

A Gamified Approach for Learning Elementary Arithmetic Operations

Nurul Amira Sallik
Faculty of Computer Science and
Information Technology
Universiti Malaysia Sarawak, Malaysia
65128@siswa.unimas.my

Irwandi Hipiny
Faculty of Computer Science and
Information Technology
Universiti Malaysia Sarawak, Malaysia
mhhipni@unimas.my

Hamimah Ujir
Faculty of Computer Science and
Information Technology
Universiti Malaysia Sarawak, Malaysia
uhamimah@unimas.my

Abstract—It is essential for children to learn in a fun and interesting way so that they can maximally absorb difficult concepts in a stress-less manner. With children nowadays being exposed to various interactive digital media types, offline and online, teachers are finding it hard to compete for their focus and attention when using only conventional teaching aids, such as flashcards and posters. We studied a gamified app-based approach for learning elementary mathematical operations to see the effects of its implementation, if any, to young children. The game mechanic involves the player seeking Non-Playable Characters (NPCs) positioned randomly around town to receive game quest(s). Each quest requires the player to solve a simple arithmetic problem (i.e., addition and subtraction) to earn game points. Based on the pre- and post-test's results, we found a statistically significant difference between the mean scores.

Keywords—game-based learning, mobile games, gamification, mathematics, early childhood education

I. INTRODUCTION

Mathematical competency is a highly relevant skill for achieving the learning outcomes of elementary school's education and beyond. Low mathematical competency amongst kindergartner or pre-schoolers might cause them to experience difficulties with math subjects later in primary school [1]. Whilst research shows the value of children having a strong math foundation to increase the likelihood of future academic success, there is a lack of agreement on the best pedagogy to support early math learning. Some scholars argue that direct instruction is best for supporting math learning, e.g., [2] and [3], whilst others, e.g., [4, 5, 6], advocate for play-based pedagogies.

According to [7], Malaysia preschool education has always been championing a holistic approach paired with a developmentally-appropriate curriculum. Preschool teachers are trained to conduct "child-centred" education to promote active learning. The National Preschool Standard-based Curriculum [8] provides a set of comprehensive preschool curriculum guidelines that promote such attribute. Hence, incorporating gamification elements during the lesson delivery is very apt in the Malaysian context.

Gamification in education can be described as the application of game elements in a non-game context [9, 10]. We have developed a gamified mobile app that teaches simple arithmetic operations, i.e., addition and subtraction. The concept of using mobile app as an educational tool is not new. The use of such devices for learning has been validated and endorsed by many, e.g., [11, 12], inside the literature. The gamification elements implemented inside our app are in the

form of collectable points and an overall leader board. The leader board feature encourages repeat plays as the player seek to accumulate points and moves up the ranking. The game mechanism follows a typical casual Role-playing Game (RPG) which allows the user to explore a virtual world and interacts with NPCs and in-game objects. Multimedia elements are incorporated in-game, for example, audio, graphics, and animations, to enhance the immersion level and user experience.

We evaluated our gamified app by investigating the following research question: Using the gamified mobile app will have a positive impact on the children's understanding of addition and subtraction operation. The evaluation is performed by testing the followings:

H_0 : There is no statistically significant difference between means obtained from pre- and post-marks,

H_1 : There is a statistically significant difference between means obtained from pre- and post-marks.

II. EASE OF USE

Gamified learning software/apps are fast becoming a norm as a companion learning tool in modern classrooms. Existing studies supported this move as there are strong evidences for its inclusion. The first randomized control trial in the United Kingdom [13] demonstrated the benefits of using interactive math apps in early childhood education. After a 12-week period, participants demonstrated greater math learning gains compared to the control group. In [14], a team of researchers developed a total of 32 digital games for computer and tablet use. The games were designed based on three Realistic Mathematical Education (RME) levels that targets the fundamental preschool-level mathematical concepts. The research instrument used in [14] was the Test of Early Mathematics Ability – Third Edition (TEMA-3) [15]. The 72-item standardized test assesses the conceptual understanding and mathematics skills of young children. Participants with access to the digital games posted significantly better TEMA-3 scores compared to the control group (without access). The control group receives the same mathematic activities in a paper-based form. In addition to the performance gains, there are also evidences to support the notion that the use of gamified learning tools enhances mathematical thinking [16] as well as improving learners' attitude and motivation towards learning mathematics [17].

