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Ashmun Express: A Mobile-based Study Application for STEM Students

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Abstract

There has been an increase in the usage of technology in classrooms nationwide, from smartboards to study applications. The dearth of the latter as a part of the curriculum for STEM students in higher education and particularly at a historically black university prompted two professors in biology and computer science to develop a mobile application that focuses on math applications in a variety of biological fields.

The prime objective of the mobile app - codenamed Ashmun Express - is to serve as a tool for early career STEM majors, almost all of whom have to take Introductory Biology and Elementary Statistics to provide them a chance to work on examples, view tutorials and take quizzes at their leisure to enhance their classroom experience.

Up until Spring 2020, the application was developed and maintained solely as an iOS App, with Swift serving as the primary language as Apple products are common in the educational setting. A recent survey among our students showed that of 26 students in a class in which the app was tested, 17 or 65% used an iPhone or an iPad. Additionally, there are sound development reasons to focus on one platform or another[1]. Unfortunately, there were problems like the absence of tests for classes/methods and refactoring issues for the student developers. Also, users found it difficult to navigate through the app and complained about designs and other minor issues. Ultimately, the project was temporarily halted and a new application is currently being designed and developed with the same objectives. It will only have a different framework and personnel on the project.

The new path for the project includes switching to React Native for cross-platform mobile development and a goal to create a functional product for evaluation for final exam review.This change also follows best practices in app development as described by Wardynski1 and would serve all students with a mobile phone[1]. Future plans would include creating a Professor functionality that helps the professor see the efforts made by the students and assign grades based on work completed in the app.

Introduction

Biology students often struggle with math application problems and are often unable to connect abstract math skills to application problems in their field. Traditional pen and paper problems given in class helped some students, but too many students are still unable to confidently

recognize and solve math application problems. Additional practice time with a greater range of problems might help some students, but this is very time-consuming with paper and pen problems. As the use of technology in classrooms has increased nationwide, from smartboards to study applications, it is believed that technology could assist students and faculty alike, by providing readily available e-tutorials and e-problems. A paper by Stark, who tested a variety of Apple digital products for use in teaching science, technology, engineering, and math (STEM) concepts found that with the right programs and proper guidance from the instructor, digital platforms and apps held great promise for enhancing student understanding of biological concepts[2]. Some digital resources are already available through textbooks, and the breadth and quantity of resources is expanding every year. However, students need to purchase a new textbook to access these resources, and some of them are available for only a limited period of time. In addition, there are some websites that provide practice in math application problems in STEM areas, but not all websites are interactive and many have a paywall. The emergence of the COVID-19 pandemic with the large increase in remote and on-line learning, some of which is expected to continue post-pandemic, underscores the need for more digital interactive learning platforms. A recent paper by Lellis-Santos and Abdulkader which focused on smartphone accessible e-mobile labs, discusses the importance of developing a range of tools for faculty and students to use[3]. The trend in technological advances coupled with the pandemic, support the need to develop a robust app that can assist students and faculty with teaching and learning of critical skills necessary for success in STEM fields.

Mobile STEM Education in Higher Education

In a report on 2019 mobile phone ownership, it was reported that 99% of 18-29 year old Americans surveyed owned a mobile phone; 96% owned a smartphone, specifically[4]. The average college student corresponds to this same demographic, thus there is no surprise that there is a higher prevalence of mobile learning use in the higher education domain than in K-12 learning[5,6]. Mobile learning, which has a variety of definitions associated with the concept, can be loosely defined as learning that occurs on wireless/mobile devices that is inclusive of being away from a typical,designated learning environment or using a device within a standard learning setting[7].This method of learning allows for a greater range of learning outside of the classroom by “allowing flexible and instant access to rich digital resources”[8]. Mobile learning has been found to have numerous effects on learning including having a positive impact on student learning[9], reinforcing traditional classroom teaching[10], and allowing the opportunity for exploratory learning[11]. Mobile phone applications, in particular, have been integrated in many subjects at the higher ed level.

