3]. This chronic stress not only impacts academic performance but also affects overall well-being and mental health. The challenge of balancing multiple classes, assignments, studying for exams, and maintaining personal responsibilities creates an environment where effective study tools become essential rather than optional.

The Study Bearbot addresses this need by serving as an interactive desktop companion designed specifically to enhance the studying experience while reducing stress. Unlike conventional study aids that focus primarily on organizational tools, Study Bearbot integrates multiple sensory features to create a holistic study environment that promotes both focus and relaxation. Research has shown that aromatherapy can improve sleep quality by 46% and overall quality of life by 39.7% [7], highlighting its effectiveness in stress reduction. By incorporating a built-in scent diffuser alongside tactile fidgeting elements and sound therapy, Study Bearbot leverages scientifically supported interventions to create a calming and productive study atmosphere. The device combines physical and digital elements to help users maintain attention spans, manage study sessions, and incorporate healthy breaks.

Our target audience consists of students aged 13 and older who struggle with task focus, experience study-related stress, and respond positively to interactive companions. By addressing both the psychological and practical aspects of studying, Study Bearbot fills a gap in existing educational technology tools that often neglect the emotional components of effective learning.

Current market alternatives such as Eilik [4] (an emotionally intelligent robot companion) and Miko [5] (an AI-powered robot) primarily focus on general companionship or entertainment rather than study-specific functionality. While these devices employ advanced AI to simulate social interaction, Study Bearbot takes a more practical approach by combining tactile fidgeting elements, aromatherapy, sound therapy, and time management tools specifically designed to create an optimal study environment. Furthermore, unlike AI-dependent companions, Study Bearbot focuses on physical, sensory interventions that have been empirically shown to reduce stress, which may aid in creating a conducive learning environment [6].

The primary goals of this project are to: (1) create a portable, user-friendly study companion that effectively reduces study-related stress; (2) incorporate evidence-based features that enhance focus and study session effectiveness; and (3) provide an accessible alternative to complex AI-based companions that maintains functionality without requiring continuous internet connectivity or extensive computing power.

II. Use-Case Requirements

Based on our understanding of students' needs and existing study aid technology, we've established that the Study Bearbot is required to: (1) have a response time of at most 500 milliseconds to ensure immediate feedback during interaction, (2) have the scent diffusion last for approximately one hour per study session, with a minimized refill interval rate of 30 minutes during continuous use, (3) have a battery life of 2 hours to support users throughout the typical length of a study session without requiring recharging, (4) have silicon skin and gel components to create the soft and squeezable exterior for tactile comfort, and (5) have a weight less than 2 lbs to allow for easy portability. These requirements are derived from user research, competitive analysis, and established best practices in human-computer interaction. They provide the foundation for our design decisions and will serve as benchmarks for testing and validation.

III. Architecture and/or Principle of Operation

The architecture of the Bearbot system is illustrated in a comprehensive block diagram (Fig. 1), with all processing managed through the Arduino Nano Connect RP2040. The hardware components within the system include inputs, a power supply, and various outputs. The software component consists of a web application that facilitates user interaction via a browser.

The interactive inputs to the system comprises four buttons, a rotary encoder, and switches. The buttons are utilized for mode selection and menu navigation, the left switch powers the humidifier module, and the rotary encoder adjusts the speaker volume.

The output components include an OLED screen, a diffuser, and an LED. These elements collectively contribute to Bearbot's expressive personality through dynamic facial expressions and arm movements. Furthermore, they enhance the user experience by fostering a calming study environment with soothing music, scent diffusion, and a night light feature.

