Mobile App Development for the WPI Gordon Library

An Interactive Qualifying Project submitted to the Faculty of WORCESTER POLYTECHNIC INSTITUTE in partial fulfillment of the requirements for the Degree of Bachelor of Science.

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i. Abstract

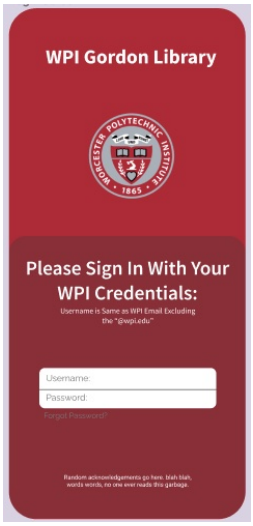
Technology is constantly advancing, and in an academic context, the need for updated technology is great. An academic library offers many helpful resources and services to students. The goal of our project was to develop a mobile application for the George C. Gordon Library to facilitate the delivery of several heavily used services and resources. Efforts included a substantial amount of both comparative research and technical exploration prior to development. A WPI student survey was conducted additionally to determine which resources and functions would be of value in a library mobile app. Five resources were selected for implementation: occupancy tracker, tech suite booking, library hours, library chat, and news events. Preliminary designs, including themes, layouts, and user flow, were developed to inform the production of an operational, usable, and relevant product. Due to time constraints, prototyping and production of the functional application was not completed. Recommendations were provided to the Gordon Library to facilitate the development of an operational mobile application to be approved on major app stores for public use.

ii. Executive Summary

In this project, as a team of three, we developed the frameworks for a mobile app for the WPI Gordon Library. The first step was the literature review. We analyzed the current literature on mobile library applications. We reviewed different articles discussing current relevant technology, concluding that the application should be lean and adjustable, so that it can be maintained and improved upon in the future. Furthermore, the application should incorporate other relevant technologies.

We developed a survey to send out to the students to gauge which services and resources students would find most relevant in a library app. The survey asked about a number of things, including major, year of graduation, and which library features were most used by the student body. From these results, we narrowed the application down to a few key features which we thought would be both easy to implement and useful for the student body. We then developed various mock-up designs using the Figma - a software for wire-framing.

The designs for our application can be seen below:



(a) Design #1

(b) Design #2

(c) Design #3

Figure 1: Login Screen Concepts

Due to the time constraints and other factors, prototyping and production of the functional application were not completed.

iii. Glossary

API Application Programming Interface

AWS Amazon Web Services

CSS Cascading Style Sheets

GUI Graphical User Interface

HTML HyperText Markup Language

HTTP HyperText Transfer Protocol

HTTPS HyperText Transfer Protocol Secure

JSON JavaScript Object Notation

OS Operating System

PWA Progressive Web App

SCSS Sassy CSS

UI User Interface

iv. Authorship

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iii. Executive Summary	**John Muirhead**	**John Muirhead**
iv. Authorship	**Brandon Scanlon**	**All**
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1. Introduction

The overall use of handheld devices has increased dramatically within the past decade or so, especially in academic practices. As technology grows, our environment adapts to such changes. However, to keep up with the advancements of technology is no simple task and public services can fall short. The WPI George C. Gordon Library, for instance, offers high quality information resources, expert consultations and instructional services, and a variety of work spaces to support the WPI community. Students can utilize the library for its quiet study spaces, private group study rooms, research consultations, and more. On the technical side, the library staff is able to provide their services through a handful of different systems. These resources, on the other hand, are made available strictly on web-hosted applications, requiring a web browser. This is quite cumbersome and not user friendly on mobile devices whatsoever as a mobile website is merely a stripped-down version of the source web page. In our world, where convenience is key, the student demographic as turning away from using the library services.

As few steps had been taken towards improving the accessibility of such services, this project aimed to produce a mobile-first web application, centralizing many library services into one place to cater to mobile devices and promote convenience. We believed that by establishing a fully functioning mobile application, the ”traffic” to the library’s resources and services would increase, along with the foot traffic within the Gordon Library building.The expansion of other requested services, such as individual computer occupancy tracking so that users can know how many computers are available at a given time, and a remote book check-out service were beyond the scope of this IQP project.

The Progressive Web Application (PWA) standard was utilized for the development of the mobile application. This means that our application meets the following criteria:

- ✓ Progressive – Works for most users on most devices and web browsers.
- ✓ Responsive – User interface (UI) fits any common form factor: desktop, table, mobile.
- ✓ App-like – Feels and acts like a native mobile app on mobile devices.
- ✓ Safe – Content served via encrypted HTTPS to secure user accounts and interactions.
- ✓ Discoverable – Identifiable as a website, found on search engines.
- ✓ Installable – Able to be added to a mobile device's homescreen as a normal app.
- ✓ Linkable – Easily shared via a URL and does not require complex installation.

The PWA standard is still being adopted by some browsers and devices. At the time of the WPI Library app development, support for every feature may not be available to all users, depending on device and browser.

2. Literature Review

2.1 Introduction

Within this chapter, we share an overview of the problem pertaining to the library resource's mobile capabilities, academic and otherwise. We will describe the pros and cons, as well as the possible solutions. Next, we delineate best practices related to mobile application development that have been refined and certified by experts within this field. To conclude, we introduce the requirements to develop a mobile application from the ground up.

2.2 Significance of the Topic

Our world is becoming more and more reliant on devices such as our mobile phones. These mobile devices unlock a connection between the user and a vast and seemingly endless supply of helpful and sometimes not so helpful resources. With this in mind, this connective architecture, according to Yip et al., ”serves as a virtual platform for learners to engage with their learning activities in a more spontaneous, personal, informal, contextual, portable, ubiquitous and pervasive way” (2021, p. 389). Mobile applications are greatly utilized in the academic world on all levels. From elementary school to college graduate students, such applications aid each one to some extent, broadening their learning capabilities and resources.

Mobile apps can often emulate desktop-based websites, but are streamlined in comparison. The use of this is to take a website that is accessible through a desktop or laptop and enable the same or more stark access to the same website. While developing a mobile website that could house the resources of a library may be a more simple task, it leaves for less capabilities and utilities for the mobile user. Developing a native application that can support any mobile platform is a more daunting task, however, the results are of a much higher quality in the end. The user experience in this case is far superior to that of a website (Margam & Saleeq, 2017, p. 110).

Shih-Chuan Chen states, based on the results from a survey of undergraduate students, ”Many libraries provide mobile app services because of the rapid increase in smartphone users” (2019, p. 731). He also goes on to note how many elementary tasks are accomplished more efficiently on a mobile device than on a computer, however, the inverse is true for tasks that require the use of searching and web browsing. Laptops and desktops alike were proven to supersede mobile devices in this case, however, mobile devices are still useful for these tasks. This survey shows that, having academic options such as mobile resources that are engaging and user friendly could negate the necessity of in-person attendance to a library or other academic facility. Certain resources such as occupancy tracking, tech suite booking, library hours, and others would not only help students

to use their time more efficiently, and potentially reduce the number of people in the library and thereby help follow any local social distancing guidelines in a safer manner.

After all, we live in a time where convenience is of utmost importance. No one of us desires to wait for access to something we need to use. It is a natural human behavior. Technology has amplified that mentality as it provides its users relatively instant access to just about anything at anytime (Shahriza et al., 2006).

When developing a mobile application, many factors have to be considered well in advance before code starts to be structured and written. For example, a native application is typically developed to be supported on a specific device platform such as IOS devices. Thus, when developing a mobile app, additional steps need to be taken to include the possibility that the app can be supported by all or most other mobile devices as well. After development, the application will need to be verified and reviewed by the various app stores, i.e. Android's Google Play Store and Apple's App Store, to be displayed and downloadable for any user on each respective platform. Since the application is intended to be public and accessible by many, it has to be run on a network server (Huy & vanThang, 2012, p. 25-26). These App stores have a significant amount of user traffic, and billions of application downloads and dollars in revenue have transpired on just the Apple App and Google Play stores. These conditions make for a seriously competitive industry (Wang et al., 2017, p. 163).

Acknowledging the features a mobile application should embody can be relatively easy, but determining the delivery format and final product in which the user consumes such an app is far more difficult. In a study conducted by Ngu Phuc Huy from Norwegian University of Science and Technology and Do vanThanh from Telenor & Norwegian University of Science and Technology, four different types of mobile app paradigms were analyzed: Mobile native applications, Mobile widgets, Mobile Web applications, and HTML5 mobile applications. From their research, Huy and vanThanh devised what they called "Evaluation Criteria" (`https://doi.org/10.1145/2428955`

.2428968) which outlines a rigorous and detailed template for mobile app development (2012, p. 26-27). This evaluation criteria spells out the necessary steps, some perhaps unnecessary in some cases, that aid a developer in structuring and designing a mobile application. Each criterion is carefully considered in the development process to deliver a product to the selected demographic in the best and most effective way possible.

2.3 Known and Unknowns

Any experienced programmer can effortlessly throw together a quick application, but developing a user-facing application that people will want to use is entirely another beast. A development team requires more resources, such as designers for the look-and-feel of a mobile application. This also applies to the development of a mobile library application. According to Saragossi et al., ”the adoption of mobile apps as an emerging format within the Libraries’ collections necessitates a varied outreach strategy that endeavors to make apps accessible and approachable” (2018, p. 202). So, how does one design and implement an accessible and approachable mobile application? Through research. This research includes, surveys and credible sources to provide evidence and a concrete background that will lead the reader to the point in which the team’s work will embark.

Shih-chuan Chen, a professor of Library and Information Sciences, researched the potential benefits for students when using mobile applications to search library catalogs. The study ”demonstrates that the participants spent more time completing tasks while using the laptop than that they did while using the mobile app” (Chen, 2019, p. 727). This research clearly shows that users can be more efficient on a mobile device, specifically in the case of utilizing academic library resources.

However, not all features of applications are best used on mobile devices. For example, the same study proved that:

> ten participants [out of 16 undergraduate students] reported that it was easier to search the library catalog using the laptop. They explained that they were familiar with the interface of web OPACs [library catalog], and more information was displayed. Moreover, the web OPAC offered more functions. (Chen, 2019, p. 728)

2.4 Current Models in This Field of Study

A 2018 study by Mansouri and Soleymani, investigated the necessary features for a library mobile application. The research was performed at the University of Isfahan, known for science, humanities, and engineering.

	Academic library		Public library	
Services	Count	(%)	Count	(%)
Search	10	100	5	100
Search by barcode scan	1	10	5	100
Search by QR code scan	0	0	0	0
Tutorial	7	70	0	0
Ask a librarian	10	100	3	60
New books	4	40	3	60
Databases	10	100	5	100
Local search	2	20	3	60
Order	6	60	1	20
Renew and circulation	10	100	2	40
Browse	8	80	0	0
Audio tours	2	20	0	0
Virtual tours	0	0	0	0
Citation	5	50	0	0
Audio books	0	0	0	0
Selective dissemination of information	3	30	1	20
Employees	8	80	1	20
Hours	9	90	2	40
Library maps	6	60	0	0
Google Maps	6	60	0	0
Events	6	60	5	100
My Library	9	90	5	100
Help	7	70	2	40
Contact us	6	60	3	60
FAQ	3	30	0	0
Feedback	3	30	2	40

Figure 2.1: Frequency and percentage of components in library mobile applications by type of library

Note: From "Assessing mobile application components in providing library services," by A. Mansouri and N. Soleymani Asl, 2019, *The Electronic Library*, 37(1), p. 53 (https://doi.org/10.1108/EL-10-2018-0204). Copyright 2019 by Emerald Publishing Limited. Reprinted with permission.

Figure 2.1 shows the breakdown of all services found within the library mobile applications reviewed by the study, and how frequently they were utilized. The ”Public library” column is irrelevant in this report. This is a great example of a model for features that are used in the field already. Such features (see Appendix 6.3.2 for a detailed outline of each) include a search, either by barcode or QR code or both. This enriched set of features was made a common resource within each of the library applications reviewed in this study. Tutorials to help viewers to learn the platform and its capabilities for those who are perhaps new to it are yet another useful feature. The ask a librarian resource would bridge the gap between a librarian and an individual who may have questions for a librarian. A simple, yet helpful feature quite commonly seen in other library applications is the library hours. Having access to the hours of a library provides the users with much of the information they should need to utilize it. The remaining details that may be missing from the user's knowledge would be event and calendar information. Nearly every library mobile app reviewed in this study by Mansouri and Soleymani, provides such a feature. Lastly, a FAQ (Frequently Asked Questions)/Feedback element, not quite as commonly included within a library mobile application, was considered useful nonetheless.

2.5 State of the Art

Throughout the years, app development has improved in both efficiency, quality, and accessibility. As a result, library apps - as well as similar learning-based apps - have improved in these criteria congruently. One feature of modern day mobile applications is an emphasis on integration with other relevant software. For example, an Ex Libris press release about the Libris CampusM Mobile App, stated: ”The flexibility of the app enables it to be integrated with learning management systems such as Blackboard®, Canvas, and Moodle™”(Ex Libris, 2017). This cross-platform paradigm is essential in applications which were built to service existing technologies and state of the art library mobile applications, and integrate with existing programs and databases. Pu et al. (2015) describes the origins of a library mobile app; ”A number of libraries gradually sensed this trend and combined their services with mobile technology to created so-called Mobile Library or M-Library”.(2015, p.15-31).