There have been various applications developed by educational researchers for those undergraduate students in statistics and biology courses. There are numerous commercially available apps that can be used for statistical problems such as SimpleStat and Probability Distributions, which compute various probabilities and perform various t and Z tests[12]. However, many apps lack an educational component. NutriBioChem was developed for targeted use for two biochemistry and nutrition courses at the University of Guelph[13]. The app covered the main topics of Biochemical Pathways, Macronutrient Characteristics, and Micronutrient Characteristics; these topics were further divided into various subtopics. App features included

review cards with figures and related characteristics of various molecules, substrates and other important topics and two quiz options. The "Take Quiz" feature offers a multiple choice-based quiz that covers multiple review cards for a selected topic and the "Quick Quiz" option gives an assessment for a particular card. Detailed feedback is immediately given to the student showing the answer given and the correct response. A majority of users (75%) indicated that NutriBiochem was useful but only 45% thought that it helped them increase their performance in the course. Other examples include two recent application which focus on different and specific areas of cardiac physiology [14,15]. A difference between the apps discussed above and AshmunExpress is that these apps tend to focus on one narrow topic and do not integrate concepts across disciplines. Thus, AshmunExpress provides students with access to a large number of different and integrated topics within a single app.

Ashmun Express: The Application

Data previously gathered for the 2010 and 2011 Biology cohorts at the researchers' university showed that only 11% of them entered at the level of pre-calculus (Figure 1), but 100% of those students graduated within five years of matriculation (Figure 2).

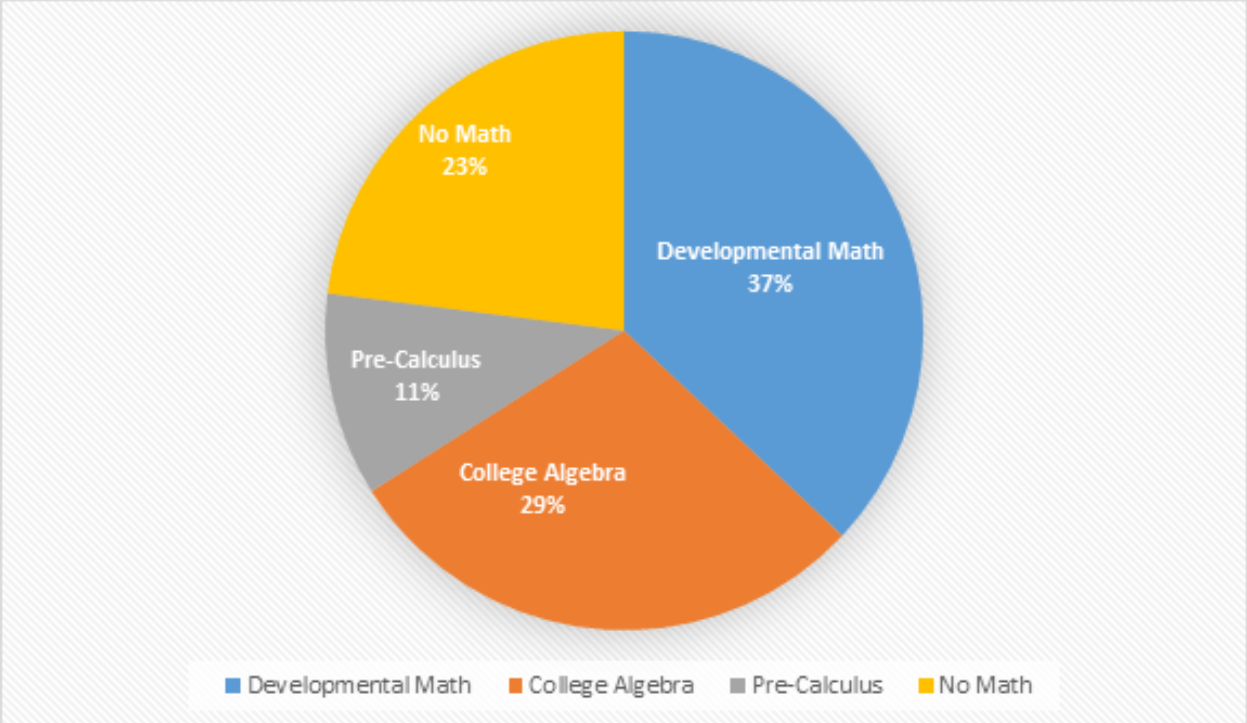

Figure 1: Math Entry Level Courses of Freshmen Biology Majors from 2010 and 2011

The remaining students entered at lower levels of math (College Algebra or Development Math) and their five-year graduation levels were under 60% (Figures 1 and 2). Thus, any on-line math tool developed should accommodate the students' math levels and assist professors in improving their math literacy to help increase STEM student success. The research team believed that creating a stand-alone low cost app that was not tied to a textbook or course, and that focused on

