Z^3-Wellness:

An Enhanced Sleep Health Application for Better Sleep and Mental Wellness

A Major Qualifying Project report submitted to the faculty of
Worcester Polytechnic Institute in partial fulfillment of the requirements
for the Degree of Bachelor of Science

By

Patrick Mejia

Eri Kim

Project Advisors

Professor Carolina Ruiz

Department of Computer Science

Dr. Ermal Toto

Academic Research Computing

Abstract

Building on the success of two previous MQPs, this project further enhances the Z^3-Wellness application. Z^3-Wellness is a comprehensive sleep management web-based application that empowers college-age users to monitor their sleep health and achieve better overall well-being. The primary objective of our project was to implement additional functionality that helps users to better understand and manage their sleep health. To achieve this, our group conducted research to identify factors that affect sleep and strategies for improving sleep. Based on the findings, we added new features such as a water intake tracker, mood tracker, Spotify and Outlook integration, and a baseline for recommendation features. Additionally, we improved existing features by updating dependencies in the server and making it more user-friendly with user interface (UI) changes.

Acknowledgments

The success of this project was the result of collaborative effort, and it would not have been feasible without the valuable guidance and expertise offered by the faculty and staff of Worcester Polytechnic Institute. Their unwavering support enabled us to gain a distinct learning experience, which has significantly enhanced our skills in software engineering and teamwork-based projects.

We express our sincere gratitude to Professors Richard Lopez, Diane Strong, Soussan Djamasbi, and Dr. Paula Fitzpatrick for providing us with valuable feedback on our application. Our team had the privilege of meeting with these esteemed professors and their diverse perspectives and ideas helped create an application that is more professional and user-friendly. These professors' insights had a positive impact on the success of our application.

Our gratitude goes to Dr. Ermal Toto for providing server support and guidance that significantly contributed to our project. With his expertise, he assisted us in reviving the server that had been inactive for several years and resolving any errors that emerged during the process. Furthermore, he supported us in setting up the development environment, which was crucial to the success of our project.

We owe our deepest appreciation to Professor Ruiz, our advisor, who is an exceptional mentor to us. Her continuous encouragement and guidance inspired us to strive for excellence and work collaboratively as a team. The valuable lessons she has taught us will undoubtedly benefit us not only in our professional field but also in all aspects of our lives.

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1. Introduction

Sleep is essential for everyone, but it is particularly crucial for college students. College students face a variety of academic, social, and personal challenges that can impact their mental health and overall well-being. Good sleep health can significantly improve their ability to manage these challenges and promote better mental health.

College students require adequate sleep for several reasons. First, academic performance. Sleep has a direct impact on cognitive function and memory retention. Getting enough sleep helps students to concentrate better, stay alert, and retain information better, which can lead to better academic performance [1]. Second, better physical health. Sleep plays a key role in maintaining physical health. Healthy sleep is vital to human health and necessary for life as it serves critical roles in brain functions such as cognitive functioning, mood regulation, mental health, cardiovascular, cerebrovascular, and metabolic health [2]. Third, enhanced mental health. Getting enough sleep is critical for good mental health. Sleep deprivation has been linked to increased anxiety, depression, and stress levels. Proper sleep health can help students manage stress and maintain emotional stability [3].

Overall, promoting sleep health among college students can have a significant impact on their academic success, physical health, and mental well-being. Numerous factors are bidirectionally related to sleep that could affect the well-being of students. Despite the importance of sleep, studies show that approximately three-fourths of college students report never receiving information about sleep from their university [1]. By utilizing our sleep health app, students can learn effective strategies for improving their sleep health by monitoring their sleep and the factors discussed in the following sections. The goal of this app is to promote happier and healthier lives by providing information regarding sleep health.

2. Background

In this chapter, we begin with a definition of sleep health and its importance. Then, we address the major factors that affect sleep, including sleep environment, physical exercise, diet, hydration, and mood. Further, we examine existing sleep applications and tools and the previous version of our sleep health application – Z^3.

2.1 Sleep Health

Sleep is essential for optimal cognitive performance, physiological processes, emotional regulation, and quality of life [4]. Therefore, an evaluation of an individual's health and wellness necessitates an assessment of sleep health [4]. Sleep health is often defined as a multidimensional pattern of sleep-wakefulness, adapted to social and environmental demands, which promotes the physical and mental well-being of an individual [5]. Healthy sleep is vital to human health and necessary for life as it serves critical roles in brain functions such as cognitive functioning, mood regulation, mental health, cardiovascular, cerebrovascular, and metabolic health [2]. However, data from surveys conducted by the U.S. Department of Health and Human Services and Centers for Disease Control and Prevention (CDC) show that 34.4% of children [6], 77.9% of high school students [7], and 27.7% of adults [8] do not get a sufficient duration of sleep regularly, which makes sleep duration an important target for health improvement. While sleep needs vary, the American Academy of Sleep Medicine (AASM) and Sleep Research Society (SRS) recommend 7 or more hours of sleep per night regularly to promote optimal health [9]. The National Sleep Foundation (NSF) provides similar recommendations of 7 to 9 hours of sleep for adults [10]. These recommendations provide standards to assess sleep health for the Healthy People 2030 objectives–data-driven national objectives to improve health and well-

being over the next decade–to increase the proportion of people who get sufficient sleep [11].

2.2 Sleep Health in College Students

Insufficient sleep duration, irregular sleep timing, and insomnia are common among college students, and they are associated with anxiety and depression symptoms. Sleep disturbances also are a significant predictor of academic problems as each additional day per week that a student experienced sleep problems raised the probability of dropping a course by 10% and lowered the cumulative GPA by 0.02 [1]. However, approximately three-fourths of college students report never receiving information about sleep from their university [1].

Promoting and educating students on sleep health is essential. Numerous factors are bidirectionally related to sleep that could affect the well-being of students. The goal of this MQP, therefore, is to provide students with applications that have helpful features to monitor their sleep health for improved quality of life. Several factors we focused on while implementing the application are described in the following section.

2.3 Factors Related to Sleep Health

Numerous factors can contribute to an individual's sleep health. It is important to recognize them to improve mental health and well-being. The major factors that determine sleep health covered in this section are the sleep environment, physical exercise, hydration, and mood.

2.3.1 Sleep Environment

Creating the correct sleep-friendly environment is important for getting restful and restorative sleep. The sleep environment refers to the physical and psychological conditions in

which a person sleeps. This includes factors such as the comfort and cleanliness of the bed, room temperature, lighting, noise levels, and the presence of electronic devices [12]. A comfortable and supportive sleep environment can help promote relaxation and reduce stress, leading to better sleep. On the other hand, an unfavorable sleep environment, such as a bed that is too hard or soft, a room that is too warm or too bright, or exposure to electronic devices, can have a negative impact on sleep quality. By providing information about the ideal sleep environment, a sleep health application can help users create a supportive and comfortable environment for sleep, leading to improved sleep quality and overall health. It is essential that the bedroom is cool, dark, and quiet. Light influences our internal clock through light-sensitive cells in our eyes. Exposure to light in the evening delays the phase of our internal clock and makes us prefer to sleep later [12]. Research has shown that dimming the lights two hours before an individual wants to fall asleep can improve the quality and duration of sleep [13]. To minimize the reset or delay of the internal clock, nightlights in hallways and bathrooms can be used.

Figure 1. Recommendations for the Ideal Sleep Environment by the National Sleep Foundation [14]

In addition, it is recommended to avoid light-emitting electronics such as cell phones, TVs, or laptops an hour before bedtime since they enhance alertness, which would disturb sleep [14]. Having a calm activity routine like bathing or any relaxation techniques before sleep promotes better sleep. The Centers for Disease Control and Prevention (CDC) recommends that individuals go to bed at the same time each night and wake up at the same time each morning,

even on the weekends [13]. Although this may be challenging with busy schedules, it is recommended to be consistent to maintain one's circadian rhythm [15].

Some other factors that may affect an individual's ability to sleep include temperature and noise of the environment. Although there is no prescribed best room temperature that produces optimal sleep, REM sleep is sensitive to temperature-related disruption. It is important to keep the temperature at which individuals feel most comfortable by avoiding very cold or hot environments. To prevent the increased frequency of awakenings that may prevent transitions to deeper stages of sleep, it is recommended to keep the sleep environment quiet. Some may prefer having relaxing background sounds; however, it is advised to keep the volume low.

2.3.2 Physical Exercise

Exercise can be an important part of mood management and improving sleep. There was a study conducted to determine whether students who are regularly physically active have higher sleep quality, higher well-being, and higher positive affect during academic stress periods than those who do not [16]. The results of the study showed a positive effect of physical activity on sleep quality. Exercise has also led to reduced stress and anxiety levels and improved self-esteem and overall mood.

Exercise can also help reduce the amount of time it takes to fall asleep and can help to increase the total amount of time in deep sleep. It is recommended to maintain physical activity levels in times of high academic stress. The moderate-intensity activity of 150 minutes (about 2 and a half hours) per week seems to provide health-promoting effects. A low-impact fitness program such as walking, swimming or yoga is helpful for improving sleep as well (Figure 2). In addition, having regular physical activities that are not too close to bedtime as a daily routine

promotes better sleep because the release of endorphins can create a level of activity in the brain that keeps some people awake [17].

