Enhancing STEM Majors' College Trigonometry Learning through Building Mobile Apps

Yu-Chang Hsu
hsu@boisestate.edu
Yu-Hui Ching
Janet Callahan
Doug Bullock
Boise State University

Abstract

This study aimed to strengthen students' trigonometry knowledge and skills by providing authentic contexts for knowledge application. An innovative approach was applied to guide students to integrate trigonometry in programming mobile apps and in developing learning content. Three research questions guided this study: 1) How do students apply trigonometry concepts in developing their mobile apps? 2) How do students perceive the experiences of applying trigonometry concepts in developing their mobile apps? 3) What motivates students in a Trig-APPS course? We found students were overwhelmingly positive about their experiences of reviewing, revisiting, and utilizing trigonometry through programming mobile apps. The innovative approach is promising in motivating students to learn foundational mathematics while solving design problems.

Objectives

Many students enter colleges with a need to strengthen their foundational mathematics, such as trigonometry. In addition, college students in STEM majors (science, technology, engineering, and mathematics) often struggle to apply trigonometry concepts in post-requisite courses. For example, in statics, a sophomore engineering course, even though many students are able to find the sine or cosine of a right triangle oriented in any of the four quadrants as taught in mathematics, they struggle with correctly applying the sine function if the triangle is presented in a different orientation. Similarly, students have little number sense when applying the sine, cosine, or tangent functions, and many cannot recognize an obviously wrong result generated by a calculator. Further, students have very little sense of how to resolve a vector into components. In this study, we aimed to strengthen students' knowledge and skill development in trigonometry by providing authentic contexts for knowledge application with mobile app development.

Creating mobile apps can help motivate learners because they can create their own applications that work on the mobile devices that are important in their lives (Morelli et al., 2011). It also can help build their confidence in programming and creative problem solving, especially when a good visual programming tool (e.g., App Inventor) is used (Hsu, Rice, & Dawley, 2012; Hsu & Ching, 2013; Wolber, 2011). Hsu and Ching (2013) found students had strong feelings of empowerment and success when making mobile apps because they could unleash their creativity and turn their ideas into something real and tangible. Students also enjoyed testing peers' apps—this process helped others and also provided inspiration for their own app development.

Our study piloted an innovative approach to mathematics learning. It engaged college STEM majors studying trigonometry by asking them to develop mobile apps for learning/reviewing trigonometry. These apps were expected to help in two ways by: (1) meeting immediate trigonometry course needs. In this constructionist approach, students who simultaneously act as both learners as well as app developers will be more engaged and gain improved learning outcomes from trigonometry instruction; (2) serving future mathematics and engineering course needs. Students who developed the apps can leverage them as interactive study aids to refresh their knowledge, should they advance to the calculus and engineering statics courses that follow for STEM majors one to two semesters later.

Two potential student benefits were expected to result from this approach. First, to develop apps, trigonometry students need to revisit and apply the knowledge they have learned in class. Doing so provides mathematic content practice and review opportunities. Second, developing their own mobile apps empowers and motivates students to take ownership of their learning. Producing thoughtful app designs also helps them see that mathematics is relevant to authentic projects and can have real-world impact. These benefits are important for students and their ability to transfer their understanding of trigonometry to other STEM contexts later in their academic programs and careers.

The following research questions (RQ's) guide this study:

1. How do students apply trigonometry concepts in developing their mobile apps?
2. How do student perceive the experiences of applying trigonometry concepts in developing their mobile apps?
3. What motivates students in a Trig-APPS course?

Theoretical Framework

Artifact Construction

Artifact construction is a well-known learning approach; it engages students in their learning by having them create tangible artifacts. Students can apply content knowledge and skills through artifact construction and collaboration (Harel & Papert, 1991). When students construct artifacts, they also construct ideas simultaneously (Noss & Holyes, 2006). During the construction process, students can and need to iteratively refine artifacts and ideas to achieve the learning goals and solve design problems. Artifacts can be physical (e.g., furniture, robots, clothes) or digital (e.g., graphics, computer programs, or mobile applications). A study found that after a semester in mobile app development, students showed significant improvement in their ability to design comprehensive solutions to a given problem (Dekhane, Xu, & Tsoi, 2013).

