# PRACTICE THROUGH PLAY USING MOBILE TECHNOLOGY

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**ABSTRACT**

This paper discusses the *Just Keep Solving* apps that are designed based on deliberate practice model for developing mathematical skills. Features of deliberate practice include well-defined goals involving areas of weakness as determined by a knowledgeable other such as a teacher. The integration of game design features provides a positive environment wherein the learning goals critical in a deliberate practice model are emphasized. Possible strategies for integrating the apps in a classroom are also discussed using Hughes, Thomas and Scharber's RAT (Replacement, Amplification, Transformation) framework. The games can replace traditional pen-and-paper classroom activities, amplify learning by personalizing a student's experience and providing opportunities for deliberate practice, and transform instruction from being teacher-centered to student-centered.

**KEYWORDS**

Mobile Technology in Teaching Mathematics, Mathematical Apps, Drill-and-Practice

## 1. INTRODUCTION

In school year 2022-2023, the Department of Education (DepEd) in the Philippines implemented the gradual transition to the in-person learning modality after purely distance learning due to the Covid 19 pandemic. The DepEd developed the *Basic Education Learning Recovery Plan* to guide schools in addressing learning gaps brought about by the pandemic (DepEd Memo 664, 2022). Under a government-funded project *Mathematical Resources for Distance Learning Utilizing Community LTE Networks and Television Frequencies*, the authors collaborated with local DepEd school divisions to deliver mathematical content that included mathematical applications (apps), teaching guides/instructional videos, and performance tasks or activity sheets that are distributed not just through the internet but also through community LTE networks (De Las Peñas et al., 2022) and local networks powered by datacasting technology (De Las Peñas et al., 2023). The mathematical apps were designed to address the Most Essential Learning Competencies (MELCs) prescribed by DepEd (DepEd, 2020) as well as to help narrow the existing learning gaps on particular competencies determined by the school administrators and teachers.

The apps have also been developed to be compatible with the use of mobile technology, which offer additional advantages. First, given the growing popularity and access to mobile technology (e.g., smartphones, tablets) in the Philippines, majority of the project's apps are compatible with a large range of Android devices and have relatively small storage requirements. Secondly, the use of mobile technology can potentially improve the learning opportunities and experiences of students. The portability and convenience of mobile devices mean that students use them more often (Norris et al., 2011). Consequently, students become capable of personalizing their learning experiences (Shuler, 2009) because their mobile devices are available for use even outside the classroom and/or without the supervision of their teachers.

This paper discusses two particular mathematical apps, namely *Just Keep Solving* and *Just Keep Solving 2*, that focus on linear equations and inequalities, and statistics and probability, respectively. These apps are based on a strategic application of the deliberate practice model for developing mathematical skills, particularly those that have not yet been learned (Lehtinen et al., 2017). The interested reader can access *Just Keep Solving* and *Just Keep Solving 2* as well as all the mathematical apps of the project from the website https://mathplusresources.wordpress.com/.

## 2. DRILL-AND-PRACTICE AND DELIBERATE PRACTICE IN MATHEMATICS EDUCATION

The approach of using game-based drill-and-practice activities has been previously used and studied in different fields and has been associated with some positive outcomes. For instance, Foss et al. (2014) assessed the use of an online game that provides medical calculation drills intended for student nurses. For learning vocabulary, Yip & Kwan (2006, p.246) report that their research results indicate, "both quantitatively and qualitatively, that learners playing online vocabulary games tend to learn better and could retain the learnt vocabulary for a longer period and retrieve more words than those who simply attended face-to-face lessons without accessing the vocabulary games." It is important to note that the vocabulary games in Yip and Kwan's study are all drill-and-practice games. As a last example, in mathematics education, Ke (2008) has reported that computer math drill games (particularly ASTRA EAGLE, a series of web-based games consisting of drill-and-practice math activities) have a positive effect on students' attitudes towards learning mathematics.

While drill-and-practice is often associated with low-level or procedural skills, deliberate practice involves the learning of higher-order skills (Lehtinen et al., 2017). Deliberate practice is typically associated with music or sport (Ericsson et al., 2006). Applying this concept to mathematics education, Lehtinen summarized features of deliberate practice based on Ericsson's (2016) work. These include developing skills that have not yet been learned but are known by a knowledgeable other (such as a teacher) who can provide support, and the provision for feedback. Further, the emphasis on well-defined goals involving areas of weakness suggests that the process is not necessarily enjoyable (Lehtinen et al., 2017).

