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Research Article

DEVELOPMENT OF DIGITAL TECHNOLOGY LEARNING MEDIA FOR PHYSICS ON SIMPLE HARMONIC MOTION USING INTERACTIVE SIMULATION VIA THE OBEC CONTENT CENTER FOR GRADE 11 STUDENTS

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Abstract

The purposes of this research were to, 1) develop digital technology learning media for Physics 3 on the topic of Simple Harmonic Motion using interactive simulation via the OBEC Content Center, 2) evaluate the efficiency and effectiveness of the developed media, and 3) assess students' satisfaction towards using the media. The sample consisted of 72 Grade 11 students from Longwittaya School under the Phrae Secondary Educational Service Area Office. The learning media was developed by integrating Artificial Intelligence as an assistant, utilizing the 5E learning model, and applying active learning principles. The results revealed that the developed digital media achieved a validity score of 1.0 from experts. The efficiency of the process and the result (E1/E2) was 80/79, which met the specified 75/75 criteria. After utilizing the media, 100% of the students passed the post-study assessment criteria. The students' post-test learning achievement was significantly higher than their pre-test scores at the .05 statistical level, with an effectiveness index of 0.6458. Furthermore, the distribution of post-test scores was more consistent than the pre-test scores, indicating that the interactive simulation effectively reduced learning inequality and universally elevated student learning outcomes.

Keywords: Digital Technology Media, Interactive Simulation, Simple Harmonic Motion, Artificial Intelligence, OBEC Content Center

Introduction

Rapid technological advancement and digital transformation have substantially changed the nature of teaching and learning in the twenty-first century. Contemporary education increasingly emphasizes the effective integration of digital technologies to support active participation, higher-order thinking, problem solving, and self-directed learning (Hew & Brush, 2007, Means et al., 2013). This transformation is particularly important in science education, where learners are expected not only to acquire factual knowledge but also to interpret evidence, connect scientific concepts with observable phenomena, and apply knowledge to authentic situations. In Thailand, the integration of digital technology into education is also consistent with national policies on human resource development and digital education, which encourage educational institutions to expand access to high-quality digital learning resources and develop learners' competencies for a technology-driven society. Physics is one of the subjects in which digital technology can play an important instructional role because many physics concepts are abstract and involve simultaneous conceptual, mathematical, and graphical representations. Students often experience difficulty connecting equations and theoretical principles with observable physical phenomena (Rutten et al., 2012, Smetana & Bell, 2012). Simple harmonic motion (SHM), an important topic in upper-secondary physics, illustrates this challenge. Understanding SHM requires learners to recognize relationships among displacement, acceleration, period, frequency, amplitude, force, and energy and to interpret these relationships through mathematical equations and graphical representations. Students may therefore develop fragmented knowledge or misconceptions when learning relies primarily on verbal explanation, static diagrams, or mathematical manipulation without opportunities to visualize dynamic relationships (Wieman et al., 2008, Zacharia & Olympiou, 2011). A preliminary review of Grade 11 learning outcomes at Longwittaya School indicated that students required further development in their understanding of SHM, particularly in connecting theoretical concepts with physical motion and interpreting graphs that represent relationships among relevant variables. Several instructional limitations were identified. First, the abstract and dynamic nature of SHM makes it difficult for learners to visualize changes in displacement, velocity, and acceleration simultaneously. Second, conventional laboratory activities may be constrained by limited instructional time, equipment availability, experimental measurement errors, and differences in students' practical skills. Third, students frequently encounter difficulty connecting mathematical equations with physical phenomena. Finally, individual differences in learning pace and prior knowledge create a need for learning resources that allow repeated exploration and self-directed practice. These challenges suggest that instructional approaches enabling learners to actively manipulate variables, observe immediate outcomes, and connect multiple representations may improve conceptual understanding. Interactive simulations have been widely recognized as useful tools for addressing these challenges. They enable learners to change parameters, observe dynamic responses, repeat experiments, and explore scientific relationships that may be difficult to demonstrate through conventional laboratory activities. Previous studies have reported that well-designed simulations can reduce the abstractness of physics concepts, promote conceptual understanding, increase learner engagement, and facilitate self-directed exploration (Adams et al., 2008, Podolefsky et al., 2010; Rutten

et al., 2012). Simulations are particularly valuable for SHM because they can simultaneously display physical motion, numerical values, equations, and graphs, thereby helping learners construct relationships among different forms of scientific representation. However, the educational benefits of simulations depend not only on technological functionality but also on the pedagogical framework through which learners interact with the media.

