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Design of a Mobile App to Promote Understanding and Fluency in Finding the Equation of a Line

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Abstract: This paper focuses on the design of a mobile app called *Pick or Fish* that fosters comprehension and mastery of the concepts of slopes, *y*-intercepts and equations of lines. The app's pedagogical value lies in its potential to help students understand and become proficient in these concepts. The app is suitable for use on low-cost mobile devices. It functions within an engaging game-like setting featuring visual elements that enable students to see the effect of parameter changes on the direction of a line. The beginner and advanced levels of the app have scaffolding features that gradually introduce the students to the key aspects of linear functions. The mechanics of the app, its pedagogical basis and how integration in the classroom may be achieved as teachers plan the lesson, facilitate open-ended discussion and encourage independent use of the app are also discussed.

Keywords: Lines, slopes, *y*-intercept, equations of lines, mobile app

1. Introduction

There is a view that from both a mathematical and pedagogical perspective, the core and fundamental concept underlying algebra, trigonometry, probability, statistics and calculus is that of *function* (Schwartz & Yerushalmy,1992). In the Philippine high school mathematics curriculum, linear function is one of the first types of functions that students learn. In Grade 8, the topics of slope, *y*-intercept, and equation of a line are discussed. An in-depth understanding of these concepts is necessary in problem solving and mathematical modeling involving linear functions. Furthermore, this is also necessary for doing more advanced work in linear regression, interpolation, and rates of change in calculus. The skill of writing equations of lines enables students to make correct mathematical models of real-world data exhibiting linear trends and make forecasts. Thus, the acquisition of conceptual knowledge and procedural fluency on calculations involving linear functions are important for high school students to have.

In this paper, we present the design of a mobile app called *Pick or Fish* that is intended to help students gain a better understanding of slope and y-intercept and acquire fluency in forming the equation of a line. The app is one of the technological tools developed and designed by the authors made available for use in Philippine schools through the internet, community LTE networks (De Las Peñas et al., 2022) or local networks powered by datacasting technology (De Las Peñas et al., 2023). These tools support the twin goals of mathematics education in the Philippines, which is to develop critical thinking and problem solving (DepEd, 2016). In emerging economies such as the Philippines, studies have shown that mathematics is only superficially learned (Verzosa & Vistro-Yu, 2019), and that the focus of mathematics classrooms is on rules and procedures (Nag et al., 2014; Verzosa, 2020).

Pick or Fish was designed as a mathematical mobile application (app) that runs in an interactive, game-like environment. It is intended to be played by students to gain proficiency

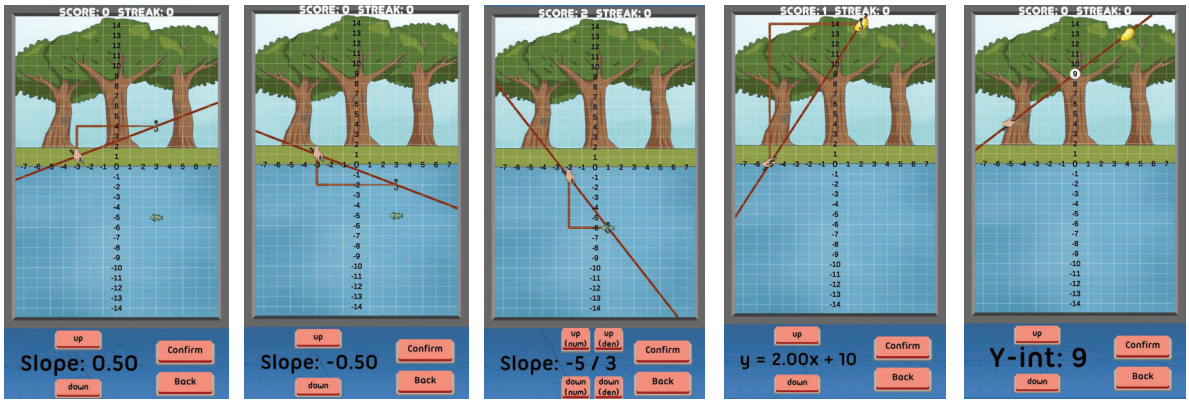
in finding slopes and forming equations of lines. Interactive digital tools such as mobile apps designed in a game -like environment have the potential to enhance the interest of students (Chao et al, 2018). Interest to carry out the tasks is important for students to gain mastery and fluency in the topic. While there are other existing apps and software that allow the exploration of slopes and equations of lines, one of the important features of *Pick or Fish* is that it is built in a game like environment, and there is the inclusion of scaffolding mechanisms that allow a student to work at a particular level of difficulty based on their learning progression on the topic. The latter feature makes the app apt for student centered learning. As an emerging economy, the Philippines has also comparatively limited educational resources. Further, many Filipino students come from low-income families who could not afford graphics calculators, laptops/computers or medium- to high-range mobile phones. Thus, the *Pick or Fish* was designed to be freely available and able to run on earlier Android versions of mobile phones.