Figure 2 Recommendations for exercise by the National Sleep Foundation [14]

2.3.3 Hydration

Hydration is essential for sleep health. Some research including large cross-sectional data on adults from the US nationally representative survey and a large Chinese cohort found that short sleep duration (6 hours), compared with 8 hours of sleep, was associated with higher odds of inadequate hydration using urinary biomarkers [18].

According to this study, hydration status is part of a tightly linked and regulated hormonal system of the renin–angiotensin–aldosterone, which controls urine concentration and body water conservation. Vasopressin increases in the late sleep period to help avoid dehydration and neglecting this sleep period through short sleep (less than 7 hours) may affect vasopressin release and disrupt body water homeostasis. In addition, long sleep (more than 9 hours) may also be associated with dehydration due to changes to vasopressin release, higher water losses from respiration, and longer periods of water intake restriction. Therefore, both short and long sleep may consequently negatively affect hydration status.

Drinking enough water can help regulate body temperature, maintain physical performance, and support cognitive function. Lack of water can cause dehydration, leading to symptoms such as headaches, fatigue, and difficulty concentrating, all of which can negatively impact sleep quality. Additionally, proper hydration can help regulate the body's internal

circadian rhythm, which is responsible for regulating sleep and wake cycles. By tracking water intake, the sleep health application can help users maintain proper hydration levels and make recommendations to improve their overall health and sleep quality. As a result, dehydration from inadequate sleep may create barriers to sleep. Although research is still in progress to discover why hydration affects sleep, experts state that even minor symptoms of dehydration can negatively impact sleep due to discomfort. To address the dehydration issue, keeping track of water intake to maintain adequate hydration status is crucial.

2.3.3 Caffeine

Caffeine is important to consider in terms of sleep because caffeine is a stimulant that can disrupt sleep patterns and negatively impact the quality of sleep. Consuming caffeine in the evening or before bedtime can make it difficult to fall asleep, reduce the amount of deep sleep, and result in feelings of restlessness or anxiety. Moreover, caffeine can have a half-life of up to 5 hours, which means it can still have an impact on sleep even if consumed several hours before bedtime [19]. Understanding and monitoring caffeine intake is an important aspect of maintaining good sleep hygiene and improving sleep health. By tracking caffeine intake, a sleep health application can provide personalized recommendations and insights into how caffeine consumption affects sleep patterns and provide guidance on how to minimize its negative effects.

2.3.4 Mind and Mood

There are five sleep stages: wake, N1, N2, N3, and rapid eye movement (REM). Stages N1 to N3 are considered non-rapid eye movement (NREM) sleep, with each stage a progressively deeper sleep [20]. Each stage plays a role in brain health since they affect overall

brain activity, and enable better thinking, learning, and memory. Further, sufficient sleep, especially during the REM stage, aids the emotional processing of the brain. The brain evaluates and keeps track of thoughts and memories while sleeping. A lack of sleep, therefore, is harmful and unhealthy to the consolidation of a positive emotional state, which affects mood and emotional reactivity, and hence mental health as shown in Figure 3.

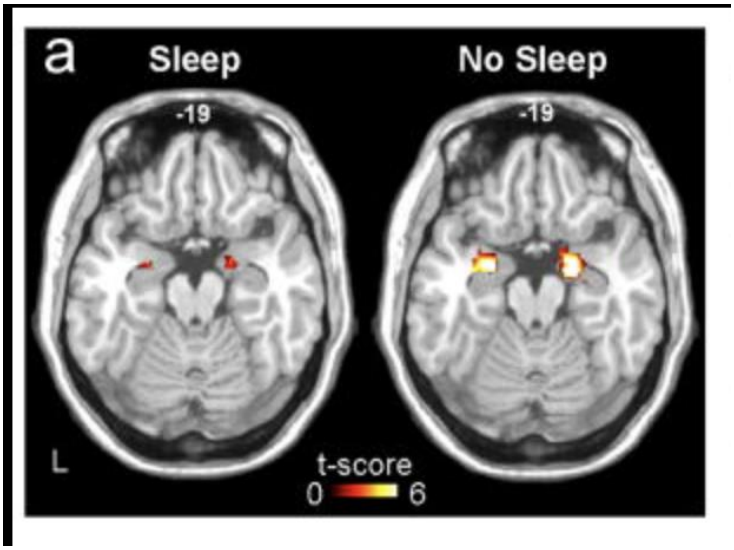

Figure 3 The image on the right depicts a higher amygdala (processes memory, decision making, and emotional responses) response to negative emotional stimuli in the sleep deprivation group in comparison with that on the left for normal sleep. Taken from [21].

Sleep and mood are closely linked since inadequate sleep can cause stress and vice versa [3]. For example, anxiety increases agitation, which makes it difficult to sleep. Stress also makes the body awake and alert, which causes sleep problems. Sleeplessness is a symptom of mood disorders, and it raises the risk of developing some mood disorders as well. A negative mood can lead to a vicious cycle since an increase in stress results in bad sleep health. People who experience negative moods such as depression, anxiety, and stress are more likely to have difficulty falling asleep and staying asleep, as well as to experience waking up more often at night [3].

Some research has shown that greater improvements in sleep quality led to greater improvements in mental health. They suggest that sleep is related to the experience of mental health difficulties and that future research should consider how interventions that improve sleep could be incorporated into mental health services, as well as the mechanisms of action that explain how sleep exerts an effect on mental health [22]. Monitoring moods can be a way to raise awareness of mental well-being since it can help make informed health decisions, prevent, or avoid triggers of negative moods, and work towards a better quality of life [23]. Since self-monitoring is free and takes hardly any time, making it a daily routine would provide some time to self-reflect and improve one's mood.

2.4 Existing Sleep Tools and Apps

This section covers a selection of existing sleep tools or apps that have features to help improve sleep health. To brainstorm ideas, we decided to examine the applications currently available in the market and examine useful features that could be beneficial for our target users. This approach allowed us to conceptualize potential functionalities for our application. These apps include Sleep Reset, Sleep Cycle - Smart Alarm Clock, Reflectly, and Daylio.

2.4.1 Sleep Reset

Sleep Reset is a sleep clinic program that provides assessments and a personalized program to help improve the user's sleep health [24]. It offers features such as in-depth assessments to identify causes of sleep problems, an introductory video call with a sleep coach, library with a wealth of sleep-improving content including relaxation techniques, meditations, and cognitive exercises. In addition, using the tracked sleep patterns offers personalized

recommendations to improve sleep. Another key feature that Sleep Reset has is its library of sleep content. This includes audio files and videos on relaxation techniques, meditations, and cognitive exercises that all help improve the quality of sleep for its users.

2.4.2 Sleep Cycle - Smart Alarm Clock

Sleep Cycle is an app that tracks and interprets the user's sleep data and wakes them up during their lightest sleep phase in the morning to make waking up easier and reduce fatigue upon waking [25]. It offers other features such as sleep movements and cycle tracking, statistics and graphs, sound recordings, sleep aids such as relaxation sounds, stories, guided meditations, heart rate measurements, and sleep notes. One innovative feature of Sleep Cycle is that the app can wake users up during their lightest sleep phase in the mornings. This helps users feel more refreshed and reduces grogginess and fatigue that is common with normal alarm clocks. The app also provides especially useful visuals for the users so they can note any trends or patterns with their sleep habits.

2.4.3 Reflectly

Reflectly can be used to aid the user to practice better sleep hygiene such as journaling [26]. This app is a digital journal that has prompts to help the user destress and identify any stressful events. This can help release thoughts and feelings that could have interfered with sleep. Moreover, Reflectly also provides insights into user's sleep patterns and habits, which help identify any issues or patterns that the user may be experiencing.

2.4.4 Daylio

Daylio is a user-friendly mobile application that tracks the user's mood and daily habits [27]. This app uses a mood scale based on emojis and quantifies each emoji to a number and sends it to their database. Users can create a daily entry by picking their mood. The logged data is displayed in charts.

2.4.5 Apple Watch Sleep Tracker

Users with Apple Watch and iPhone can create personalized sleep schedules to help meet their sleep goals and improve their overall health. With the Sleep app available on Apple Watch, users can create bedtime schedules, which helps them meet their sleep goals [28]. Wearing the watch during sleep enables the application to estimate the time spent on each sleep stage. Users can also view their sleep history on iPhone through the health app, which displays the average time or percentage spent in each sleep stage. It also displays sleep duration details such as average time in bed and average time asleep, as well as heart and respiratory rate during the time spent asleep.

2.4.6 Fitbit

Fitbit devices can also be used to improve sleep health. By tracking sleep patterns, users can identify any problems that may be causing difficulty sleeping. Fitbit devices can also track heart rate and exercise throughout the day, which can be helpful for the app to learn the user's daily habits. By using the data collected from Fitbit, users can create a personalized plan that can help to improve their overall sleep health. Moreover, Fitbit offers detailed information on a user's sleep including the sleep score. The user can track the quality of sleep, not only the

amount of sleep and can see their distinct phases of sleep including, light, deep and REM sleep, which prove especially useful for the users in learning their sleep patterns.

2.5 Previous Versions of the Z^3-Wellness Sleep Health Application

This project continues the work of two prior MQPs. The first MQP [29] investigated the relationship between sleep and personality type, and created an app that captures the user's personality type and chronotype using well-established tests. The app also tracked sleep, caffeine, and exercise. The second MQP [30] created an in-depth sleep health application that provides habit trackers such as stress logging, mindfulness activity modules, creation of bedtime routines, and Fitbit and Google Calendar integration. The group created a new user interface using ReactJS. The group successfully implemented a frontend, backend, and database for the sleep health application. The application structure diagram we created to better represent it is shown in Figure 4 below.

