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The Impact of Computer-Based Simulation on Primary Students' Achievement and Interest in Learning Earth's Rotation and Revolution

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ABSTRACT

Many students hold misconceptions about the concepts of Earth's rotation and revolution, often due to factors such as prior knowledge, associative and humanistic thinking, incomplete reasoning, incorrect intuition, and differences in cognitive development, abilities, and interests. These misconceptions hinder students' understanding of fundamental astronomy concepts, particularly in primary science education. This study aims to examine the effectiveness of Computer-Based Simulation (CBS) in enhancing students' achievement and interest in learning the topic of Earth's rotation and revolution. CBS is an Information and Communication Technology (ICT) tool that facilitates meaningful learning by modelling real-life situations through computer programs, enabling students to explore complex scientific phenomena interactively. This quasi-experimental study involved 42 Year 4 students selected through purposive sampling. Participants were divided equally into a treatment group (n = 21) that received instruction using CBS and a control group (n = 21) that received conventional instruction. Data were collected through pre- and post-tests to measure achievement, and an interest questionnaire was administered before and after the intervention. The data were analysed using descriptive statistics (mean and standard deviation) and inferential statistics (independent samples t-test). The findings indicate that the use of Computer-Based Simulation had a positive and significant effect on students' achievement and interest in the topic of Earth's rotation and revolution. The results suggest that CBS is an effective instructional tool for addressing misconceptions and promoting interactive learning in primary science. It is recommended that science educators integrate CBS into teaching abstract astronomy concepts and develop training programs to equip teachers with the necessary skills for implementing ICT-based simulations in the classroom. Future research should explore the long-term effects of CBS on conceptual retention and its applicability to other science topics.

Keywords: Computer-based simulation, achievement, interest, rotation and revolution of earth

INTRODUCTION

Science and technology are rapidly expanding globally, necessitating the advancement of science education. The UNESCO Congress Report emphasises the importance of science education in improving people's material and cultural conditions (Smyth, 1986). In Malaysia, science education began in 1937 and has been a top priority since 1957 (Halim & Subahan Mohd Meerah, 2016). The Ministry of Education has prioritised improving STEM education through curriculum enhancement, teacher training, and testing (Ministry of Education, 2013). However, there has been a downward trend in the country's educational performance, as seen in the recent low Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) rankings (Goh and Blake 2015). Malaysia's PISA results dropped by 6.26% from 431 in 2018 to 404 in 2022, while TIMSS saw a drop from 5% in 2015 to 3% in 2019 (Avvisati & Givord, 2023).

Education is a socially organised process that transfers experiences from previous generations to future generations (Krishnamurthi, 2021). One approach to achieving conceptual understanding in science learning is through the use of simulation strategies (Arif, 2018), which involve replicating real-world situations or tasks. Simulation activities allow students to practice science by simulating their behaviour in a specific environment (Jones & Barrett, 2017). Active student participation in simulation activities fosters student-centred learning, deepens conceptual understanding, and encourages peer support and the celebration of success (Baeten et al., 2016; C. H. Chen & Tsai, 2021). Effective teaching techniques attract students' interest, achieve curriculum goals, and promote inquiry-based learning and simulation games (Grigg, 2016). The success of the future educational system depends on early schooling exposure (Bello et al., 2016), and different teaching methods have different effects on students (Krishnamurthi, 2021).

According to Rafika and Syuhendri (2021), students often hold misconceptions about the theories of Earth's rotation and revolution. The factors that contribute to misconceptions include students' prior knowledge, associative thinking, humanistic thinking, incomplete reasoning, wrong intuition, cognitive development, abilities, and interests (Uliyandari et al., 2021). According to Nuri Seftiani Rosmiati et al. (2023), students perceive the lesson as difficult and boring due to the lack of variety in learning media, which in turn reduces their motivation to engage with the topic. Additionally, in schools, teachers often represent the three-dimensional movement of celestial bodies—such as the Earth's orbit around the Sun—on two-dimensional surfaces like blackboards or textbook diagrams, which can lead to confusion in students' understanding (Trumper, 2001).

Computer-Based simulation is a student-centred approach that promotes student engagement and motivation in learning. Therefore, by applying this approach, learning activities can enhance student engagement and increase their motivation to learn (Makransky et al., 2020). Furthermore, it encourages students to demonstrate their understanding through role-play, which enhances their grasp of the concepts of Earth's rotation and revolution. Moreover, the integration of three-dimensional (3D) computer-based simulators with the predict-observe-explain (POE) teaching strategy has been shown to effectively support students in understanding the causes of astronomical phenomena, particularly the Earth's rotation and revolution (Sneider et al., 2011).