In addition to being highly integrated with existing technology, state of the art mobile applications utilize technologies built into smartphones in order to give users the best possible experience. Hu Neamtiu (2016) state, ”The behavior of smartphone apps is driven by input from sensors such as GPS, microphone, or camera” (p.50-56). State of the art library applications also utilize the technology provided by mobile phones in order to maximize their utility. For example, a library app might use the camera in order to scan bar codes. Furthermore, a library application could utilize the GPS technology to inform users about their distance from the library. Essentially, state of the art apps, including library apps, utilize the state of the art technology features on smartphones.

Another feature of modern technology, particularly software, is change. State of the art applications are dynamic entities; they improve with time and require consistent maintenance (Hu & Neamtiu, 2016). Anand et al. (2020) writes, ”Thus, to keep the software and its data safe, software developers perform continuous testing of the product in its operational phase and release software upgrades or software updates/patches to fix any uprising issue and to improve it (p.1071-1085). Es-

sentially, state of the art software, mobile applications specifically, including library applications, are upgraded, maintained and modified on a regular basis.

Yet another feature of state of the art software is the ability to provide value in multiple ways. State of the art tools not only provide useful services to the clients, but also provide the client with value. With respect to library application specifically, this means the software is designed such that data can be collected from the users to exponentially improve the software. Chen (2019) notes, "This indicated that Mobile Library has become a vital resource for learners to acquire knowledge" (p.721-734).

2.6 Relation to the Larger Problem Area

As the world becomes more digitized, and tools once only accessible in person are made accessible via the internet, projects such as this become increasingly relevant. One particular field in which modernization is occuring is mobile development. Specifically, mobile development with respect to the virtualization of already existing tools. This includes mobile apps to make delivery placements for food, mobile applications to handle transportation, and generally any service that can be digitized. According to Genuitec, an enterprise-consulting company, "The open-source community is helping to rapidly advance mobile Web application development. To date, no less than eighteen different mobile frameworks exist just for the iPhone" ("MobiOne Developer 1.0 M4", 2009). Mobile application is one of the broadest and most widely used examples of the digitization of the modern world.

A number of factors explain this trend towards digitization via mobile applications. Firstly is the decreased cost. A major advantage of software is its repeatability. If software is developed once, it could be re-implemented as many times as desired with virtually no additional cost. Furthermore, mobile applications save users a significant amount of time; virtually any good or service is a few clicks away. Another factor in the popularization of mobile applications is the popularity of smart phones. Genuitec noted, "This time next year we expect the mobile Web to have matured significantly as smartphones get cheaper and more diverse, and desktop developers spend more energy creating applications for the computer in your pocket," ("MobiOne Developer 1.0 M4", 2009). As smartphones become more popular, digitization implemented with this software will become more popular, leading to the further popularization of smart phones. The result, then, would be a positive feedback loop between smartphones and mobile apps.

Application development with respect to library services in particular, is a fast-growing niche. Hu Neamtiu (2016) wrote, "Recently, mobile technology combined with mobile devices has become an important information collecting channel. A greater number of students and teachers also

use tablet PCs and smartphone to search for e-journals, e-books and other e-resources" (p.50-56). In essence, library features become a particularly fruitful avenue for the area of the modernization and digitization of existing tools. This trend can be attributed to the data-driven services libraries provide. Libraries provide excessive amounts of data, giving developers solid materials to work with. Furthermore, libraries tend to be affiliated with higher education - often a university for example - which further increases the inclination of software developers, often affiliated with these places of higher learning, to develop mobile applications for these institutions.

Furthermore, mobile library-specific application development has been proven to be highly for library administrators. This is because mobile apps serve not just the function of aiding its users in whatever tasks they have been designed to aid with, but also because they can be regarded as a data collection tool for individuals overseeing the institution with which the application is connected. Therefore, numerous libraries introduced mobile technology in library services and developed mobile information systems compatible to mobile devices in order to allow their users quickly search for desired information(p.721-734). Mobile apps allow library administrators to get nearly instant feedback with regards to the various services and features offered by the library, making it a useful tool for growing and developing libraries and library services.

2.7 Closing Thoughts

Mobile devices are being increasingly utilized within academic contexts. Easy access to academic library resources and services is just one need students have throughout their academic careers. As this need is still in its infancy, little is known about mobile library applications specifically. However, much is known about the development of standard mobile applications and the requirements of a mobile app. Based on research in this field, connections and patterns were drawn between the state of the art library applications. An example pattern was how mobile applications are often integrated with the already existing library features; as opposed to developing features from scratch, they built on the existing tools offered by libraries.

3. Methodology

3.1 Introduction

In this section, we discuss how we went about developing the app. including the ideation for the applications features or the process by which we decided which features would be implemented in the applications. The technical aspects of the development process are also provided. Furthermore, describe the methods in which we got relevant data for the app - data for the initial design and data for subsequent improvements.

The approach to produce a final product was a simple one. We identified our goal: create a mobile app that provides WPI students with some sort of value. Next we listed linear steps and tasks necessary to reach this goal. were able to assign these processes to individuals and then brainstorm how we would accomplish each one.

3.2 Needs Analysis

In order to develop a mobile library application from start to finish, many variables must be considered in advance. We began by determining the exact resources the Gordon Library supplies and which of them would be worth implementing into our application. Additionally, we thought of other resources perhaps outside of the library's scope that may aid our future users in their academic endeavors. We devised a campus-wide survey for WPI students with the aid of Google Forms that demonstrated which library services they actually used and, of those, which resources should be implemented into our mobile application for the library. This survey was comprised of a series of optional questions that not only gauged utilization of each of the library's resources and also the demographic, user interface preferences related to other mobile applications, as well as, the option to volunteer for application testing later on (See Appendix 6.5 for the detailed survey used).

For the actual development of the mobile application, we employed Java, a widely-utilized programming language that handles the backend development or more simply, the code that lives "under the hood" and JavaScript, a scripting language which dealt with the frontend aspects which directly controls what is immediately seen by the user. These tools allowed us to fully develop our goal of a mobile application for the Gordon Library at WPI.

In the background of our project's iterative process, we determined that the use of Jira and Confluence by Atlassian - two pieces of software that aid in project management - would be a great utility for organizing our tasks and goals throughout the three-term project. After we gained the requisite fluency with these utilities, both Jira and Confluence were utilized for every aspect of the project. Jira enabled our team to keep track of our deliverables and goals as defined as tickets in the software, which lived sprint to sprint (week to week), keeping us on track and organized. Confluence, on the other hand, provided us the capability to create and organize notes and documentation throughout the project's duration. With this fluency, tasks were distributed evenly,

project efficiency increased, and all the tasks could be tracked for later reference as needed in our results.

3.3 Functions (Specifications)

Creation of the library mobile application required the following items:

- Integrated Development Environment (IDE) - Where a given programming language lives and the development of code exists. In our case, we used IntelliJ as the IDE to house our project's code in which multiple programming languages and frameworks are used.

- Programming Languages - Coding languages that allow for writing code. A programming language, when approaching a software-based project, is determined based on what is to be accomplished and in our case, what language each member of the team was most comfortable with. For the frontend development, and to allow for a pleasant layout and user interface for our mobile application, JavaScript, HTML, and Sass/SCSS were chosen as the scripting languages to best provide the capabilities and interface we sought for our mobile app. For the backend development, the language chosen was Java, as it turned out that each member of the team was most comfortable with Java. This language pertains to and handles all the "under-the-hood" code. Using these languages, buttons can have mapped functionalities, API consumers can be built and later displayed, etc.

- Programming Frameworks - Frameworks are essentially reusable software environments which can be used for numerous different applications and enable one or many functionalities for the main program. Some of the frontend frameworks/libraries we used were Lit, Polymer, and Vaadin. These three frameworks/libraries not only provided us with additional functions for our primary program, they also simplified larger functions for implementation. Lit is a library that helps make the process of building web components fast and efficient. The Polymer library makes the process of creating custom elements easier. Vaadin, a Java web application development framework, supports the creation and maintenance of web-based user interfaces of high quality more simplistic. For the backend frameworks, Spring, Hibernate ORM, Logback, and Lombok were used. Spring, an open-source application

framework, supports the development of Java-based applications. Hibernate ORM works in conjunction with SQL and handles the mapping of object-oriented domain models to a relational database. Logback is a logging framework that deals with data logging within Java. Lombok is a Java library that enhances the programming experience by automating certain trivial yet repetitive tasks.

3.4 Conceptual Designs

In the adolescent stages of development, we aimed to design a mobile application that conformed to WPI standards. WPI Marketing & Communications department handles the look-and-feel standards for webpages and associated applications and systems under the WPI umbrella. Therefore, we contacted the department and were provided with vector graphics of the WPI logo and more, and the standards for user interface components such as buttons, text fields, headers, etc. We needed to begin wireframing.

Numerous designs for our mobile application were considered. These designs were discussed in detail. However, we later mapped our ideas to a concrete design with the use of the software Figma. Figma provides many capabilities to create conceptual designs that emulate a prototype or even a final product. With Figma, we were able to get a sense of the look and feel, or user interface, of what we wanted for our mobile application.

Our first approach to implement the mobile application in code was through a framework called ”Vaadin.” In parallel, and after we had tinkered with Figma wireframing, a style sheet and suite of reusable user interface components for the Vaadin framework that conformed to WPI’s standards were developed.

3.5 Preliminary / Alternative Designs

Due to initial limitations, there was no precedent for what we were building - our application would be unique. Common library application features would not be included in our application:

- Catalog search.
- Book availability & checkout.
- E-books.
- Audio books.

We discussed many features that would be feasible to implement in our three-term timeframe:

- Library hours.
- Tech Suite booking.
- Occupancy count.
- News & events.
- Library chat.

Based on the results of the student survey and our research on features that are prevalent in other mobile library applications, Tech Suite booking and occupancy count were selected as the most critical components of the application. No precedent exists for these features, so the team needed to not only program, but to also develop them. Develop, in the sense that we had to design these features prior to implementation.

3.6 Feasibility Study

Technical Feasibility

Our application required a backend, meaning a server for hosting our mobile application. WPI has access to various servers as well as Amazon Web Services, so our hosting options were sufficient.

Legal Feasibility

We, the student team members, operated under the guidelines set forth by WPI and our IQP advisor.

Economic Feasibility

The application we proposed had no serious economic implications. Usually, an application of this magnitude costs hundreds, often thousands, of dollars. Our method for addressing this was systematic. We listed everything which would require some degree of funding, with the associated price. If it was a subscription we determined the cost for the duration of the project. We then ranked all of these features from most important to least important. We discarded the unimportant expensive items and tried to obtain funding for the more-important cheaper things. Some of this funding was obtained through third-party sources, some we paid for out of pocket.

Operational Feasibility

Operational feasibility is the measure of how well solutions proposed match the problem statement at hand. The problem which we were addressing was somewhat vague: lack of easy access to certain library resources. Our proposed solutions addressed these concerns. We proposed ways in which library users could access certain library features from anywhere with a WiFi connection.

Scheduling Feasibility

A major component to making this project run smoothly was to align our schedules so that we could productively work, as a team, on the tasks at hand. This was done using the when2meet software. At the start of each week, each member filled out when they were available. Then we would select a time in which we were all free and meet via zoom, usually for two or three hours.

3.7 Modeling

To model the application, we designed some preliminary mock-ups using Figma, a software designed for story boarding. We experimented with various color themes, settling on a theme which encapsulated the school colors without being overtly overwhelming. We also determined how we wanted to implement the features we planned on using in the application, settling on a one-page design with some features on the top (such as capacity), and a news feed which the user could scroll through from the bottom.

3.8 Final Design Strategy

To produce a product that was operational, usable, and relevant to WPI's students, we needed to use familiar development tools. Thus, we chose IntelliJ-based IDEs in our development environment. We also needed to use languages that we were all familiar with, and ultimately chose Java (but later switched to JavaScript).

We aimed to produce a usable mobile app. We were able to establish the "do"s and "don't"s from our background research, which included research on potential library apps and their production. However, we also had to consider the needs of WPI students, from look to feel. In order to make an app which was usable, we would need to see what our potential library app users found attractive. The plan was to complete a prototype, have potential users (WPI students) test it, and adjust the look-and-feel in accordance to their feedback.

We also wanted to create an app relevant to the *wants* of WPI students. To adhere to this objective, we concluded that we must obtain information from potential users on which library services they use and those which they do not. For this, we conducted a school-wide survey. The results of this survey were incorporated into our design strategy.

We now had three tasks in order to complete our broad goal: obtain information via a survey as for which library services are most relevant to potential users, develop prototypes and test them with potential application users to gauge which design respondents were most receptive to, and to develop a functional application based off the feedback from the prototype testing.

After analysis of the survey results, we settled on which features we would include in the app and which we would not. From here, we developed mock ups to see, at a sub-functional level, how this application would look when finalized. Prototyping and production of the functional application was not completed.

4. Results

4.1 Introduction

In the following sections, we will discuss our final results from two perspectives: student survey and technical. The student survey was distributed on November 2, 2021 to all applicable departments for distribution. The goal was to gain insight into what services we should offer in our final mobile library app. The technical results address the planning stages of the application development.

4.2 Student Survey

To best determine which services our mobile application should have, we created a campus wide survey that was distributed to the student body at WPI. The survey asked twelve thorough, yet optional, questions our team could analyze to determine current resource utilization, and to also study if those results would change if the resources were integrated within a mobile application. Would more library resources be used if they were simply easier to access? Finally, the survey also helped our team determine the demographics of the individuals who use the library resources. See Appendix 7.4 for the list of survey questions and 7.5 for the graphs of the survey results.