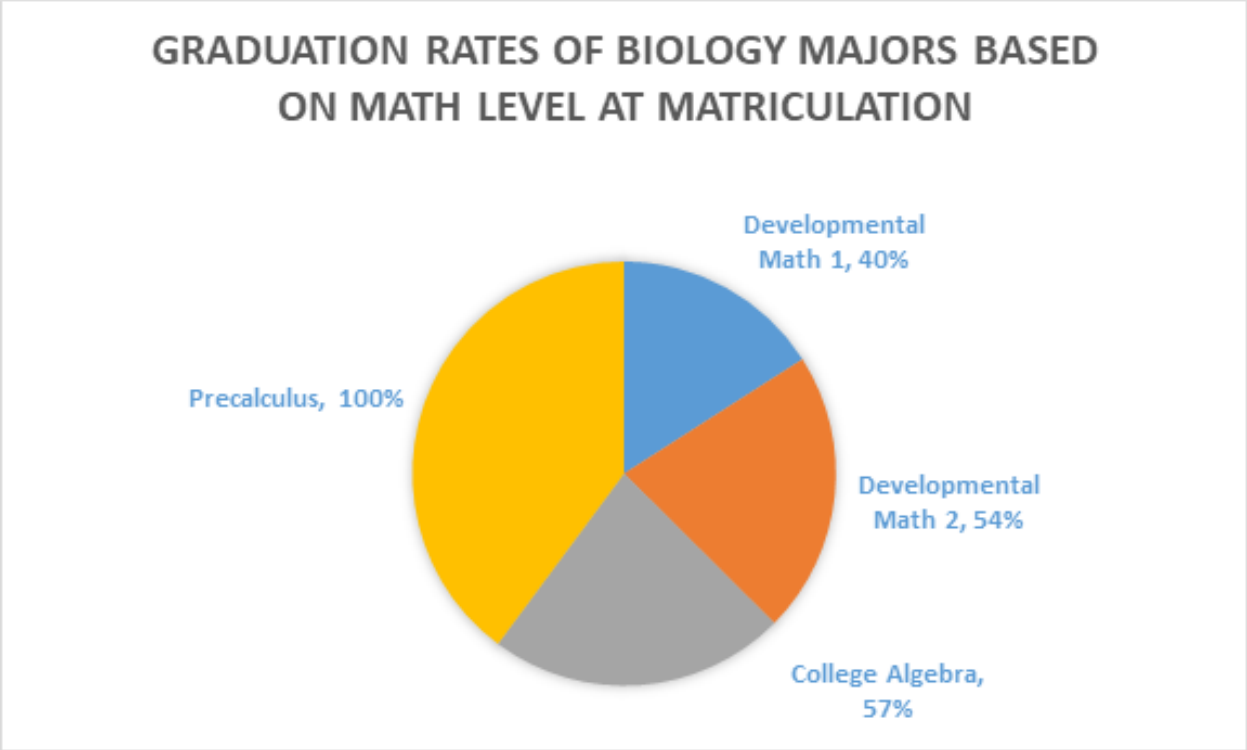

Figure 2: Graduation Rates of Biology Majors from the 2010 and 2011 Classes Based on Math Level at Matriculation

application problems common to many biology classes would be of assistance to a large number of students, not just those attending the researchers' university[16].

The application was designed with the primary objective of providing students with learning opportunities to apply mathematical concepts, prevalent in both biology and math classes. The app was also intended to provide instructors with real time feedback on how students were performing on problems given within the app. Students gain access to the app by first logging in with a username and a password (Figure 3a). After a successful login, students are taken to a main menu which shows the topics and subtopics (Figures 3b and 3c), depending on the content matter, available in the app.

The application covers topics found in general Biology courses as well as some topics featured in the Elementary Statistics course, which expands the target population of this app to go beyond those enrolled in the Biology degree program. General Biology and/or Elementary Statistics are required courses for many of the STEM undergraduate degree programs at the researchers' university. Programs such as Biology, Chemistry, Environmental Science and Engineering (Electrical and Computer track and Civil and Environmental track) require students to take both of the aforementioned courses in their curriculum; Computer Science students must take Statistics, but can choose between Biology or Chemistry to fulfill their science requirement. Other programs such as Biochemistry, the Bioinformatics minor and those in Health Science are all required to at least take Biology. Thus, the application has a wide range of students who would benefit from its use.