Research Objective

The primary objective of this research is to determine the effectiveness of using Computer-Based Simulation in enhancing Year 4 students' learning outcomes in science, specifically in the topic of the rotation and revolution of the Earth. The specific research questions are as follows:

1. Is there a significant difference in the achievement of Year 4 students on the topic of Earth's rotation and revolution between those taught using Computer-Based Simulation (CBS) and those taught using conventional instruction?
2. Is there a significant difference in the interest of Year 4 students towards the topic of Earth's rotation and revolution between those taught using Computer-Based Simulation (CBS) and those taught using conventional instruction?

B. Hypothesis

H_{01}: There is no significant difference between pupils’ achievement use Computer-Based simulation (treatment group) and pupils’ achievement who are not using Computer-Based simulation (control group).

H_{02} There is no significant difference between pupils’ interest in using Computer-Based simulation (treatment group) and pupils’ interest who are not use Computer-Based simulation (control group).

LITERATURE REVIEW

The utilisation of educational technology, particularly computer-based simulations, has garnered attention for its ability to positively impact student engagement, motivation, and academic performance across various disciplines. A substantial body of research highlights the effectiveness of such technological innovations in improving learning outcomes for students. For instance, Yu et al. (2020) elucidated that educational games contribute favourably to students' learning outcomes, motivation, and engagement, emphasising that engagement is fundamental to effective learning (Yu et al., 2020). Complementing this perspective, Dita et al. (2021) noted that interactive learning media stimulate new interests among students and fortify their motivation, leading to more impactful educational experiences (Dita et al., 2021). Interactive computer-based simulations facilitate visual engagement with abstract concepts, such as Earth's movements, enabling students to attain a deeper understanding and retention of the material (Dita et al., 2021).

Computer simulation was initially used as a supplementary tool to help students better understand the theoretical concepts presented by the teacher (Bowen & DeLuca, 2015). This practice remains common in many schools today, where students engage with conceptual simulations during classroom instruction. Conceptual simulations have been shown to enhance students' understanding and foster the development of critical thinking skills (Lovelace et al., 2016). Moreover, they allow students to manipulate variables and observe outcomes, thereby deepening conceptual understanding through experimentation and iterative learning. Through computer-based simulations, students can also apply theoretical knowledge in practical contexts and develop higher-order cognitive and critical thinking skills (De Jong, 2006). Compared to text-based and static visual materials, dynamic and interactive computer simulations promote higher engagement and often lead to greater learning outcomes (Chen et al., 2014).

Despite these benefits, existing literature reveals a critical gap: most studies focus on the general effectiveness of simulations without adequately considering their contextual alignment with learners' real-world experiences, particularly in primary science education. While evidence supports the use of simulations to enhance engagement and critical thinking, limited research examines how integrating locally relevant phenomena or culturally familiar contexts influences learning outcomes (Rutten et al., 2012; Zacharia et al., 2015).

This alignment across the literature suggests that simulation-based learning has a unique capacity to bridge theoretical and practical knowledge. While the consensus highlights student engagement and critical thinking development, such tools may be even more effective when grounded in authentic, real-world phenomena familiar to students. For example, in astronomy education, embedding local environmental patterns or observable celestial events into simulations could strengthen the connection between abstract content and students' lived experiences (Plummer & Krajcik, 2010; Barnett & Morran, 2002). Addressing this gap could offer new insights into how context-sensitive simulations impact conceptual understanding and critical thinking development.

A. Richard Mayer's Cognitive Theory of Multimedia Learning

In the various of cognitive learning theories, the cognitive theory that related to this research is about the Cognitive Theory of Multimedia Learning, which discover by Richard Mayer in year 1997 (Rudolph, 2017). According to Richard Mayer, a learner has two information processing systems: verbal information processing system and visual information processing system. As a result, auditory narration belongs to the verbal system, whereas animation belongs to the visual system (Mayer, 1997). The Computer-Based simulation such as Earth's Rotation and Revolution model or other types of virtual labs, can provide an animation, interactive elements, or models as a good visual systems in education which can providing the experience for students that are related to real-world situation (Rieber, 1996). By using the Computer-Based simulation, students are able to utilized the coming visual information to create an image base (Wu et al., 2001). For instance, when students are expose to the Earth's rotation and revolution simulator, students will have an image about the path of Earth movement around the Sun. Then, student can build a verbally-based model of the to-be-explained system and a visually-based representation of the same system (Johnson-Glenberg, 2000). For example, through the application of Earth's rotation and revolution simulator in classroom, students can analyse the information in the simulator (path, direction or time taken), then create a model themselves such as drawing, performance, writings, and others. Lastly, student able to makes connections between related events in the verbally-based model and the visually-based model (Mayer & Anderson, 1992). This theory is applied in the current research because it provides a clear framework to explain how computer-based simulations can enhance students' understanding by engaging both their visual and verbal cognitive systems, thereby improving interest and comprehension of abstract scientific concepts like Earth's rotation and revolution.

