MOBILE MATH APPS: INNOVATIVE SMARTPHONE TECHNOLOGY

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Mobile devices, including smartphones and slate computers, offer an exciting array of possibilities in the way we use technology to teach mathematics. The Mobile Math Apps project, supported by NSF DUE 1140299, is focused on the development of precalculus modules created as "apps" for smartphones, the dissemination of best practices for mobile mathematics teaching, and research into how use and efficacy of mobile devices differ from traditional computer platforms. This paper will describe the motivation, objectives, and assessment plan for this project.

Why Precalculus?

It is easy to make a case that the precalculus course is a bottleneck for students studying STEM disciplines. In Figure 1 we see that during a recent fall semester at Shippensburg University, over 50% of the enrolled students were in STEM majors. More importantly, over 25% of the enrolled students were undeclared and "leaning toward" a STEM discipline without yet formally declaring a major.

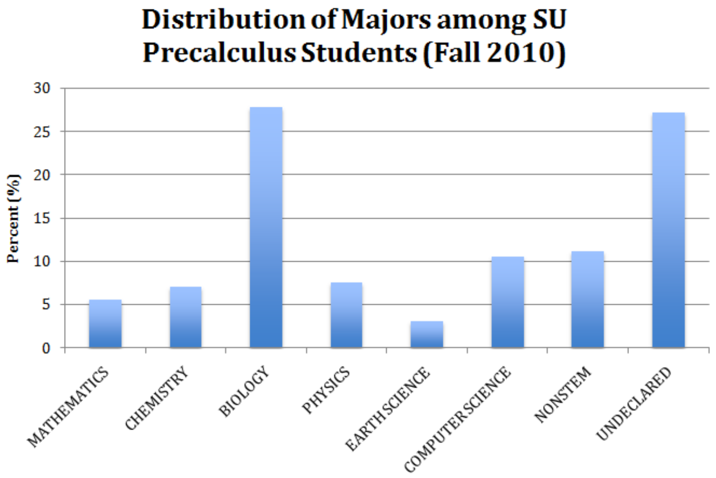


Figure 1: Majors in Precalcuus at Shippensburg University

So STEM majors account for the vast majority of students taking precalculus at Shippensburg University. How do they do? The more relevant question is, “How do they do in subsequent courses?” In other words, do these students persist in their STEM major?
At Shippensburg University, students who took precalculus in Fall 2009 saw their grade fall by an average of 1.5 points (on a 4.0 scale) when they took Calculus I the next semester. Among these students, 35% failed or withdrew from Calculus I in the subsequent semester. So the data suggests that real learning in precalculus (as measured by success in Calculus I) is a significant indicator of students’ persistence in STEM majors.

Why Smartphones?

As the paradigm for online activities shifts from computer to mobile device, there needs to be careful thought given as to how this shift can potentially affect student learning. In this project, we are meeting students where they are – namely, on the phone. We are reaching students through the device they use continuously during the day. With intuitive interfaces and attractive designs, we will make student contact with the learning material on this device more frequent, more effective, and more enjoyable.

Technology pundits agree that mobile computing will play an increasingly important role in general, and in college campuses in particular. As of September 2012, the Pew Internet and American Life Project [1] reports 45% of all American adults owning a smartphone – as opposed to 35% from one year earlier. More relevant to college instruction is the fact that much higher rate (66%) of ownership was reported in the age group 18-29. The following provides even more reasons to focus on smartphone development:

- Smartphone owners became the majority of mobile phone users for the first time in 2012. [8]
- As of June 2012, 54.9% of U.S. mobile subscribers own smartphones. [6]
- Two out of three Americans who acquired a new mobile phone in the the second quarter of 2012 chose a smartphone instead of a feature phone. [6]
- As of September 2012 the majority of American teens (58%) reported owning a smartphone, compared to 36% of teens saying they owned a smartphone the previous year. [7]
- Educause Center For Applied Research reports that a greater percentage of undergraduate students in 2012 (62%) than in 2011 (55%) said they own a smartphone. [4]
- Nearly twice as many undergraduate students in 2012 (67%) than in 2011 (37%) reported using their smartphone for academic purposes. [4]

