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Integrating Technology in Physics Learning

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Abstract

Physics has always been perceived as a difficult subject by high school students as the subject involves abstract concepts and mathematical calculation. This study explains challenges faced by high school students Physics learning and discusses how Cognitive Theory of Multimedia Learning and self-directed learning approach would assist Physics learning. The study also explains how the application of technology such as audio, video, animations, and augmented reality would develop an interactive and joyful learning environment in Physics classroom learning. Using the application of Cognitive Theory of Multimedia Learning, self-directed learning approach, audio-visual elements of technology and augmented reality, the study propose a conceptual framework and learning activity for Gravitation topic for form four Physics subject and involve both abstract concepts and mathematical calculation.

Keywords: Cognitive Theory of Multimedia Learning, Physics, Augmented Reality, Technology, Self-Directed Learning

Introduction

The term "science, technology, engineering, and mathematics" (STEM) development refers to curricular choices and educational policies that aim to make students more competitive in the fields of science and technology. This is codified in the Malaysian Education Development Plan 2013-2025 (Kementerian Pendidikan Malaysia, 2013), which places a strong emphasis on STEM education through extracurricular and curriculum-based activities in schools. The younger generation needs to be proficient in STEM fields to meet the difficulties of Industry 4.0. In the field of future technology, which is the foundation of Revolution Industry 4.0, this is done to generate skilled human capital.

Using the Malaysian Education Development Plan (2013–2025) as a guide, students are aiming the thought skills that clarify how students apply curiosity and engage in lifelong learning to acquire information. It is consistent with building curiosity about a subject to pique students' interest and ultimately raise their academic performance. To improve the quality of Science, Technology, Engineering, and Mathematics (STEM) education, which emphasizes the exploration of the use of multi-mode learning models that utilize technology

is crucial to strengthen student learning, which aims to provide equal access in national quality education.

Students who are in the Pure Science Stream under the Malaysian Ministry of Education (KPM) must learn Physics as one of the required courses. The package consists of Physics that includes the Chemistry, Biology, and Additional Mathematics courses in addition to the current core subjects. Physics is perceived as a challenging topic to study (Dina Handayani & Ummas Genisa, 2019; Jufrida et al., 2019; Otero & Meltzer, 2017; Wibowo et al., 2023) which involved abstract concepts (Nordin, 2019), that is hard to visualize with the imagination. Some of the focus of physics is on ideas and concepts that are not perceivable with the senses. However, the ability of students to make connections between the ideas, theories, and applications of physics is incredibly lacking (Nordin, 2019).

Physics Education

One of the academic fields that requires knowledge of nature analysis and comprehension is physics (Al-Masarweh, 2021). Physics involves some mathematical calculation principles (Retnawati et al., 2018) in addition to requiring students to translate and grasp concepts. New technologies have been developed with the help of physics. Branches of physics are involved in the fundamentals of engineering, chemistry, and technology. Physics education is crucial for giving students basic comprehension of the natural world and its guiding principles. When learning physics, one needs to be able to reason and think to understand topics (Al-Masarweh, 2021). A student's comprehension of physics must grow via both concept interpretation and reasoning. It is the nature of physics requires understanding abstract concepts and makes complex assumptions, many students are not as interested in studying the subject(Afjar et al., 2020). Mathematical aspects in calculation are burdening and teacher's teaching is less interesting in the classroom is also a factor of students getting bored with physics (Mohd Noor Badlishah et al., 2016).

Difficulty in imagining a concept is still a problem among students (Susantini et al., 2021). In a study in Indonesia related to Physics, students' understanding to learn science about the concept of refraction of light has serious problems because light particles that cannot be observed, even learning methods through practical or hands-on can create active students so that students not only memorize formulas but also understand the concept physics learned (Solihin et al., 2022). Students' ability will face problems if the subject is something that is difficult to observe and difficult to explain, thus they might encounter misconceptions.

A Newton’s Gravity study in Physics education was carried out in Indonesia. The goal of the project is to create an interactive simulation that can enhance students' understanding of Newton's Theory of Gravity (Susanti et al., 2022). This study has demonstrated that well-designed teaching materials also enhance student learning results, particularly when it comes to the idea of Newtonian Gravity. A study on the application of High Order Thinking Skills (HOTS) to the topics of Gravitation was conducted in Perak, Malaysia among form four secondary school students. The two subtopics of Kepler's Law and Universal Gravitational Law are the main subjects of research. The topic is frequently associated with misconceptions, so a study was carried out to help students' HOTS (Halim Roslan et al., 2022).