Of the 273 responses to our survey, 254 of them were undergraduates. That is 93% of the total respondents (see Appendix 7.5.1)! Undergraduate students have a higher likelihood of a campus presence, compared to other academic statuses such as graduate students. Most graduate programs, WPI's included, provide more remote learning than that of undergraduate programs. Therefore the results we received came primarily from individuals who are physically on campus and interacting with the various resources at WPI. Further questions provided additional demographic data for us to analyze and gain a solid understanding of what groups of people visit the library (see Appendix 7.5.2, and 7.5.3 for those results).

Once this analysis was completed, it was apparent that the remaining feedback in the survey would be a realistic judgement for each service under investigation. Figure 4.1 exhibits nine different library features that our team considered for possible implementation to our mobile app. The distribution in the figure pertains to the direct results from our survey. It can be seen in the graph that very few of the nine suggested services are actually utilized. Most are used only occasionally, if at all.

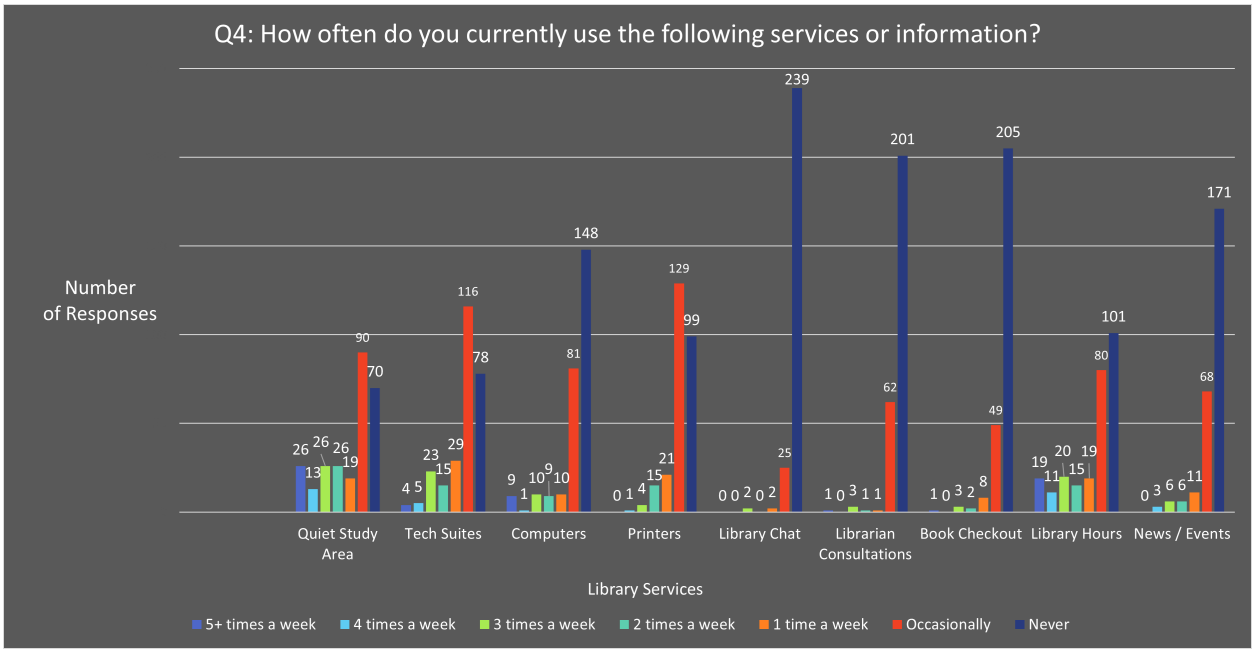


Figure 4.1: Current Library Resource Usage

In addition to this, the subsequent question in the survey simply asked whether or not the participant would use a mobile library application at all. The majority of responses were either yes or maybe. The corresponding question in the survey (see figure 4.2) provided the respondents with another, similar list of features to consider in the context of a mobile application. This encouraged them to think about which of the proposed features should be included in a mobile app for the Gordon library and which they would realistically use in such a context. This data showed that these features, in theory, would have a greater chance of being used if they were accessible through a mobile app, versus a web page or in-person usage when compared to the previous data in the previous chart.

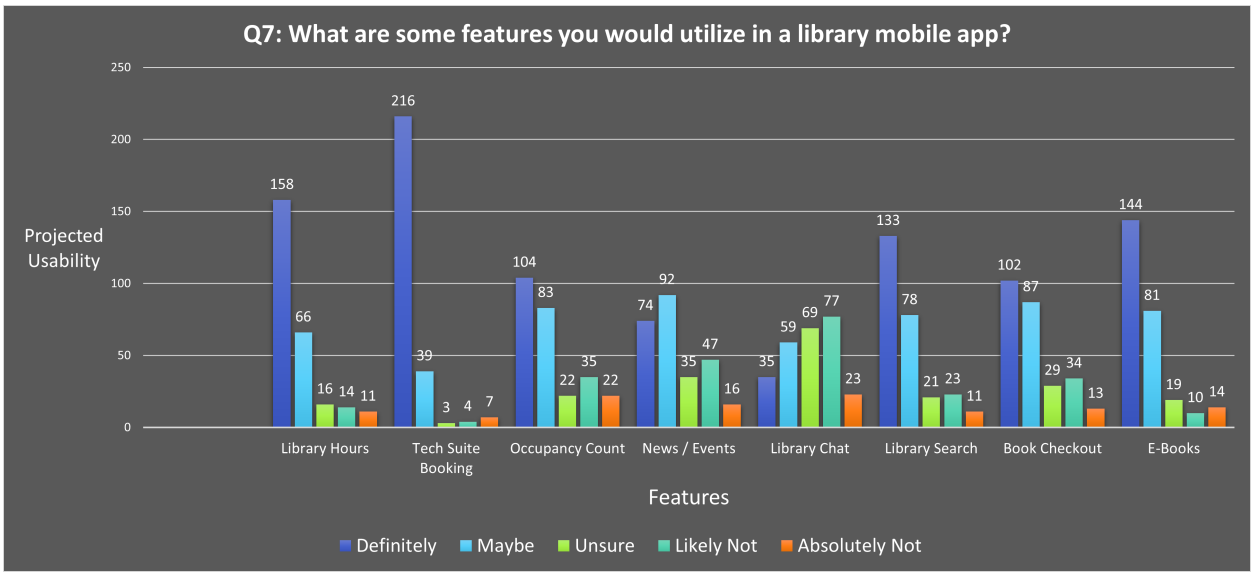


Figure 4.2: Features That Might Be Used In A Mobile Environment

This allowed us to then narrow our list of features being considered for implementation to only five: library hours, tech suite booking, occupancy tracking, news and events, and library chat. This list was influenced by both the survey results as shown above, as well as by additional factors regarding the implementation of such features. An example of this was the potential implementation of the library search, book checkout, and e-book features. Each brought steep challenges and were beyond the scope of this project. Therefore, the list was reduced accordingly.

Stepping away from the primary features of the mobile app, user interaction and flow had to be considered. Figure 4.3 shows th usage of other non-categorized mobile applications. These apps were chosen simply on the basis of popularity.

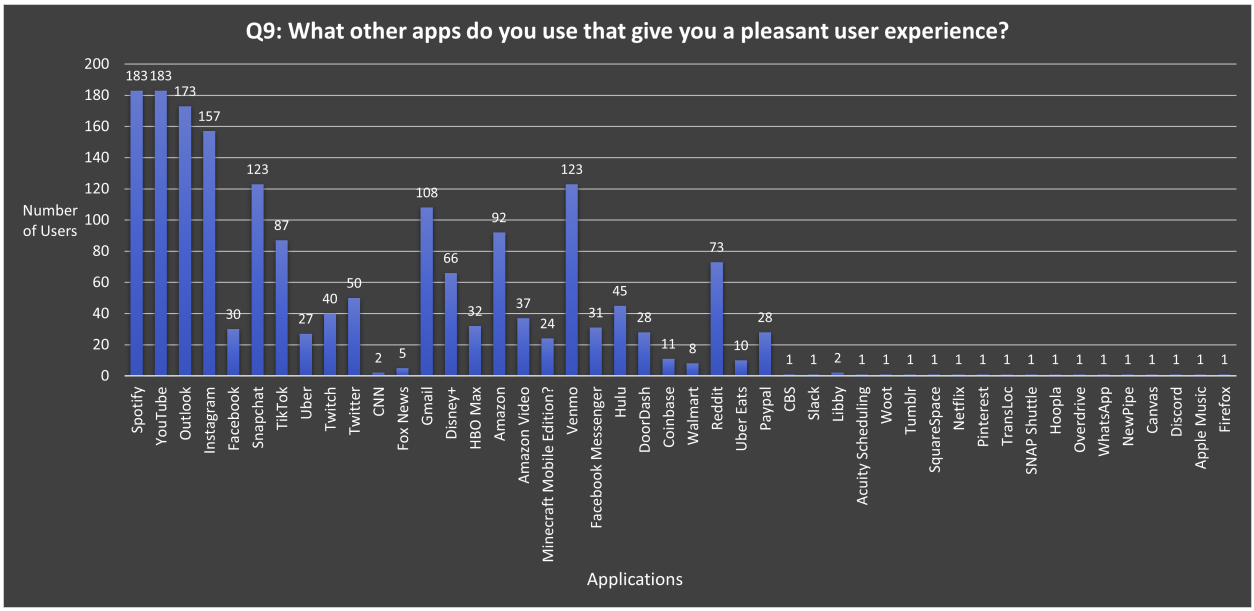


Figure 4.3: User Experience Gauge

The corresponding survey question allowed the participant to choose as many predetermined apps as they desired, as well as the option to provide additional apps that we did not include. Taking these results into account helped ensure that our application would follow similar modern UI (User Interface) designs like those chosen by the participants in the survey.

The final questions the respondents completed in the survey pertained to their willingness to participate as a volunteer tester for the impending prototype. Most respondents, understandably, declined their testing participation, however, 92 individuals chose to participate and 90 of them provided their academic emails for later contact regarding testing our application.

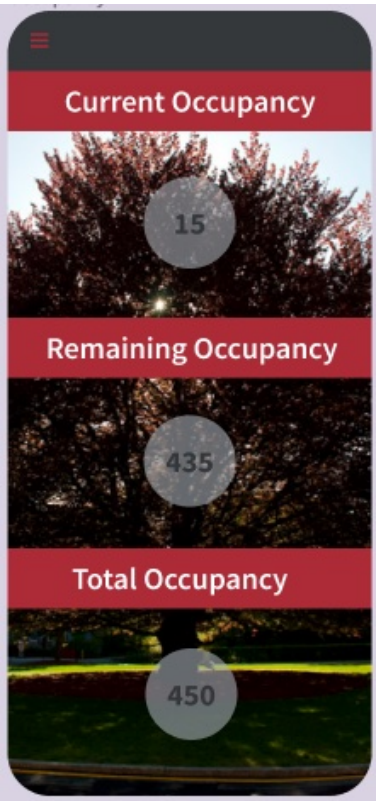
4.3 Technical

From a technical perspective, progress was made in the design realm. We used Figma to collaborate on these designs. Figma is an online collaborative interface design application. It enabled us to mock-up wireframes in real-time that we would then implement in code later. We began with designing a login page. Our goal was to enable users to only have to log in once, or at least not very often, as it is with various WPI single-sign-on services such as Hub and Canvas. We developed three options as pictured below. There was nothing special about the three designs specifically. We just sought to offer ourselves some options to implement later.

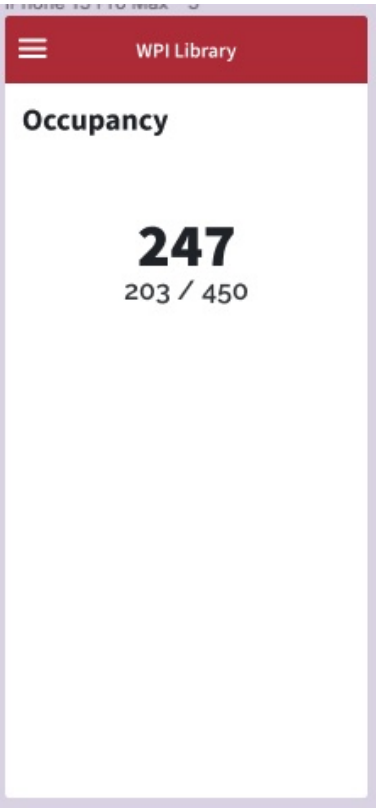
(a) Design #1 (b) Design #2 (c) Design #3

Figure 4.4: Login Screen Concepts

As the planning of the implementation progressed, we decided that a ”sign-in” feature would be too cumbersome to implement in the current iteration. We moved on to designing the main page that users would see. Before receiving and reviewing the survey results, we discussed what we would like to see in the app. Considering the pandemic, we knew how important the occupancy count was, so we designed a dedicated page for it. Here are the design concepts we developed:



(a) Design #1



(b) Design #2

Figure 4.5: Landing Screen Concepts

Neither of these designs satisfied the goals brought forth by the survey results. From our analysis of the survey results, we determined that we would implement something similar to the right figure above, but with more features and functionality. Below the occupancy feature we wanted to embed the library's calendar in a format similar to the WPI website: `https://www.wpi.edu/news/calendar?og_group_ref_target_id_entityreference_filter=84091`. Based on the survey results, the feature sought after the most was tech suite booking. So, we planned for a fixed area on the bottom of the page, with a button linking to a page to book a tech suite. "Fixed," meaning that the content remains in place as the user scrolls through the page.

After we had determined the look-and-feel according to WPI standards (discussed in our Methodology), we were able to develop a style sheet and suite of reusable components that could have been used in the final product. Dozens of CSS files and Web Components using the Lit and Vaadin

frameworks were written.