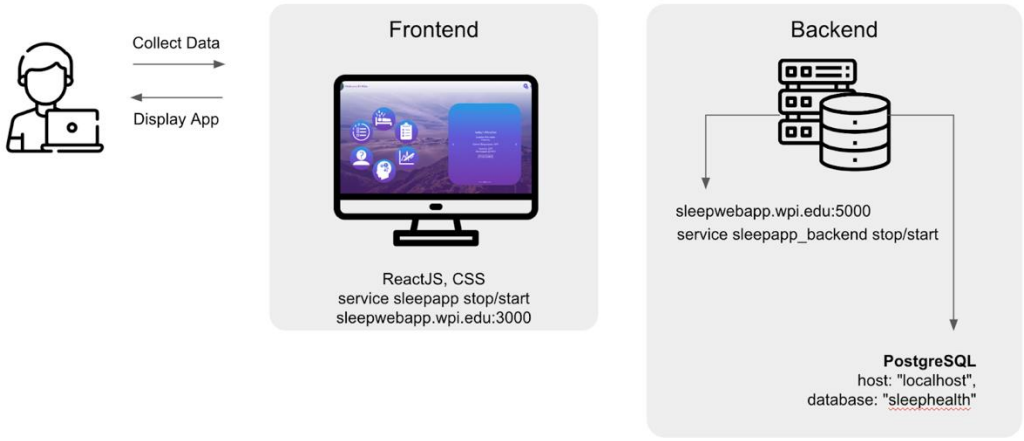

Figure 4. Application structure diagram.

2.5.1 Front-end: ReactJS

The front end was implemented using ReactJS and the previous group created a new user interface to the application (Figure 5). Their objective was to make their application more engaging than the previous MQP and encourage more people to sign up for the application.

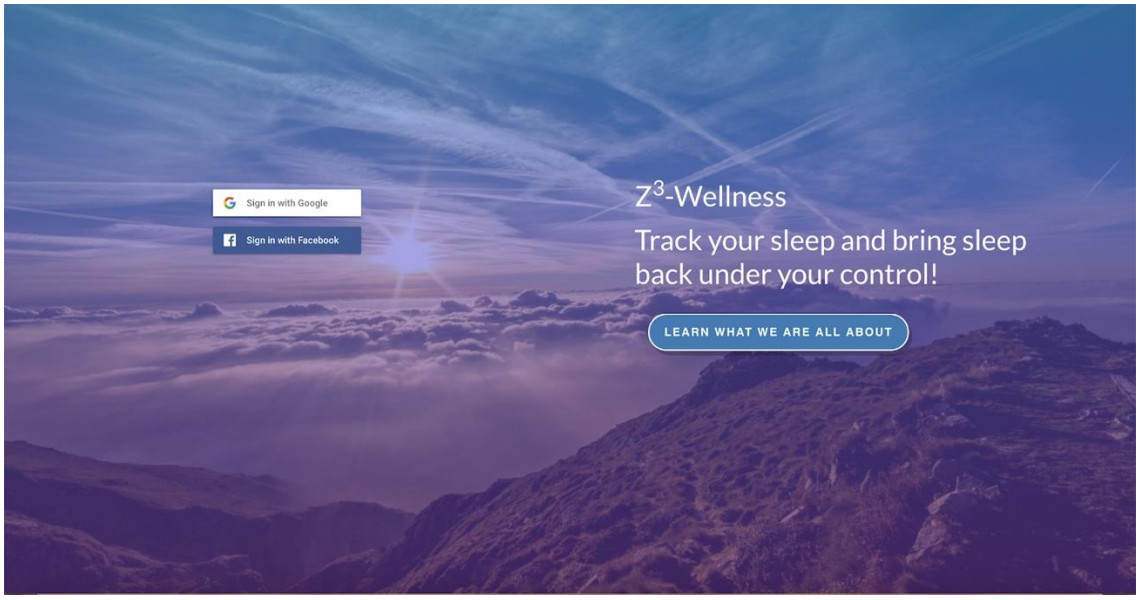

Figure 5 Landing page sign-in screen. Taken from [30].

In addition to the sign-in options, users can view the primary features of the application as they scroll down. This was intended to encourage users to review all the features available on the application. This is shown below in Figure 6.

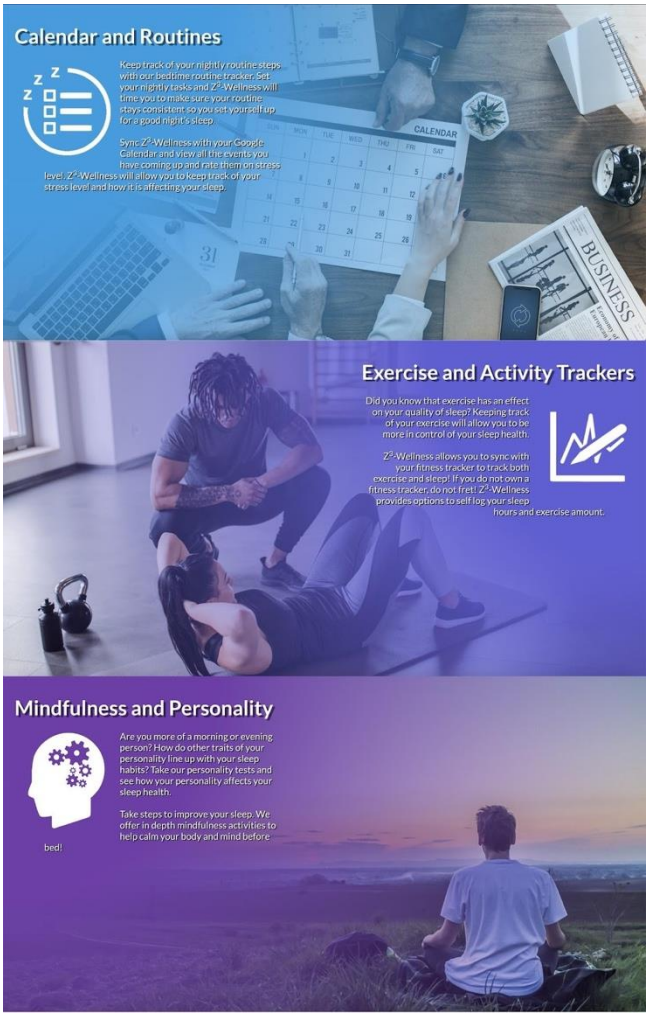

Figure 6 Section of the landing page with information about the app. Taken from [30].

Similarly, the group wanted users to have easy access to all the features in the application, which led to the home page design of six circular buttons for each feature on the left half side of the screen. In Figure 7, on the right half, the group put together some helpful information such as weather and recommendations based on the user's personality type result, as well as a fun fact of the day related to sleep.

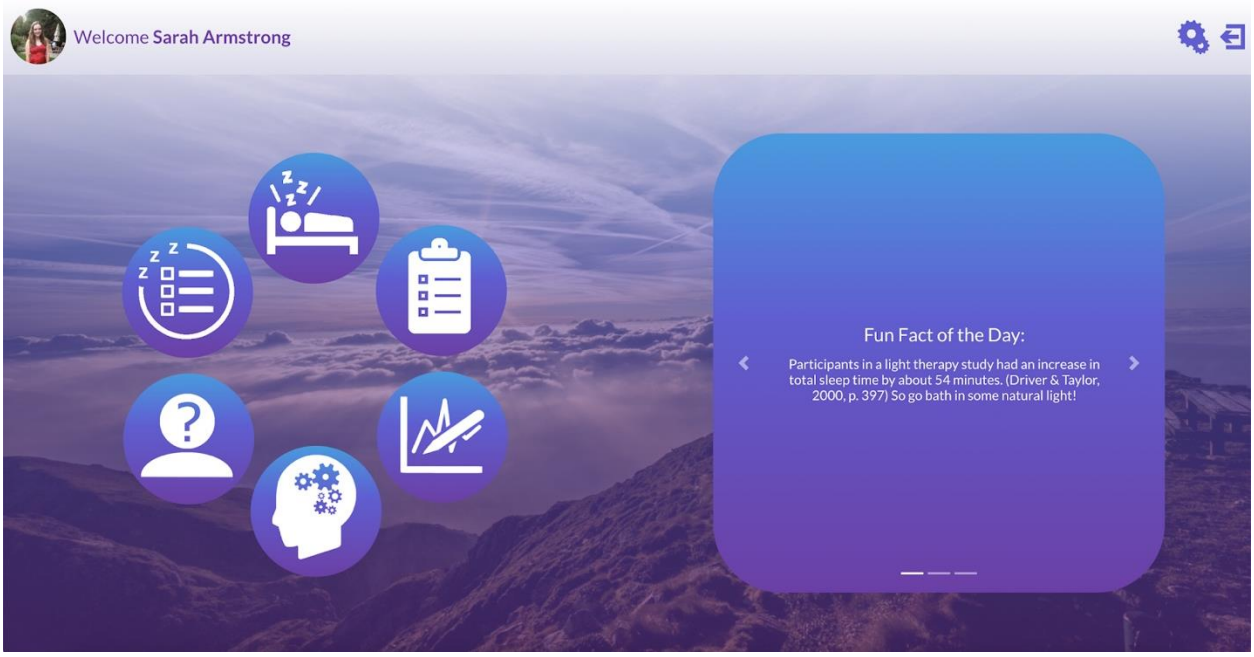

Figure 7 Home page. Taken from [30].