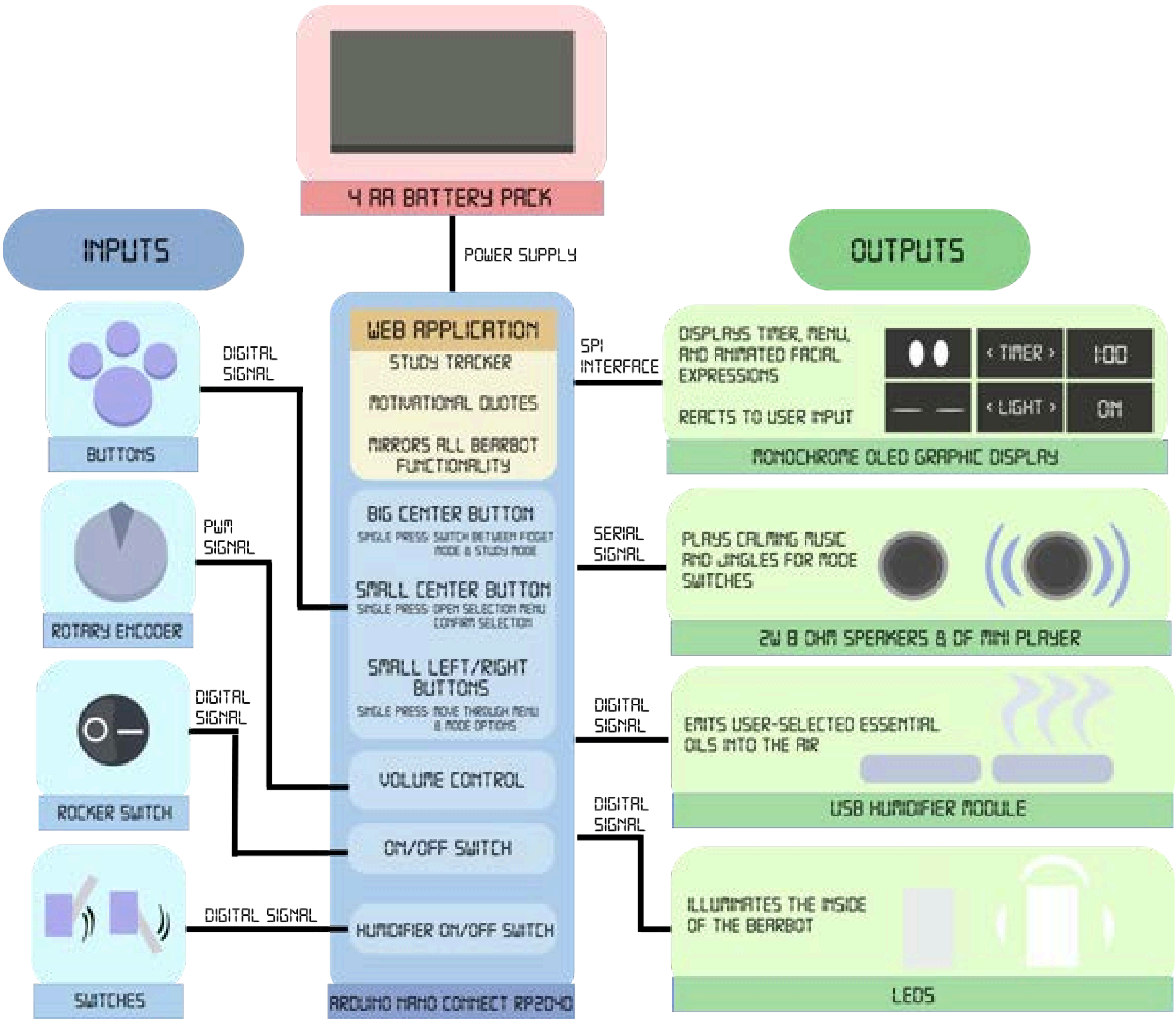

Fig. 1. The full block diagram of the Bearbot system.

IV. Design Requirements

The Study Bearbot must adhere to specific design requirements to effectively meet the use-case needs outlined earlier. Each subsystem within the robot must be engineered to ensure optimal functionality, performance, and user experience. The following sections elaborate on key design constraints and their implications.

One of the primary considerations in designing the Study Bearbot is power management. To maintain portability and user convenience, the device must function independently of a power outlet. This eliminates the need for a continuous power connection, allowing students to use the Bearbot in various study environments. A plug-in power source would be impractical for users who require available outlets for laptops or other essential devices. Thus, the Bearbot is designed to run on battery power, ensuring uninterrupted operation during study sessions. Battery life is also a critical design requirement. Study sessions typically last around two hours, so the Bearbot must maintain power for at least this duration. Given the estimated power consumption of the system, including its microcontroller, sensors, and diffusion module, a battery solution capable of sustaining a minimum of two hours of continuous use is essential. The selected battery configuration must also balance capacity with size and weight constraints, ensuring a compact and ergonomic design.

The essential oil diffusion system is another key design element of the Bearbot. The compartment housing the essential oil and water mixture must have sufficient volume to sustain diffusion for the entirety of a study session. This is driven by the requirement that the user should only need to refill the Bearbot once per session. To meet this requirement, the fluid reservoir must be designed to support at least one hour of continuous diffusion. Given standard diffusion rates, a compartment capable of holding at least 4 ounces (approximately 120 mL) of liquid will be necessary. Additionally, the positioning and sealing of this compartment must prioritize safety to prevent leakage or spills that could damage internal electronics or pose a hazard to the user.

The Study Bearbot must offer seamless interactivity to enhance the user experience. A crucial performance metric is the reaction time of the device, which directly influences its ability to engage with the user in real-time. The responsiveness of the OLED screen and microcontroller must be within an acceptable threshold to ensure an intuitive and fluid interaction.To achieve this, the selected microcontroller and display system must communicate efficiently, with a response time of no more than 500 milliseconds. This ensures that user inputs and commands are processed and displayed almost instantaneously. The chosen microcontroller must support rapid processing speeds and reliable connectivity with the display and other system components to maintain this standard.

By defining these quantitative and qualitative design requirements, the Study Bearbot is structured to meet the intended use-case specifications effectively. The power system guarantees portability and reliability, the diffusion system ensures adequate operation time with safety considerations, and the responsive microcontroller enhances user interactivity. These design decisions collectively ensure that the Bearbot delivers an optimized study companion experience.

V. Design Trade Studies

Selecting the appropriate microcontroller is crucial to ensuring the Bearbot meets its use-case requirements, particularly in terms of processing capability, power consumption, and ease of integration with peripheral devices. The primary candidates for this project were the Raspberry Pi 4 and an Arduino microcontroller.

A. Microcontroller Selection

With a Serial Peripheral Interface (SPI), the Arduino Nano Connect RP2040 and the OLED screen can communicate at rates between 10MBPs to 20MBPs. Furthermore, the Nano can achieve reaction times on the order of milliseconds, making it highly responsive for real-time applications. We originally planned to select the Raspberry Pi 4 8GB as our controller for the Bearbot, but more challenges were encountered while learning how to utilize the Raspberry Pi instead of the Nano Connect. In addition, the Nano that was chosen has a Raspberry Pi module embedded, which still allows us to connect with the internet and still has a low response time.

- Raspberry Pi 4: More powerful, better suited for web-based applications, but higher power consumption.
- Arduino: Lower power consumption and familiar, simpler architecture, but limited libraries for OLED and network connectivity.

Using the Arduino Nano Connect RP2040 allows us to stick with the familiarity of the Arduino interface while utilizing the internet connectivity of the Raspberry Pi.

B. Material Fabrication

The choice of material for Bearbot's exterior is essential for balancing durability, light diffusion, and ease of manufacturing. Two main materials were considered: resin and plastic.

- Resin: More robust, provides better diffusion for internal lighting, and protects internal components better.
- Plastic: Lower cost and quicker production but inferior in durability and light diffusion.