Fuchs et al. (2010) investigated whether deliberate practice can improve low-performing mathematics students' skills in strategic counting, which is a skill that typically developing children usually learn on their own. They found that low-performing students who received deliberate practice performed significantly better on strategic counting tasks than the control group who did not receive any form or instruction, and another group who received instruction but no opportunity to practice. By isolating the effect of deliberate practice on learning, they argued that practice is indeed valuable for students with mathematical difficulties.

In another study, Pachman et al. (2013) investigated the effect of deliberate practice on the learning of geometry. Similar to Ericsson (2016), they considered an emphasis on weakness as a critical feature of deliberate practice. They found that more knowledgeable students derived the most benefits from deliberate practice. For these students, the teacher can impose that they focus solely on their weak areas. By contrast, less knowledgeable students improved more if they practiced in both their weak and strong areas. These results suggest that some level of competence must first be attained before students are compelled to focus solely on their weak areas.

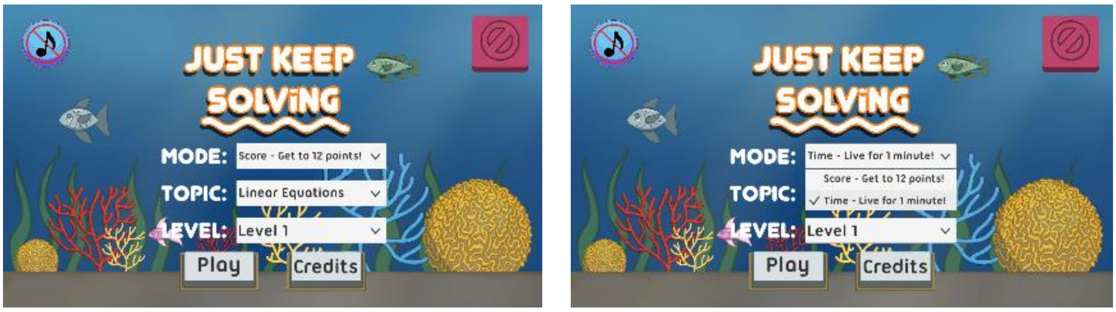
## 3. THE *JUST KEEP SOLVING* APPS

The *Just Keep Solving* apps are designed in a game-like environment to address particular learning competencies in mathematics, based on a deliberate practice model. Both apps are compatible with and run efficiently in a wide range of Android devices (e.g., smartphones, tablets). Versions for use in Windows computers (laptops or desktops) are also available. Each app focuses on topics, and a topic has several levels. The apps show an underwater environment with bombs that threaten to destroy the ocean corrals. The questions are written on the bombs, and to prevent a bomb from reaching the ocean floor, the student must answer the question corresponding to the bomb correctly. A wrong answer results in some destruction to the corals. After a certain number of wrong answers, the game is terminated.

### 3.1 *Just Keep Solving*

One of the five content areas in the mathematics curriculum given in the K to 12 Curriculum Guide in Mathematics in the Philippines is that of Patterns and Algebra (DepEd, 2016). In particular, one of the Most Essential Learning Competencies (MELCs) in Grade 7 mathematics under this content area is: solve linear equations and inequalities (DepEd, 2020). The achievement of this competency is a prerequisite to solving quadratic and higher order equations.

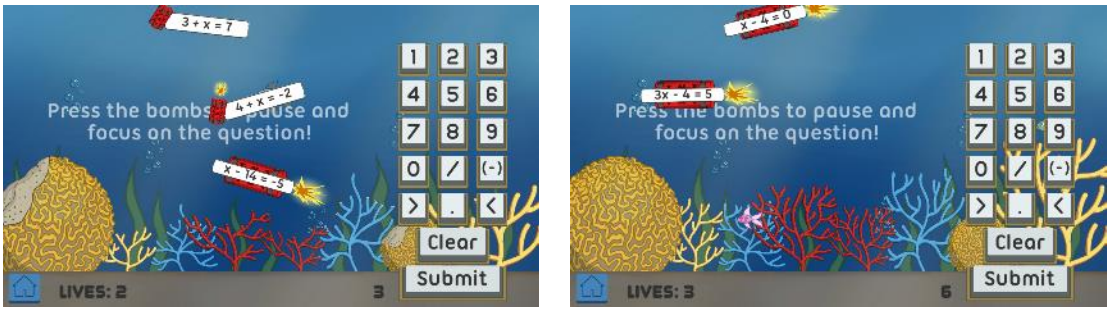
The *Just Keep Solving (JKS)* app (Figure 1(a)) offers students opportunities to practice solving linear equations and inequalities. It is meant to provide repetitive exercises necessary for students to master algebraic skills.