2.5.2 Back-end: PostgreSQL, Node.js, and Firebase

The back end of the application was implemented using PostgreSQL and Node.js. The previous group used them to allow for high levels of security and support. The previous group's database schema is shown in Figure 8.

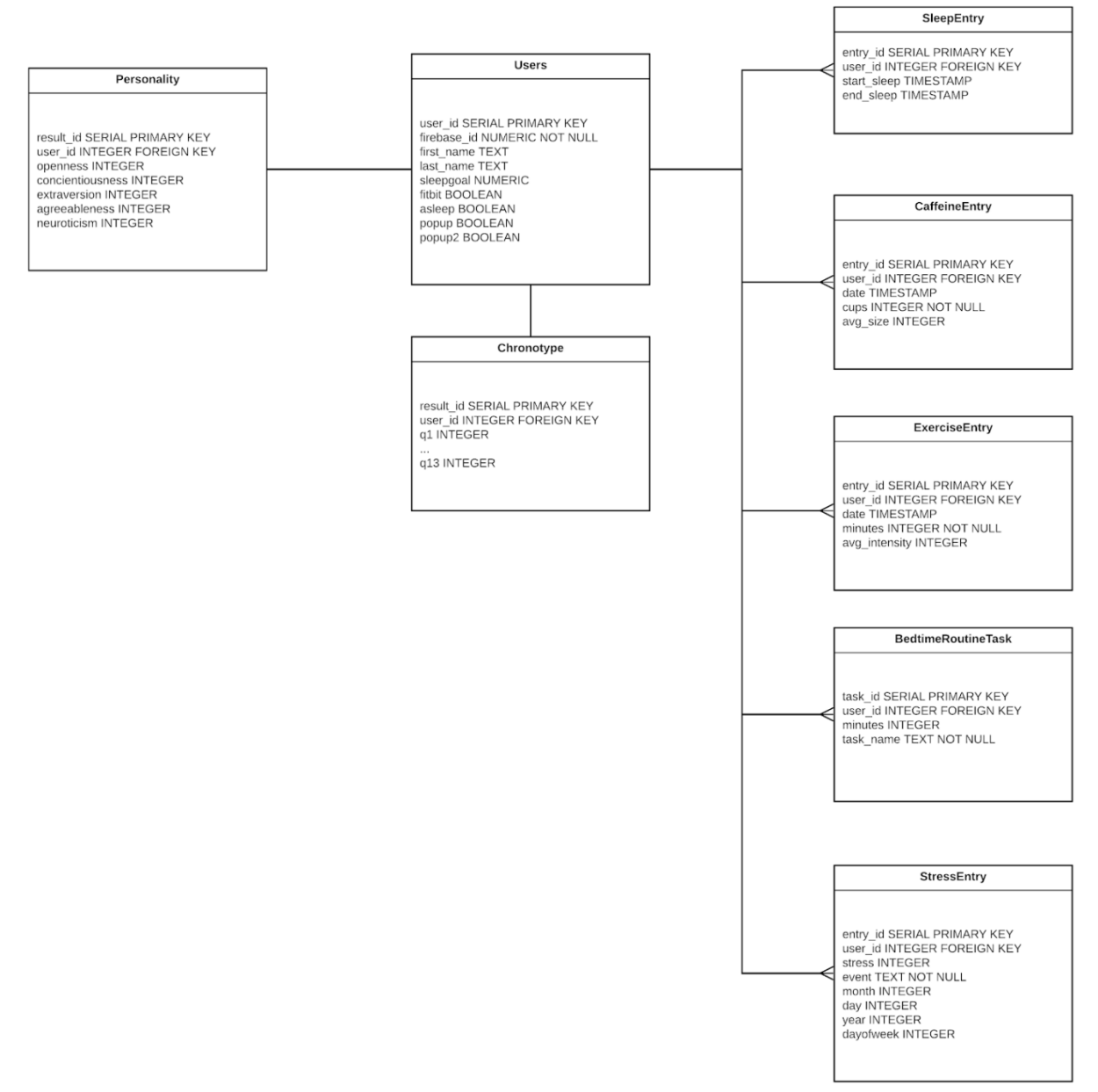

Figure 8 Database Schema. Taken from [30].

Additionally, Firebase was used for user authentication. It provides many tools with multiple alternative user login credentials that use the user's Google, Facebook, Twitter, and GitHub accounts.

3. Design and Implementation

The goal of this project was to add new features and improve the user experience of the sleep app created by the previous MQP group. The purpose of this app is to help college students track their sleeping habits and provide recommendations based on their sleeping patterns. We split this goal into five objectives for this project:

1. Update WPI sleep server and database
2. Update/improve existing features
3. Implement new features
4. Improve and extend the integration of the application with compatible devices
5. Gather and incorporate feedback from professors external to this project and iterate objectives 1-4

The Gantt chart below shows the detailed timeline of each objective (Figure 9).

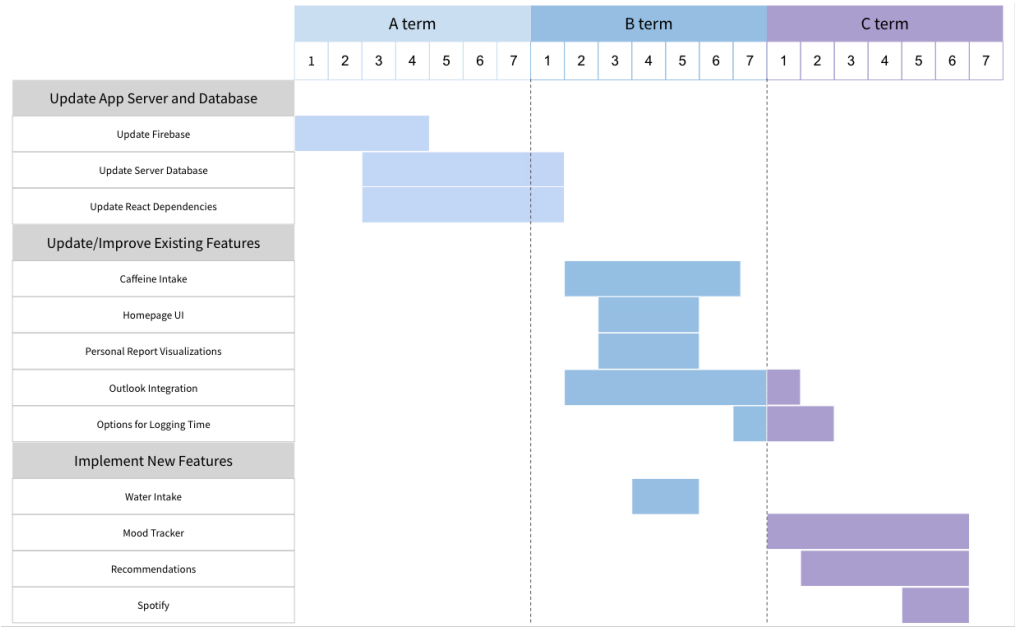

Figure 9 Gantt chart for MQP timeline

3.1 Work Carried Over from Previous MQP

Using the source code developed by the two previous groups, our group improved the existing components and implemented new features to enhance the user experience and provide recommendations regarding sleep health. Our group used the back end the previous group implemented because PostgreSQL and Node.js provide industry-standard security and can support our application without compromising the security of the users.

The previous group also expressed interest in future groups working with mindfulness in the application. We incorporated more features to improve the effectiveness of the features they previously implemented. With the additional feature of a mood tracker, we believe this can properly encapsulate the effectiveness of the mindfulness features.

The prior MQP group implemented features to track sleep, caffeine, stress, and exercise through user input and Fitbit integration. We added more features into the application such as water intake logging, outlook integration, mood tracker, and user interface modifications as discussed in following sections.

3.1.1 Update WPI Sleep Server and Database

The WPI sleep server is located at: sleepwebapp.wpi.edu:5000. Since the application was inactive for two years (2020-2022), the servers and dependencies were incompatible. To resolve this issue, our group updated the dependencies for backend services such as Firebase with the help of our advisor, Dr. Ermal Toto. We also reactivated the database used for the application that is on the server.

The database, which uses PostgreSQL, an open-source, industry-standard database management system, was updated. Using the previous group's schema, we incorporated our newly implemented features. We added WaterEntry and MoodEntry tables for our new features. WaterEntry has entry_id, user_id, date, cups, and avg_size columns whereas MoodEntry has entry_id, user_id, date, and mood columns. Although we updated a few existing features, we made changes to the code instead of the database so the prior database tables from the previous MQP team remained intact. The updated schema is shown in Figure 10.

