Enhancing Trigonometry Learning through a Mobile App

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Abstract: A mobile app called *Trigomatch* is designed for students to gain an in-depth understanding of trigonometric concepts in an engaging and dynamic learning environment. A description of the app as well as the pedagogical framework and game design principles that form the backbone of the app are discussed.

Keywords: Mobile app, trigonometry, trigonometric ratios

1. Introduction

Trigonometry is one of the topics in high school mathematics that involves developing skills in algebra and geometry, which is essential in studying pre-calculus and calculus. Moreover, knowledge of trigonometric functions is needed for understanding topics in Newtonian physics, architecture, surveying, and many branches of engineering (Weber, 2005).

Oftentimes, students have difficulties in problem solving in trigonometry. One reason is due to lack of motivation (Nurmeidina & Rafidiyah, 2019). Difficulty is also due to understanding the concepts of trigonometry and its applications (Nanmumpuni & Retnawati, 2021). Understanding multiple representations of trigonometric functions can also be challenging to students (Marchi, 2012). Students have difficulty in the presentations of the topic: the unit circle and the right triangle approach (Jenkins, 2022).

Studies in the literature have shown the benefits of technology in studying trigonometry. Bedada and Machaba (2022) showed that teaching trigonometric functions with the aid of GeoGebra (https://www.geogebra.org/) has significant effects on the achievement of students. Similarly, Rahman et al. (2016), using an interactive GeoGebra Learning Module, showed that students developed positive motivation in studying trigonometry. Emerging technologies such as *TrigReps* (Bornstein, 2020) and *Tangible User Interface (TUI)* (Zamorano Urrutia et al., 2019) proved to have the potential to facilitate learning of trigonometry. The representations offered by *TrigReps* (Bornstein, 2020) assisted the students in connecting their modifications to the algebraic representation with the subsequent modifications to the graphical representation. Moreover, *Tangible User Interface (TUI)* (Zamorano Urrutia et al., 2019) provides a pedagogical experience that prioritizes physical manipulation-based exploration and encourages intuitive and group learning.

Taking advantage of the benefits of technological tools (Haleem et al., 2022) to build knowledge, understanding, and skills in trigonometry and to increase engagement and learning motivation in students, we designed a mobile app called *Trigomatch.* Designed through an interactive game with interactive feedback, the app focuses on the understanding of fundamental concepts in trigonometry such as reference angles and trigonometric ratios.

2. Pedagogical Basis

Drawing on the work of Hans Freudenthal, Martín-Fernández et al. (2022) distinguished between trigonometry from the perspective of elementary geometry and goniometry,

corresponding to the right triangle and unit circle approaches presented by Jenkins (2022). In the former, angles are absolute and static, and are determined by the sides of a right triangle in a non-oriented plane. In the latter, angles are dynamic, and determined by a rotation of half-lines in an oriented plane. They found that transitions between these two systems of thought are not straightforward–even pre-service teachers cling to their conceptions of a static angle and barely know how to draw oriented angles in a circle.

A possible intervention for facilitating understanding of trigonometry is through the presentation of trigonometric representations through interactive computer-aided instruction (CAI). Jenkins (2022) argued that when visual representations of trigonometry are presented using interactive technology, they are more accurate and allow the learners to proceed at their own pace. Further, because of the accuracy of these presentations, they can be used to reinforce images in a person's memory, which is not the case for hand-drawn images which tend to be distorted. While she found that students can learn as well from CAI as from traditional instruction, the use of CAI allows the teachers to differentiate instruction and personalize tasks for their students.

In common with computer-aided technology described by Jenkins (2022), the *Trigomatch* app presents visual representations of basic trigonometric concepts to allow students to extend their understanding of trigonometry from the right triangle to the unit circle approach. The app is interactive in the sense that it presents the concept with feedback mechanisms in a game-like environment. More details on the app are provided in the next section.