A value-added feature of the app is the direct connection that can be made from mathematical concepts to their application in a discipline specific problem. Professors often assume students carry content between courses and make connections, but this frequently does not occur. All the tutorials for Probability were written by a mathematician using terms and concepts taught in Elementary Statistics. Some of this math language is carried over into the biology problems to show the connection. Below are pertinent excerpts taken from the Tutorials for Probability Level 2 (Statistics) and Monohybrid Crosses Level 2 (Biology). The underlined words represent key terms within the tutorial.

Probability Level 2 Tutorial

"In probability theory, we often have to calculate the number of ways in which certain events can occur or, in other words, count the number of outcomes with a specific property. There are three important formulas which are useful in such instances. In this tutorial, we will understand these formulas."

Monohybrid Level 2 Tutorial

"It is not always possible to tell an organism's genotype from their phenotype, so geneticists perform parental crosses and F_1 and F_2 crosses. In a parental cross, two true breeding parents are used. A true breeding parent is one with either a homozygous dominant genotype (XX) for a trait or a homozygous recessive genotype (xx) for a trait. Each homozygous individual will express the phenotype associated with its genotype. As seen in Punnett square 1 below, all of their offspring are heterozygous, but express the dominant phenotype. The prefix homo- means same and hetero- means different. If an organism is homozygous dominant it means that both the alleles in the genotype are the same and represented by capital letters. If an organism is homozygous recessive it means that both the alleles in the genotype are the same and they are represented by lowercase letters. If an organism is heterozygous it means that the two alleles are different and represented by one uppercase and one lowercase letter.

The offspring from a parental cross are called the F_1 generation. ***Calculating the expected numbers of each genotype relates to Probability Theory. As covered in probability level 2 in the app, we often have to calculate the number of ways in which certain events can occur or, in other words, count the number of outcomes with a specific property. Thus Probability Theory is used to calculate that when F_1 generation individuals are crossed, they should produce the typical Mendelian ratio of 1:2:1 homozygous dominant:heterozygous:homozygous recessive offspring as shown in Punnett square 2 below****. This means that on average, 25% of their offspring are homozygous dominant, 25% are homozygous recessive and 50% are heterozygous. The homozygous dominant and heterozygous individuals express the dominant phenotype, so 75% of the offspring will have the dominant phenotype. The remaining 25% of offspring will express the recessive phenotype. This means that the ratio of the F_2 generation will have a phenotypic ratio of 3:1, where the 3 represents the proportion that express the dominant phenotype and 1 represents the proportion that express the recessive phenotype."*

Most of the material featured within the app was written by student researchers from the biology department. Content relevance is an important factor needed for successful mobile application use in the educational realm[5] The questions used within the app were intended to mirror content being taught within the targeted courses in which the app was to be later evaluated. Within each

topic, there are three levels of increasing difficulty, aptly named Level 1, 2 and 3 (Figure 3d). At each level, students are exposed to four different modes of learning: tutorial, examples, practice problems and a test. The linear progression of the modes, as well as the increasing levels of difficulty, was implemented as a scaffolding technique to ensure that students would progressively gain a greater understanding and greater independence as they interact and advance through the app.

Figure 3: A-D: The screens students view on Ashmun Express App as they progress through the pages

The tutorial section offers students an introduction to the topic and then provides students with a walkthrough on how to solve problems related to that topic. The tutorial may also include a list of key terms that students should be familiar with after exploring the tutorials. The definitions of the key terms can be viewed by clicking on the respective term.

Figure 4 depicts the tutorial mode of the app, while Figure 5 corresponds to the result of clicking on the key term “sample space.” The example problems are similar in format to the tutorial, but forego any of the introductory material (Figure 6). Students are still guided through how to solve one or more related problems. Following the example problems, students are directed to begin practice problems on the topic. The practice problems feature content related to the material included in the tutorial and examples. For example, in the topic on Probability and Statistics, the tutorial and example components, introduce students to the subject matter using the concept of flipping a coin to determine the probability of landing on heads or tails. The practice problems on this topic also featured questions with the same theme of coin flipping as seen in Figure 6.