Since Bearbot is intended to be visually appealing and durable, resin was chosen despite its higher cost, but time constraints and the size of the robot led us to fabricating the body out of clear plastic instead.

C. Diffuser Model Design

At the top of Bearbot is a cylindrical indentation designed to hold essential oils and water for diffusion (Fig 1). The size of the cylinder directly impacts how long the device can diffuse before needing a refill. The design requirement states that at least 4 ounces (118 mL) of liquid is necessary for 1 hour of diffusion. Using the formula for the volume of a cylinder:

$$V = \pi r^2 h$$

With a chosen radius of 4 cm and a height of 3 cm:

$$V = \pi(4)^2(3) = 150\, cm^3 \approx 5.07\, ounces$$

This volume exceeds the use-case requirement, ensuring sufficient runtime. The humidifier connection is placed at the base of the cylinder to prevent spills from reaching internal components.

D. Power Supply Considerations

To ensure ease of replacement and accessibility, the Bearbot uses AA batteries. The number of batteries and their capacity were evaluated based on the Raspberry Pi 4's power consumption.

Given:

- Each AA battery = 1.5V, 2000mAh
- Using 4 AA batteries: 6V total
- Raspberry Pi 4 consumes 5W (moderate load)

$$\frac{2000\, mAh \times 4 \times 6V}{5W} = 9.6\, hours$$

This far exceeds the requirement of 2 hours. A voltage regulator is implemented to ensure stable voltage output without damaging the Raspberry Pi.

Even though the Raspberry Pi 4 was swapped out for the Arduino Nano Connect RP2040, since the chip still has a Raspberry Pi module, the power consumption equation is still applicable to the newly selected chip.

- Rechargeable Li-ion pack: Longer battery life but less accessible and harder to replace.
- AA batteries: Easily replaceable, commonly available, but shorter runtime per charge.

Since Bearbot prioritizes ease of use, AA batteries were selected despite the need for more frequent replacements.

The design trade studies demonstrate that by prioritizing performance, durability, and ease of use, the Bearbot effectively meets its use-case requirements. The Arduino Nano Connect RP2040 was chosen for its superior software capabilities, plastic for quicker production and lower cost, a 5-ounce diffuser volume to ensure sufficient runtime, and AA batteries for user convenience.

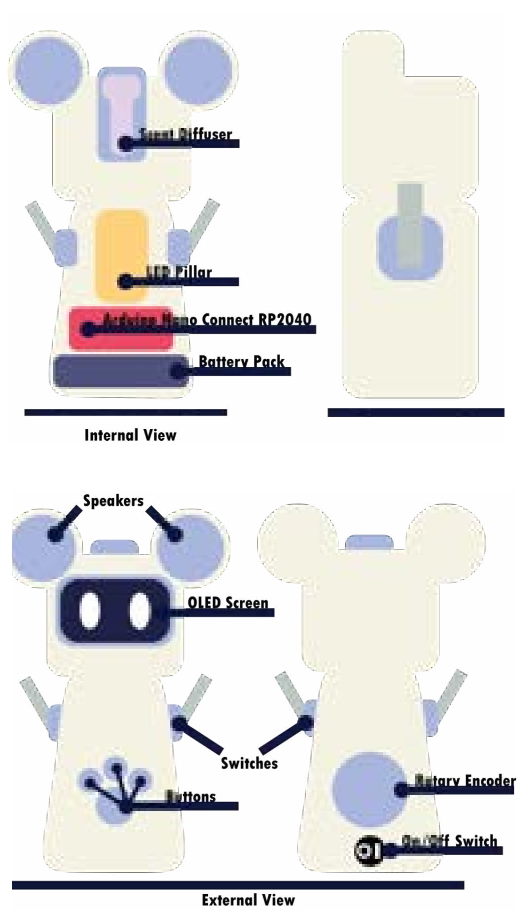

Fig. 2. (a) Internal view and **(b) External view** of the Bearbot in a 2D high-level schematic, illustrating key components including sensors, actuators, and electronic modules.

VI. System Implementation

This section details the implementation of both hardware and software components of the Study Bearbot and its constitutive subsystems. The implementation builds upon the architectural design outlined in Section III, providing specific details about components, connections, and programming approaches.

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A. Hardware subsystem

a) Power Management

The central processing unit of the Study Bearbot is an Arduino Nano Connect RP2040, which offers built-in Wi-Fi and sufficient performance for controlling all onboard peripherals. It is mounted in the central body of the Bearbot as shown in Figure 2a (internal view). Power is supplied by a 4-AA battery pack (LAMPVPATH 4AA-2PC) providing 6V, which is regulated to 5V using a Step-Up/Step-Down Voltage Regulator (Pololu 2572) to ensure stable operation. A Mini Rocker Switch (MXRS B07L9JWVVR), located on the back of the Bearbot, is used for power control. This configuration reliably powers Bearbot for over 5 hours, exceeding our 2-hour requirement while maintaining portability.

b) Control Components

Bearbot features four tactile buttons embedded in a paw-pad layout for navigating the user interface. A 30mm translucent arcade large button (Adafruit 476) is mounted on the Bearbot's front center area, used for toggling between study and fidget mode. There are three smaller buttons, positioned above the large button, to be used for menu navigation. The left and right buttons are used for menu navigation, while the middle button is used for menu option selection. A Rotary encoder (MBLKJ MBL600-100P-5L) is mounted on the lower back area of Study Bearbot and is used for volume control. On the sides of the Bearbot are two long bat handle toggle switches (Gardner Bender GSW-111). The left switch allows the diffuser to be turned on and off. The right switch switch is non-functional and is used as a fidget component.

c) System Outputs

An OLED (Solomon Systech SSD1305) monochrome graphic display, positioned on the Bearbot's face, displays timer information, menu state, and animated expressive eyes. Inside the Bearbot's is an LED light that can illuminate its body through the translucent plastic casing. This is controlled via the menu screen and small middle button or the toggle present on the web-application. Two magnet speakers (Weewooday HAG-FBM-3824) are positioned in the Bearbot's ears and play the selected relaxation audio file. Volume control is managed through the web application and the rotary encoder input. Positioned at the top of the Bearbot's head in the cylindrical indentation (as shown in Figure 2b, external view), is the ultrasonic humidifier module (EC Buying B0C1C79BH3). The diffuser reservoir has a capacity of 150cm³, providing over 5 ounces of liquid storage.