3. The *Trigomatch* App

3.1 App Description

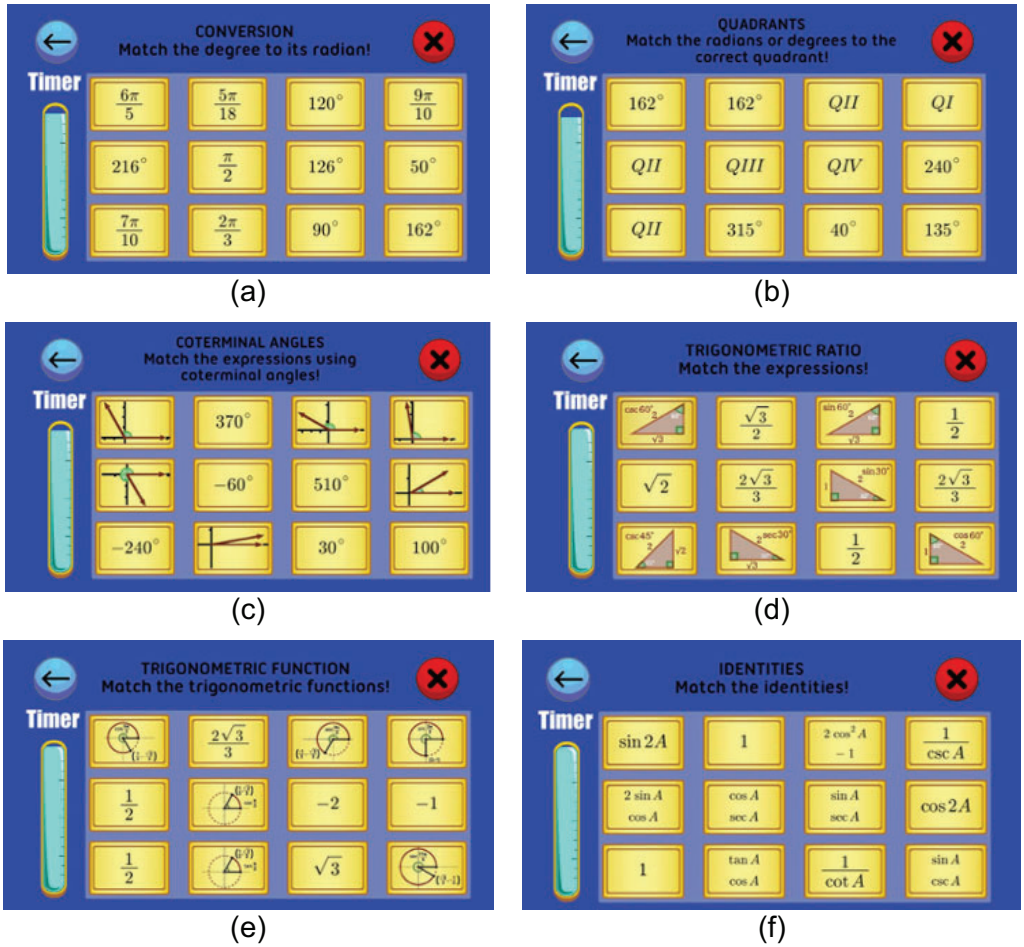
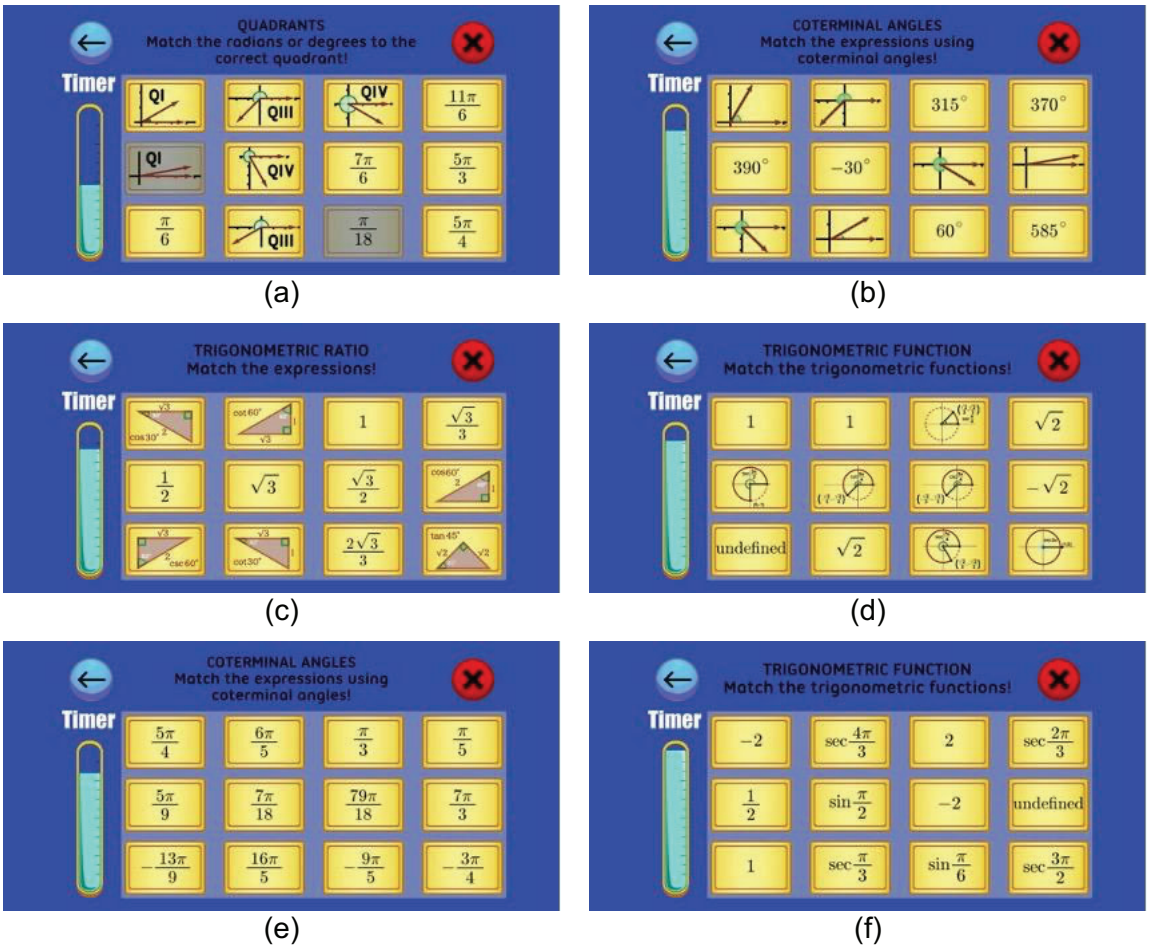