Smartphones in Minority groups

Pew’s data for the last few years consistently showed higher ownership of smartphones among minority Americans. That trend is confirmed this year. While 45% of all

American adults owned a smartphone as of September 2012, the Pew studies [1] also provides data by ethnicity is as follows:

White, non-Hispanic	42%
Black, non-Hispanic	47%
Hispanic	49%

Another 2012 Pew study of mobile phone usage *Cell Internet Use 2012* [9], shows that black (64%) and Hispanic (63%) of cell phone owners outpaced their white (52%) counterparts in using their cell phones as Internet portals. This same study also reports that twice as many blacks (51%) and almost twice as many Latino (42%) as white (24%) cell Internet users access the Internet “mostly” via their cell phone.

Therefore, we believe that development of sound teaching/learning material for smartphones has great potential to benefit groups not typically reached by traditional means.

Tablet ownership

The physical dimensions of smartphones present significant challenges to the development of effective teaching tools, so there is a temptation to apply efforts in ‘mobile development’ only to tablets such as the iPad. However, the data presented on the ubiquity of smartphones is not matched by comparable statistics on tablets. For example, even though tablet ownership among undergraduates grew significantly during 2012, this growth was from about 6% in 2011 to 15% in 2012 [4]. According to the more recent Pew study [10], 25% of American adults owned a tablet as of October 2012. These numbers are significantly less than those for smartphones for an obvious reason: tablets are often the third piece of technology (after computers and mobile phones) among tablet owners. One could make an argument that tablets will replace books, or even that tablets will replace laptop computers, but the phone remains the piece of technology common to all users. In addition, the data in the previous section suggests that for some populations a smartphone will be the one and only connection a user has with educational content on the Internet.

Android vs. iOS

When considering smartphone development, one is immediately confronted with the segmented population of smartphone operating systems. Native applications for Android phones are written in Java while native applications for iPhones are coded in Objective-C. No one wants to develop apps in two different languages, and no one wants to be faced with guessing which platform will prevail. The Educause study of 2012 [4] finds that 46% of students who own a smartphone use an Android-based phone, 44% the iPhone. Other operating systems are nearly extinct among college students. In the general American population Android has a much higher advantage over the iPhone, but the two of them together still hold 90% of the market [6].

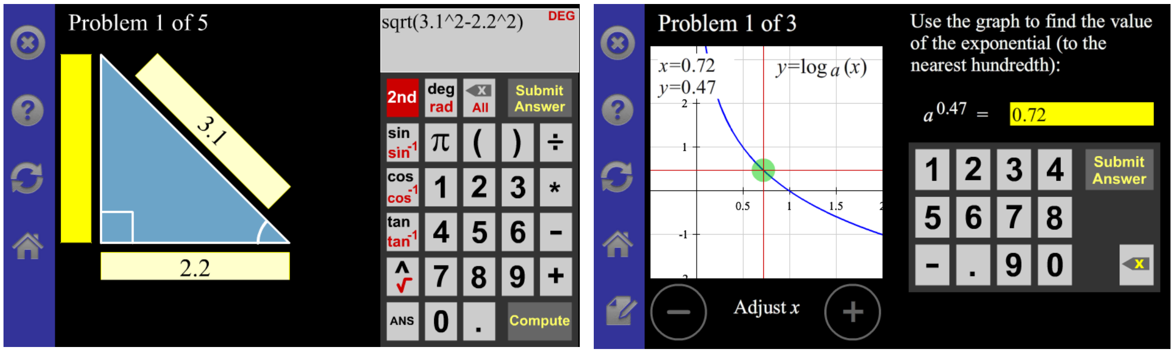
Fortunately, Adobe AIR (Adobe Integrated Runtime) and its programming language ActionScript 3 (AS3) make it possible to target both Android and iPhone operating systems from one set of source code. Other popular tools for cross platform development include Corona, Appcelerator, and PhoneGap, but our project uses the Adobe solutions.