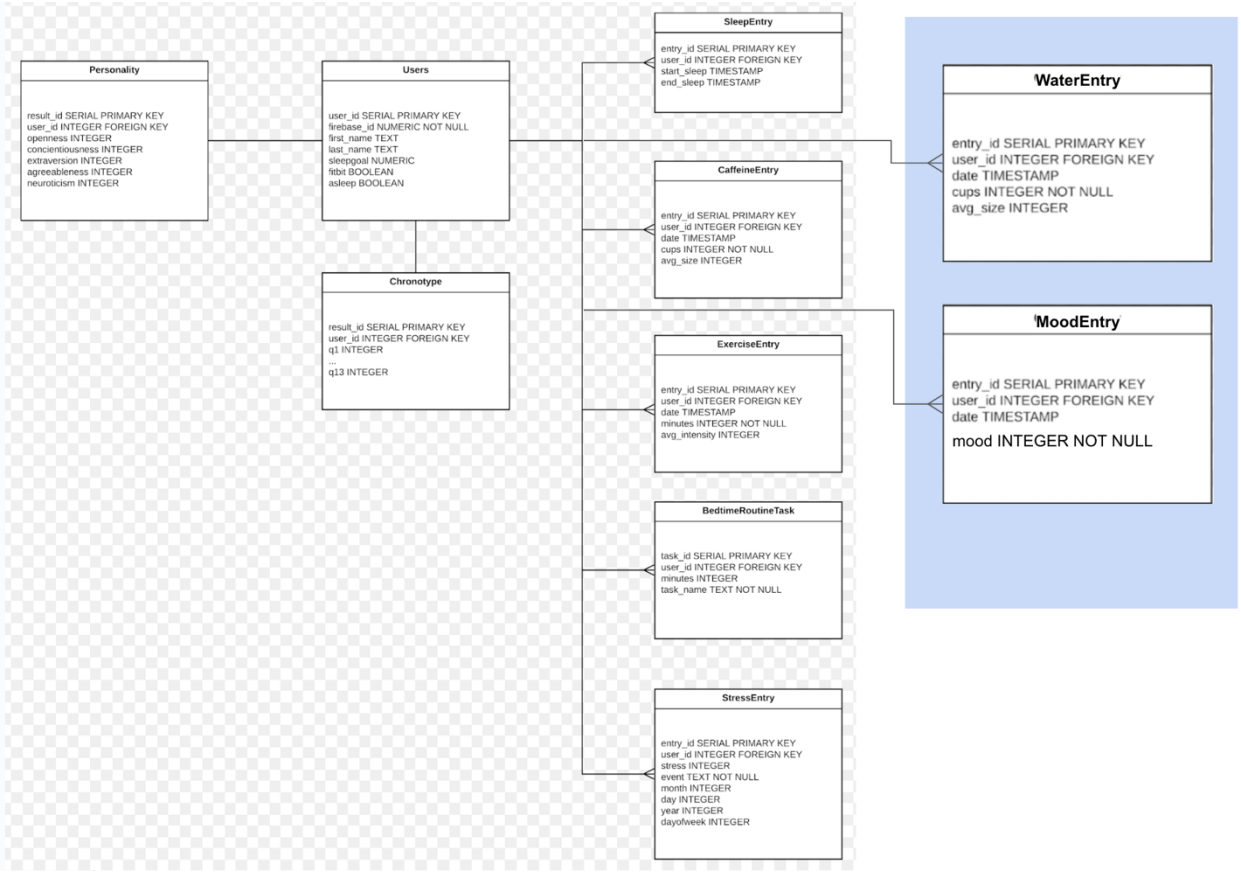

Figure 10 Updated Database Schema with New Features: Water and Mood. Prior database tables from the previous MQP team remained intact. The new tables are highlighted in blue.

In addition to the database update, React Native dependencies had to be updated. Once the dependencies were updated to the most compatible versions, the application ran successfully

on the WPI sleep app server. Our group documented all the issues regarding updating the servers and dependencies in Appendix A.

3.2 Update Existing Features

Although the previous group implemented useful features, some of the features needed to be updated or improved.

3.2.1 Caffeine Intake

Caffeine intake can have a negative effect on sleep health. Caffeine is a stimulant that can disrupt normal sleep patterns, causing difficulty falling asleep and staying asleep. The caffeine intake logging feature only considered the number of cups, neglecting the beverage size. To generate the personal report for users more accurately, we updated the application to take both cup size and number of cups into account (Figure 11).

Figure 11. Updated caffeine intake feature

3.2.2 Homepage UI

We also updated the user interface of the homepage. The previous group had separate buttons for settings and sign-out options. To polish the header of our application, we removed these two buttons on the top right and added a hamburger button on the top left corner to provide users with options to select a feature, settings, or sign out (Figure 12).

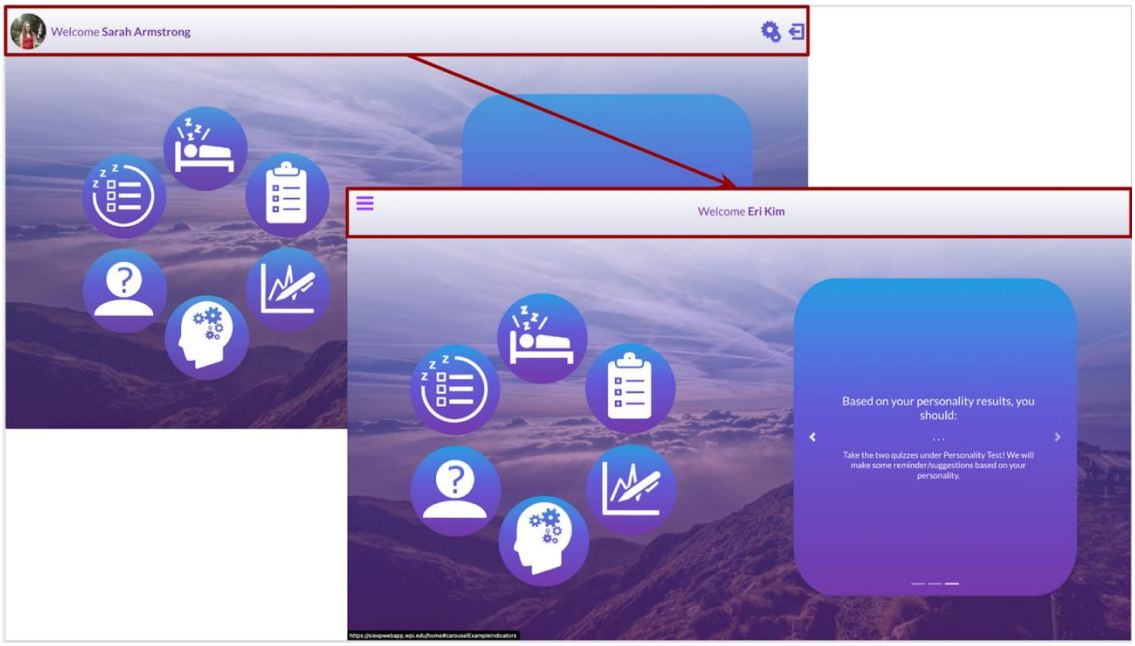

Figure 12 Before (left) vs After (right): Home page - header

Additionally, the introduction or brief description of the application was missing. We replaced the rectangular container with the name of our application but retained the useful information below (Figure 13).

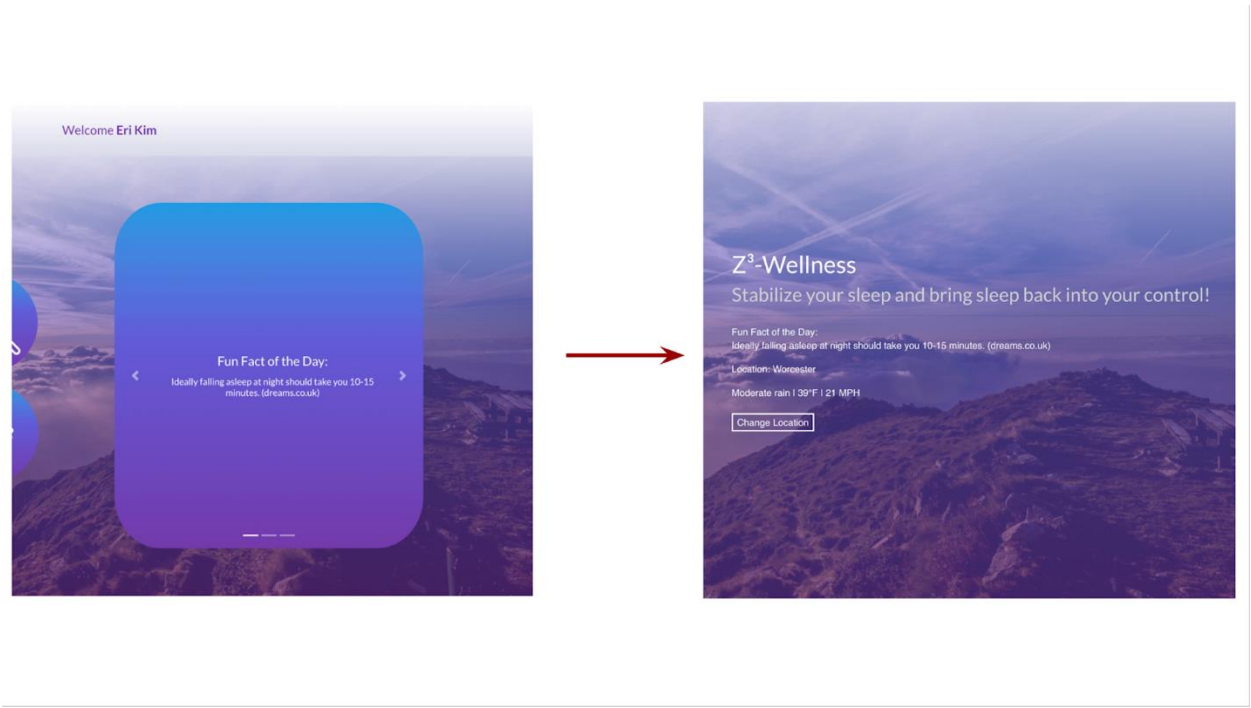

Figure 13 Before (left) vs After (right): Home page - App Introduction

3.2.3 Personal Report Visualizations

Considering all the data that the application is tracking, our group implemented more visualizations to analyze the data. Instead of having numerical or categorical values displayed for each day, we created six different charts to visualize the user's daily habits and they are presented weekly as shown in Figure 14. This helps the user compare their patterns to the recommended amount of sleep, stress, caffeine, water intake, exercise, and mood easily with visualizations.