These theoretical insights converge to reinforce the pedagogical value of computer-based simulations. However, it is crucial to recognize that the design of such simulations must consider students' cognitive load and familiarity with the content. Therefore, simulations that are tailored to the students' developmental level and contextual background may foster a more intuitive and meaningful learning experience.

Computer simulation was initially employed as an additional tool to assist students in understanding the theoretical notion given by the teacher (Bowen & DeLuca, 2015). This is still occurring in many schools today. Students conduct experiments in conceptual simulations that are utilized in classrooms. Conceptual simulations help students learn and develop their critical thinking skills (Lovelace et al., 2016). Besides, students can change variables in conceptual simulations to see what happens, which helps them understand concepts more deeply as they keep changing the variables. Through computer-based simulations, students can apply their knowledge practically and develop higher-order and critical thinking skills (De Jong, 2006). And, compared to text and static images, the dynamic and interactive computer simulations that let students engage and become involved have an equal or greater impact on the learning outcome (Chen, S.F., et al., 2014).

METHODOLOGY

Research Design

In this research, a quasi-experimental research method and quantitative approach had been used, which involved manipulating an independent variable to evaluate the hypotheses. The usage of computer-based simulation applications as teaching tools was the independent variable in this study, and test (achievement) and questionnaire (interest) results from the students were the dependent variables.

Sampling

The accessible population included all Year 4 students from a primary school in Pulau Pinang, Malaysia. However, a sample of 42 Year 4 students had been chosen for this research. Of these, 21 students were placed in the treatment group and another 21 students in the control group. The sampling strategy used in this study was purposive sampling. Purposive sampling is a non-probability sampling technique where the researcher had selected participants for the sample based on a variety of factors. All of the samples came from the same school's Year 4 cohort but from different classes. In order to guarantee the precision and coherence of study findings, both participant groups possessed roughly the same level of knowledge and expertise in the topic of Earth's rotation and revolution.

Instrument

In this study, two sets of instruments were developed for the pre-test and post-test to assess the students' achievement before and after treatment. Ten objective questions and two subjective questions were created for both pre- and post-tests. Both tests had the same sets of questions, but they were presented in a different order. There was a seven-day interval between the pre-test and post-test. Different difficulty levels, including easy, moderate, and difficult, were included in the design of the questions. The Standards-Based Curriculum and Assessment Document (DSKP), curriculum descriptions, and Bloom's Taxonomy served as the basis for the questions that were included in the pre-test and post-test. The identification of the Earth's rotation and revolution, including its direction, duration, and impact, was allowed within the scope of the questions. The DSKP's requirements for the subject content of the Year 4 students' achievement levels in the rotation and revolution of Earth meant that the instruments employed in this study had content validity.

Next, the study's questionnaires had been developed to ensure the authenticity and accuracy of the sample feedback. The purpose of the questionnaire was to gather information on students' interest in the computer-based simulation. This questionnaire was designed with two categories and 26 items. Items 1 to 13 were related to students' interest in the general learning process, and items 14 to 26 were related to students' interest in science learning.

Data Collection

Pre-test and post-test assessments had been used in this study to gather data. Forty-two eligible participants were randomly selected before testing. Twenty-one pupils made up the treatment group, and the other 21 comprised the control group. The researcher administered a pre-test to each participant after ensuring they were all properly identified. The pre-test was designed to collect data on participants' scientific knowledge of Earth-related topics prior to the intervention phase. The researcher then conducted interventions for both groups. The treatment group was instructed by the researcher on how to use computer-based simulation as part of the intervention. Following the intervention period, the researcher administered a post-test to the same participants to gather additional data on the topic of Earth's rotation and revolution.