Collaboration

Collaboration initiates more complex and iterative refinement of ideas and mental models (Harel & Papert, 1991) than artifact construction pursued alone. Collaboration in small teams or a large community leads to feedback that requires learners who build artifacts to critically examine their working products and ideas. Learning through collaboration includes a wide spectrum of methods that can take many different forms, such as cooperative learning, collaborative learning, and collective learning. Each emphasizes different levels and ways of learning by the group and community (Dillenbourg, 1999), which all lead to collaborative knowledge construction (Barab, Hay, Barnett, & Squire, 2001) and varying ways for participants to interact during the process (Hsu, Ching, & Grabowski, 2014). Noss and Hoyles (2006) discussed how students can explore mathematics through construction and collaboration. In one of the projects, students worked together to apply their mathematics knowledge to program animated robots to achieve desired sequence and actions. In a subsequent project, Noss and Hoyles developed a system and specifically built in a mechanism (asynchronous discussion) for learners to communicate their emerging understanding of mathematics and share their developing mental models regarding mathematics knowledge they have learned. Considering the class size, benefits and efficiency of collaboration, and multiple knowledge/skill sets required in the Trig-APPS course (discussed below), the students in our study were asked to work collaboratively in pairs on app development.

Methods

A two-credit co-curricular course was created for students who enrolled in college level trigonometry courses in a northwestern public university in the United States in spring 2016. Twelve students from six STEM majors enrolled in the class participated in this study. Among them, 10 were males and two were female, with an average of age at 22.8 years old. Five were first-year students and seven were in Computer Science.

This course requires 2-hour meeting time across 15 weeks. Students learned about the foundations of App Inventor for mobile app programming in the first 4 weeks by creating individual apps while working through assigned tutorials. In the following three weeks, students were introduced to three example apps incorporating or demonstrating trigonometry concepts. Students worked in pairs on debugging, customizing, and improving the provided source codes of these apps. For the rest of the semester, students worked in pairs to conceptualize mobile apps that applied trigonometry concepts, created app proposals, and built the actual apps they proposed. Students were provided with online discussion forums to communicate and collaborate throughout the semester, in addition to interacting face-to-face.

Data Sources

Content analysis on the app development process and projects was conducted to examine students' application of trigonometry concepts in designing and developing mobile apps. Data sources included students' reflective journals and developed mobile apps, and the codes of student-developed apps. Student perception of the learning experience and group process of designing apps was investigated through interviews with 10 students. The innovative Trig-APPS curriculum aims to excite and motivate students in learning trigonometry through authentic app development activities. We slightly modified a validated survey, Instructional Materials Motivational Survey (Keller, 2010) to measure the motivational characteristics of the instructional materials through 36 Likert-scale items. We also added several open-ended questions to obtain input from students to help improve the design of the curriculum.

Results

RQ1: Students' application of trigonometry concepts in developing their mobile apps

A total of 5 complete team apps were developed by 10 students. One of the teams did not complete a final project app due to one student's attendance and participation issues. The types of mobile apps the students developed included some combination of the following: quiz, game, and review guide.

Trigonometry was applied in coding the mobile apps and also in the apps' content. The concepts included degrees and radians conversion, unit circle, and trigonometric functions, which were covered in the two apps we discuss below.

For example, one team created a quiz+review app that allows users to take a quiz regarding different angles on a unit circle. The trigonometric functions were used in the codes to make the app draw different graphs based on the pre-assigned angles in the question bank. The app presented, along with the angle, the three representations (coordinate, degree, and radian) of the tested angle for review purpose, after the app users have made their selection. The team also developed a review guide that provided clear and concise text and graphics related to major concepts of a unit circle.

Another app took advantage of game mechanics and the orientation sensor in mobile devices to create a quiz/game. It required users to tilt their devices left or right for a spinning boomerang image from top to collide with one of two choices at the bottom. It helped provide a sense of excitement that encouraged game players to quickly make a correct choice on degree-radian conversion. The team also incorporated random assignment in their codes to display various lengths of triangle sides to generate a series of questions on trigonometry functions.

RQ2: Student perception of the experience of applying trigonometry concepts in developing their mobile apps

Student responses were overwhelmingly positive. Many students commented on how app making fostered their learning of trigonometry. A sample comment reads, "The app we created made me think about the trig conversion from radians to degrees so much while testing it, I'll probably never forget it." Another student stated "The fact that I had to research concepts within trigonometry and create games/quizzes for this material allowed me to understand trigonometry at a more conceptual level. This made going to math class much more enjoyable and relevant to the real world."