The practice problems, as well as the test questions, utilized a multiple choice answer format. Students answer the questions and receive immediate feedback based on their answer selection. Students are free to move forward or return back to any questions in this section. This is slightly different from the test section. In the test section, students advance through the questions and

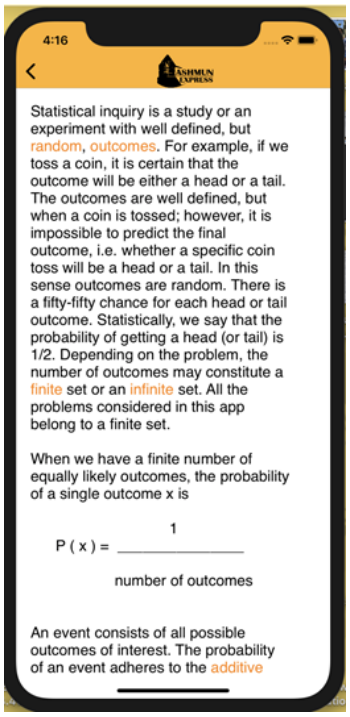

Figure 4: Tutorial Mode Screenshot

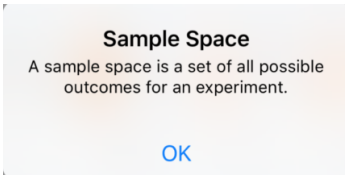

Figure 5: Key Term Pop-Up Window

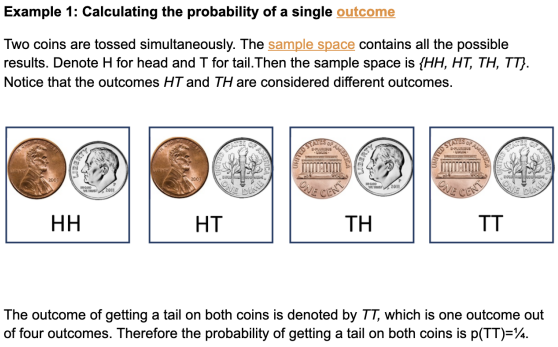

Figure 6: Example problem for coin flipping in statistics

receive feedback as well as a summary after they conclude the test. Students are not able to return to any previous questions after they are answered.

Evaluation of the Application

In order to test the potential effectiveness of the Ashmun Express application, the app was evaluated in the fall of 2019 and spring of 2020. In both evaluation periods, students enrolled in Elementary Statistics I, were introduced to the Ashmun Express App in their courses, were given the opportunity to attend tutoring sessions to receive any additional assistance in using the app, and asked to participate in a survey on app functionality upon completion of use of the app. The survey was designed by student interns with input from the two co-PIs. This survey was reviewed

by the external evaluators and modified by the students after consideration of the evaluator's recommendations. Student responses were collected under IRB Approval # 2018-09-12-SS.

Results

Fall 2019

In the fall of 2019, a total of 42 students enrolled in the class were invited via email to participate in the confidential on-line 26-question survey and 26 students, representing 62% of the class, responded.

App Design and Functionality

About 80% of the respondents accessed the app on a phone, and most used an iPhone. The feature of the app that consistently worked the best was the buttons, with 88% agreeing that the buttons worked well. Slightly more than 50% of the students agreed that navigation through the app and Main Menu were easy, and the same percentage were positive about the fit of the image on their devices and the app logo. All of the students felt that the process to create an account did not run smoothly and the frustration with the initial encounter of the app was reflected in individual student comments. Almost 50% of respondents had at least one experience with the app crashing. Over 70% of the respondents described specific issues they encountered using the app and/or made suggestions on ways to improve it. Some specific issues included some of the questions not loading and occasional navigational redirection.

Learning Modes and Content

With regards to the learning modes, 48% of the students thought that the Tutorial feature was easily understandable and 40% felt that there was just enough content coverage. All of the students were either in agreement or neutral with regards to the Example section preparing them for the Practice and Test sections. Students expressed a more neutral opinion in regards to the Practice section. Only 36% agreed that they felt capable of completing the problems in this section without assistance; the same percentage felt that these problems reflected the content in the Example section. Students also responded more neutrally to questions concerning the Test portion of the app. 32% felt capable of completing the test problems alone and 44% would have preferred a greater number of test problems. 24% agreed that the app was more helpful than traditional pencil and paper study methods, but only 12% utilized the Test section more than once.