Cognitive Theory of Multimedia Learning

Richard E. Mayer established the concept of Cognitive Theory of Multimedia Learning (CTML), which is a component of multimedia that aids in student learning (Mayer, 2014). The ability

of people to learn something more thoroughly through text plus diagrams rather than text alone is the fundamental tenet of multimedia (Mayer, 2014). Three components of students' cognitive capacity are highlighted by multimedia learning theory: generative processing, external processing, and crucial processing (Wan Ali & Wan Yahaya, 2022). The advancement of technology-based learning is aided by this theory. According to Mayer's Multimedia Learning Theory, a study on multimedia-based lecture learning that incorporates specific design principles such as cues, segmentation, redundancy, visuals, and embodiment able to engage students in learning in a more joyful environment.(Castro-Alonso et al., 2021).
Integrating the five processes involved in the cognitive theory of multimedia learning results in development that is appropriate and effective when using the right media and resources. This has taken into account that while choosing acceptable media to create a meaningful learning kit, specific topics, specific subjects, and specific student levels are taken into mind.

Table 1
Shows the proposed five principles that is being used in the development of learning material. The framework will follow the criteria of each of the principles to make the learning material suitable and achieve the learning outcomes during implementation.

Principles	**Description**
Coherence Principle	People learn better when extraneous words, pictures and sounds are excluded, rather than included.
Signalling Principle	People learn better when cues that highlight the organization of the essential material are added.
Redundancy Principle	People learn better from graphics and narration than from graphics, narration and on-screen text.
Spatial Contiguity Principle	People learn better when cues are added that highlight the organization of the essential material,
Temporal Contiguity Principle	People learn better when corresponding words and pictures are presented near rather than far from each other on the screen or page or in time

Figure 3: The Five principles of CTML (Sources: Mayer, 2014)

Integrating CTML in the design of a product shows good impact. A study in Indonesia which explains that there are twelve principles used in multimedia studies related to WhatsApp has shown that the adaptation of Mayer's multimedia cognitive theory is best assimilated (Radisti Ananda Hanum et al., 2023). Emphasis on Mayer's Cognitive Theory of Multimedia Learning which involves five principles namely coherence, redundancy, temporal contiguity, signaling, and spatial contiguity (Nor Farhah Saidin et al., 2019). The study is integrating the five principles to develop a learning material. A study has shown the effects of modality, redundancy, and signaling principles in multimedia learning for animation-based learning based on abstract and concrete concepts (Ekrem Kutbay & Yavuz Akpinar, 2020). In addition,

(Murugan Mini Ratamun, 2018) in his study that developed and examined the effectiveness of Virtual Labs compared to Physical Labs in learning the topic of Chemical Salts in Form Four also used Cognitive Theory of Multimedia Learning shows good impact among students. The study focused on five principles which are Coherence Principle, Signaling Principle, Redundancy Principle, Spatial Contiguity Principle and Temporal Contiguity Principle.

A study shows there has been a rise in student involvement and interest in multimedia and You Tube videos among health students in Dublin (Doherty, 2023). The study employed elements from Mayer's Cognitive Multimedia Learning Theory (CTML). According to this theory, instructional media should focus on using the human mind as a channel for learning, which will eventually add words to images (Aravind & Rajasekaran, 2021).

Self Directed Learning

It is obvious that self-directed learning is a complex idea that should not be viewed from just one angle (Loeng, 2020). Self-Directed Learning (SDL) is an approach to students develop their own lesson plans, learning objectives, and study regimens on their own (Win & Ahmad, 2023). The students take control on the learning at their own pace. According to: "A self-directed learner ought to have able to identify what is needed to be learned."(Loyens et al., 2008), pp. 417–418. SDL has been said that has larger notion of context. With or without the assistance of others, Self-directed learning (SDL) is described as “a process in which individuals take the initiative in diagnosing their learning needs, formulating goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes” (Williams, 2004). SDL should be viewed as a collaborative effort between the teacher and the student in a formal learning environment(Garrison, 1997).