Additionally, a consumer for the LibCal API was implemented. This was completed through the OpenAPI specification. With administrative access to the LibCal platform at WPI, an OpenAPI specification of the API was written, which would later be used to generate client consumer code. This code would have been used by the mobile app to interact with LibCal's features, specifically so that students could book tech suites directly within the application. Testing of the consumer was not possible as the prototype was not developed.

In summary, in lieu of a prototype, we were able to develop candidate designs based on survey results and libraries to be used by a final product.

5. Conclusion

5.0.1 Introduction

In this project, as a team of three, we laid the groundwork for a mobile application for the WPI Gordon Library. More specifically, we laid out a potential application to meet the Gordon Library's stated objectives. We conducted research on the current trends in mobile application development, specifically as it pertains to application development. From there, we sent out a survey to the student body of WPI to help determine which features would be most valuable. We analyzed these results and developed some prototypes in Figma, a mock-up tool for software development.

5.0.2 Key Findings

Each member of the team reviewed literature pertaining to the current technology used in mobile application development. In our research, we emphasized app development for educational purposes, specifically library-based applications. We found modern applications have some similar characteristics. First, they are integrated with other technology. As the scale of technology increases, so too does the intersection between seemingly different technologies. Mobile applications, being extraordinarily broad from a developer's perspective, allow for such technology to be integrated with other technologies. Furthermore, another feature of modern application technology - in fact, modern software in general - is adaptability; applications need to be designed such that they can be modified in cadence with the ever-changing world.

The survey sent to the student body helped gauge which features would be valuable in a potential application. From this, we determined which features would be included and excluded. For example, fewer students reported using the book checkout functionality from the library. From

this result, factoring in the difficulty of such a feature, we were able to rule this feature out of the potential application. Furthermore, we were able to see which kinds of applications students used regularly, and which designs users preferred. From these results, we were able to develop mock up applications prototypes using Figma, a wire framing software.

5.0.3 Project Limitations

Given the time constraints, we were not able to produce a fully deployable application. A variety of intertwining factors account for this. Time constraints and decreased productivity at certain stages of the project made it challenging to complete a fully functioning application along with the other requirements for this project, such as the research phase, surveying phase and prototyping phase, all of which were essential steps for building the application.

6. Recommendations

6.1 Development Approach

This section discusses our approach to the development process toward the final product and offers critiques and recommendations.

The project could have been completed in three terms, but it was not. The major factor was teamwork. During the first term, consisting of mostly discussion and planning, every member of our team contributed significantly. It was not until the second term that the speed and quality of the team's work fell. The issue lied not only with one or more teammates, but also in the effort made by all teammates to support others. We did make strides to support our team and even involved our advisor, who helped where she could. However, we could have asked for more intervention from our advisor. So, our advice is: every teammate should continuously support other teammates, and if that does not work, teammates should seek a stricter management style from their advisor.

From a technical perspective, mistakes were made. The project's goal was to develop a mobile application, but we first decided to use a framework named Vaadin. Vaadin can only be used to write web applications. Eventually, we transitioned away from Vaadin, but there was still significant time wasted. The method of implementation should be discussed in depth before development begins to eliminate this type of error.

After Vaadin, we moved to Node.js and the Lit framework. The decision to use Lit presented a time problem. If this project is to be completed by the library team, a framework with a larger foundation should be used. For example, React or Angular, both of which can be used to develop

applications targeting mobile devices (rather than the web) through frameworks React Native and NativeScript, respectively.

6.2 Techniques for Deployment

The choice of development frameworks greatly affect the deployment process. For example, our choice to use Vaadin and Lit meant that deployment to the iOS app store would have proved difficult, if not impossible. A framework such as React Native or NativeScript would provide much easier solutions, enabling the use of native deployment methods.

For example, on macOS, both React Native and NativeScript build Xcode compatible native code. You can use Xcode and the deployment tools offered from Apple to deploy to their App Store. Similarly, for Android deployment, both frameworks can build APKs, which can then be deployed like any other application to various Android app stores. Therefore we recommend the library team utilize React Native or NativeScript as the framework for deployment.

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8. Appendix

8.1 Timeline

Our timeline (Figure 8.1), named *Muirhead-Scanlon-Yasuna Chart*, depicts a similar setup to the popular Gantt Chart, however, it is not the same. It could be considered a derivative of a stripped-down Gantt Chart. Like a Gantt Chart, the x-axis expresses time and the y-axis lists tasks. In our particular case, time is divided into three sections, one for each WPI term. Under these sections, there exists a subsection for each week of the term. The lowest unit of measurement displays the week of the term, listed as Sunday through Saturday. This chart aided in the team's productivity, keeping each member responsible for their individual efforts, as well as, allowing us to keep track of our deadlines.