Additional Observations

Although the evaluation did not elicit favorable results from all questions, it is important to note that this could be partially attributed to low app usage. When asked "How often did you use the app during your study of the content covered in this course?", 62.5% of the respondents reported seldom or never. However, some comments associated with this question indicated that low usage may have been a result of technical difficulties. Thus, the app needed work to make it more engaging and user-friendly. It was subsequently discovered that the recently developed dark mode by Apple was not compatible with the platform and coding language, which could explain some of the issues students encountered. The dark mode issue was resolved quickly and the app was

tested with students in the Statistics I course in the following semester before any major application redesigns were initiated.

Spring 2020

In the spring of 2020, 55 students enrolled in the course were invited via email to participate in the confidential on-line survey and 29 students, representing 53% of the class, responded.

Design and Functionality

Some of the issues found with the app in Fall 2019 were corrected and the app was retested in the same Elementary Statistics class in Spring 2020. In contrast to Fall 2019 when 80% of the students accessed the app on a phone, only 45% accessed the app on a phone in this cohort. Most of the remaining students used a tablet and a few used a computer. In contrast to the fall when only slightly more than 50% of respondents agreed that navigation through the app and Main Menu were easy and that the image fit their device, three fourths of the respondents (72-79%) were positive about all these aspects of the app. About two thirds of the students (66%) felt that creating an account was a smooth process, whereas none of them did in the fall. Over half the spring respondents also agreed that the app loaded quickly and was visually appealing. Thus, many of the issues encountered with the first trial in the fall of 2019 were corrected by the spring semester. About one quarter of the respondents expressed reservations and concerns about the app, including several remarks about the app being too slow. Other comments included that the same question repeated itself in a test, the unit commands were clunky and there were (unspecified) glitches.

Learning Modes and Content

With regards to the learning modes, a larger percentage of respondents (62% vs. 48% in the fall) thought that the Tutorial feature was easily understandable and 55% (vs. 40% in the fall) felt that there was just enough content coverage. Similarly, to the fall respondents, all of the students were either in agreement or neutral with regards to the Example section preparing them for the Practice and Test sections. In contrast to the fall respondents when only a third of the students agreed they were capable of completing problems without assistance, over half (55%) of students in the Spring classes felt capable of completing problems by themselves. A majority of the students in the spring (59%) felt capable of completing the test problems alone and 48% would have preferred a greater number of test problems. Almost twice as many from the spring classes (41% vs. 24%) agreed that the app was more helpful than traditional pencil and paper study methods, and almost three times as many (35% vs. 12%) utilized the Test section more than once. Although this question wasn't asked, it is possible that students felt more positive about the content of the app because they encountered fewer technical problems in the spring using the app. The students had to leave campus immediately after using the app in class and the disruption caused by the pandemic made it difficult to follow-up on these findings. One negative finding was that most of the students (62%) were either neutral or disagreed that the app led to more interest in the statistics and an even larger percentage (72%) were neutral or disagreed that the app made statistics easier to understand. This is an outcome that will be followed up on when students return to campus.