The test was intended to gather data regarding the students' understanding of scientific concepts linked to the Earth's rotation and revolution both before and after the implementation of computer-based simulation. Test results supported further analysis by serving as an indicator of the effectiveness of the computer-based simulation. The Year 4 DSKP served as the basis for the design of the study's pre- and post-tests. The Earth's rotation and revolution were the only test items included. Furthermore, a questionnaire survey was administered to both groups by the researcher before and after the treatment phase to determine the participants' interest in learning about Earth's rotation and revolution using computer-based simulation versus traditional methods.

Data Analysis Procedure

Quantitative data were collected through the pre- and post-tests and the interest level questionnaire. These tools had assessed how using the virtual lab to study the topic of computer-based simulation impacted students' achievement and interest. Descriptive statistics were used to summarize and describe the data, while inferential statistics, such as the t-test, were employed to determine whether there were statistically significant differences in achievement and interest between the treatment and control groups.

FINDINGS AND DISCUSSION

This study employed both descriptive and inferential statistics to address its two primary research questions. Descriptive statistics (mean and standard deviation) were used to summarize student achievement and motivation scores, while inferential statistics (Shapiro-Wilk test, Levene's test, and independent samples t-test) were used to examine differences between control and treatment groups.

Effectiveness of Computer-Based Simulation on Year 4 Students' Achievement in Rotation and Revolution of the Earth

Independent t-test have been used to analyse and determine whether there is a significant difference between the means of two independent groups.

TABLE 1 Independent Samples T-Test for Pre-Test of Both Groups

T-test for Equality of Means			
	t	df	Sig.(2-tailed)
Equal Variances Assumed	0.298	40	0.771

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Based on the Levene test results, it was indicated that the variances of the two groups data were approximately equal during the pre-test. The results of the independent samples t-test indicated t(38) = 0.298, with a 0.771 p-value. Considering that the p-value (0.771) was higher than the significance level of 0.05, the null hypothesis could not be rejected. This indicated that there was not a significant difference in mean value between the treatment group and the control group during the pre-test stage.

TABLE 2 Independent Samples T-Test for Post-Test of Both Groups

T-test for Equality of Means			
	t	df	Sig.(2-tailed)
Equal Variances Assumed	-2.644	40	0.012

Based on Levene's test for equality of variances, the result showed F(1, 40) = 0.005, p = .942, indicating that the assumption of equal variances was met. The independent samples t-test analysis, as presented in Table 1, revealed a statistically significant difference in the post-test mean scores between the control and treatment groups. The test indicated t(40) = -2.664 with a p-value of .012. Since the p-value was lower than the significance level of .05, the null hypothesis was rejected. This indicated that there was a significant difference in the mean value between the treatment group (using Computer-Based Simulation) and the control group (using the traditional approach) during the post-test stage.

Drawing from the descriptive and inferential statistics conducted for this research, it can be concluded that the use of Computer-Based simulation can help to improve students' understanding of the topic rotation and revolution of Earth. Based on the another study by Towbin et al. (2008), which also investigated the effectiveness of using Computer-Based simulation in learning, both studies produced the same results, proving that the Computer-Based simulation can help in increasing students' achievements. This is because the Computer-Based simulation can help students develop critical thinking skills by allowing them to change variables and apply knowledge practically when using it (Lovelace et al., 2016). Besides, the simulation strategy using Computer-Based Simulation also has a greater impact on learning outcomes than text and static images (Chen et al., 2014), as illustrated in Fig. 1, which demonstrates how interactive and dynamic simulations enhance students' engagement and conceptual understanding compared to static representations.

Furthermore, this study found that using the Computer-Based simulation improved students' understanding of the concept of Earth rotation and revolution by comparing post-test results across two separate groups. In addition, the integration of technology in science education aligns with the demands of 21st-century learning (Yu & Samri, 2024). This is especially relevant in today's global economy, which is driven by rapid technological advancements and increasingly requires a skilled and adaptable workforce (Er & Samri, 2024).