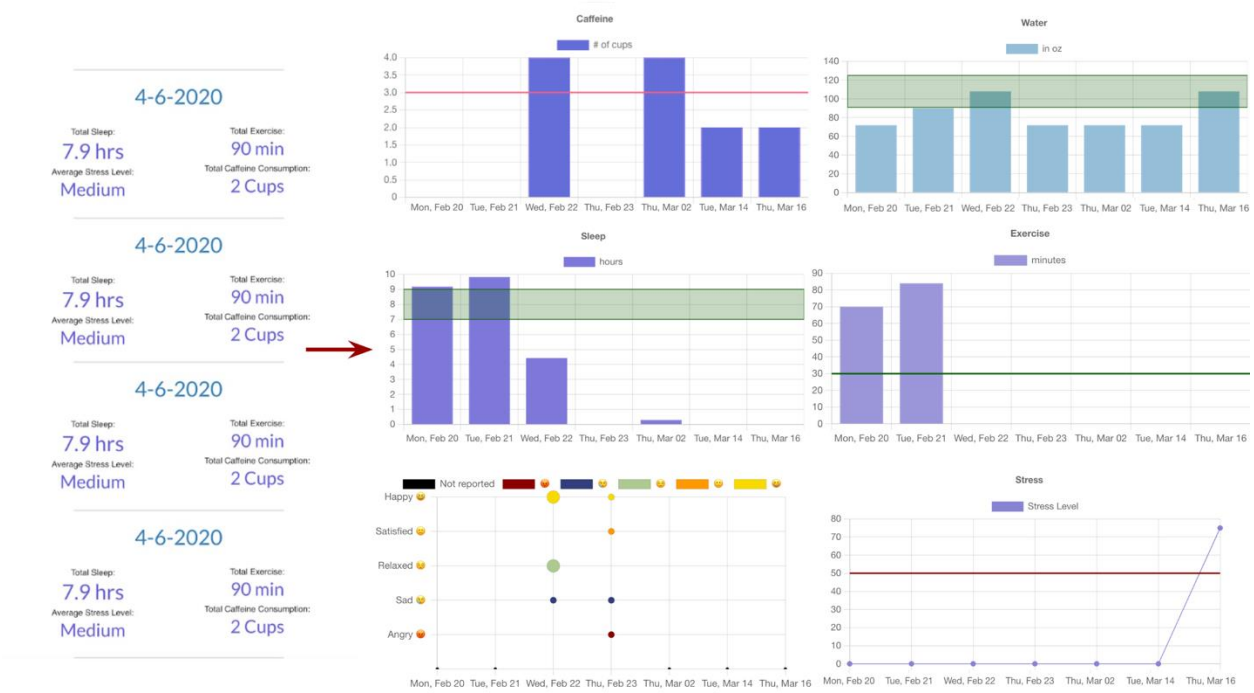

Figure 14. Before (left) vs After (right) Personal report page. The red horizontal lines indicate the maximum amounts recommended. The green areas or lines represent the recommended amounts.

3.3 Implement New Features

To accomplish the goal of this project, our group researched factors that contribute the most to sleep health. In addition to the existing features, our group added new features that capture the sleep-related factors identified in our research.

3.3.1 Water Intake

Adding a water intake feature can help users monitor their hydration status, hence improving their quality of sleep. The water intake feature allows users to log their water intake, water bottle size in ounces and number of bottles. The water intake feature was added to the

"Log Your Daily Stats" page. It has an animation that represents the amount of water that the user drinks compared to the recommended amount of water to drink every day (Figure 15).

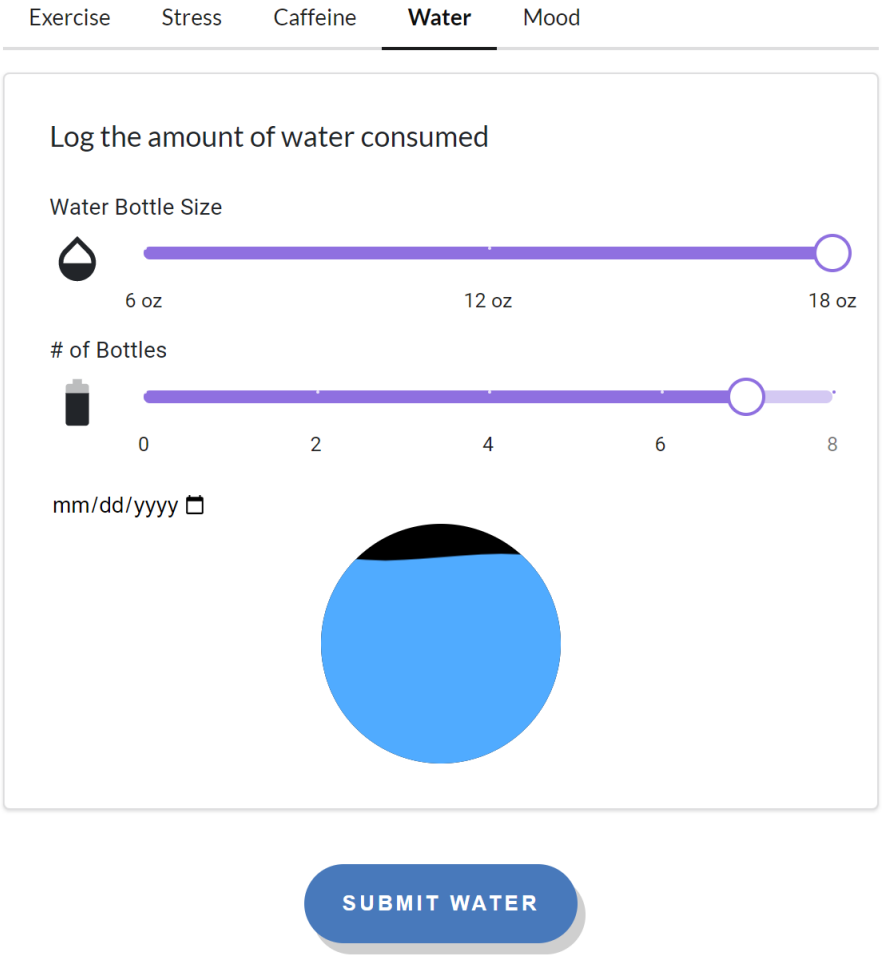

Figure 15 Water intake feature

3.3.2 Mood Tracker

Mood tracking can help users identify patterns in their sleep and mental health that may be causing difficulty in sleeping. By tracking mood, the app can have a better understanding of how their sleep and mental health influence one another. This can be helpful for future groups to apply Machine Learning over the data collected by the app to see the relationship between sleep and mood. Our group created a similar mood scale to the one of Daylio based on the same emojis

and sent the quantified value to our Firebase database. This will be useful for future work, where the group can implement user-based recommendations based on the user's mood.

Mood tracking was implemented in the application by using an emoji scale (Figure 16). Some research has shown that the emoji-based measure provides an ultra-brief measure of mood and current experience [31], which enhances the user experience of the application. The emojis were chosen based on the most frequent ones logged by users [31].

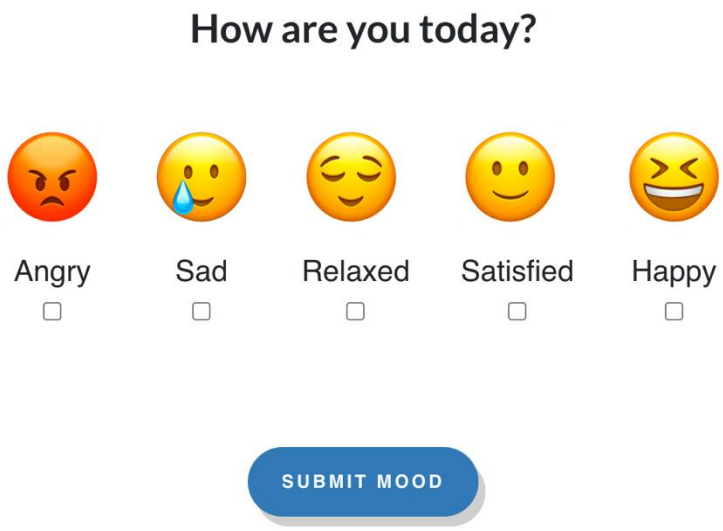

Figure 16 Mood Tracker

To visualize the mood logged by user, we added a bubble chart to the report page using Chart.js (Figure 17). Chart.js renders charts using the Canvas element instead of SVG (Scalable vector graphics), which results in reliable performance especially with a large amount of data. It also provides interactivity such as hover effect. The y-axis corresponds to the five different emojis of mood whereas the x-axis represents the date logged. The radius of a circle is proportional to the number of times the user logged the specific mood.