Learning Express 2.0

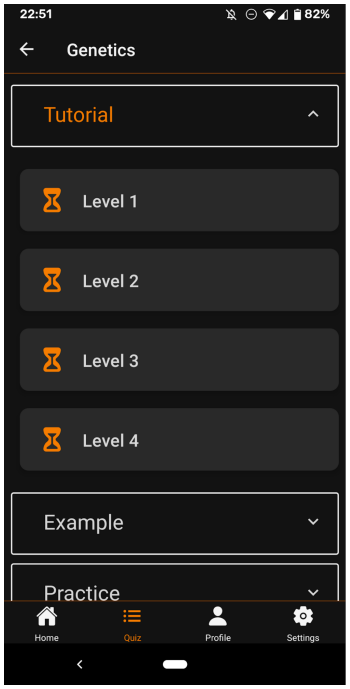

Figure 7: Dark Mode

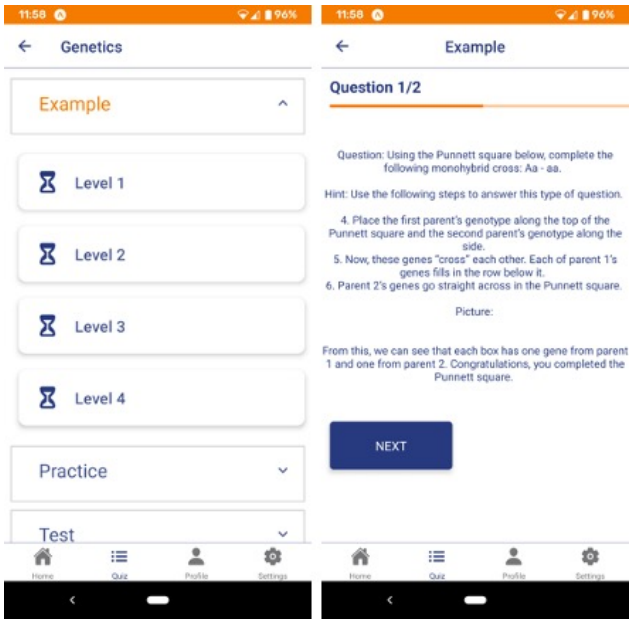

Figure 8: Ashmun Express 2.0 Typical UI

As mentioned previously, after correcting the issue for the Dark Mode feature, students were able to better interact with the app in the second round of testing. However, there were issues with the app that affected student use and suggestions given in the survey, as well as made by the student researchers, in which the app could be improved upon. While the app was initially developed using the Swift programming language which is intended for use on Apple devices (primarily iPad and iPhone), it was decided after testing to change the platform of the app and recode the app using React Native. Not all students own Apple devices nor was there a “class set” of devices for students to use, outside of devices made available during the tutoring sessions for those who participated in the user testing. By rewriting the app in terms of cross-mobile platform development (iOs, Android,etc.), it would be more beneficial than the previous iteration of the app in terms of quantity of users and accessibility. It would increase the amount of students who have access to the system despite their choice of cell phone operating system. It would also allow students the ability to access the system outside of class time or tutoring sessions, giving them more opportunities to engage in the application.

In terms of user interface (UI), while the students who interacted with the app did not have many negative comments in regards to the visual appearance of the app, the developers decided to make minor tweaks to the UI. One feature included incorporating a dark mode which uses light icons/text on a dark background as depicted in Fig. 7. It is useful when interacting with mobile phones in dim lit rooms or simply at night. Other updated UI features included the overall color scheme of the app to better reflect the university’s colors, style of the navigation, and the style of listing of the topics, subtopics and learning modes. Previously, as depicted in Fig. 3b-d, the app showcased a block format. After the redesign, the aforementioned UI elements are now displayed

in a list format and after selecting the learning mode, the difficulty levels appear as a sublist as seen in Fig. 7 and 8.