2. Description of the *Pick or Fish* App

The app is designed to help students develop their understanding of the concept of slope and *y*-intercept of a line and consequently help build their skill in forming the equation of a line. There are two levels: *Beginner* and *Advanced* and there are several topics per level. In each level, the task is to pick a fruit or fish by either varying the value of the slope, or the *y*-intercept, or both.

2.1 Beginner Level

In all topics in the *Beginner* level, the screen shows a hand with a rod and a target object (either a mango fruit or a fish). The student needs to press the “up” and “down” buttons found at the bottom of the screen to move the rod so that it would touch the fruit or the fish. Doing this, the student can see how adjusting the slope corresponds to changing the steepness of the line as represented by the rod. By playing the game repeatedly, the student can connect positive and negative slopes to the orientation of the line (Figures 1(a) and 1(b), respectively).



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

Figure 1. Screenshots of the *Beginner* level of *Pick or Fish*

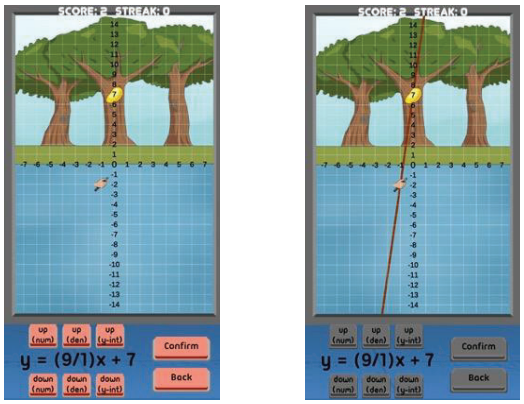
The app scaffolds instruction by first focusing on slopes having integer values, then fractional values. The student can see how the slope also corresponds to the ratio of the vertical and horizontal changes in the line. For example, in Figure 1(c), the slope is -5/3 which corresponds to the ratio in a triangle with vertical dimension 5 and horizontal dimension 3.

In the succeeding topic, *Slopes—Equation of a Line,* an equation of a line in the form $y = mx + b$ is given, but only the value of m needs to be changed (Figure 1(d)). This is the first introduction of the student to the slope-intercept form of the equation of a line. Familiarity with this form is important as it shows that a line is determined by two parameters m and b. The next topic is the *y-intercept.* where the student presses the up and down buttons to get the correct value of the *y*-intercept (Figure 1(e)). Here, the student sees how changing the *y*-

intercept will not change the steepness but would rather shift the line up or down. The last topic under the Beginner Level is the *Slope-Intercept Form of a Line.* Here, the student provides the values of the slope *m* and *y*-intercept b in the equation $y = mx + b$.

2.2 Advanced Level

In the *Advanced* level, the student can utilize their developing notions of slope and *y*-intercept to make the line reach the targeted mango or fish. The topics in this level are like those in the *Beginner* level, except that the rod is not visible at the start–only the hand and target are shown (Figure 2(a)). Thus, the student must apply what they learned in the *Beginner* level and press the necessary buttons (without visual scaffolding) to produce the correct equation that would make the rod reach the target (Figure 2(b)).