There is strong evidence that those who actively seek out information learn more and do it more effectively than those who are taught anything by a passive method (Knowles, 1975). The most widely accepted definition, offered by Knowles (1975), consists of eight parts: (a) it is a process; (b) it is started by the individual; (c) it may or may not involve outside assistance; (d) it identifies their learning needs; (e) it develops learning goals from these needs; (f) it locates the resources needed to achieve these goals; (g) it chooses and employs the appropriate learning strategies to meet their goals; and (h) it decides how to measure learning outcomes. SDL students typically work independently and with confidence, researchers think that SDL can help students become more competent (Win & Ahmad, 2023). It has been demonstrated that SDL is a very successful strategy for motivating and preparing adult learners (Andrea D Ellinger, 2004). It is in line with a study done in secondary school to investigate the impact of SDL among students. It shows that SDL in using mobile application able to make learning becomes more flexible and effective (Nur Hafizah Razali & Fariza Binti Khalid, 2021). A study shows that in situations where students did not already have a high degree of self-directedness in their learning, cooperative learning has raised students' perceived SDL. This study was among the first-year students in South Africa (Mentz & Van Zyl, 2018). The ability of SDL approaches was able to help students in their learning environments.

Technology In Physics Education

The use of technology has shown itself to be a very useful tool for assisting in education. Even it is still thought to be less effective, physics textbooks and other printed teaching materials are still used in classrooms, which makes them less engaging for pupils (Astra et al., 2022).

Studying physics enhances one's comprehension of the advancement of science and technology since the science relies on experiments, observations, and mathematical calculations and analysis to describe a variety of natural occurrences (Suyidno et al., 2022). The role of technology in physics education is to facilitate the development of knowledge and retention strategies (Abdüsselam, 2014). Technology is thought to have the potential to improve physics education. The paradigm of education in the twenty-first century has changed, favoring technology-based learning over traditional methods (Sumardani et al., 2019). A study involving methods of Mobile Learning (M-Learning) which is a communication tool that acts as a teaching and learning medium that requires students to bring a smartphone for learning purposes (Arif et al., 2021) . It is known as Bring Your Own Devices (BYOD). The study suggests a need analysis of bringing devices to assist learning in a matriculation in an electromagnetics topic. A study using Phet simulation among students in using video has also been done in Modern Physics proven to have achieve positive impact (Nasbey & Raihanati, 2022).

Augmented Reality

An emerging field of technology called augmented reality (AR) modifies and enhances the real world with computer-generated images and sounds (Gunčaga et al., 2020). AR allows computer-generated sensory input, such as photos, videos, or even sounds, to precisely overlay real-world items (Suhaimi et al., 2023). AR allows the user to observe a combination of real-time virtual and physical items (Dunleavy et al., 2009; Wu et al., 2013).AR is sometimes defined by researchers as a broad system that includes data like photos and streaming videos (Cubillo et al., 2014).

Utilizing cutting-edge augmented reality technology, it was possible to build a dynamic and simultaneous interaction between the actual and virtual worlds and understand the concepts in multiple dimensions, thereby contributing to the acquisition of 21st century skills (Baba & Zorlu, 2022). The study is using experimental and group in Physics students in the topics of Solar Systems and Eclipses using AR. It can be presumed that the lab for augmented physics has been suitable for increasing students' higher order thinking abilities. It is aligned with a study using Dick and Carey research development in Indonesia that shows good impact on students (Sumardani et al., 2019).

A study claimed that augmented reality technology might enhance learning and cognitive skills in students by making abstract concepts easier for them to understand (Bujak et al., 2013; Cai et al., 2017; DiSerio et al., 2013; Laine et al., 2016). Augmented reality has helped the students in learning geography in a study among Form One students in Malaysia (Ong Ace Hong et al., 2022). Augmented Reality is effective in improving problem-solving skills (Guntur & Setyaningrum, 2021). The study involved students in th topic of vector using AR to help them solve mathematical problems. Finding from the study that been using quasi-experimental method shows that Augmented Reality learning is more effective than conventional learning. According to a recent study conducted in Spain, secondary students' assessments on the usage of AR in a chemistry class were satisfactory (Moreno Martínez et al., 2018).