Figure 1. Screenshots showing the six options in *Trigomatch*.

In the *Trigomatch* app, six (6) different options can be played: *Conversion* (Figure 1(a)), *Quadrants* (Figure 1(b)), *Coterminal angles* (Figure 1(c)), *Trigonometric Ratio* (Figure 1(d)), *Trigonometric Function* (Figure 1(e)), and *Identities* (Figure 1(f)). Moreover, learners may choose to display 12, 20, or 36 cards at a time and then match two equivalent representations or trigonometric expressions shown by the cards. The objective is to locate every pair that matches within the allotted time. The game's time aspect feature has the potential to motivate and thrill the learners while they play.



(a) (b) (c) (d) (e) (f)

Figure 2. Screenshots showing the different levels, *with* or *without pictures.*

3.2 Game-design Factors

One of the challenges that students face in learning trigonometry is the presence of several trigonometry facts, conversions, and identities that they need to memorize. These include, among others, conversions between radians and degrees, the trigonometric function values for special angles, and the sum, product, half-angle, and double-angle identities. While these can be learned through rote memorization or drill-and-practice, students usually tend to find such tasks tedious and uninteresting. Thus, a game-based learning approach has the potential to support students' learning of these trigonometry topics. With game-based learning, we aim to increase students' motivation and engagement by situating the learning of trigonometry within a game that can create high situational interest (Hidi & Renninger, 2006).

In the design and development of *Trigomatch*, we took into consideration 11 crucial game-design factors identified in the Game-based Learning (GBL) Design Model of Shi and Shih (2015). Figure 3 presents a summary of how these 11 game-design factors have been applied for *Trigomatch*.