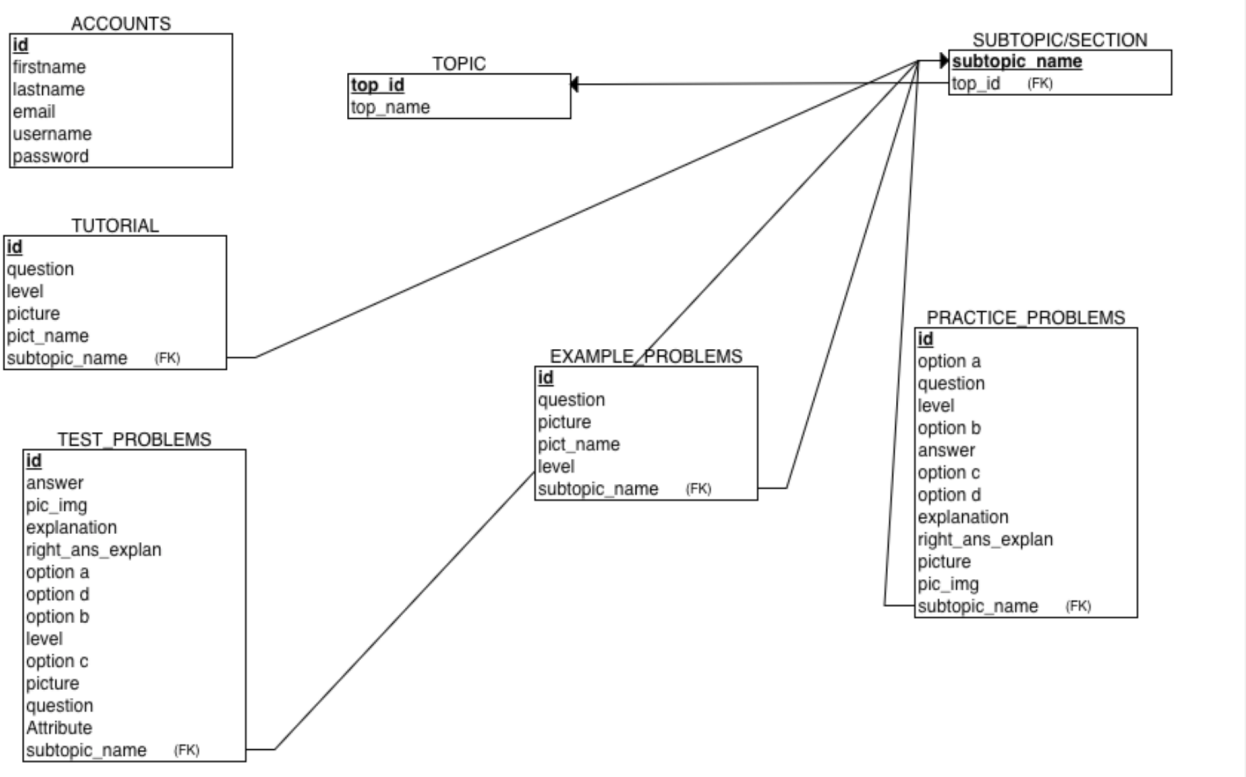

Figure 9: Ashmun Express Database Schema

There was also a change in the database design structure. Figure 9 shows the database schema, a visual representation of the database, used for the current development of the Ashmun Express app. This schema shows how the different entities in the database relate to one another. There are a total of seven entities in this relational database: accounts, topics, subtopic, tutorial , example _problems, practice and test . These entities serve as tables that will contain different details of what they are named after. For example, the entity “account” is a separate table in the database that will store the accounts of the different users using Ashmun Express.

Initially, the back-end of Ashmun Express was designed in such a way that data was received synchronously; this meant that instructions were executed in blocks, so another task could not be completed unless the previous task was finished. The scripting language used in the original development was PHP, and the main problem with this approach was limited scalability. This meant that as more users used Ashmun Express, the time taken to execute the users’ tasks increased significantly. As a result, this problem had to be solved using asynchronous programming; in this type of programming instructions were not executed in blocks, so another task can be completed if the previous task has not been completed. Therefore, a new back-end infrastructure that supports asynchronous programming was employed for the back-end development of Ashmun Express. To start, a Cpanel and a Heroku web host were utilized to deploy the developmental files and to provide a mySQL database. mySQL database was used in

this project because the Ashmun Express App is a test-taking application that requires storage for the numerous questions. Node.js and the Express framework were used to build the RESTful API- this is an interface used for connecting our database to the front-end. Node.js is a scripting language that supports asynchronous programming thus fixing the initial problem of limited scalability encountered when using PHP.

Future Work

One of the key features to be added as the development continues for Ashmun Express 2.0, is the addition of a Professor Profile. The Professor Profile will allow professors access to the students enrolled in their courses and monitor their app usage. Ideally, it will give them insight into how often and how long students are interacting with the app, which topics they are spending more time and what topics they are finding success in and conversely, those in which they are struggling with. It is the hope that this will bring awareness to what concepts may need additional coverage in the classroom. While the app is designed to be used for practice at any time, professors could potentially use the app in the classroom to get a quick assessment of students' knowledge on the various topics and subtopics. Students indicated in both surveys (Fall 2019 and Spring 2020) that they would also like for the app to be utilized during their instruction time. Students also suggest more practice problems, which can be easily addressed by creating more content for Ashmun Express.

Conclusion

Despite the onset of the COVID-19 pandemic, testing in the Fall 2019 and Spring 2020 did offer useful insight into the design, functionality and practicality of the app. Feedback resulted in the ongoing redevelopment of an app that has cross-platform capabilities, has a sleeker user interface, as well as a faster and more efficient back-end component. At the conclusion on this redevelopment phase, it is the intent to retest the application with students in applicable courses in which the professor has used the app during lectures. If proven successful at the researchers' university, it is the belief that this app will be a beneficial addition to both app stores (Apple and Android) and be made available for biology students on other campuses.

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