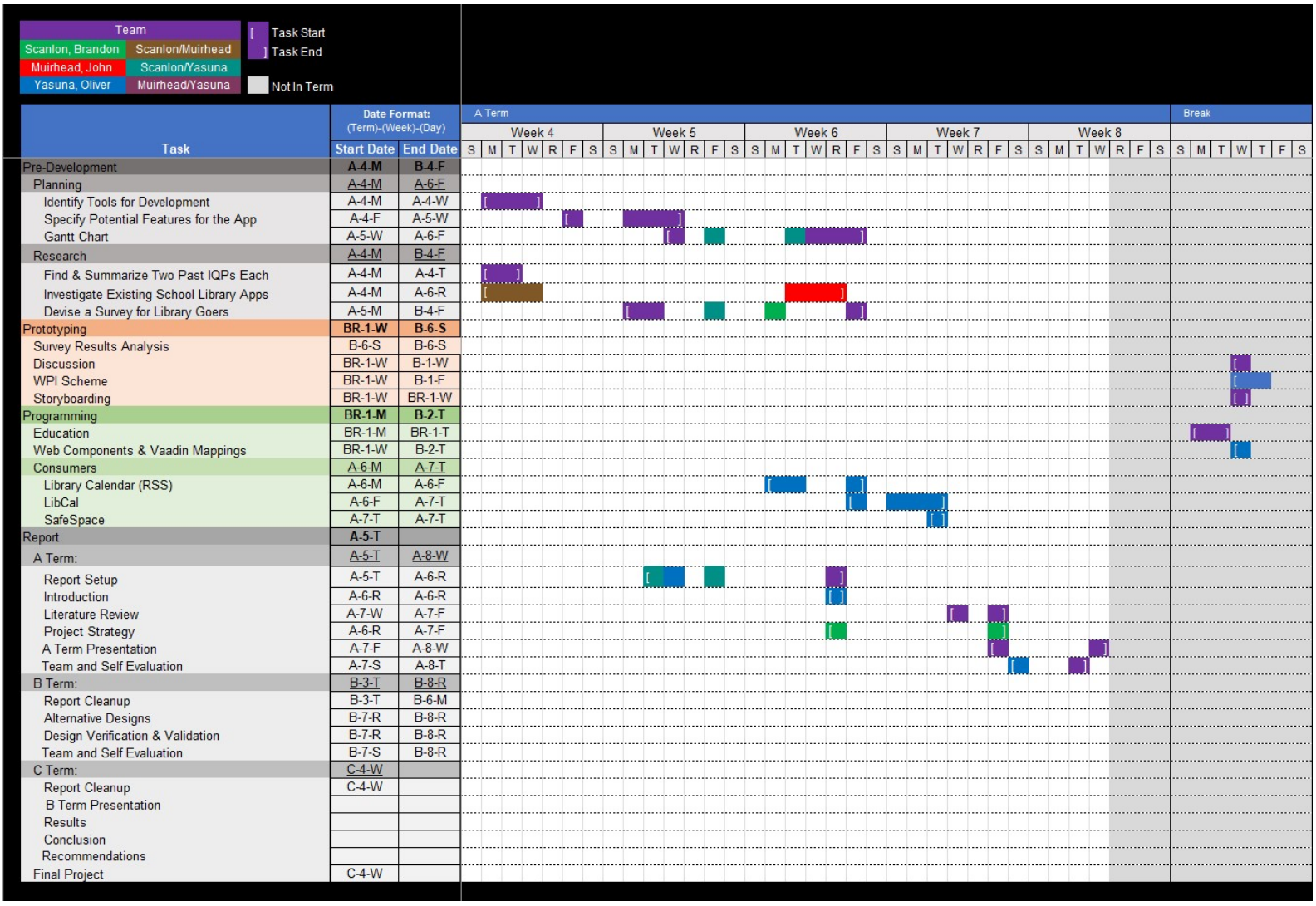

Figure 8.1: Term A Project Timeline

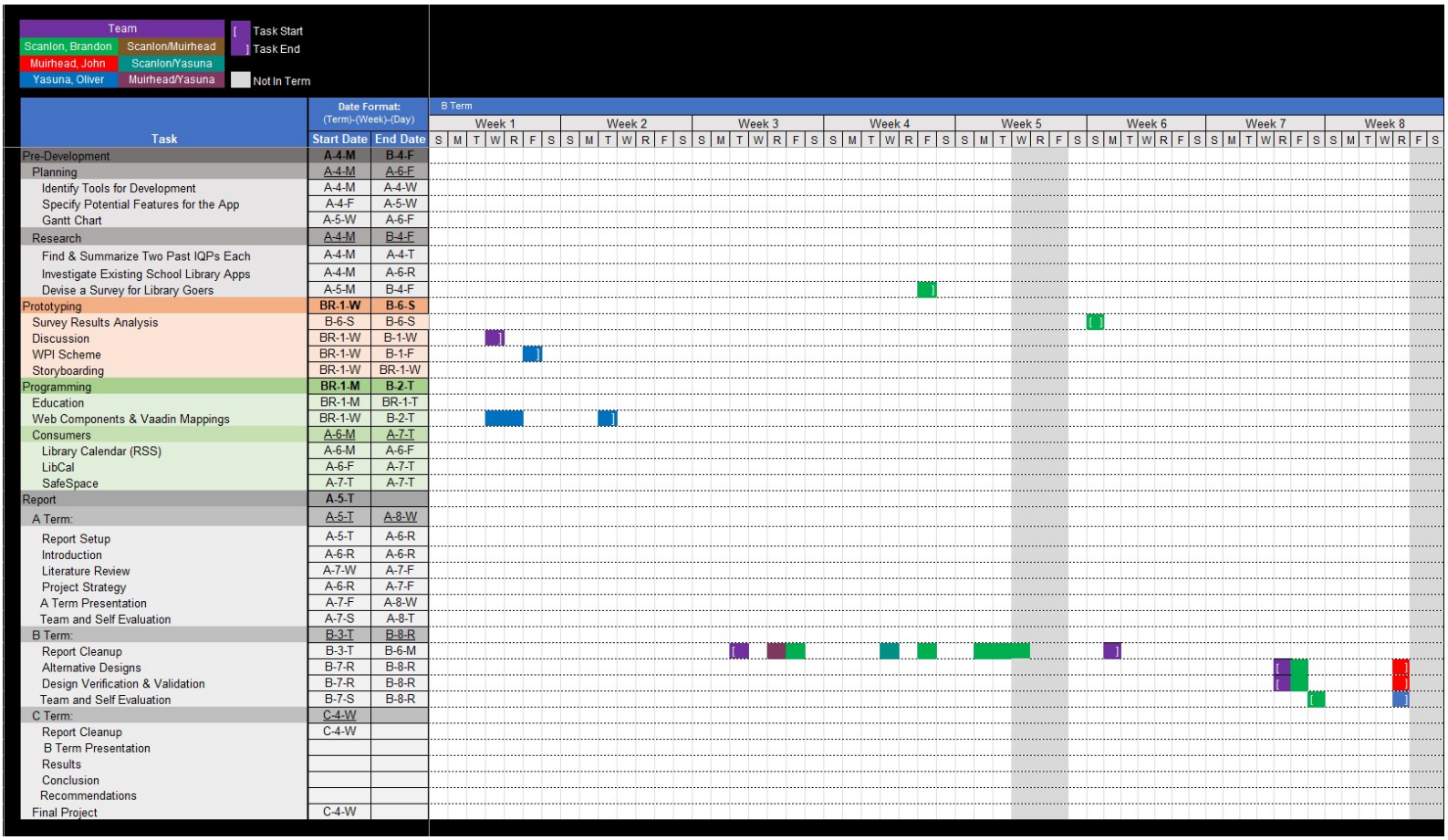

Figure 8.2: Term B Project Timeline

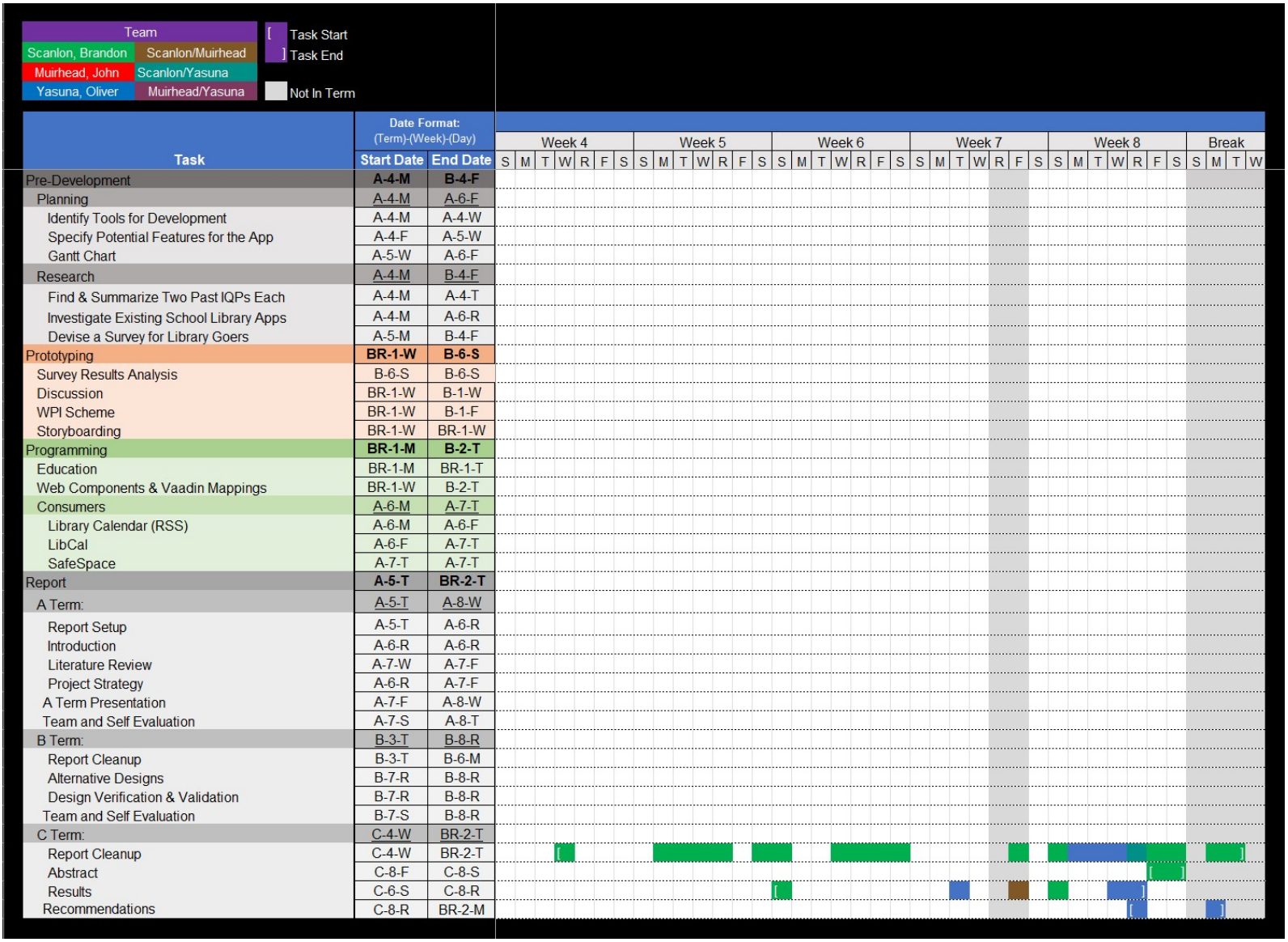

Figure 8.3: Term C Project Timeline

8.2 Additional Mobile Academic Library App Research

8.2.1 Harvard and Bennett University

Harvard and Bennet university had simnular app designs. Harvard's library app, Harvard Library, featured a minimalist home screen with the school logo in the upper-right hand corner, a help button in the lower-left, a 'login' feature in the lower right, and a circular 'start' button in the center. The screen featured only three colors; white, black and crimson red. Clicking the 'start' button pulled up the same login screen that clicking the 'login' button pulled up. Unfortunately, we were not able to further explore this mobile app because we do not have account affiliated with the University. The home screen for this application can be seen in the following image:

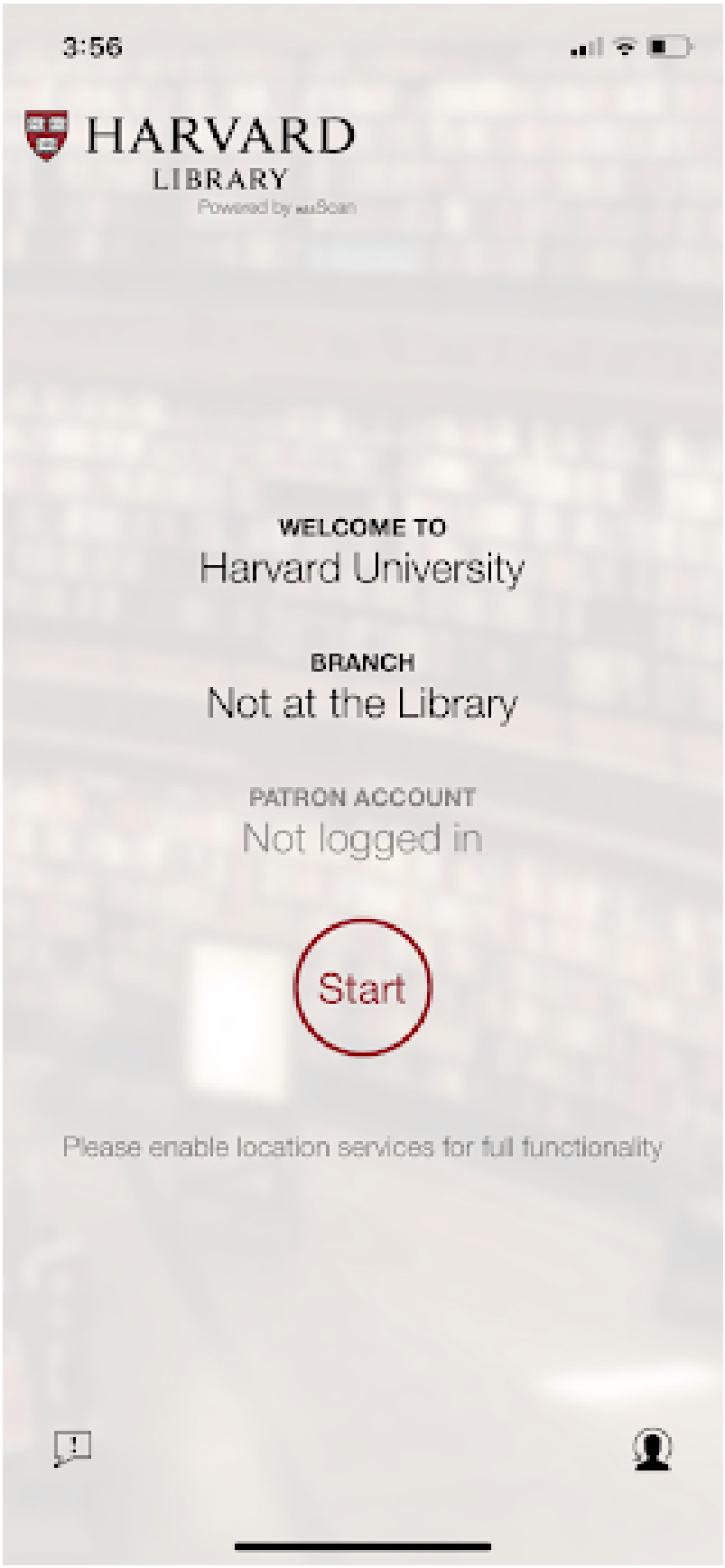

Figure 8.4: Harvard Library App Home Screen

The Bennet University app was similar in that unless you had an account, you could not log in and work with it at all. This application had less slick of a design. Some application developers, seem to value exclusivity and privacy.

8.2.2 Salisbury

Sailsbury Universitie's Library app, SU Libraries, featured a noticeably less minimalist design than Harvard's, and had a more unrefined look. Fortunately, we were able to access the applications features. The home screen included a search bar, and nine features: "Library Hours", "Research Help", "Room Reservations", "Self Checkout", "SU Libraries MakerLab", "Device Availability", "Building Maps", "Helpful Links" and "Contact Information". It also contained a bar at the bottom with five navigation options: "Home", "Library News", "Chat", "My Card" and "About". Additionally, there was a link to the libraries social media accounts. The home screen of this application can be seen in the following image:

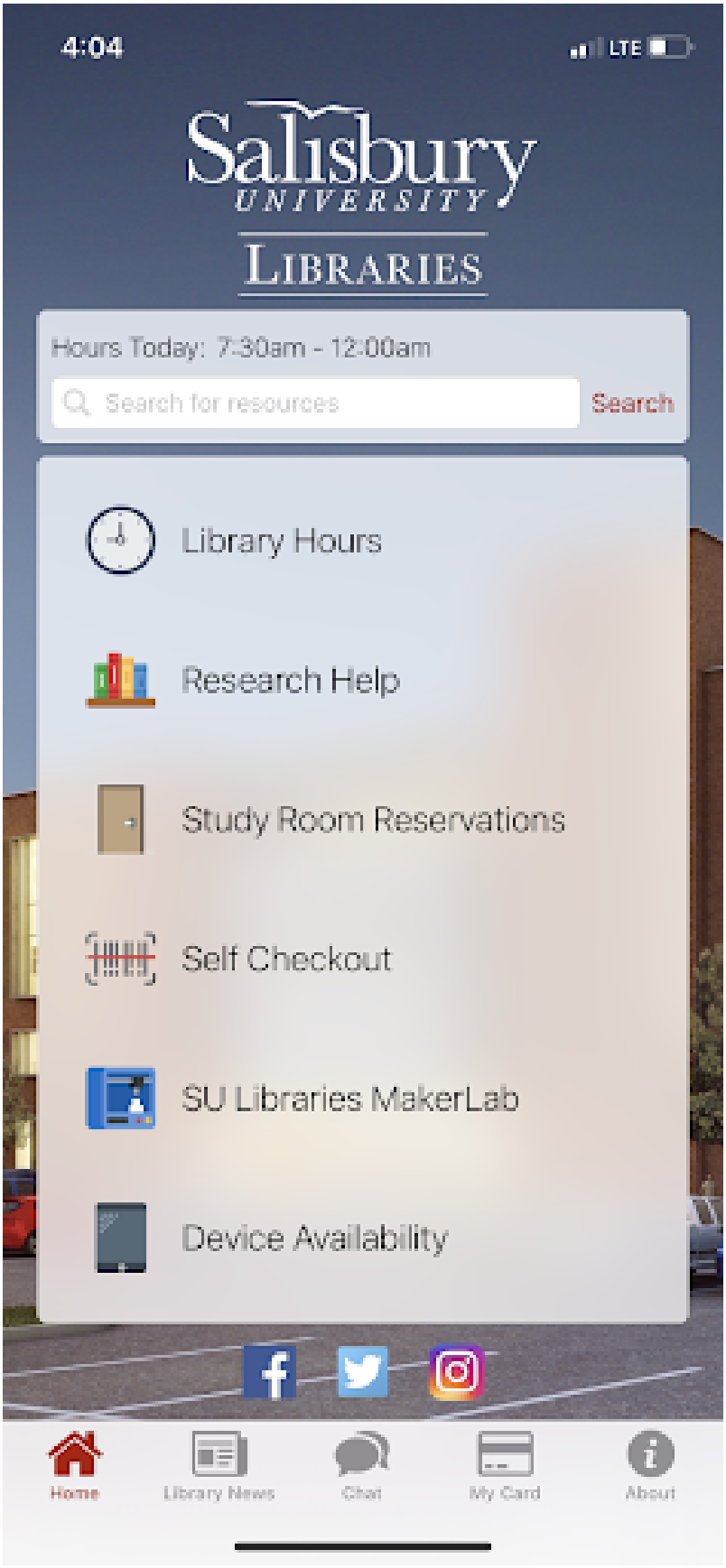

Figure 8.5: Salisbury Library App Home Screen

The ”Library Hours” feature lead to a screen with minimal interactivity. The screen contained the opening and closing times for all days from the current day to approximately three months in advance. The ”Research Help” feature took the user to a page with a somewhat similar layout; a page in which you could scroll downward, containing the subjects in which you could get research help. This page, however, was interactive. The user could click on each subject option, taking them to a page with information about who to contact, and how to contact them, if they are seeking research help in that specific area. The ”Study Room Reservations” feature as well as the ”Devise Availability” feature has a similar layout to these two.

The ”Building Maps” feature lead to a page containing the layout of each floor of the building. The only interactivity on this page was the option to click on any of the diagrams for an enlarged view of the diagram.

The ”SU Libraries MakerLab” feature took the user to a page which seemed to function like an app in and of itself. The page it took the user to contained a variety of features relating to the Maker Lab. Such as a feature displaying the time it’s open for today as well as a feature displaying which days it is open. It also had a feature taking the user to a page with the Maker Lab policies, a feature allowing users to make an appointment in the maker space, and finally the contact information for the maker space.