(a) (b)

Figure 2. Screenshots of the *Advanced* level, Topic: *Slope-intercept Form of a Line* rod is not shown at the start; (b) rod is shown after pressing “Confirm” button.

A student who makes a mistake has the chance to correct himself. For instance, when working on a sample question related to Slope-*Intercept Form of a Line*, both slope and *y*-intercept values are needed. The student may correctly input the value of the *y*-intercept, which is visible on the screen. However, determining the value of the slope requires more thought. Without visual help he must calculate the ratio of the vertical and horizontal distances between the hand and the object. If the student enters an incorrect value, he receives feedback that the rod misses passing through the object. This feedback serves as a clue, helping the student identify whether the slope must be increased or decreased and gives him an opportunity to input the correct answer.

2.3 Topic/Level Progression

The scaffolded questions built into the app help students to work at the appropriate level of difficulty. Students can go back to any of the levels and topics at any time if they need more practice, or they can do so as guided by their teacher. In each level, once the student presses “Confirm,” the app provides visual feedback and a bell or buzzer sound for the student to know if the answer entered is right. In addition, a score found at the top part of the screen enables students to monitor their progress and explore other topics in the app. These features help learners gauge their level of mastery and guide them as they progress through the topics.

3. Pedagogical Basis

The *Pick or Fish* app was designed to elucidate how variables express a relationship in a linear equation. The concept of *variable* is not easily learned because students may not have limited conceptions of how variables are used in mathematics. For Küchemann (1981, p. 104), a

variable represents “a range of unspecified values, and a systematic relationship is seen to exist between two such sets of values.” Ely and Adams (2012) identified two critical properties from Küchemann’s definition: First, a variable is indeterminate, and can stand for a range of values such as in “$y = x + 7$,” and second, it is part of a systematic relationship such that when one variable changes, another quantity may vary with it. Drawing on the history of mathematics, they further argue that the development of the notion of a variable represented a major breakthrough from using letters merely to represent an unknown or determinate quantity, such as in the equation “$2 + x = 5$.” This development took centuries, making it understandable why students struggle with the transition from unknown to variable–they think that a letter must represent a specific value (Ely & Adams, 2012). This is possibly why students find it difficult to solve tasks involving representational transitions from a graph to an equation or vice versa (Ceuppens et al., 2018).

The visual scaffolds in the *Pick or Fish* facilitate the cognitive shift required to help students see relationships between the equation of a line to its graph and gain a better understanding of the systematic relationship between the variables in the equation. This is done through a game environment, particularly in the *Beginner* level, where students can see how adjusting coefficients in a linear equation leads to changes in the corresponding graph. These scaffolding elements which are introduced gradually through the progression of topics, along with visual aids and feedback mechanisms, help students cultivate a strong conceptual understanding of slope and *y*-intercept concepts, as well as to improve their fluency and proficiency in forming the equations of lines.

4. Game Design Features

Shi and Shih’s (2015) Game-Based Learning (GBL) Design Model was used as the framework for the development of *Pick or Fish*. This model highlights 11 game design factors (*game goal, game mechanism, interaction, freedom, challenge, game fantasy, narrative, sociality, sensation, mystery, and game value*) for the design, analysis, and evaluation of game-based learning applications. Ten of these factors were incorporated into *Pick or Fish* and are discussed in detail below.

The *game goal* for *Pick or Fish* is to deepen one’s understanding of slopes and the formulation of the equations of lines. This is achieved via its drill-like *game mechanism* where the player must provide the correct slope, *y*-intercept or equation of a line that passes through two given points (the hand and the fruit or fish). This drill-like mechanism complements the game goal as it allows players to repeatedly practice with different questions or tasks provided in the app to develop their fluency in the topic. Contributing to the *game mechanism* are the factors *interaction, freedom, and challenge.* Players *interact* with the game by tapping buttons to increase or decrease the slope and/or *y*-intercept of a line. They are given the *freedom* to select from multiple topics and levels that, as previously mentioned, allow for scaffolded instruction. These levels *challenge* the player to correctly answer five questions in succession, after which they will receive a prompt to move on to the next topic. These elements are important for developing learners’ fluency in the topic as they can use the app to set their own learning pace (i.e., staying with a current topic or level until they have developed sufficient mastery) or to address specific learning gaps (i.e., selecting the topic or level that corresponds to a competency that they need to improve).