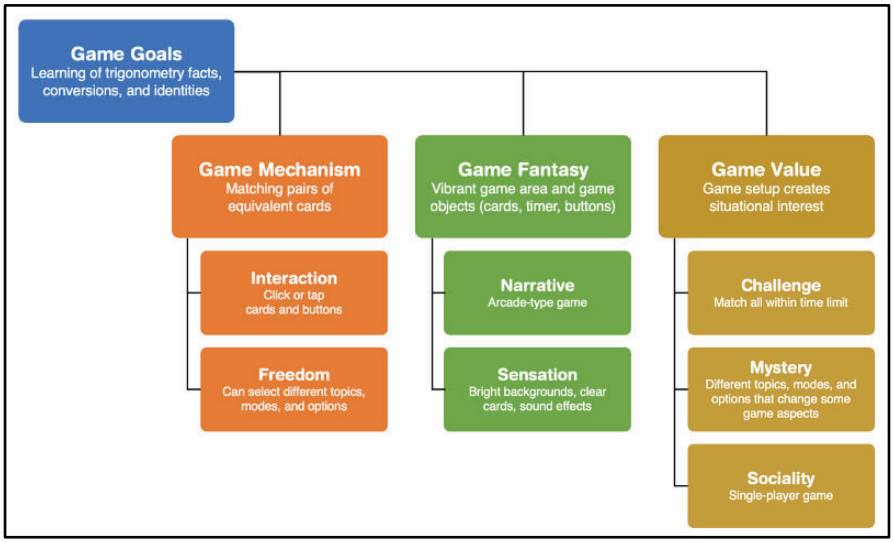


Figure 3. Game-design factors (Shi & Shih, 2015) for *Trigomatch*

The first game-design factor is the game goal, which significantly influences all the other game-design factors. In the case of *Trigomatch*, the game goal is a learning objective focused on trigonometry topics. The game mechanism is then decided towards achieving the game goal. As previously described, the mechanics of *Trigomatch* involve matching pairs of cards (akin to some memory games) that contain equal or equivalent trigonometric expressions. Learners interact with the game through simple click or tap actions on game buttons and cards. An important feature of the game mechanism is adaptivity (Plass et al., 2015) in the sense that learners have the freedom to select from different topics, modes, and options. This allows learners to align their playing experiences with their current level or interest with respect to the learning content. The availability of these different topics, modes, and options also contributes to the game's mystery, which in turn can keep learners interested in progressing in the game. The main challenge in *Trigomatch* is to match all the cards within the time limit. As part of adaptivity, learners can disable the timer if they are still beginning to learn the topics.

Trigomatch is envisioned to be a simple arcade-like game with relatively short rounds that can be played repeatedly. Thus, the game fantasy and narrative are kept simple and are delivered mainly through the game area and game objects such as cards, timer, and buttons. In terms of sensation, *Trigomatch* has display and sound prompts during gameplay. Moreover, as the game is also intended for independent use, *Trigomatch* has been designed to be a single-player game. However, teachers can use the app as part of group activities in the classroom, face-to-face or virtual. All the features of *Trigomatch* contribute to its game value, which is oriented towards creating situational interest among learners.

4. Integration and Use of *Trigomatch*

This section describes how the *Trigomatch* can be used as a pedagogical tool based on the RAT (Replacement, Amplification, Transformation) framework (Hughes et al., 2006). Using this framework, the app can replace the traditional method of providing examples and exercises for students to solve without changing the learning goals of a lesson. The printed worksheets or exercises from a textbook have been replaced by a set of cards shown in a more appealing game-like setting. This function can help teachers offer exercises in an engaging and enjoyable manner.

Playing the app can enrich or amplify a student's experience in solving problems involving concepts in trigonometry. The design of the app (*with or without pictures*) gives students the option to work at just the correct degree of difficulty and includes components that can excite and push them to work on various levels.

Finally, the *Trigomatch* app may encourage teachers to shift from teacher-centered to student-centered instruction. This is achievable because the app was made to be simple enough for students to use and comprehend without much help from a teacher. Students who are learning asynchronously or remotely can thus utilize the app. Task redefinition is another way that transformation might take place. For instance, utilizing the app, one may convert individual work into group activities. This allows the students a chance to interact and instruct one another on the problem-solving strategies needed to match two trigonometric representations displayed on the cards.

5. Conclusion and Future Outlook

Advanced mathematics and other allied disciplines, such as engineering and physics, depend heavily on trigonometry. However, many students struggle to understand and apply trigonometric principles and often lack the motivation to learn these. The *Trigomatch* app presented in this paper is a tool that aims to help students gain a better understanding of trigonometric concepts and reinforce the skill of recognizing equivalent trigonometric representations. Game design principles were employed in the app's design to keep students motivated and engaged. By playing the app, students can recall trigonometric ratios, conversions, identities and coterminal angles in an enjoyable and productive way. The option to display pictures as one plays the app is a useful feature especially for learners who may benefit from the visual representations of trigonometric ideas.

This study is work in progress. Opportunities for further research on how *Trigomatch* is used by students and how effective it can be to improve their trigonometric skills is currently being pursued. An experimental study with pretest and posttest research design is going to be used to accomplish this. Furthermore, the app may be expanded by adding other options such as trigonometric functions and their graphs or using the laws of sines and cosines. This will help build on the skills that students have learned and allow them to advance in other topics.

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