The Proposed Conceptual Framework and Learning Activity For Physics Learning

This paper proposed a conceptual framework and learning activity for Physic learning which is based on the application of Cognitive Theory of Multimedia Learning (CTML), self-directed learning approach, technology and augmented reality. Figure 1 shows the conceptual

framework that involves in a study to design and develop a learning material in Physics education. The approach that is being involved is SDL among students. CTML will be used in design and develop the learning material that will be integrating the animation, video, audio and augmented reality. The learning material is intended to be developed in stages. The effectiveness of the learning material will be evaluated by pretest, posttest, documents analysis and semi structured interviews among students during the implementation. It is a desire to have impactful learning material to achieve learning outcome and make Physics learning more joyful.

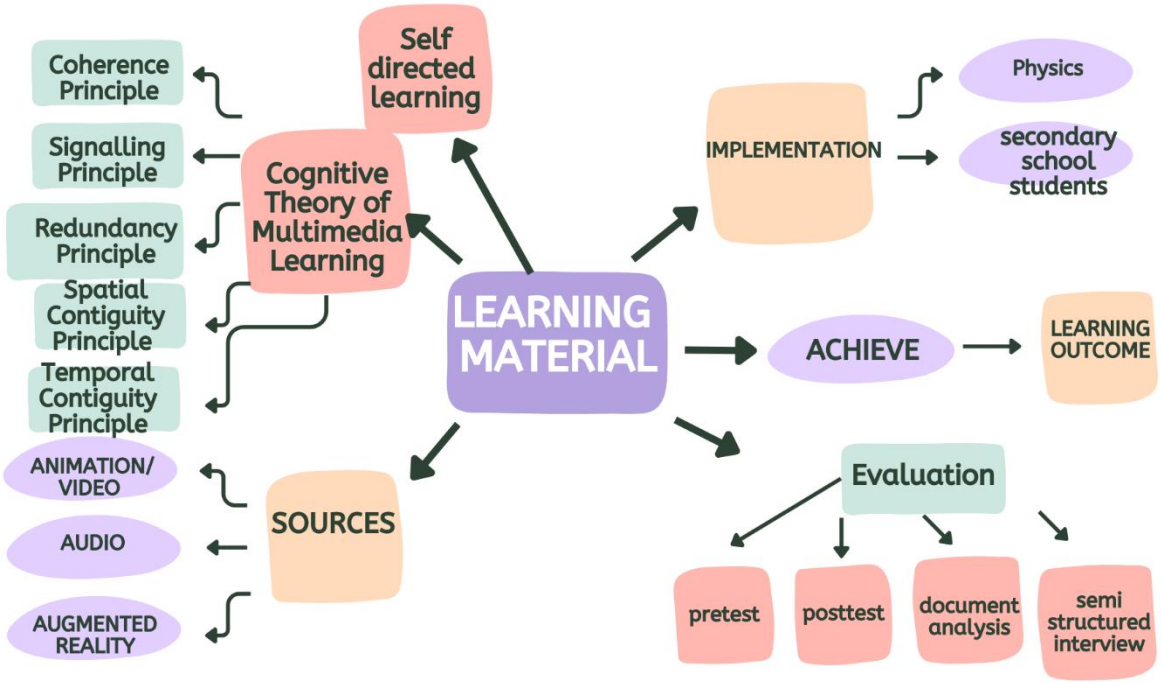

Figure 1: The proposed conceptual framework for Physics learning

Based on the proposed conceptual framework for Physics learning, the study further proposes learning activity that integrate the Cognitive Theory of Multimedia Learning (CTML), self-directed learning approach, audio-visual technology and augmented reality. The proposed learning activity is for Physics subject for form four students within the Gravitation topic. Specifically the proposed learning activity is for subtopics of Keplers Law I,Keplers Law II , Keplers Law III and finding the value of escape velocity which involves both abstract concepts and mathematical calculation. During the implementation of the proposed learning activity, the students will be required to bring their own mobile devices as part of the learning kit in their classroom learning. The students are involved in self-directed learning as they will navigate the video, audio and AR simulation in achieving the learning outcomes. At the end of the lessons, the students would be required to work in pairs to prepare a presentation accordingly. The presentation will be done using their mobile devices in which the students will present and share their slides with their classmates.