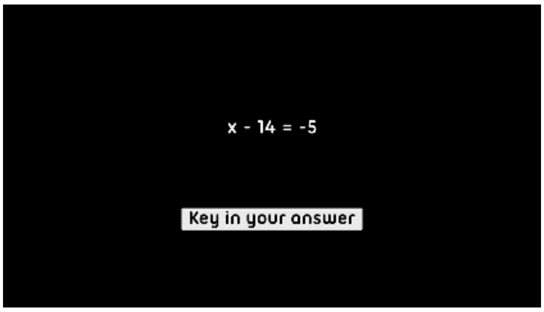

(a) (b)

Figure 1. (a) Home screen of *JKS*; (b) Two modes to play *JKS*

The *JKS* app is divided into two topics: *Linear Equations* and *Linear Inequalities.* Each topic can be played in two modes: one where the student can score up to 12 points before the game ends, and the other, where the student is given one minute to answer as many questions correctly as he can (Figure 1(b)). There are two levels under the topic *Linear Equations*. The first level deals with one-step linear equations (Figure 2(a)) and the second level deals with one and two-step linear equations (Figure 2(b)). When a bomb is selected, a screen containing only the question appears and allows students to focus on solving the question (Figure 2(c)). At this point, the falling of the bombs is paused. The equations are basic and are meant to invite students to play while providing practice needed for procedural fluency in algebra.




(a) (b)




(c)

Figure 2. *JKS* topic *Linear Equations*: (a) Level 1; (b) Level 2; (c) screen displaying a question

Likewise, there are two levels under the topic *Linear Inequalities*. The first level displays linear inequalities which are solvable using addition or subtraction of positive or negative numbers (Figure 3(a)), while the second level deals with linear inequalities which are solvable using multiplication or division of positive or negative numbers (Figure 3(b)). Under this topic, the correct answer requires the student to provide the appropriate inequality symbol ($<$ or $>$) as well as the correct number. For example, in answering the question $x - 1 > 0$, the inequality "$>$" and the number "1" is provided.


(a) (b)

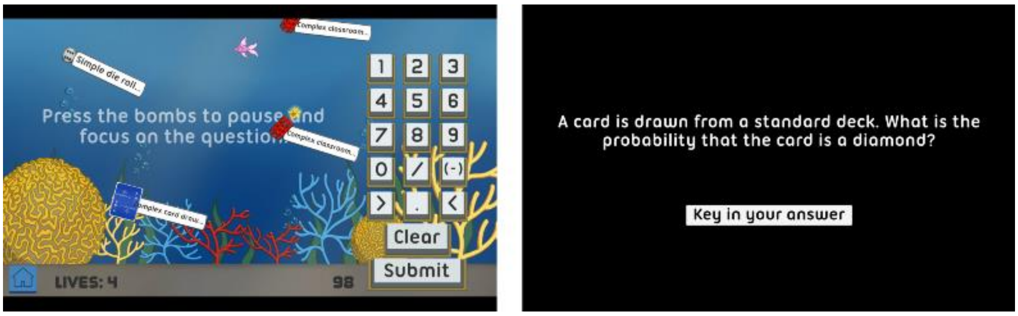
Figure 3. *JKS* topic *Linear Inequalities*: (a) Level 1 and (b) Level 2

## 3.2 *Just Keep Solving 2*

Given the potential of *JKS* in developing students' skills on implementing simple computations and applying mathematical formulas, *Just Keep Solving 2* (*JKS* 2) (Figure 4) has been conceptualized as an expansion of *JKS* with topics *Statistics* and *Probability*. The topic *Statistics* has three levels that are intended for Grade 7 students and are focused on the following Most Essential Learning Competencies (MELCs) under Statistics: i) calculates the measures of central tendency of ungrouped data; ii) uses appropriate statistical measures in analyzing and interpreting statistical data; and iii) calculates the measures of variability for ungrouped data (DepEd p.307, 2020). Moreover, there are also two levels on the topic *Probability*. The first level is intended for the following Grade 8 MELCs under Probability: i) finds the probability of a simple event; and ii) solves problems involving probabilities of simple events. (DepEd p.312, 2020) On the other hand, the second level involves MELCs under the Grade 11 content area Random Variables and Probability Distributions. These MELCs are: i) illustrates a probability distribution for a discrete random variable and its properties; ii) computes probabilities corresponding to a given random variable; and iii) solves problems involving mean and variance of probability distributions. (DepEd, 2013; DepEd, 2020).