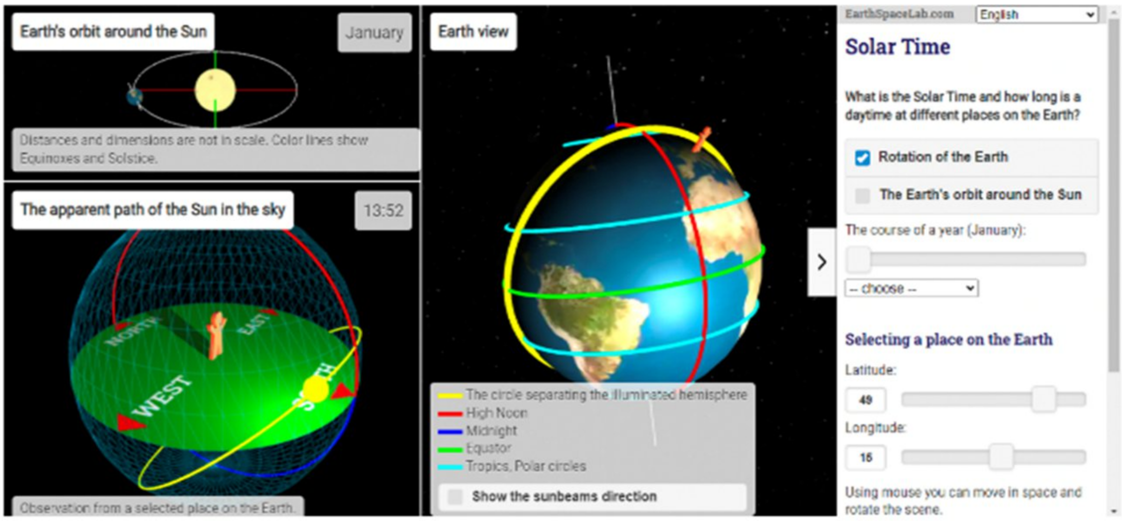

Fig. 1 Computer-Based Simulator of Rotation of Earth

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Effectiveness of Computer-Based Simulation on Year 4 Students' Interest in Rotation and Revolution of the Earth

To assess the effect of the computer-based simulation on student interest, a 26-item questions which divided into two domains, which are General and Science, and required the responses with 5-point Likert Scale. Pre-test mean scores for both control (M = 2.19) and treatment (M = 2.21) groups indicated moderate interest level. Post-test results (control: M = 2.75; treatment: M= 3.74) were analysed using a t-test to determine significant differences.

TABLE 3 Interpretation of Mean Value for 5 Point Likert Scale (Mohammad Issam Khalil Abu-Baker et al., 2019)

Mean Score	Interpretation of Mean Value
1.00-1.80	Very Low
1.81-2.60	Low
2.61-3.40	Average
3.41-4.20	High
4.21-5.00	Very High

TABLE 4 Independent Samples T-Test for Pre-Questionnaire of Both Groups

T-test for Equality of Means			
	t	df	Sig.(2-tailed)
Equal Variances Assumed	-0.165	40	0.870

Based on the Levene test results, it was indicated that the variances of the two groups data were approximately equal during the pre-questionnaire. The results of the independent samples t-test indicated t(38) = -0.165, with a 0.870 p-value. Considering that the p-value (0.870) was higher than the significance level of 0.05, the null hypothesis could not be rejected. This indicated that there was not a significant difference in mean value between the treatment group and the control group during the pre-questionnaire stage.

TABLE 5 Independent Samples T-Test for Post-Questionnaire of Both Groups

T-test for Equality of Means			
	t	df	Sig.(2-tailed)
Equal Variances Assumed	-6.566	40	<.001

Based on Levene's test for equality of variances, the result showed F(1, 40) = 1.473, p = .232, indicating that the assumption of equal variances was met. The results of the independent samples t-test, as shown in Table 2, indicated t(40) = -6.566 with a p-value of < .001. Since the p-value was less than the significance level of .05, the null hypothesis was rejected. This indicated that there was a significant difference in the mean value between the treatment group (using Computer-Based Simulation) and the control group (using the Traditional approach) during the post-questionnaire stage.

As supported by the descriptive and inferential statistical analyses conducted in this research, it can be concluded that the use of computer-based simulation can help to cultivate students' interest in the topic of the rotation and revolution of the Earth. Furthermore, another study also produced the same result, showing that computer-based simulation can help to increase students' interest in science learning (Rutten et al., 2012). This can be explained by De Jong (2006), who stated that computer-based simulations can ensure that students engage in learning and develop their higher-order and critical thinking skills, which in turn can increase their interest in learning.

CONCLUSION

In conclusion, this research demonstrated that employing computer-based simulations significantly improves students' understanding and performance in the topic of Earth's rotation and revolution. The findings of this study carry important implications for various educational stakeholders, particularly the Malaysian Ministry of Education and educators. They emphasize the necessity of integrating these simulations into teaching practices to enhance learning outcomes. The recommendations provided in the study serve as valuable guidance for future researchers who are interested in exploring the effectiveness of computer-based simulations in education and their broader applications.

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