B. Software subsystem

a) Web Application

The web application provides a user-friendly interface for controlling the Bearbot remotely. It is implemented using React for the frontend, the forismatic API [9] to fetch motivational quotes to display to the user, Bootstrap for the sound-selection dropdown menu [10], and uiverse for ready available code snippets of toggle icons [11]. It communicates with the Bearbot over a local network using HTTP requests and periodic polling, enabling two-way synchronization between the physical robot and the web interface in real-time.

The interface, shown in Figure 3, includes:

- **Timer Control:** A circular progress indicator showing the remaining study time with a start button.
- **Mode Selection:** Toggle switches for Fidget Mode and Study Mode.
- **Sound Control:** Volume slider and sound type selection.
- **LED Control:** Toggle switch for the internal lighting.
- **Study Tracker:** Weekly visualization of study session durations. Records study sessions and environmental data to browser's localStorage
- **Connection Status:** In the footer, a colored indicator shows whether the Bearbot is currently connected to the web application, providing users with immediate feedback on the system's status.

The full web app includes an About page describing Bearbot and showing a short demo video, a login/signup system to simulate personalized access, the main control interface described above, and a nonfunctional settings page accessible via the username (demonstrating what a settings panel might look like in a full product). Screenshots of the web application can be seen in Appendix A.

b) Firmware

The Study Bearbot firmware runs on the Arduino Nano RP2040 Connect, written in C++. It interfaces with hardware components such as buttons, toggle switches, the LED, the humidifier, and the DFPlayer Mini via direct pin control. The firmware listens for HTTP POST requests from the web application to trigger actions (e.g., start timer, toggle LED) and responds to periodic GET requests to return its current state.

The firmware manages all interactive elements locally, while also maintaining two-way synchronization with the web application. This ensures that changes made via the physical robot (e.g., pressing a button) are reflected on the UI, and vice versa.

The complete system implementation creates a cohesive and responsive study companion that integrates hardware and software components seamlessly. The modular design allows for future enhancements and maintenance without requiring complete system redesign.

VII. Test, Verification and Validation

A series of trials have been conducted to verify that the Study Bearbot functions as intended and meets all use case requirements. Some tests were conducted internally, while others will require user participation. Trials involving users concluded with a survey, which will be measured quantitatively to assess the Bearbot's effectiveness.

Tests for Battery Lifetime

The battery life of the Study Bearbot is a critical factor in ensuring a positive user experience. The Bearbot must operate for the full duration of an average study session, which is approximately two hours. Therefore, the minimum required battery life is two hours.

Five trials were conducted to determine the maximum operating duration. At the beginning of each trial, a new set of AA batteries were installed in the Bearbot's battery pack and a timer was set for 30-minute intervals. At the end of each interval, the Bearbot was examined to confirm operational status by testing all inputs and monitoring all outputs for a brief period. If the Bearbot remains functional, another 30-minute interval was commenced. This process continues until the Bearbot fails to pass the examination phase.

A trial was considered a success if the Bearbot remained operational for at least four consecutive 30-minute intervals (two hours). To pass the power supply lifetime test, the Bearbot must successfully complete all five trials.

Results for Battery Lifetime

The batteries utilized for the trials were AA Amazon rechargeable batteries and standard AA Duracell batteries. The first two trials were conducted with the Amazon rechargeable batteries while the final three were conducted with the Duracell batteries.

Bearbot passed each trial and was operational for 7.8 hours on average with a standard deviation of 1.9 - surpassing the use case requirement of 2 hours (Fig 3a). The lowest trial of the battery tests was a battery lifetime of 5 hours, with the longest trial lasting up to 10 hours. This will allow the user on average to have ~4 study sessions with Bearbot before replacing the batteries in the robot.

Tests for Diffuse Lifetime

The diffuser's operational lifespan is another key aspect of the Bearbot's performance. If the diffuser depletes its liquid supply too quickly, users will need to refill it frequently, which could disrupt study sessions and negatively impact the user experience. The diffuser should maintain functionality for at least one hour per refill.

Five trials were conducted to test the diffuser's longevity. At the start of each trial, four ounces of liquid will be measured and added to the Bearbot's diffuser. A 10-minute timer was set, after which the Bearbot will be inspected to verify that the diffuser remains operational and that the liquid supply is intact. If the diffuser continues to function, another 10-minute interval will begin. This process will repeat until the diffuser fails to meet the operational criteria. A trial was considered successful if the diffuser remains functional for at least six consecutive 10-minute intervals (one hour). To pass the diffuse lifetime test, the Bearbot must complete all five trials successfully.

Results for Diffuse Lifetime

Bearbot did not meet the target performance during diffuser lifetime testing, requiring a refill on average every 46 minutes and 55 seconds, with a standard deviation of 5 minutes and 45 seconds—falling short of the one-hour use case requirement (Fig. 3b). The shortest trial recorded a diffuser runtime of 42 minutes and 25 seconds, while the longest lasted 56 minutes and 40 seconds.