Figure 4. Home screen of *Just Keep Solving 2*

While *JKS 2* retains most of the features of the first *JKS*, certain changes had to be applied to adapt to the relatively lengthier questions and computations involved in the aforementioned statistics and probability MELCs. The most significant of these changes is that only the first part of each question, or a key phrase to represent the question, is displayed on a falling bomb (Figure 5(a)). The complete question can only be shown by tapping on the bomb itself. The students get access to a full-screen view where the question is displayed (Figure 5(b)). Another change, as shown in Figure 5(a), is that some questions use different icons (e.g., a card or a die) instead of the bomb icon. This is to give a visual cue about the corresponding question's context, when applicable.




(a) (b)

Figure 5. (a) In *Just Keep Solving 2*, only the first parts of the questions are shown beside the falling bombs. (b) Tapping a falling bomb gives access to the full-screen view of the corresponding question.

Each level of *JKS 2* features six to eight types of questions. Specific questions are generated randomly within prescribed parameters. Due to this variety, some game aspects in *JKS 2* have been adjusted to allow for longer game play. Specifically, the modes are now "Score – Get to 20 points!" (previously 12 points) and "Time – Live for 2 minutes!" (previously 1 minute) while the number of game lives has been increased from three lives in *JKS* to five. At the end of each game, regardless of the player succeeding or failing to complete the mode's goal, relevant game records are displayed (Figure 6) for easy recording (e.g., via a screenshot).


(a) (b)

Figure 6. (a) Game screen after a successful completion of a level of the "Time – Live for 2 minutes!" mode; (b) Game screen after failing to complete a level "Score – Get to 20 points!" mode.

## 4. GAME DESIGN FACTORS

The *Just Keep Solving* apps have been designed to enhance the potential benefits of traditionally pen-and-paper or flash-card-based activities by transforming them into digital game applications. As many students are fascinated with playing games in smartphones, tablets, and/or computers (Castellar et al., 2014), it is envisioned that the *Just Keep Solving* apps can increase the interest and attention of the students. The gamelike environment can positively transform their experience in doing deliberate practice activities which, due to its demands and emphasis on weak areas, can tend to be unenjoyable (Lehtinen et al. 2017).

While some have expressed that drill-and-practice games may lead to some players developing the undesirable behavior of "try[ing] actions with no reflection on outcomes" (Kiili, 2005 p.14), previous studies (Foss et al., 2014; Ke, 2008 Yip & Kwan, 2006) exemplify that well-designed drill-and-practice games may lead to positive outcomes on learning. Thus, the Just Keep Solving apps were designed to promote features of the deliberate practice model through the integration of game-design factors. For this purpose, we employed Shi and Shih's (2015) Game-based Learning (GBL) Design Model, which has been developed as a result of an extensive review of research on game design factors. The GBL Design model identifies 11 game-design factors (game goals, game mechanism, game fantasy, game value, interaction, freedom, narrative, sensation, challenges, sociality, and mystery) which form the environment wherein learning goals, a critical feature of deliberate practice, can be emphasized.

For both *Just Keep Solving* apps, the *game goal* can be identified by a knowledgeable other, such as a teacher, to enable students to work on weak areas in Algebra, Statistics, or Probability. Since it had been shown that purely focusing on weak areas may not be optimal for the weaker students (Pachman et al., 2013), other game-like features were necessary to make the experience more enjoyable and effective. The *game fantasy* is established by using clear and aesthetically appropriate graphics in the background (i.e., ocean floor with fishes and corals) and other game elements (i.e., falling bombs, damaged corals). These graphics assets, together with the playful background music and sound effects (e.g., for correct or wrong answers), form the multimedia presentation of the game's setting and contribute to players' *sensation*. The game's *narrative* is implied both by the multimedia presentation and the game *mechanism*, which as previously described, requires the players to answer questions that are attached to falling bombs so that they do not fall and explode on the ocean floor.