Mobile Math Apps

The Mobile Math Apps project is largely about research into *how* one should develop and implement interactive mathematics applications for smartphones, but obviously it must also include the actual development of a coherent of collection of material that will allow the research study to progress. Our initial segment of material will cover fundamental concepts on trigonometry, logarithms, and exponential functions, which will comprise a significant portion of most precalculus courses.

The website flashandmath.com will be the vehicle for disseminating shared classes and discussions of best practices for the development of teaching and learning material for the smartphone. Below are screenshots illustrating some of the interface issues we have tackled so far:

- Custom keyboards allow mathematics input specific to particular problems. Compare the two keyboards shown in Figure 2.



Problem 1 of 5

sqrt(3.1^2-2.2^2)

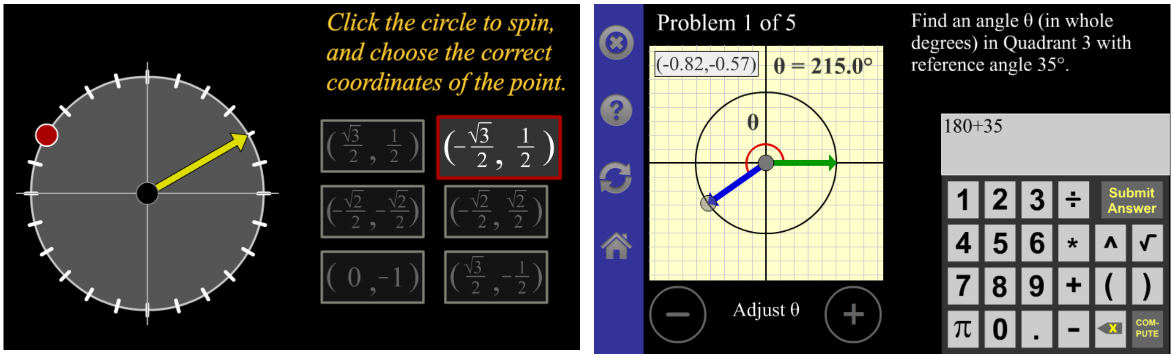
Problem 1 of 3

Use the graph to find the value of the exponential (to the nearest hundredth):

$a^{0.47}$ = 0.72

Figure 2. Custom keyboards preserve screen real estate

- Touch screen interface for intuitive interaction, especially for concepts that have a pedagogically important visual component.



Click the circle to spin, and choose the correct coordinates of the point.

Find an angle θ (in whole degrees) in Quadrant 3 with reference angle 35°.

Figure 3. Touch screen interface for important visual concepts

- Saving local user data in order to track progress. This allows app to be globally adaptive (i.e., the app knows what the user has done correctly and incorrectly). It also allows the app to have a game-like interface to motivate students. See Figure 4 to see how students are motivated to repeat problems until they can move on to a new topic.

Figure 4: Game-like interface motivates student progress

Research Questions and Evaluation Plan

The primary goal of the project is to understand the impact of smartphone-based learning material, so all evaluations will be focused on this goal. The following are our initial research questions:

1. Will students use tutorial applications voluntarily on a smartphone to supplement instruction in a mathematics course? That is, are well-designed academic/educational mobile applications compelling to students to the extent that they will voluntarily interact with them?
2. How does student usage of mobile mathematics tutorials compare to the usage of browser-based tutorials accessed on a computer? This comparison will be based on behavioral measures, such as time on task, successful completion of problems, number of problems attempted, etc.