During testing, an unaccounted-for component was added to the diffuser assembly. This additional part reduced the internal volume available for water storage, thereby decreasing the overall diffusion duration. To address this in future iterations, the volume of the inserted component should be measured and considered when designing the diffuser. Adjustments to the height or radius of the cylindrical reservoir can then be made to maintain the intended diffusion lifetime.

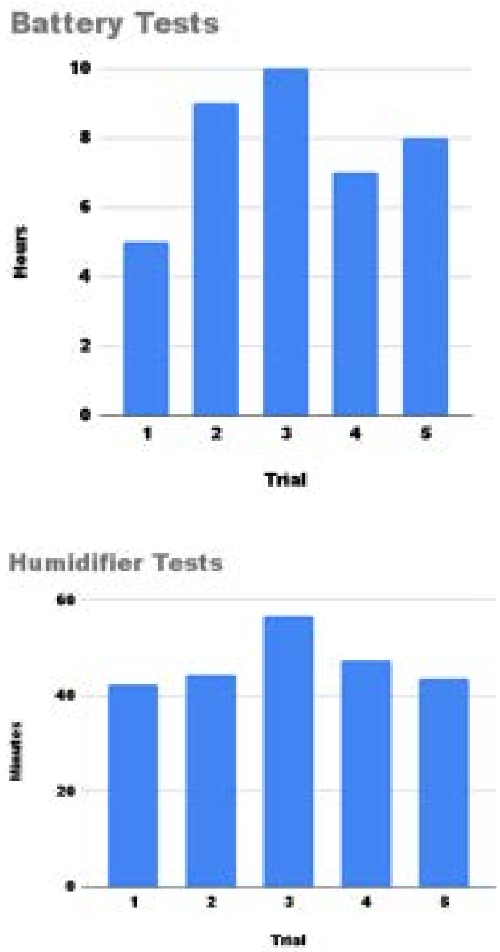

Fig. 3. (a) Battery Trial and **(b) Humidifier Trial** results. Bearbot passed the use - case requirements for the battery trials, and failed the use case requirements for the humidifier trials.

Tests for Stress Relief, Ability to Focus, and Interactivity

Assessing the Study Bearbot's impact on stress relief, focus, and interactivity requires a more qualitative approach. These factors are inherently subjective and were evaluated through user surveys and behavioral observations.

To evaluate Bearbot's impact on stress relief, focus, and interactivity, we conducted eight trials, each with a different participant. All participants were CMU students currently pursuing STEM degrees, with an age range between 20 and 24.

Each participant entered a private study room containing a desk, Bearbot, and a laptop running the web application. After a short in-person walkthrough of Bearbot's features (about 5 minutes), the participant began a 20-minute study session with their own materials. During this time, a screen recording of the web application captured all user interactions, which remained synced with the physical Bearbot in real time.

Before the session began, each participant filled out a pre-study survey assessing their current levels of stress and focus .Following the session, participants completed a post-study survey evaluating their stress, focus, and overall experience. These responses, combined with the interaction logs from the web recording, were used to assess Bearbot's effectiveness.

The survey assesses the Bearbot's effectiveness in enhancing focus and reducing stress, with key questions addressing:

- Level of concentration during the study session
- Level of relaxation during the study session
- Likelihood of using the Study Bearbot in future study sessions

A trial was considered successful if the participant reported a positive experience (i.e., selected Agree or Strongly Agree on key post-survey questions related to stress relief, focus, and comfort) and if they interacted with Bearbot at least five times during the session, as observed from the screen recording.To pass the overall evaluation of stress relief, focus enhancement, and interactivity, the Bearbot must achieve a successful outcome in at least 7 out of 8 trials.

Results for Stress Relief, Ability to Focus, and Interactivity

We evaluated Bearbot's effectiveness in promoting stress relief, focus, and interactivity through a controlled user study with 8 participants. Participants completed pre- and post-session questionnaires using a 1–7 Likert scale, where 1 = Very relaxed/unfocused/strongly disagree and 7 = Very stressed/focused/strongly agree.

A) *Quantitative Measures*

The first chart below shows the average change in reported stress and focus before and after interacting with Bearbot. Participants experienced an average decrease in stress and an increase in focus following their session.

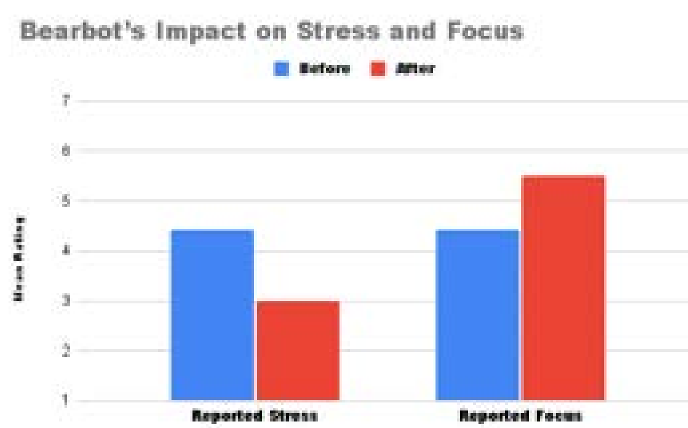

Fig. 4 Bearbot's Impact on Stress and Focus. Most participants reported feeling less stressed and more focused after using Bearbot. (n = 8)

The second chart summarizes participant agreement with key statements about Bearbot's comfort, supportiveness, and effectiveness. High agreement across the board demonstrates that users generally found Bearbot to be a helpful and calming study companion.