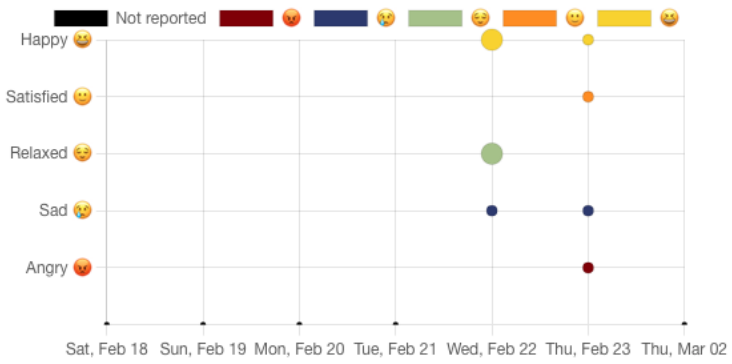

Figure 17 Bubble Chart Showing Mood Logs in Report

The mood tracker was implemented so that this information can be used to identify relationships between mood and sleep quality. For example, if the user has a pattern of logging “Angry” or “Sad” when they also slept poorly, this information can be used to make recommendations on how to improve both their sleep and mood. Additionally, tracking mood can provide a more comprehensive picture of the user's overall health and well-being. A mood tracker can also help users become more aware of their emotional patterns and identify any triggers that may affect their mood and sleep. Overall, the integration of a mood tracker in a sleep health application can lead to a more comprehensive approach to improving the user's sleep and overall health.

This is useful because it allows the app to collect relevant data about the user’s daily habits. For example, if a user has three exams in one day and logs that they are “Sad,” the application could recognize this, and recommend daily habits such as exercise or meditation to improve the mood.

3.3.3 Logging Time Options

Based on the feedback we received from Professors external to this project, we decided to add an option for users to log the date and time of exercise, caffeine, and sleep. This allows users to log any missing data from the past. Our group decided to add this feature for more accurate data analysis by reducing the amount of missing data (Figure 18).

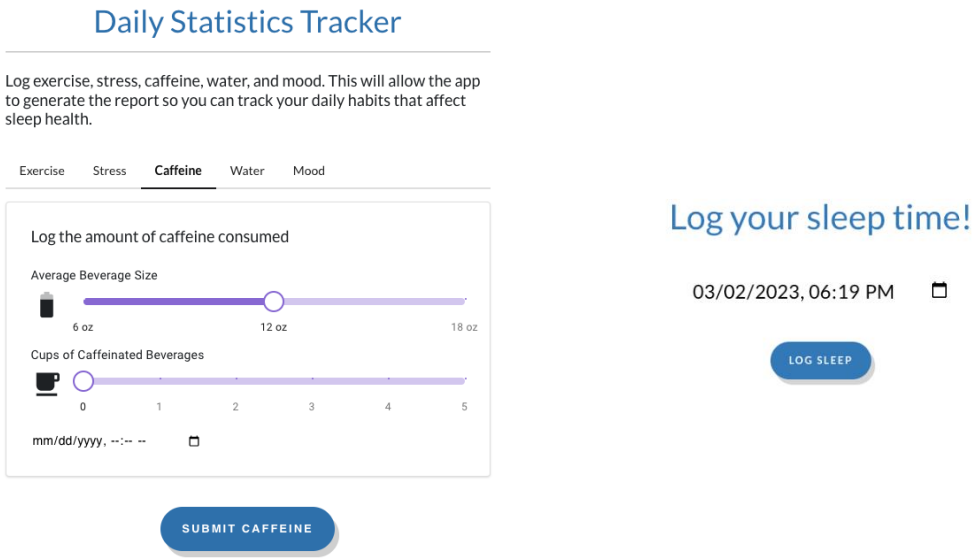

Figure 18 Timestamp Option for Caffeine Logging (left) and Sleep Logging (right)

3.3.4 Recommendations

In this section, we discuss a recommendation strategy that our group implemented based on the user's daily habits and aim at improving their quality of sleep.

Our group created a simple recommendation system based on the user's habits during the week, as proof of concept which can serve as a guideline for future groups. By taking the average statistics available on the report page, the app recognizes the lack of sleep and notifies

the user that it is recommended to sleep more (Figure 19). The main use of this is to encourage users to sleep the recommended amount per day.

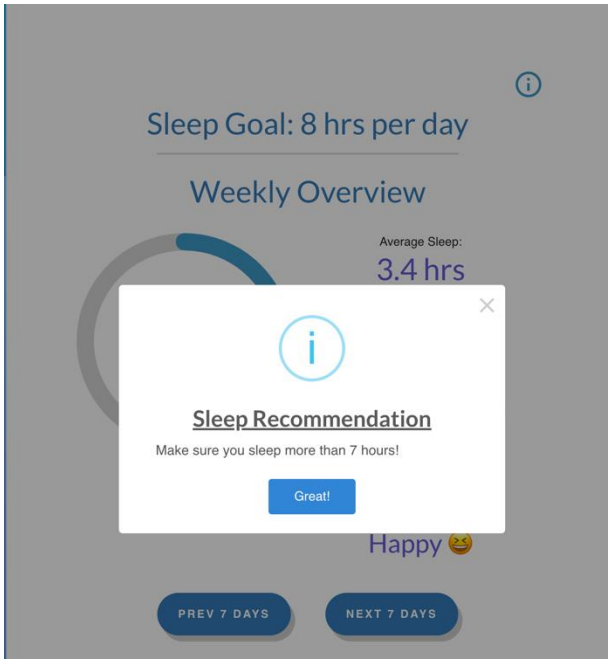

Figure 19 Sleep Recommendation

A similar approach can be used for exercise and water intake; if the user is not exercising or not drinking enough water, the app can notify the user that it is recommended to drink more water every day and exercise for at least thirty minutes per day. If the user has stressful events such as exams or project due dates, the app can recommend a leisurely walk or direct to the mindfulness module to relieve the user's stress and improve their quality of sleep.

By tracking and analyzing the user's daily habits, the application can identify patterns and make recommendations that are specific to their needs. This leads to a more tailored and effective approach to improving sleep health. Additionally, the recommendations can help raise awareness and encourage users to make positive changes in their habits, such as getting enough

sleep, exercising, drinking water, and managing stress. All these factors contribute to overall sleep quality and can have a significant impact on the user's well-being.

Lastly, when users log their sleep time, the app has a pop-up that contains information regarding the ideal sleep environment based on our research as described in Section 2.3.1.

3.3.5 Mindfulness Module

The user interface of the mindfulness module was modified to make it more consistent with other pages (Figure 20). To achieve this, six circles that directed users to other pages have been removed and replaced with tabs. These tabs allow users to access videos related to a specific module with a single click without changing the page. Additionally, we replaced the outdated videos on each page with videos that are more current and relevant.

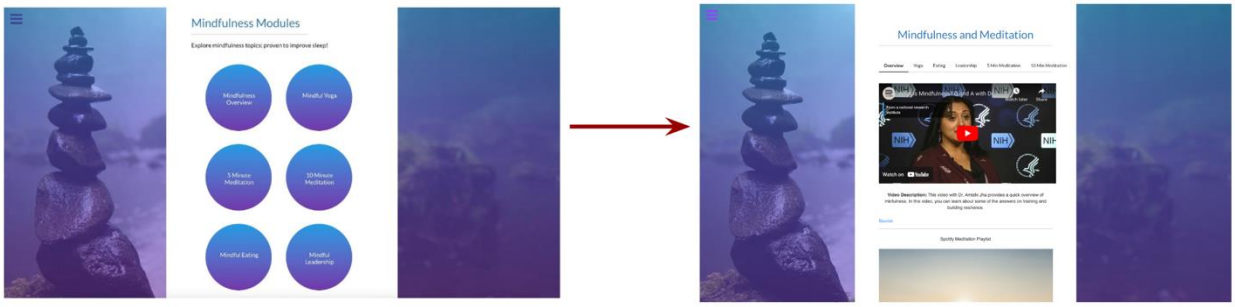

Figure 20 Mindfulness Module Before (left) vs After (right)

3.4 Integrations with Other Platforms

Our team has made the app more accessible to users by integrating with Microsoft Outlook and Spotify. This eliminates the need for manual entries and makes it even easier for users to use our app.

3.4.1 Microsoft

Integrating Microsoft Outlook into our platform was a strategic move aimed at enhancing the user experience. Given that Outlook is the most widely used platform among students at WPI, we felt it was important to offer them the convenience of logging in with their WPI account. We leveraged the integration of the app with Google calendar, created by the previous MQP group. We provided links on how to integrate Google Calendar and Outlook or Canvas Calendar to synchronize all their data, including homework assignments, meetings, quizzes, and exams, making it easier for the app to stay up to date with their schedule. By having access to this information, the app can then make personalized recommendations, such as suggesting a specific bedtime, to ensure the user is fully prepared for any upcoming events. The integration of Microsoft Outlook into our platform makes it a highly functional and user-friendly tool for WPI students.

3.4.2 Spotify

Our group decided to add Spotify playlists to enhance the mindfulness module. In addition to the videos that the previous group included, we decided to add Spotify playlists for yoga, meditation, mindful eating, and mindful leadership because it is one of the most popular platforms for college students for music and podcasts. When a user clicks on the image, the app redirects to the Spotify playlist (Figure 21). The images featured for the Spotify playlists were sourced from Getty images and were carefully selected to align with the playlist themes.