Players *interact* with the game by tapping the bombs to access a full-screen view of the questions and by using a digital number keypad for inputting answers. While the bombs' falling pauses on the full-screen view of questions, the game's *challenge* is that there is only a limited time for each bomb to reach the ocean floor and explode and that bombs continue to appear as the game progresses. This means that players can only afford a limited number of incorrect answer inputs and, thus, must perform their computations carefully and precisely.

In the *Just Keep Solving* apps, each player has the *freedom* to choose between two game modes and from a variety of levels that are dependent on the topic covered and its difficulty. This freedom also provides less knowledgeable learners the opportunity to achieve a certain level of competence before they are subjected to deliberate practice that focuses primarily on their weak areas (Pachman et al., 2013). Further, the availability of these modes and levels contributes to the game's *mystery* and might lead students to spending more time with the game. Since both apps have been designed to be single-player games, they have limited *sociability*. It is worth mentioning, however, that when used in the classroom setting and with teacher supervision, the *Just Keep Solving* apps may allow for friendly competitions and/or cooperative playing experiences.

The implementation into the *Just Keep Solving* apps of all the game-design factors mentioned above contributes to the game's value. In addition, students might find it more engaging or preferable to conduct their drills and practices, or assessments, using the games instead of pen-and-paper or flash-card modalities. Lastly, as previously mentioned, both *Just Keep Solving* apps are compatible with mobile technologies that can allow students to use the apps even outside the classroom. This enables them to have opportunities for independent or asynchronous learning.

## 5. INTEGRATION AND USE OF JUST KEEP SOLVING APPS

This section describes how the *Just Keep Solving* apps can be utilized as a pedagogical tool based on the RAT (Replacement, Amplification, Transformation) framework (Hughes, Thomas, & Scharber, 2006).

Using this framework, the *Just Keep Solving* apps 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 the textbook are now replaced by the questions which appear in the more inviting game-like setting of the app.

Playing the apps can enrich or *amplify* a student's experience in solving problems. The design of the app enables students to choose to work at just the right level of difficulty and provides elements in which students can be excited and challenged to work on advanced levels. Furthermore, the teacher as a knowledgeable other (Lehtinen et al., 2017) may identify students' areas of strength and weaknesses in order to design appropriate deliberate practice activities for more knowledgeable students, or a combination of deliberate practice and drill-and-practice activities for less knowledgeable students (Pachman et al., 2013).

Finally, the *Just Keep Solving* apps may give impetus to *transform* instruction from being teacher-centered to student-centered. This is possible because the apps have been designed so that students can easily understand and play them with little to no guidance from a teacher or a guardian. Hence, the apps are suited for use by students who are learning asynchronously or remotely. Transformation can also happen when tasks are redefined. For instance, individual tasks can be changed to collaborative activities using the apps. This gives students an opportunity to discuss and teach each other the problem-solving techniques required to answer the questions.

The apps, particularly *JKS* can be used for remediation. As mentioned in the introduction, a *Basic Education Learning Recovery Plan* was set in place in the Philippines to address learning gaps brought about by the pandemic. The repeated solving of similar problems provided by the apps aims to have a transformative effect to help reduce the gaps in specific MELCs. Moreover, a gradual improvement in skills can provide encouragement to weak students and increase their confidence.

## 6. CONCLUSION AND OUTLOOK

The *JKS* was developed to provide a tool in which students can repeatedly solve certain mathematical problems on linear equations and inequalities while playing a game. Expanding on *JKS*, a second mobile game *JKS 2* was designed using similar mechanics but applied to topics on statistics and probability. The competencies covered by both apps are aligned to the Philippines' Department of Education Most Essential Learning Competencies. Both apps are based on the strategic application of deliberate practice through the incorporation of game design principles with the aim of maximizing the games' value and their potential to enrich students' learning experiences and help students develop the intended learning competencies.

The apps can be used as a pedagogical tool to provide opportunities for deliberate practice in a classroom setting and in an asynchronous or remote learning set-up. The app can also be further extended to include additional mathematical competencies that are identified to be areas of weakness among students. The next step is to study the effectiveness of the apps in addressing the MELCS and/or increasing students' engagement and interest towards learning.

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