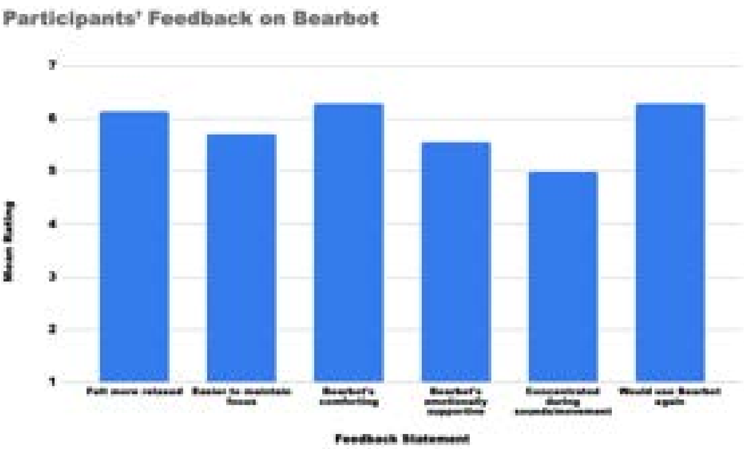

Figure 5. Participants' Feedback on Bearbot. Responses to key feedback statements (1 = Strongly Disagree, 4 = Neutral, 7 = Strongly Agree). High ratings suggest that users found Bearbot comforting, supportive, and effective in enhancing focus. (n = 8)

During the course of user testing, several refinements were made based on participant feedback and observed interactions.

1. The servo-powered arms were removed and replaced with simple physical toggle switches, as the servo motors produced noticeable noise that interfered with the calming atmosphere.

2. The motivational quote feature was updated to refresh automatically every 5 minutes, instead of only on page load, after a participant suggested that dynamic updates would improve the experience.

These changes were implemented mid-study and maintained for all subsequent trials. While our original plan included manually counting participant interactions from the screen recordings, time constraints prevented a full analysis. However, based on our observations during the tests and video review, it was evident that participants engaged with all of Bearbot's key features and reported an overall positive experience.

VIII. Project Management

This section outlines our project timeline, team responsibilities, and resource allocation. It details key milestones, assigned tasks, bill of materials, and our approach to risk mitigation.

A. Schedule

Our project schedule includes key milestones such as finalizing initial design mockups, 3D printing the Bearbot, implementing the web application, integration, and user testing. A detailed schedule with specific deadlines and dependencies is provided in the appendix.

B. Team Member Responsibilities

Kayla: Leads software and firmware development, including web app implementation, OLED display configuration, and API endpoint setup. Assists in hardware integration and user testing.

Taylor: Leads hardware development, including CAD design, 3D printing, and assembly. Responsible for material testing and refining the robot's exterior. Assists in firmware integration and user testing.

Both: Collaborate on hardware integration and final testing phases. Conduct user testing to evaluate effectiveness.

Fig. 2. Schedule example with milestones and team responsibilities

C. Bill of Materials and Budget

The detailed Bill of Materials can be found in Table II at the end of this report. This table includes descriptions, model numbers, manufacturers, quantities, and costs for each purchased component. The total cost to assemble the necessary hardware for Study Bearbot was $393.40, which is approximately two-thirds of the allocated $600 budget. Of the $393.40 that was spent, only 246.76 was used in the final project - which is less than half of the allocated $600 budget.

D. TechSpark Use Plan

We did not use TechSpark resources for our project, but we did utilize Robotics Club - specifically their Bambu 3D printers to create prototypes and the final print of the Bearbot's chassis. Garth Zeglin's course, Creative Soft Robotics, allowed us to create the silicone exterior for Bearbot with Ecoflex 00-31.

E. Risk Management

Risk was managed through switching microcontrollers, cutting features when time did not permit for their full integration, and getting assistance from those with more experience in the problems we were trying to solve.

For specific parts of the fabrication, the silicone exterior, this was our first time working with the kind of material that we planned to integrate into Bearbot. Reaching out to Professor Zeglin allowed us to have a professional lead us in the right direction and gave access to the required materials for our project. The officers in Robotics Club were also helpful in assisting debugging different subsystems of the hardware. Without outside help, too much time would have been spent through trial and error instead of moving forward in the assembly of the robot.

Even with extensive research into the Raspberry Pi 4 and connecting it to the OLED display, we could not get the display to function with the Raspberry Pi, and setting up the Raspberry Pi versus an Arduino took up more time than we both anticipated. This forced us to switch to a component we were both familiar with.

Time constraints also forced us to cut features that would prove troublesome to integrate: the touch sensors would either be covered by the silicone skin or placed at the top of the head where it would get wet. The photoresistor was contradictory to having the light be controlled by the user, and the rotating base was contradictory to the portability of the Bearbot.

Ethical Issues

While Study Bearbot is designed to support focus and reduce stress, it also presents the risk of becoming a distraction or a source of dependency. Some users may spend more time playing with its features—like fidget switches, aroma, or music—than actually studying, potentially reinforcing avoidance behaviors rather than productivity. This could be especially harmful for users who already struggle with focus or anxiety, such as students with ADHD, who might become overly reliant on the robot. As designers, we have a responsibility to ensure Bearbot encourages healthy habits without replacing self-regulation. From a public health and welfare perspective, Bearbot offers accessible, safe, and low-cost support for mental well-being through features like calming scents, soft materials, and visual feedback. However, its success depends on thoughtful use, clear guidance, and ongoing evaluation to ensure it remains a helpful tool rather than a hindrance.

IX. Related Work

Several existing robotic companions share similarities with Study Bearbot in terms of stress reduction and interactive engagement. However, they each serve different primary purposes and lack the study-specific functionality that our project aims to provide.

Eilik [4] is an emotionally intelligent robot designed for companionship and entertainment. It features expressive animations and interactive responses, creating a dynamic social presence. However, while engaging, Eilik primarily serves as an emotional companion rather than a tool for structured study support.