3. If mobile tutorials are an assigned part of a course, is there an impact on student behavior or student learning? Usage and success data taken from the smartphone will be correlated with level of success in the overall course as well as the subsequent Calculus I course. Also, differences between voluntary usage (Phases I & II) and required usage (Phase III) will be considered.
4. Are there specific characteristics of the applications that are associated with an increase or decrease in learning efficacy?

The smartphone material will be evaluated in three phases.

Phase I. At the outset of the semester, the 40+ students in one section of precalculus will be given standardized assessments measuring content knowledge, cell phone addiction, and math anxiety. The results of these tests will be used to split the class into two matched groups as large as possible. We will load relevant apps onto the personal smartphones of Group I in the first half of the semester, and repeat the process with Group II in the second half of the semester. For students who do not own a compatible smartphone, we will loan a "wifi only" device such as a Samsung Galaxy Player.

Student learning outcomes will be measured by a standardized posttest, but equally important will be the usage data collected from the individual phones. This data will include application contact times, number of tutorials viewed, number of problems attempted, time on task, proficiency with phone-based exercises, and other items to be determined. A subset of students will be invited to participate in focus groups during the semester, and at the end of the precalculus class, all students will take a posttest content assessment and be invited to complete attitudinal surveys and give detailed feedback regarding the design and content of the apps.

Three major types of evaluations will be performed on this data. The first involves using inferential statistics to determine if there is a significant increase in performance on course content. If the applications are compelling to the current generation of students, we expect to see a significant difference in performance simply by making the applications available to them. That is, the applications would be so compelling that students will naturally use them as a study and practice tool in precalculus.

The second evaluation will use correlational statistics to determine if there are relationships between usage behaviors of the applications (time, success, tutorial viewing, etc.) and performance. Regardless of the results of the first evaluation, the second evaluation will break down the specific behaviors that have the greatest impact on students' performance.

The third will focus on the evaluation of focus group feedback, which may inform changes in the interfaces, changes in application content, and approach to Phases II and III. All three evaluations will allow us to determine the critical characteristics of application design and student use that are specifically related to success in the precalculus course.

Phase II. In multiple sections of precalculus, some sections will receive all of the apps that have been developed and the other section will receive none. Again, pretest/posttest results will be used to assess student learning outcomes which will be correlated with the data collected from individual phones as described above (e.g., usage data, time on task, and progress through the phone- based exercises). The analysis for this phase will be similar to the analysis in Phase I.

Phase III. In multiple sections of precalculus, students will have access a single set of exercises that is available via either smartphone or traditional computer-based applets, and the exercises will be assigned as part of the course grade. Integration of the with course content will be determined from the results of the focus groups as well as from the statistical analyses, with an emphasis on integrating the applications within the course focusing on those behaviors that increase success and understanding, as well as considering students' attitudes toward the applications. The resulting integration will be mirrored by integration with the computer-based exercises.

With a more robust sample size, we can use the pretest/posttest model along with usage data for each application whether on a phone or a computer. The data will be used to compare the usage habits and impact on student learning across different instructors. We will also measure the value students place on the materials since all will be required to access the material as part of the course. The analyses will be as previously described with the type of medium (smartphone or computer) as an independent variable in the inferential statistics. The data on computer usage will be at a gross detail (Did students do the exercises? Were those exercises completed correctly?) compared with the usage data for the smartphone apps. Therefore, a direct comparison of behaviors between the two mediums will not be possible. However, we will be able to determine if one type of interaction results in greater success compared to the other. Again, focus groups will allow us to gather feedback on the strengths and weaknesses of both types of applications.

Conclusion

In education there is a constant need to bring the teaching material to where the students best learn. When motivating the importance of a topic we connect key mathematical ideas to students' interests and experiences. When creating assignments we consider how today's student goes about constructing mathematical knowledge. And when we design interactive teaching material using technology we need to determine how to use the platform that is with the students 24 hours a day. This project will give us insight into how to accomplish this while jumpstarting development of material through shareable classes and dissemination of best practices.

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