SUBJECT	PHYSICS
LEARNING STANDARDS (OBJECTIVE)	At the end of the lesson, students will be able to define Keplers' Law I and Keplers' Law II
TIME	8.00-10.00
ACTIVITY	1. Students were being asked to download the mobile learning apps on their mobile phone. 2. They will be asked to work in pairs to navigate the first lessons of the day. 3. They will be work in pairs on navigating the simulations on AR and video in Keplers' Law I. 4. Then they will be navigating the simulations AR and video on Keplers' Law II. 5. The students will do presentation in pairs and present on what they have learn. 6. The students will do presentation in pairs.

Figure 2: Proposed learning activity for Keplers' Law I and Law 2 that applies the the Cognitive Theory of Multimedia Learning (CTML), self-directed learning approach, audio-visual technology and augmented reality.

SUBJECT	PHYSICS
LEARNING STANDARDS (OBJECTIVE)	At the end of the lesson, students will be able to define Keplers' Law III
TIME	8.00-9.00
ACTIVITY	1. Students will be asked to work in pairs to navigate the first lessons Keplers' Law III. 2. They will be work in pairs on navigating the simulations AR and video in Keplers' Law III. 3. Then they will be navigating the video on introduction on escape velocity. 4. The students will do presentation in pairs about Keplers' Law III. 5. The students will do presentation in pairs.

Figure 3: Proposed learning activity for Keplers' Law III that applies the the Cognitive Theory of Multimedia Learning (CTML), self-directed learning approach, audio-visual technology elements and augmented reality.

SUBJECT	PHYSICS
LEARNING STANDARDS (OBJECTIVE)	At the end of the lesson, students will be able to define escape velocity and solve problems in calculation on escape velocity
TIME	8.00-10.00
ACTIVITY	1. Students will be asked to work in pairs to navigate the first calculation video on escape velocity. 2. They will be work in pairs on navigating the video in second video on calculations. 3. Then they will be asked to work in pairs in solving problems. 4. The students will do presentation in pairs and present on how they solve the problems with the correct calculation. 5. The students will do prepare the presentation using their mobile phone.

Figure 4: Proposed learning activity for Keplers' Law I and Law 2 that apply the the Cognitive Theory of Multimedia Learning (CTML), self-directed learning approach, technology and augmented reality.

Discussion and Conlusion

The use of augmented reality technology in education shows that it has a favorable effect on students' science course achievement (Cai et al., 2013; Cankaya, 2018; Fidan & Tuncel, 2019). Additionally, it has been discovered that AR applications help with idea comprehension and lessen misconceptions (Sırakaya & Alsancak Sırakaya, 2022; Yen et al., 2013). The use of resources like experiments, model building, and project development has a beneficial impact on students' cognitive development (Aygun, 2019). Videos, audios and animation will also help in assisting the students in imagining. Embracing AR as one of its technology tools, it allows for the integration of learning into play areas, homes, and daily interaction with others in addition to traditional classroom settings (Badilla-Quintana et al., 2020). SDL approaches has also help in assisting a meaningful learning environment. A manual on SDL to assist a learning also show positive response towards validation on the usefulness of the module (Yee Mei Heong et al., 2013). The findings of the effectiveness analysis demonstrated that enhancing students' self-directed learning is a proven benefit of the atomic physics teaching materials (Erlina et al., 2022). The study in Indonesia is being done among 121 students in school in Indonesia.

Similarly, the application of Cognitive Theory of Multimedia Learning (CTML) is also very relevant with the design process and content development in education (Amiruddin et al., n.d.). It is in line with a study in design and development of m-module in activity learning (Amani Dahaman, 2014). Hanan Ahmed Aifan (2023) investigated how students' instructional video designs benefit from incorporating Mayer's Multimedia Design Principles. The students were given the task of using iMovie to make educational videos that was integrated with Mayer's Multimedia Design Principles. It shows that the students were able to raise their video quality and score greater in achievement due to the instructional video integrating those principles (Hanan Ahmed Aifan, 2023). Thus, the principles of CTML, i.e., Coherence Principle, Signalling Principle, Redundancy Principle, Spatial Contiguity Principle and

Temporal Contiguity Principle may serve as a guide or framework for developing an effective learning materials and environment that would help students to attain learning outcomes in Physics. Specifically learning materials that integrate audio, visual, animations and AR would be beneficial for students learning in Physics because the use of such materials in classroom learning would provide a more dynamic, interactive and fun learning experiences for the students.

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