Miko [5] is an AI-powered robot, focused on personalized learning and entertainment for children. It uses machine learning to adapt to user preferences and provide educational content. While it enhances engagement, its primary function is tutoring rather than stress reduction or study optimization.

PARO [8] is a therapeutic robotic seal that has been widely used in healthcare to reduce stress and anxiety in patients. It incorporates five different types of sensors for user interaction and has been shown to have a calming effect. While highly effective for therapeutic settings, PARO lacks features tailored for studying, such as time management tools or sensory-based focus aids.

Our approach builds on these concepts by integrating tactile fidgeting elements, aromatherapy, and sound therapy into a study-specific framework. Unlike existing robotic companions, Study Bearbot is designed not just to entertain or comfort but to actively support productive study habits while reducing stress..

X. Summary

The Study Bearbot is a portable desk companion robot designed to foster a calming environment during high-stress tasks. Equipped with tactile buttons and a rotary encoder for fidgeting, integrated speakers for soothing audio, a scent diffuser, interior LEDs functioning as a night light, and an interactive OLED screen, Bearbot provides a comprehensive sensory experience to support focus and relaxation.

Initially, we aimed to incorporate additional sensors, a rotating base, and a toggleable aromatherapy feature using the Arduino Nano Connect RP2040. However, these features were ultimately omitted due to various constraints: the rotating base detracted from the user experience, the additional sensors introduced unforeseen conflicts with other system requirements, and time limitations prevented implementation of the aromatherapy toggle. Despite these trade-offs, the final product retained the majority of the originally planned features, resulting in a fully realized desktop study companion

In retrospect, conducting more extensive research earlier in the development process could have streamlined our workflow—particularly during the transition between platforms. The project saw iterations involving the Raspberry Pi 4 (8GB), Arduino Uno, Arduino Nano Every, and ultimately the Arduino Nano Connect RP2040. Earlier clarity on hardware capabilities would likely have saved several weeks of development time.

Looking ahead, future development could explore the possibility of designing a custom chip tailored specifically to Bearbot's functionality. This would enable tighter integration of features and greater efficiency. Additionally, expanding the firmware and enhancing the web application would further improve the overall user experience.

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Table II. Bill Of Materials

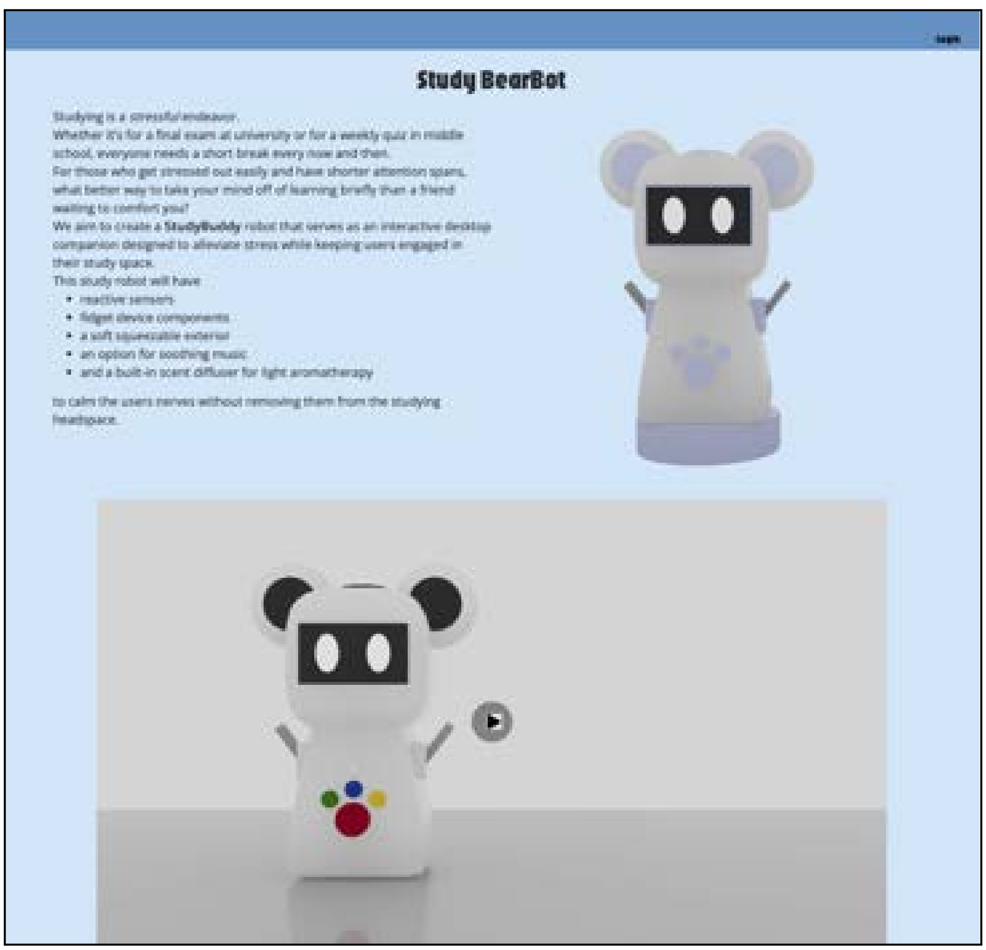
Product	Description	Model Number	Manufacturer	Quantity	Cost ($)
Arduino Nano Connect RP2040	Arduino Nano microcontroller	ABX00053	Arduino	1	30.60
*Arduino Nano Every	Arduino Nano microcontroller	TIFC00 123	Arduino	1	19.90
* Raspberry Pi 4 8GB	Raspberry Pi microcontroller	102110421	Raspberry Pi Ltd	1	75.00
Arcade Button	Translucent arcade button with a 30mm radius	476	Adafruit	1	5.95
Monochrome 2.42" 128x64 OLED Graphic Display Module Kit	Monochrome graphics display	SSD1305	Solomon Systech	1	39.95
CNC Rotary Encoder - 100 Pulses per Rotation - 60mm Black	Black rotary encoder	MBL600-100P-5L	MBLKJ	1	17.5
6 Pcs Mini Rocker Switch	Mini rocker switch (6 pcs)	B07L9JWVVR	MXRS	1	5.29
4 AA Battery Holder with Leads, 4 AA Battery Holder with Wires	4 AA battery holder with leads & wires (2 pcs)	4AA-2PC	LAMPVPATH	1	5.98
Weewooday 6 Pcs 2W 8 Ohm Small Speakers Metal Shell Round Internal Magnet Speaker Micro Internal for DVD, EVD, Mini Multimedia Loudspeaker	Magnet speakers, with ~ 1.1in in diameter (6 pcs)	HAG-FBM-3824	Weewooday	1	8.99