Spotify Meditation Playlist

Figure 21 21Spotify Meditation Playlist

3.5 Feedback from Professors

With the help of our advisor, Prof. Ruiz, scheduling meetings, our group was able to gather feedback on the app from Dr. Paula Fitzpatrick (the Director of the Center for Well-Being), Prof. Richard Lopez, Prof, Diane Strong, and Prof. Soussan Djamasbi. The feedback we received proved to be invaluable as it offered expert insights into our application. We produced the list in Appendix B summarizing the feedback and using it to improve our application by an iterative process.

4. Conclusions and Future Work

Our team built upon the project by the previous MQP teams that developed a sleep health app. Our focus for this project was to enhance the user experience and expand the app's functionality to better help users improve their sleep health.

We first worked on fixing dependency issues and updating the server to ensure that the app runs smoothly and reliably. We then worked on enhancing app features and adding new ones. One of our main additions was the water intake tracker. Proper hydration is critical for overall health, including getting excellent quality sleep. Our water tracker allows users to easily monitor and track their daily water intake and stay on top of their hydration goals. Another addition was the mood tracker. Our team incorporated scientific research that shows how mood and sleep quality are interconnected. By tracking their mood in the app, users can identify any patterns or triggers that may be affecting their sleep and take steps to address them. We also made improvements to the app's user interface, making it more intuitive and user-friendly. This included a redesign of the mindfulness page, where users can access various Spotify playlists designed to promote relaxation and better sleep. We implemented a new recommendation feature that establishes a baseline for the recommended amount of sleep. If the user is sleeping less than seven hours per night, the app will suggest increasing their sleep time to improve overall sleep health.

Overall, our team's work focused on expanding the app's capabilities to provide users with a more comprehensive set of tools for monitoring and improving their sleep health. Through the addition of features such as the water and mood trackers, as well as the redesigned user interface and improved recommendation system, we have created a more effective and user-friendly app that can help college students get better quality sleep.

For groups that proceed to work on this MQP, we suggest incorporating advanced features to improve the quality of the application and improve user retention. For instance, more Fitbit features can be integrated such as stress and self-reporting mood. This allows the mood and stress data to be collected automatically from Fitbit so that the application can learn to relate stress levels with calendar events in the future. In addition, the sleep data from Fitbit currently includes the amount of time in bed instead of total sleep time. To fix this, the future group can use "minutesAsleep" field from Fitbit data. This might require changes in the database since there are two separate columns, start and end time. Another example would be the integration of the Apple Watch API. This would work similarly to Fitbit, as the Apple Watch can track exercise data, which would require less manual entry for the users.

After researching the existing sleep and wellness apps, our team suggests that incorporating a personalized coach that uses the data collected from users to identify daily habits and make recommendations to improve the overall health and wellness would be helpful. The coach can be achieved by applying machine learning, which will be able to analyze the data and provide customized insights and suggestions for better daily habits. Our group created a basic model of this for the sleep feature, but this can be improved. This approach would enable the app to detect certain habits that may be unhealthy and can offer suggestions to improve the quality of their sleep. This would encourage users to continue to use the app and make it an essential part of their daily routine.

In terms of the visualizations on the report page, we suggest looking into D3.js as it is more flexible and provides dynamic properties to most of its functions. This could be implemented to replace the Chart.js visualizations that were created because there are more

options available. These visualizations could improve the overall success of the application and improve user retention.

Another suggestion for future MQP teams would be to leverage the flexibility of Postgres by incorporating JSON queries. This would allow the team to create a generalized database while also customizing tasks by recording task data as a JSON blob that can be queried. This would allow the teams to take advantage of the benefits of the original development as well as incorporating new upgrades, resulting in a more robust and adaptable solution.

There is a development environment that is live and has an identical environment that helps deployment. We suggest implementing continuous integration with GitLab, which allows app development without the need for extensive local setups.

Lastly, our group developed this application on Chrome; however, it encounters a few errors when run in Firefox. After research and troubleshooting, our group found out that the application works in Firefox Troubleshoot Mode, where add-ons and some other features and customizations are disabled. React applications are compiled differently in Chrome and Firefox. We recommend that future groups investigate ways to make the application compatible with different browsers.

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Appendix A

For future Sleep Health MQP students:

When we began this project, the app was using dependencies that were no longer compatible.

- Dependencies that may affect the app's functionality:
    - Node and NPM versions outdated | node -v, npm -v
        - If versions must be updated | sudo n stable, automatically updates npm version to be compatible. If not | sudo npm install npm@latest
    - Check nvm version | nvm -version
    - If nvm is not found | cd ~, ./install.sh, source .bashrc
        - sudo apt remove nodejs //remove old node jse
        - curl https://raw.githubusercontent.com/creationix/nvm/master/install.sh | bash
        - nvm install script
        - nvm install --lts // install latest stable nodejs
        - nvm use 16.17.0 //use latest stable node
        - run npm install
    - Check if nvm is available: nvm list
    - Use most current nvm use 16.17.0
    - Issue with BedtimeProgressBar.js | cd /src/components, sudo vim BedtimeProgressBar.js
    - Add following line of code to start: *import $ from "jquery;"*
    - Package-lock.json and node_modules are corrupt | sudo rm -rf node_modules, sudo rm package-lock.json

    - Firebase version outdated

- Build server using the following commands
    - sudo npm install
    - sudo npm start build
    - serve -s build
    - If error, cd ~
    - ./deploy.sh
    - Check if server started using the following commands:
    - cd /var/www
    - ls -l /displays the html files created and the time of creation

- To Deploy Changes

  SSH into sleepwebapp: *ssh* *username@sleepwebapp.wpi.edu*

    - For front end changes:
        - sudo su sleepapp
        - cd /opt/SleepApp
        - git pull
        - cd app
        - npm run build
    - For back-end changes:
        - cd /opt/SleepApp/SleepApp_backend
        - git pull
        - exit

        - sudo service sleepapp restart
        - sudo service sleepapp_backend restart

- For PostgreSQL database
    - To create a new table
        - sudo su postgres
        - psql
        - CREATE TABLE TABLE NAME
    - Grant permission to all schemas after making addition changes:
        - sudo su postgres
        - psql
        - GRANT ALL PRIVILEGES ON ALL TABLES IN SCHEMA public TO sl3ep6243;
        - GRANT ALL PRIVILEGES ON ALL TABLES IN SCHEMA information_schema TO sl3ep6243;
        - GRANT ALL PRIVILEGES ON ALL TABLES IN SCHEMA pg_catalog TO sl3ep6243;
        - GRANT ALL PRIVILEGES ON ALL TABLES IN SCHEMA pg_toast_temp_1 TO sl3ep6243;
        - GRANT ALL PRIVILEGES ON ALL TABLES IN SCHEMA pg_temp_1 TO sl3ep6243;
        - GRANT ALL PRIVILEGES ON ALL TABLES IN SCHEMA pg_toast TO sl3ep6243;

- GRANT ALL PRIVILEGES ON ALL SEQUENCES IN SCHEMA public TO sl3ep6243;
- GRANT ALL PRIVILEGES ON ALL SEQUENCES IN SCHEMA information_schema TO sl3ep6243;
- GRANT ALL PRIVILEGES ON ALL SEQUENCES IN SCHEMA pg_catalog TO sl3ep6243;
- GRANT ALL PRIVILEGES ON ALL SEQUENCES IN SCHEMA pg_toast_temp_1 TO sl3ep6243;
- GRANT ALL PRIVILEGES ON ALL SEQUENCES IN SCHEMA pg_temp_1 TO sl3ep6243;
- GRANT ALL PRIVILEGES ON ALL SEQUENCES IN SCHEMA pg_toast TO sl3ep6243;

Appendix B

Feedback from Professors Dr. Paula Fitzpatrick (the Director of the Center for Well-Being), Prof. Lopez, Prof, Diane Strong, and Prof. Soussan Djamasbi:

- Conduct research on most popular sleep/health applications and identify the most useful features.
- Find the most impactful features for university students' health and quality of sleep.
    - This led to integration of Fitbit and Spotify API for a personalized experience.
- Create a user study or IQP (Interactive Qualifying Project) to collect data and collect demographics about the users.
    - This will prove especially useful for future MQP's as they will be able to create a machine learning model.
    - The goal is to create more accurate recommendations for user's daily habits and sleep based on their demographics.
- Involve Center for Well-Being to promote our sleep application.
    - Useful for gaining more attraction to the application and encouraging better sleep habits for students at WPI.
- Change exercise levels on backend from intensity to numerical values
    - This improved our recommendation system to encourage users to exercise for at least thirty minutes every day.
- Incentivize statistics with badges or achievements when users log for their daily habits for a week or longer.
    - Encourages users to use the app daily and retains users for a longer period.
- A student group used the application for a week.

    - Useful for assuring the database registers the users and viewing their daily habits.
    - Provided feedback on the app's interface.
        - Improved functionality and made it easier for users to log their daily statistics.
- Include the recording of the time of exercise and other daily habits.
    - Our group implemented the ability to log statistics at various times of the day.
    - Incorporated the ability to log statistics for different days as well if users missed logging their daily statistics.
- Incorporate other types of events for stress, not just stressful events, but also meetings and the number of events.
    - This will help in finding a more accurate representation of a user's stress levels.
- Encourage incorporating Koru meditation into application.
    - Our group implemented the Koru meditation videos in the mindfulness module and implemented Spotify playlists to encourage users to listen to meditation audio.
- Suggest implementing a daily alcohol intake.
    - Although alcohol is a major factor in the quality of sleep for a person, our group decided to not incorporate this since our target audience is college students.