As *Pick or Fish* can be considered a single-player arcade game, it places no emphasis on *sociality* and features a simple *game fantasy* and *narrative* in which players are tasked to pick fruits off trees or catch fish by correctly identifying the equations of lines. The *game fantasy* is then further enhanced by the game’s *sensation* and *mystery* aspects. For *sensation*, the game uses a simple but vibrant background with an overlain Cartesian plane, as well as sound prompts to let the player know when they input a correct or incorrect answer. It must be noted that on this Cartesian plane, for the slope topics under the game’s *Beginner* level, adjusting the slope not only changes how the line is tilted but also changes the line’s “rise” and “run” as represented by the appropriate triangle. This topic or level progression adds *mystery* to the game, with each new topic or level providing a new experience to the player.

Finally, the *game value* arises from the combination of all these factors, as *Pick or Fish* is aimed at providing players an engaging environment in which they can develop their understanding of equations of lines.

5. Integration and Use of the *Pick or Fish* App

This section describes how *Pick or Fish* can be utilized as a pedagogical tool. The steps below were adapted from the work of Woods et al (2018).

Step 1. Determine learning goals. The app is appropriate and useful in attaining the learning competencies involving slope, *y*-intercept and equation of a line. The design makes it easier for students to make the shift needed to see connections between a line's equation and graph and to comprehend the systematic link between the variables in an equation.

Step 2. Plan ahead. The teacher should plan for the logistical requirements of using the free to download app. Students should be taught how to properly download the software on a desktop or an Android device by their teachers. An Android emulator is required to run the program if it was downloaded to a PC.

Step 3. Present and practice. This step entails the presentation of the lesson and a demonstration on how to play the app. The teacher can ask, "Should the rod be moved up or down, left or right?" or "What happens to the direction of the rod when the up button is clicked?" These instruction questions will prevent students from using guesswork as a strategy to find the slope, *y*-intercept and equation of the line. Students have the chance to practice and become comfortable with the app during this phase.

Step 4. Process and verbalize. Finally, open-ended questions will allow students to explain their thinking process and reasoning. This can be done by asking reflection questions like "What helps you determine which button to click?", "How do you know that slope should be positive? or negative?", "What is the meaning of *y*-intercept?", or "How can one form the equation of a line?"

For practice and mastery, the teacher may advise the pupils to utilize the app asynchronously or outside of class. Students can share screenshots of their outputs over time in order to monitor their development. A follow-up discussion can be done to address difficulties and misconceptions of the students.

6. Conclusion and Future Direction

A deep conceptual understanding and fluency in creating equations of lines is a basic learning competency expected of high school students. However, many students still find the ideas of slope and *y*-intercept abstract and lack the proficiency in using these elements to formulate the equation of a line. This problem is carried on to more advanced work in mathematics where the concept of linear functions and equations are necessary.

In this paper, the *Pick* or *Fish* app is introduced as an interactive tool that can help students gain more insight and fluency in finding the slope and *y*-intercept of a line and write its equation. The app is aligned with the Philippine Department of Education's Most Essential Learning Competencies in Grade 8 Mathematics (DepEd, 2020). The app's game-like features help motivate learning and entice students to play to improve their understanding of abstract concepts. The popularity of mobile phones and tablets in the Philippines makes the app easily accessible as it can be readily downloaded and require low storage.

The next step in this research is to conduct studies on determining the effectiveness of the app in student learning. The app may still be improved by the inclusion of undefined slopes of vertical lines. An aspect that may be pursued in the future is the incorporation of more scaffolding mechanisms that can offer help to students who may struggle with the transition from beginner to advanced levels. Gathering more feedback from students and teachers on the use of the app will also help direct future research in this area.

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