Some students commented on their problem solving skills and practice through the app creation process. A sample comment reads, "I think that the process of identifying a problem and creating a solution is an important lesson to learn." Some students commented on the overall course design and instruction. One student indicated that "…the instructor is amazing at keeping the attention of people in a subject like CS. Some of the people in the class weren't even CS students, but everyone seemed motivated and looked like they were having a blast every class."

RQ3: Student motivation in the Trig-APPS course

100% of the students rated "very true" or "mostly true" for the following statements:

- The content of this course will be useful to me.
- I really enjoyed working on projects for this course.
- I enjoyed this course so much that I would like to know more about this topic.
- As I worked on this course, I was confident that I could learn the content.
- Completing the exercises in this course gave me a satisfying feeling of accomplishment.

90% of the students rated "very true" or "mostly true" for the following statements:

- I could relate to the content of this course to things I have seen, done or thought about in my own life.
- This course has things that stimulated my curiosity.
- The content of this course is relevant to my interests.

Scientific/Scholarly Significance

Based on our initial findings, we found this innovative approach of creating and using a co-curricular mobile app development course to enhance trigonometry learning promising in motivating and engaging students. The students were overwhelmingly positive about their experiences of reviewing, revisiting, and utilizing trigonometry through programming mobile apps. Through the curriculum, they were able to witness and experience a real-world implementation of their trigonometry knowledge. They also created tangible products that they can relate to and that have potential impact on learning foundational subjects in STEM. The mobile apps also created a need for the students to enhance and solidify their learning of trigonometry because the integration of their knowledge needs to be 100% accurate for the apps to function.

References

Barab, S. A., Hay, K. E., Barnett, M., & Squire, K. (2001). Constructing virtual worlds: Tracing the historical development of learner practices. *Cognition and Instruction, 19*(1), 47-94.

Dekhane, S., Xu, X., & Tsoi, M.Y. (2013). Mobile app development to increase student engagement and problem solving skills. *Journal of Information Systems Education, 24*(4), 299-308.

Dillenbourg, P. (Ed.). (1999). *Collaborative learning: Cognitive and computational approaches*. London: Pergamon.

Gardner, P., Kaylor, D., Mason, S., Van Dyke, J., Zhu, P., & Landrum, E. (2013). *Employer feedback on talent needs and preparation: Collegiate employment and workforce readiness report, Part II.* Retrieved from https://career.boisestate.edu/wp-content/blogs.dir/1/files/2013/10/Employer-Feedback-On-Talent-Needs-Report-4-20131.pdf

Harel, I. & Papert, S. (Eds.) (1991). *Constructionism*. Norwood, NJ: Ablex Publishing Corporation.

Hsu, Y. -C., & Ching, Y. -H. (2013). Mobile app design for teaching and learning: Educators' experiences in an online graduate course. *The International Review of Research in Open and Distance Learning, 14*(4), 117-139.

Hsu, Y. -C., Ching, Y.-H., & Grabowski, B. (2014). *Web 2.0 applications and practices for learning through collaboration*. In M. Spector, D. Merrill, J. Elen, & M. J. Bishop (Eds.). Handbook of research on educational communications and technology (4th ed.) (pp. 747-758). Springer Academics.

Hsu, Y. -C., Rice, K., & Dawley, L. (2012). Empowering educators with Google's Android App Inventor: An online workshop in mobile app design. British Journal of Educational Technology, 43(1), E1-E5. doi:10.1111/j.1467-8535.2011.01241.x

Keller, J. M. (2010). *Motivational design for learning and performance: The ARCS model approach*. New York, NY: Springer.

Morelli, R., de Lanerolle, T., Lake, P., Limardo, N., & Tamotsu, E., Uche, C. (2011). *Can Android App Inventor bring computational thinking to K-12?* Proceedings of 42nd ACM Technical Symposium on Computer Science Education (SIGCSE '11). Retrieved from http://www.hfoss.org/uploads/docs/appinventor_manuscript.pdf

Noss, R., & Hoyles, C., (2006). Exploring mathematics through construction and collaboration. In R. K. Sawyer (Ed.), *Cambridge Handbook of the Learning Sciences* (pp. 389- 405). New York, NY: Cambridge University Press.

Wolber, D. (2011). App Inventor and real-world motivation. *Proceedings of the 42nd ACM Technical Symposium on Computer Science Education (SIGCSE '11)* (p. 601). ACM Press. doi:10.1145/1953163.1953329