8.2.3 University Of Dallas

The University of Dallas app had a simple white, black, and Navy blue design. The app consisted of a home screen with four main sections. These sections were ”Nearest Libraries”, ”My Account”, ”eBooks eAudio”, and ”Social”. The application also featured a search bar. All of the apps analyzed so far make use of a search functionality. The home screen of this application can be seen in the following image:

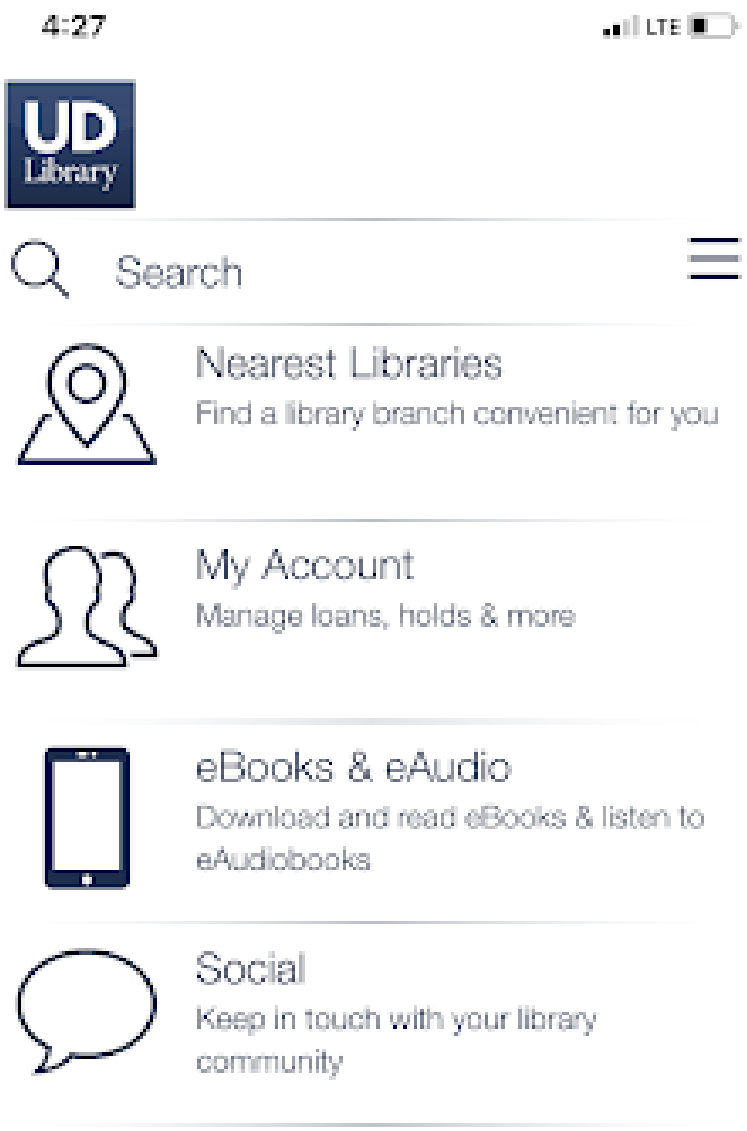

Figure 8.6: University of Dallas Library App Home Screen

Furthermore, like the Harvard app but unlike the Sailsbury app, this app featured a login option. The eBooks eAudio section linked to a bar code scanner. I think it would be fair to assume this functionality relates to some specific feature at the university of Dallas library. The social tab lead to a link to the libraries social media, namely Facebook, Instagram and Twitter. This seems like a relatively easy functionality to implement, yet still very important.

8.2.4 University of Sydney

This application featured a black white and Orange user interface. The application featured an abundant amount of functions and utilities at the users disposal. These included, but were not limited to: ”Libraries”, ”Book a Study space”, ”News-Events”, ”Services”, ”Scab ISBN” and more. Furthermore, each section had many subsections within it. For example, ”Services” encompassed ”Study”, ”Research”, ”Appointments”, and ”Disability”. They also did indeed contain a section for social media as well as a search bar. The university of Sydney created an extensive application filled with various functionality and features. While the application may seem unwieldy at first, upon familiarizing oneself with the app, it has potential to offer great utility. The home screen of this application can be seen in the following image:

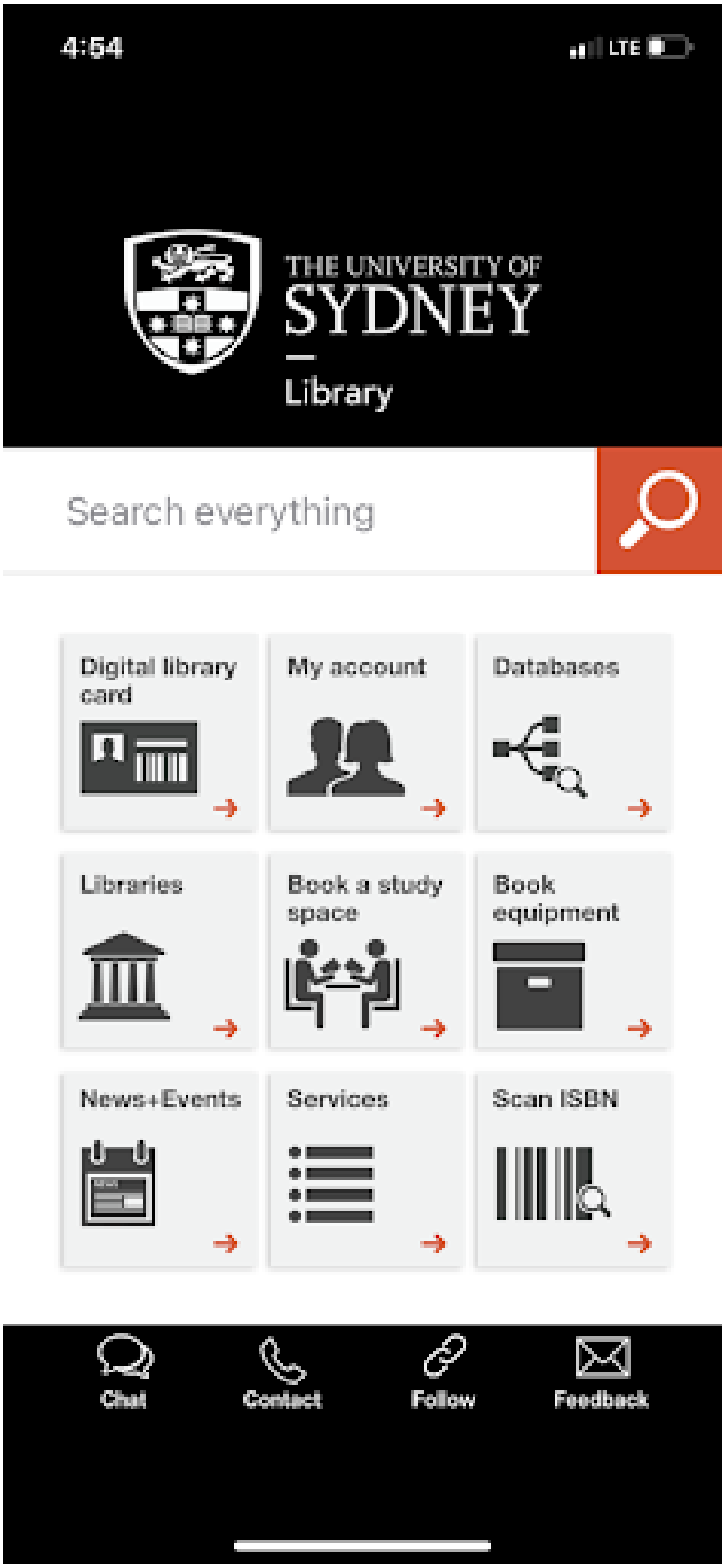

Figure 8.7: University of Sydney Library App Home Screen

8.2.5 Cairn, Parket, Ajman

Three other apps which we explored which had a very similar design were that of Cairn University, Parket university, and Ajman University. Each of them had two, potentially three, features. A search with a bar at the top. Presumably, only books could be searched for, but there was also an option to scan books. Below that, two of the apps, Cairn and Parket, featured a scroll bar of book covers at the bottom. These three apps seemed almost identical to one another in style and functionality.

8.2.6 Similarities

We noticed some similarities among the applications we analyzed. Firstly, the layout for most of them was the same; a home screen which contained a variety of possible features that, when clicked, would lead to another screen or a pop-up further elaborating on that feature. Some of the specific features were common among many of the applications. For example, four of the eight apps had a functionality for logging in. While this may offer some benefits to the user, it seems difficult to implement and only necessary if you have already implemented some other specific features, such as book checkout. Another feature available in two of the eight apps was a link to the social media; this feature has great utility and would be easy to implement. Finally, there were obvious similarities between the Cairn, Parket, and Ajman apps. They all had the exact same format.

8.3 Academic Library Features

The following is based from the research gathered by a study conducted by Mansouri and Soleymani in 2018. Each resource was considered based on the capabilities they provide and if they fit within the demographic of our mobile library application..

Search (by barcode/QR code scan) We assumed these features refer to a user's ability to search the library catalog. We decided to not implement this feature in the WPI Library app. However, it is an important one, as according to this study, all existing library apps reviewed had this feature. We believe for a mobile app that is intended to be a replacement for a desktop website to be successful, it must provide the most common services provided by its desktop website counterpart.

Tutorial We assume this feature refers to a visual tutorial provided within the mobile app that teaches new users how to use said mobile app. The study found that 70% of library mobile apps had this feature. A tutorial allows new users to get a better understanding of how to use a platform. Without a tutorial, many new users may be lost, therefore rendering the mobile app useless for them. Although we considered adding a tutorial feature to our app, it was not included in our final design.

Ask a librarian We assumed this feature refers to a user's ability to submit questions to a librarian. The study found all library mobile apps included this feature. Our design plans included a similar feature: the library chat.

Hours Straight-forward features that provides users with library hours. This feature is part of the WPI Library app design plan.

Events We assumed this feature refers to a user's ability to view library events and/or a calendar. The study found that 90% of library mobile apps have this feature. Implementation of this feature is in our design plan. Users should not have to use a separate service.

FAQ/Feedback It surprised us that only 30% of library mobile apps have this feature. The whole point of a library application is to provide students easier access to the WPI library's various services. It is impossible to make a perfect product, because there is always some disconnect between what the developers think consumers want, and what the consumers actually want. The design plan includes a platform for users of the WPI Library app to provide feedback on their experience.

8.4 Student Survey

WPI George C. Gordon Library Mobile App

Our IQP team is investigating the development of a mobile library app. We are seeking your feedback on the potential resources and services WPI users would utilize in this app. All responses to the survey are completely anonymous, and cannot be traced back to the respondent. You may however, provide your WPI email address at the end, and we may contact you to discuss additional ideas. If you have any questions or concerns about this survey or project, please choose to contact us at: gr-libappteam@wpi.edu *All of the following questions and the entire survey are both completely optional*

Question 1: What is your current academic status at WPI?

- Certificate
- Undergraduate
- Master's
- PhD
- Other:

Question 2: What is your declared major?

Choose

Question 3: What is your current enrollment status?

- Full-time
- Part-time

- Not currently enrolled

Question 4: How often do you currently use the following services or information?

Please tell us how often you use the many services offered by the WPI Gordon Library. The list is in no particular order.

	5+ times a week	4 times a week	3 times a week	2 times a week	1 time a week	Occasionally	Never
Quiet Study Area	○	○	○	○	○	○	○
Tech Suites	○	○	○	○	○	○	○
Computers	○	○	○	○	○	○	○
Printers	○	○	○	○	○	○	○
Library Chat	○	○	○	○	○	○	○
Librarian Consultations	○	○	○	○	○	○	○
Book Checkout	○	○	○	○	○	○	○
Library Hours	○	○	○	○	○	○	○
News/Event	○	○	○	○	○	○	○

Question 5: Would you use a mobile app for the WPI Gordon Library?

- Yes
- No

- Maybe

Question 6: If answered ”no” to the previous question, please explain why.

Your answer

Question 7: What are some features you would utilize in a library mobile app?

We have thought of a few features that could be included in a mobile app for the Gordon Library. Please let us know which of these features you would like to see. The list is in no particular order.

	Definitely	Maybe	Unsure	Likely Not	Absoutely Not
Library Hours	○	○	○	○	○
Tech Suite Booking	○	○	○	○	○
Occupancy Count	○	○	○	○	○
News/Events	○	○	○	○	○
Library Chat	○	○	○	○	○
Library Search	○	○	○	○	○
Book Checkout	○	○	○	○	○
E-Books	○	○	○	○	○

Question 8: Do you suggest any additional features not shown above?

Your answer

Question 9: What other apps do you use that give you a pleasant user experience?

To provide the highest quality mobile app for our library, please let us know what apps you enjoy using to use as references.

- Spotify
- YouTube
- Outlook
- Instagram
- Facebook
- Snapchat
- Tiktok
- Uber
- Twitch
- Twitter
- CNN
- Fox News
- Gmail
- Disney+
- HBO Max
- Amazon

- Amazon Video
- Minecraft Mobile Edition?
- Venmo
- Facebook Messenger
- Hulu
- DoorDash
- Coinbase
- Walmart
- Reddit
- Uber Eats
- Paypal
- CBS
- Other:

Question 10: Would you be willing to participate as a volunteer to test our mobile library app over the next two terms? If so, please provide us with your WPI email in the next section.

As we progress in the development of this mobile library app, we will be requiring a test group willing to volunteer and test the various stages of our app.

- Yes
- No

Question 11: Please provide your WPI email (optional) if you would like for us to contact you.

This is completely optional and you may choose to remain anonymous for the survey. Otherwise, please use your WPI email.

Question 12: Do you have any additional comments about the development of this library app?

Your answer

8.5 Student Survey Results

The student survey was conducted in the beginning of November 2021 using Google Forms. Twelve optional questions were included. A total of 271 responses were collected and analyzed between November 28 and December 10.