Twidec/10Pcs Momentary Push Button Switch SPST AC250V/3A AC125V/6A Mini Off(ON) ON 5 Colour with Pre-soldered Wires R13-507-5C-X	Momentary push button wwitch with ~ 7.8mm radius (10 pcs)	B08JHVLK84	Twidec	1	9.99
Pololu Adjustable 4-12V Step-Up/Step-Down Voltage Regulator S18V20ALV	Step-up/Step-down voltage regulator	2572	Pololu	1	27.95
3Pcs USB Humidifier Module USB Spray Module Circuit Board Atomization Module 5V Atomization Plate Circuit Board Atomization Module Atomizer DIY Incubation Experimental Equipment	USB-powered ultrasonic humidifier module (3 pcs)	B0C1C79BH3	EC Buying	1	8.99
*Round Force-Sensitive Resistor (FSR) - 0.3 ~ 10 Newton Force - Alpha MF01A-N-221-A01	Touch (membrane force) sensor with ~ 9.2 mm radius	MF01A-N-221-A01	Alpha	4	15.80
Majestic Pure Lavender Essential Oil with Glass Dropper | 100% Pure and Natural Lavender Oil | Premium Grade Essential Oils for Diffusers, Skin, Aromatherapy, Massage | 4 Fl Oz	Pure lavender oil	B00TSTZQEY	MAJESTIC PURE	2	19.98
*4Pcs SG90 9g Micro Servos for RC Robot Helicopter Airplane Controls Car Boat	Micro servos ~ 3.18mm x 2.18 mm (4pcs)	B07MLR1498	Deegoo-FPV	1	7.99
*MUID Benson Lying Flat Duck Night Light, LED Squishy Duck Lamp, Cute Light Up Duck, Silicone Dimmable Nursery Nightlight, Rechargeable Bedside Touch Lamp for Breastfeeding, Finn The Duck.	Silicone lamp activated by touch	PANDA	Xiamen Fellroom Household Products Co., Ltd.	1	27.95
SUNLU 3D Printer Filament PLA Filament 1.75mm, Neatly Wound 3D Printing Filament 1.75mm, Dimensional Accuracy +/- 0.02 mm, Fit Most FDM 3D Printers, 1kg Spool (2.2lbs), Transparent, Clear PLA	Clear 3D printing filament	3Dプリンター フィラメントPLA	SUNLUGW	1	18.99
Duracell Coppertop AA Batteries with Power Boost Ingredients, 24 Count Pack Double A Battery with Long-lasting Power, Alkaline AA Battery for Household and Office Devices	Duracell AA batteries	CT AA x24 - PB	Duracell Distributing, Inc	1	18.64
Gardner Bender GSW-111 Electrical Long Bat Handle Toggle Switch, SPST, ON-OFF, 20 A/125V AC, Screw Terminal	Long bat handle toggle switches	GSW-111	Gardner Bender	2	18.06
DFPlayer - A Mini MP3 Player	mini MP3 player	DFR0299	DFROBOT	1	9.90

* Was purchased but not incorporated into the final build

Grand Total **$393.40**

Appendix A - Web Application Pages



Appendix B - Project Schedule & Gantt Chart

TASK TITLE	TASK OWNER	DUE DATE
Deliverables		
Project Abstract	All	1/22/25
Website Initial Setup	All	2/1/25
Project Proposal Presentation	All	2/3/25
Design Review Presentation	All	2/15/25
Design Review Report	All	2/28/25
Ethics Assignment	All	3/12/25
Interim Demo	All	TBD
Final Presentation	All	TBD
Final Report	All	TBD
Web App Interface		
Define technology stack	Kayla	2/12/25
Refine web-app wireframes	Kayla	2/16/25
Develop web-app backend/frontend	Kayla	3/22/25
Set up basic API endpoint to connect the web app with the robot	Kayla	3/8/25
Implement motivational quotes display	Kayla	2/28/25
Implement study tracker functionality	Kayla	2/28/25
Implement timer functionality	Kayla	2/28/25
Firmware		
Configure OLED display (eye/facial expressions, clock, timer)	Kayla	3/15/25
Configure dial for volume control	Kayla	3/15/25
Implement button controls (modes, timer, scent diffusion)	Kayla	3/15/25
Hardware		
Create CAD design	Taylor	2/16/25
Create a 3D print skeleton prototype	Taylor	2/23/25
Wire components together	Taylor	3/12/25
Assemble the robot	Taylor	3/15/25
Work on silicone exterior	Taylor	2/28/25
Perform material testing	Taylor	2/28/25
Iterate and reprint if necessary	Taylor	2/28/25
Integration		
Work on system diagram	All	2/22/25
Integrate hardware components	All	3/29/25
User Testing		
Find users for testing	All	3/10/25
Small-scale user study (~10 students)	All	4/5/25
Survey to evaluate effectiveness	All	4/5/25