Besides adding gamification elements, researchers also explored the inclusion of technologies such as Artificial

Intelligence (AI) and Augmented Reality (AR) to further increase the learning efficacy. In [18], the researchers incorporated AI in their gamified app to automatically customize the learning materials to fit the player's current ability. Their approach is reported to be successful in encouraging children with different ability levels to continue playing. In [19], an AR app was developed to teach primary school children about the Solar system. The app overlays an animated 3D planetary body inside the user's egocentric field-of-view, using the scanned marker position as an anchor. In [20], the researchers developed two AR mini games for teaching multiplication table to primary school children. Similar to [19], the mini games use AR to prompt player with a multiplication problem visualized as a 3D floating text.

III. DESIGNING THE APP

A. Game Feature Preferences

We asked the respondents to rate their personal preference towards a set of common game features using a Likert scale of 1 (Not Important at All) to 5 (Very Important). The survey was conducted via Google Forms. In total, we received 17 survey responses from 6 teachers, 4 parents, and 7 students. From the survey data, see Fig. 1, more than 88.0% of our respondents had used a gamification app/website/software before. Top two most widely-used gamified tools by the respondents are Kahoot! (9 out of 17 had used it before) and Quizizz (11 out of 17 had used it before). We can conclude that our respondents are reasonably familiar with gamified tools, as such, are of good authority to rank game features.

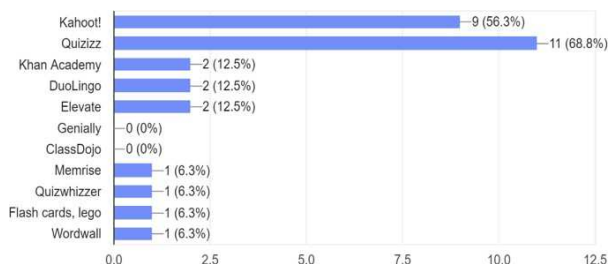


Fig. 1. Our respondents' familiarity with existing gamified tools.

Using the same approach as [21], we prepared a candidate list by canvassing for common features implemented in similar apps available in Google Play Store and Apple App Store. Table 1 shows the ranked list of game features, sorted by mean value. Since all has a high mean value each, we decided to implement the entire feature list in our mobile game app, except for Language Selection and Audio Narration. We fixed the menu and in-game texts to be in Bahasa Melayu since our participants are mostly monolingual. As for Audio Narration, we decided to play a pre-recorded gibberish audio whenever a speech text is shown.

TABLE I. GAME FEATURES, RANKED BY MEAN

| Game Feature | Mean |
|----------------------------|---------|
| Progress Bar | 4.7/5.0 |
| Achievements & Leaderboard | 4.5/5.0 |
| Badges & Points | 4.4/5.0 |
| Language Selection | 4.4/5.0 |

| Game Feature | Mean |
|-------------------------------|---------|
| Tutorial & Floating Tips | 4.1/5.0 |
| Color Scheme & Font Selection | 4.1/5.0 |
| Background Music (BGM) | 3.8/5.0 |
| Audio Narration | 3.8/5.0 |

B. User and System Interactions

Fig. 2 shows the use case diagram. We require a parent or a legal guardian to complete the player registration. Once a profile is successfully created, the player can access all screens, including game settings. The game is meant to be played under the guidance and supervision of an adult.

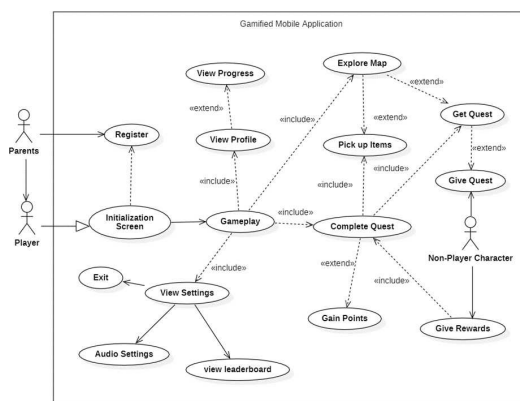


Fig. 2. Use case diagram of the proposed mobile game app.

C. Game Mechanics & Features

The game quest requires the player to solve either one or two elementary mathematical operations, i.e., subtraction and addition, see Fig. 3 and Fig. 4 respectively. The questions can be in the form of an equation or a word problem.



Fig. 3. Game quest: Subtraction question in word problem form.



Fig. 4. Game quest: Addition question in equation form.

Players are provided with visual game elements as hints. In the example shown in Fig. 5, the player can manually count