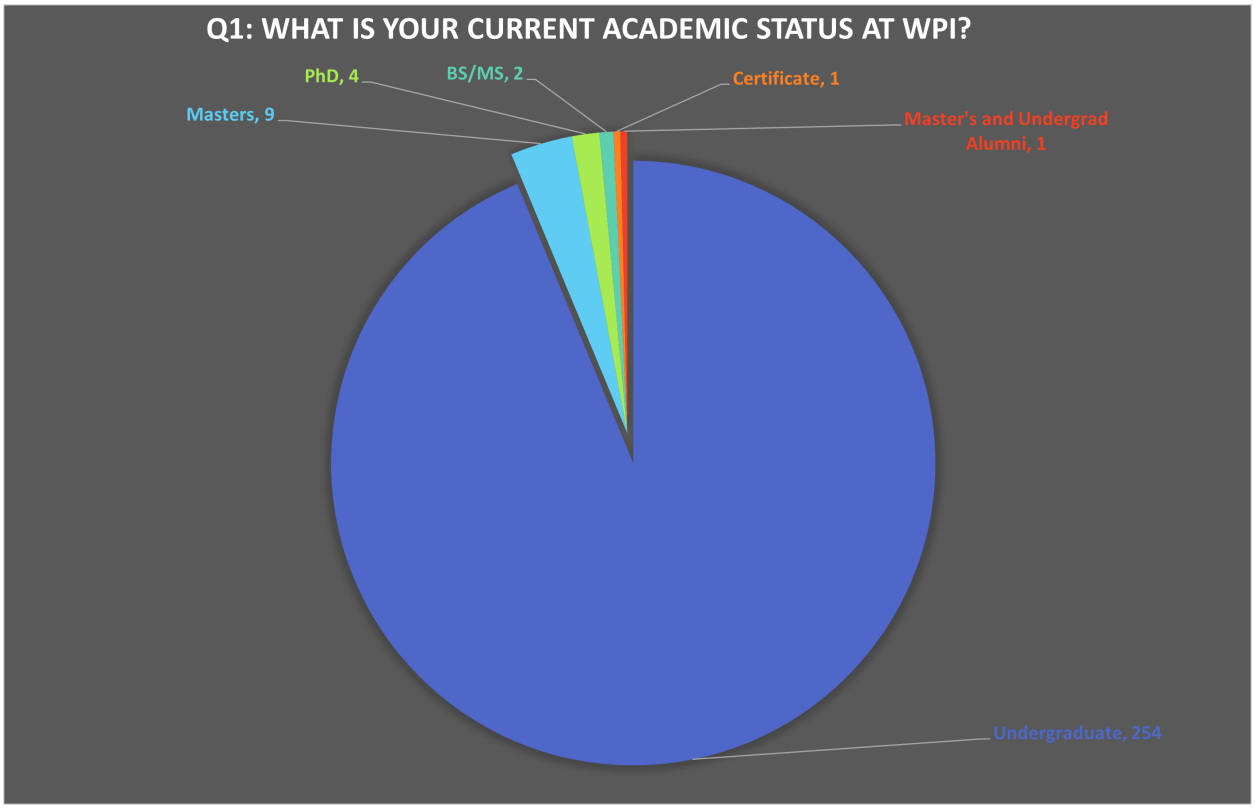

Figure 7.5.1: Academic Status of Respondents

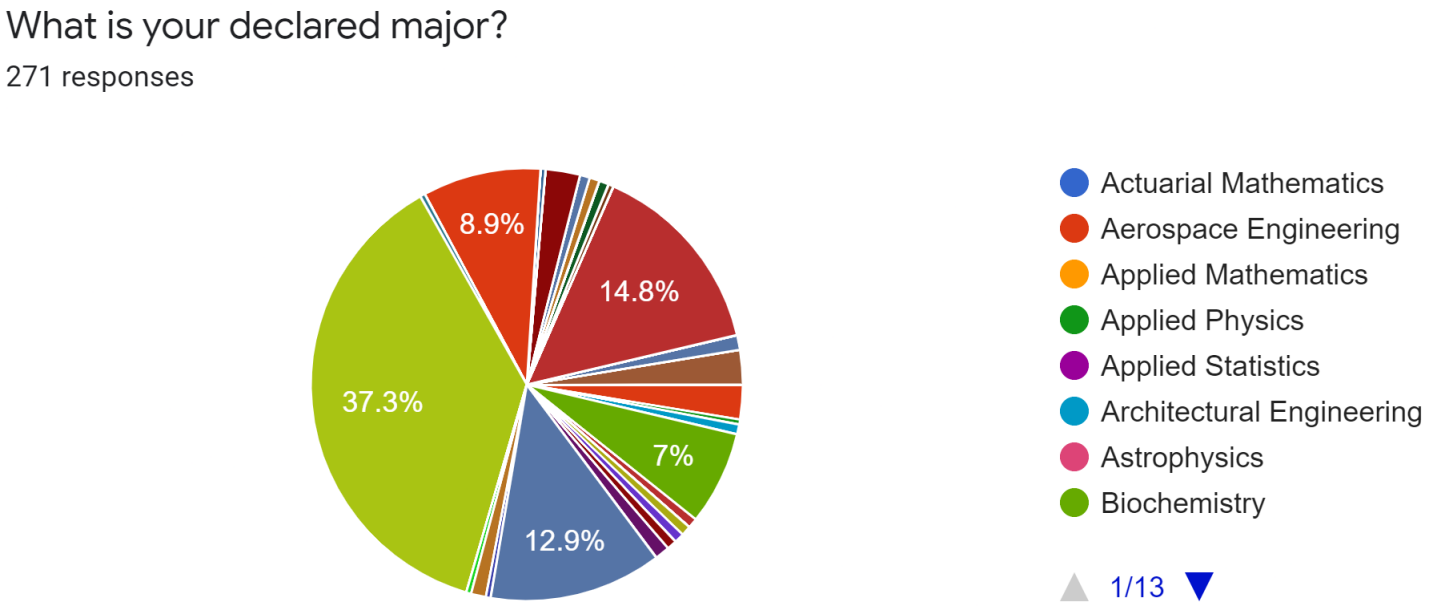

Figure 7.5.2: Respondent's Declared Majors

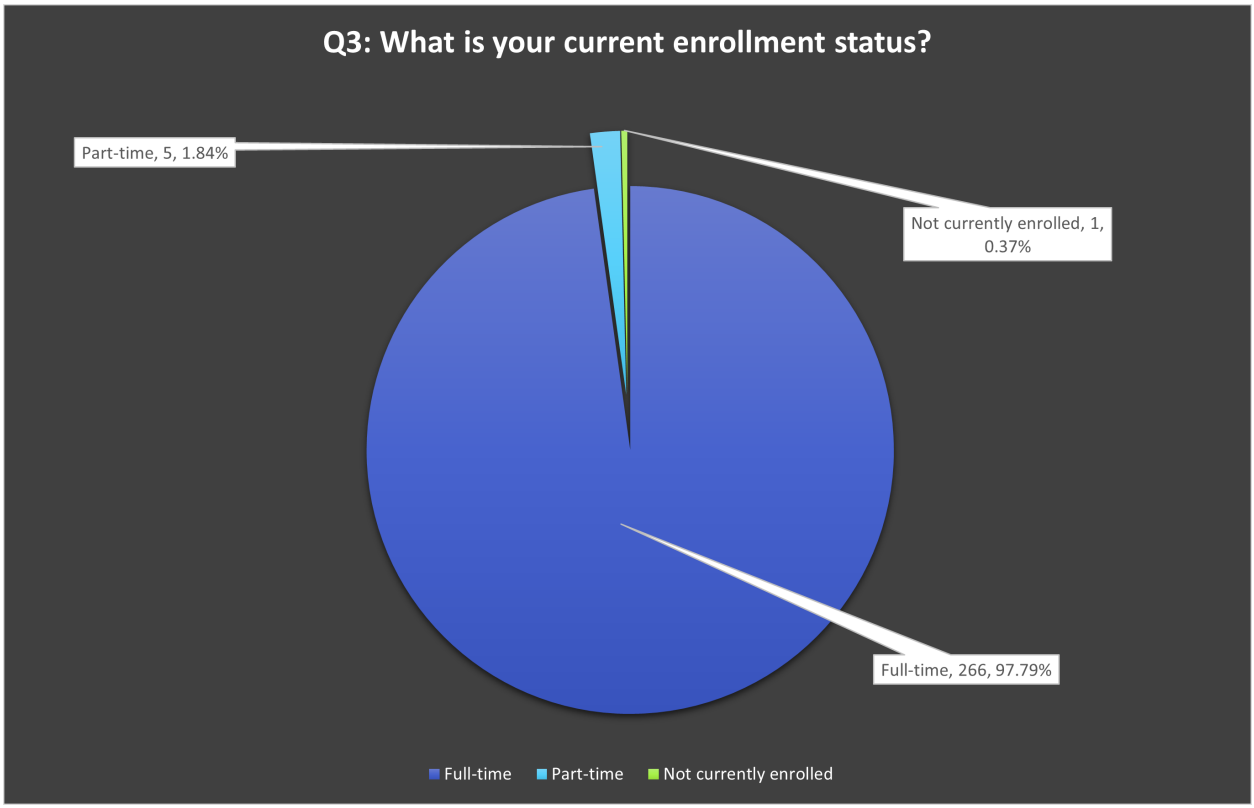

Figure 7.5.3: Respondent Enrollment Status

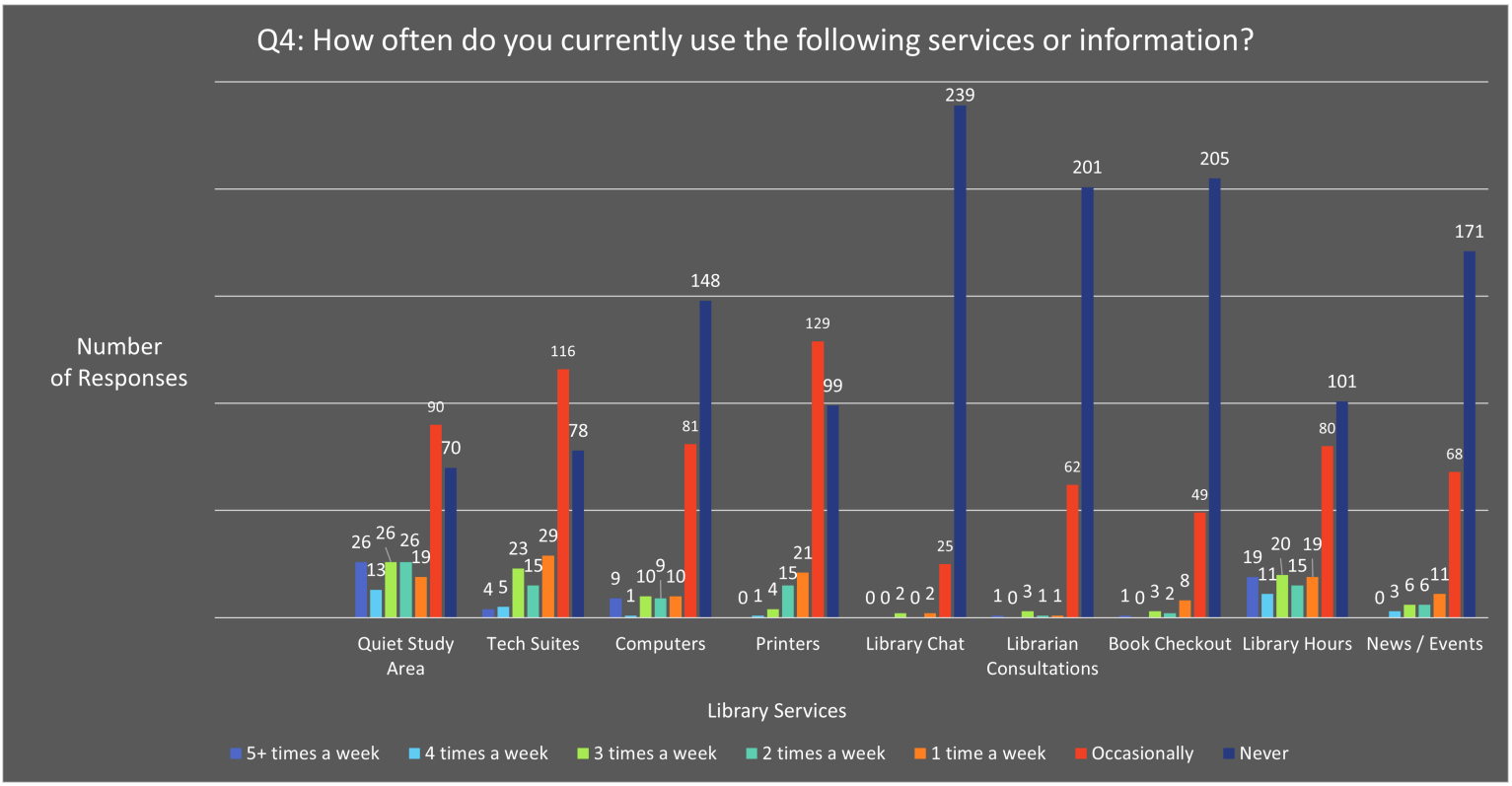

Figure 7.5.4: Current Library Resource Usage

