Game-based Learning using Augmented Reality

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Abstract—**Game-based learning with Augmented Reality (AR) is fast gaining popularity as an educational tool for primary school students due to its proven effectiveness, particularly for lower age groups. The present ubiquity of smart devices also contributes to the rapid adoption of such technology in classrooms. The gamification element and instantaneous feedback are vital to gain and maintain younger students' focus and interest. This study investigates the effects of using such tool on students' learning of the Solar system; a topic that is part of the Malaysian upper primary school's Science syllabus. The study was conducted remotely involving 20 respondents from various public primary schools in Malaysia. Pre-test and post-test results are presented in this paper. The result validates the effectiveness of the developed game-based learning app, i.e., SoLAR Kid, in improving students' understanding of the topic. From our experiment, we observed a clear mean difference between pre-test and post-test scores.**

Keywords—Game-based learning, augmented reality

I. INTRODUCTION

Science, Technology, Engineering and Mathematics (STEM) subjects are best learned through practical and hands-on activities as this approach promotes retention, active learning and student agency [1]. Unfortunately, the sad reality faced by many public schools in Malaysia is the lack of apparatus for STEM teaching and learning activities. In [2], 19 out of 40 interviewed primary school STEM teachers in Malaysia agreed that the existing government-issued teaching materials are inadequate. As the result, teachers rely primarily on textbooks to deliver the lesson plan.

Augmented Reality is a technology that overlays computer-generated information, 3D model, image, video, and audio in the real world using a smart device. AR had been used in various fields such as education, e.g., [3], [4], [5], [6], arts [7], and training [8], [9], [10]. Also, AR has been credited to improve user's focus and attention [11].

We developed a game-based AR mobile app, i.e., SoLAR Kid on the topic of Solar system. The mobile app tracks the AR marker' pose and position to render a virtual object inside a mixed reality environment. Gamification element is implemented via a local leaderboard and personal milestone tracker. Multimedia elements such as audio, graphics, video and animation are heavily utilized to improve the user experience. The app aims to provide a higher degree of inter-

activity from conventional learning. It measures students' knowledge of the topic via a set of randomised Multiple-choice Questions (MCQs). Each randomised set contains a fixed number of questions belonging to the same revised Bloom Taxonomy level [12], [13]. Implemented as a personal milestone tracker, the student "unlocks" a planet by successfully answering all questions inside a set belonging to that planet. In addition, a local leaderboard is maintained to encourage students to continually improve their scores

In our study, an experiment was conducted to evaluate the effectiveness of our proposed approach by investigating the following research question: The usage of the SoLAR Kid app will have a positive impact on students' quiz marks. The evaluation was performed by testing the null hypothesis,

H_0: There is no difference in mean pre-marks and post-marks.

and the alternative hypothesis,

H_1: There is a difference in mean pre-marks and post-marks.

II. BACKGROUND

A. Augmented Reality in Education

The term Augmented Reality was coined by Caudell [14] to describe a head-mounted display system worn by Boeing manufacturing workers during aircraft assembly. As opposed to Virtual Reality (VR), AR mixes computer-generated imagery on the user's view of the real world, thus resulting to a composite view. Pérez-López [15] claimed AR's most significant advantage over VR is the stimulation of the following sensory modalities, i.e., touch, sight, and hearing.

AR had been used intensively in the education field. Similar to ours, AR-SiS [3] is an educational mobile app for teaching primary school students about Solar system using Augmented Reality. Their app however does not implement any gamification elements. The study measures both teacher and students' satisfaction as well as app learnability. In [4], the researchers developed a mobile app i.e., SolarSystemGo, designed to be used outdoor. The app integrates Global Positioning System (GPS) technology to determine the render point of each celestial bodies inside the AR Solar system. The celestial bodies are live orbiting the Sun thus the objective of the game is to find each one of them in the least amount of time. Only qualitative findings were reported in that study using observation method. In [5], students participated in two AR lessons related to medical surgery. Once they had finished the lessons, each student completed a questionnaire to measure the user experience.