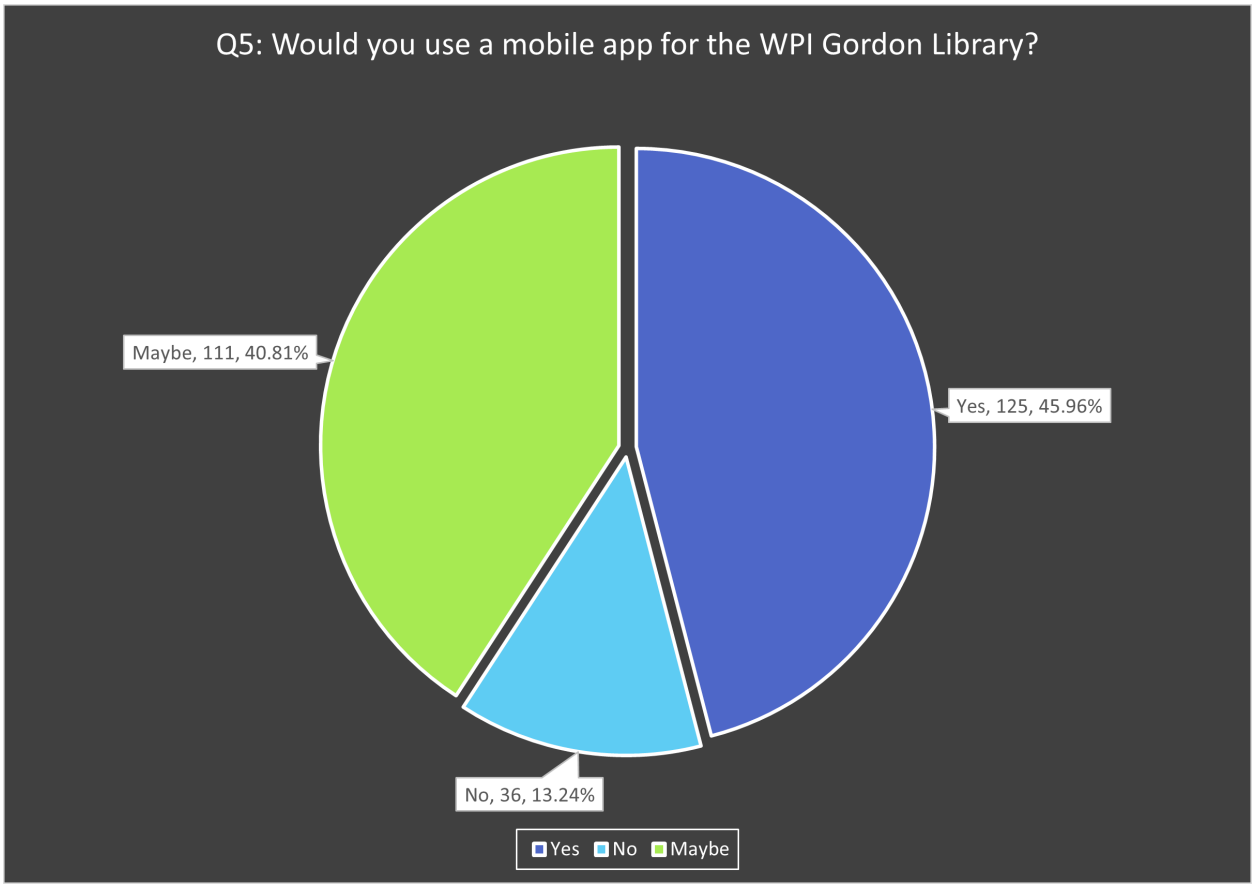

Figure 7.5.5: Mobile App Use

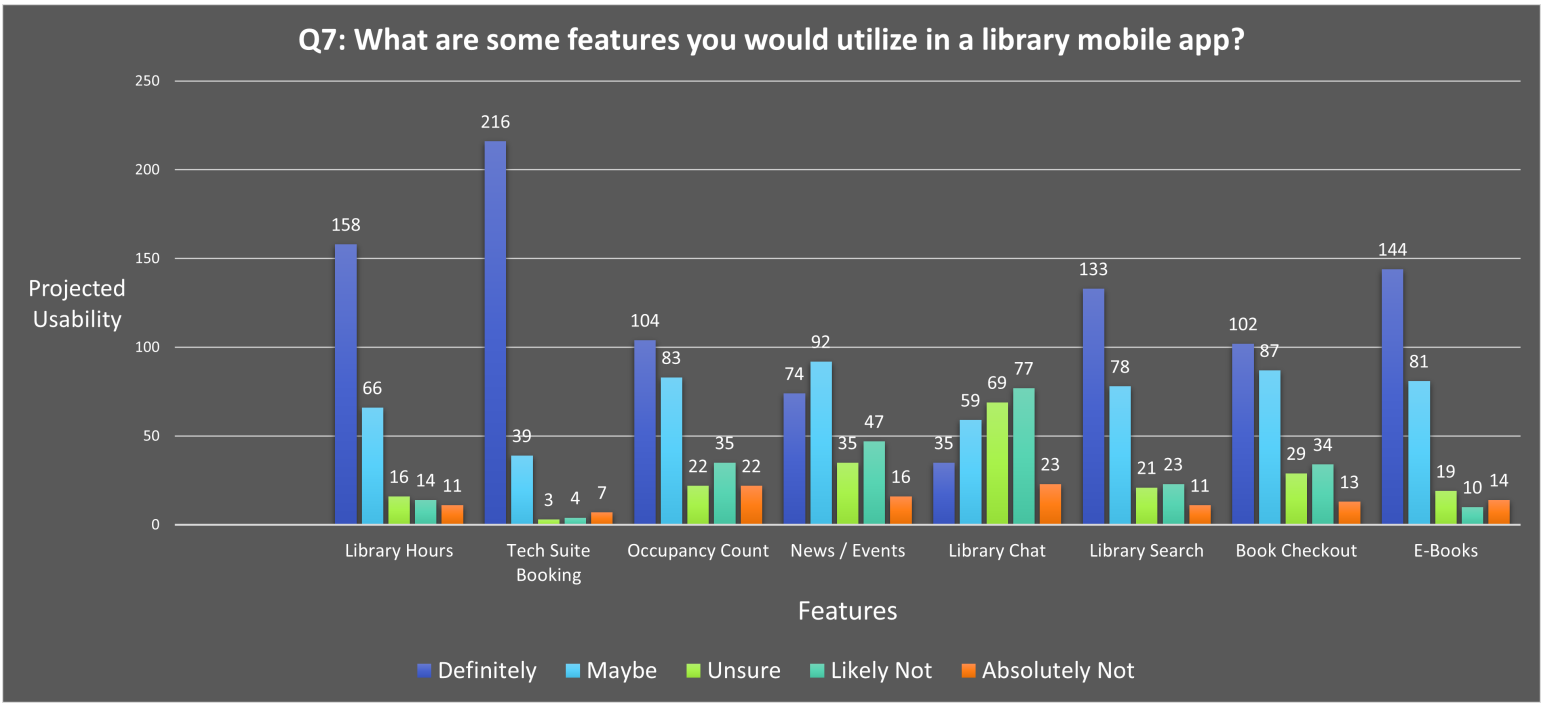

Figure 7.5.6: Features That Might Be Used In A Mobile Environment

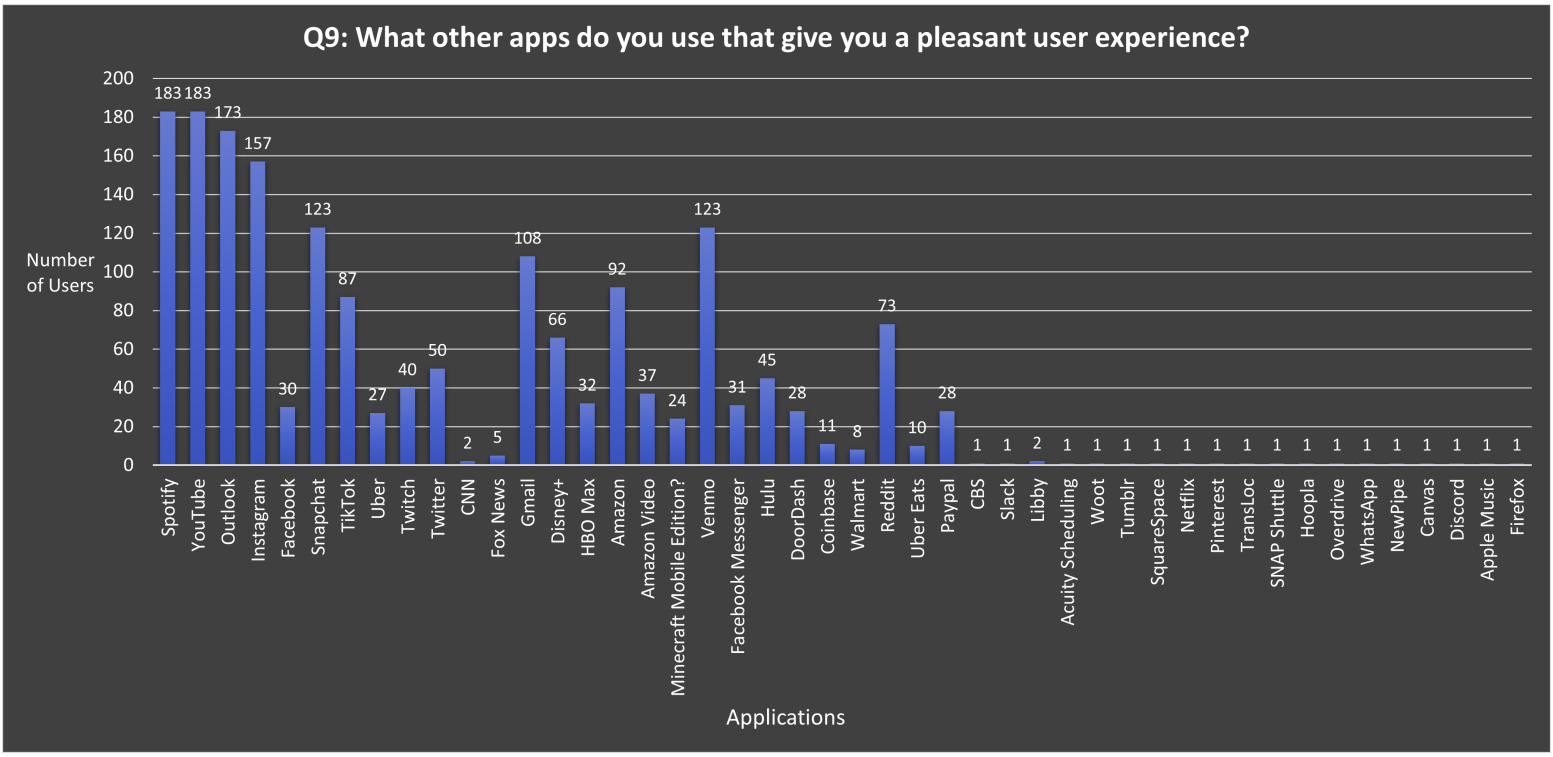

Figure 7.5.7: User Experience: Other Applications Used

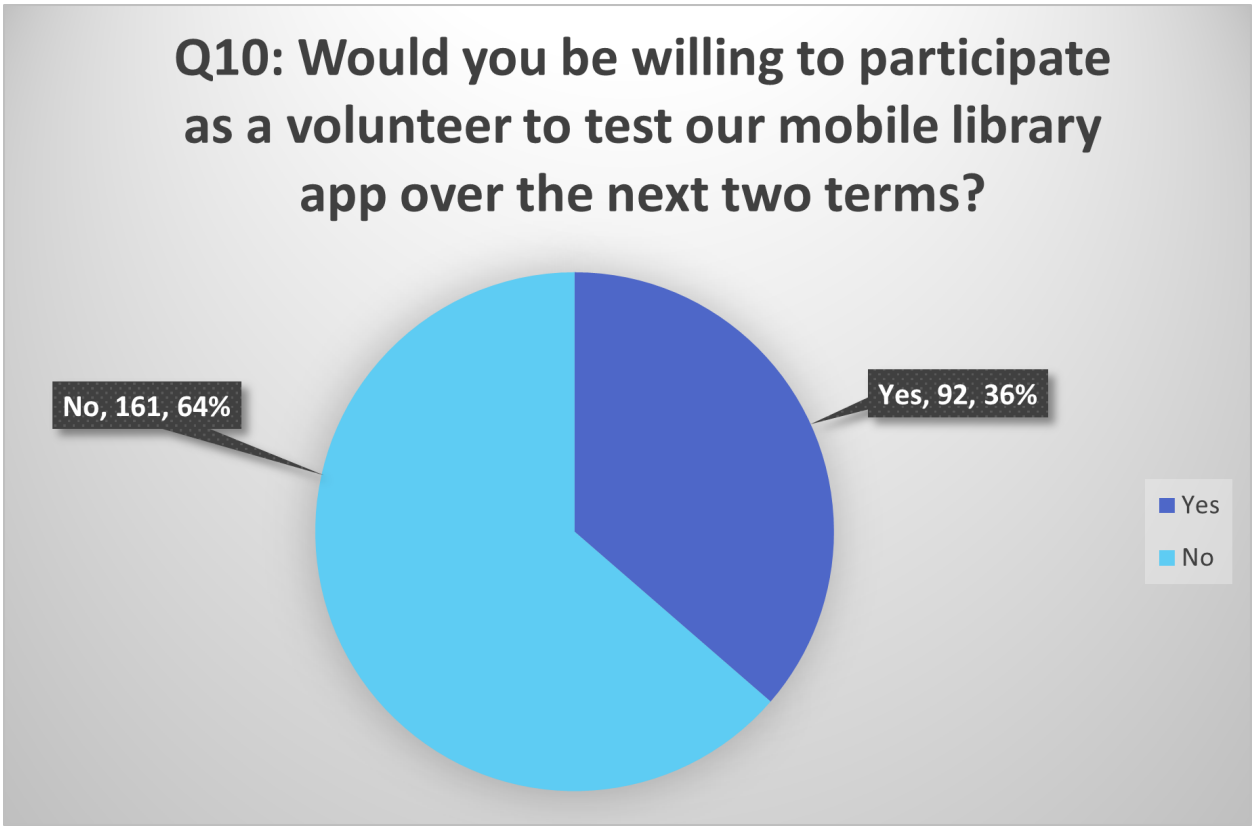

Figure 7.5.8: Volunteer Testing Participation