For this reason, the digital learning media developed in the present study were grounded in Constructivism, Active Learning, Multimedia Learning Theory, Blended Learning, and the 5E instructional model. Constructivist perspectives emphasize that learners actively construct knowledge by connecting new experiences with existing cognitive structures, while Active Learning encourages meaningful participation through observation, investigation, discussion, analysis, and problem solving (Chi, 2009, Freeman et al., 2014, Prince, 2004). The 5E model—Engagement, Exploration, Explanation, Elaboration, and Evaluation—provides a systematic learning sequence in which students are first stimulated to identify scientific questions, subsequently investigate phenomena, construct explanations, apply newly developed understanding, and evaluate their learning. This instructional structure is therefore well suited to simulation-based physics learning because students can explore the relationships among variables before formal explanations are introduced. Multimedia Learning Theory further provides an important foundation for the design of digital learning environments. According to Mayer (2009), meaningful learning can be enhanced when verbal and visual information is appropriately coordinated and presented in ways that support learners' cognitive processing. Digital simulations can combine animation, numerical information, graphical representations, explanatory text, and interactive controls within a unified learning environment. When these components are systematically designed, they can help learners select relevant information, organize it into coherent mental representations, and integrate it with prior knowledge (Clark & Mayer, 2016). Previous studies in both international and Thai educational contexts have similarly reported that appropriately designed digital and multimedia learning resources can improve academic achievement, conceptual understanding, learner engagement, and satisfaction. In addition to interactive simulation, artificial intelligence (AI) has created new possibilities for the design and development of educational media. AI-based tools can assist developers in generating ideas, organizing instructional content, designing user interfaces, generating and debugging programming code, and refining learning materials through iterative development processes (Holmes et al., 2019, Zawacki-Richter et al., 2019). In the present study, Claude AI was used as a development assistant for interface design, programming, problem solving, and iterative refinement. Its use was intended to support the efficiency of the media development process rather than replace pedagogical decision making by the researcher. Through AI-assisted development, the researchers were able to rapidly design and revise the simulation interface, real-time calculation functions, graphical displays, and automated reporting features. The development period was consequently reduced from an estimated two to three months using a conventional development process to approximately one and a half months. Despite the growing use of digital simulations and AI in education, an important research gap remains regarding the systematic integration of AI-assisted media development, interactive physics simulation, established learning

theories, and a national digital content platform within a single instructional intervention. Previous studies have commonly examined simulations as instructional tools or AI as a support mechanism separately. Less attention has been paid to how generative AI can facilitate the development of interactive simulation-based media that are explicitly grounded in Constructivism, Active Learning, Multimedia Learning Theory, Blended Learning, and the 5E model and subsequently delivered through an established educational platform such as the OBEC Content Center. Furthermore, relatively limited empirical evidence is available regarding the effectiveness of such integrated media for learning SHM among Thai upper-secondary students. This study therefore addresses both an instructional problem and a media-development gap by designing an interactive learning environment in which pedagogy, simulation technology, AI-assisted development, and digital accessibility are systematically combined. The developed digital learning media focused on Physics 3 content related to simple harmonic motion and were designed to allow students to manipulate relevant physical variables, observe simulated spring and pendulum motion, examine real-time numerical and graphical changes, and connect mathematical relationships with physical phenomena. Learning activities were structured according to the 5E model to encourage learners to engage with scientific problems, investigate relationships among variables, construct explanations from evidence, apply their understanding to related situations, and evaluate their learning. The media also incorporated automated recording and reporting functions to support systematic learning and experimental data analysis. Distribution through the OBEC Content Center further provides the potential for broader access to learning materials beyond a single classroom and supports the national objective of reducing disparities in access to quality educational resources.

Accordingly, the present study sought not merely to develop a technological instructional product but to examine whether an integrated digital learning environment could provide measurable educational benefits. The evaluation therefore considered three complementary dimensions instructional efficiency and effectiveness, physics learning achievement, and student satisfaction. Media efficiency was assessed using the E1/E2 process–outcome criterion of 75/75, while students' learning achievement was examined by comparing pre-test and post-test performance. Student satisfaction was also investigated to determine learners' perceptions of the usability, appropriateness, and overall learning experience provided by the developed media. Evaluating these dimensions together provides a more comprehensive assessment of whether the instructional media are pedagogically effective, technically usable, and practically appropriate for classroom implementation. Therefore, the objectives of this study were (1) to develop digital technology-based interactive simulation media for Physics 3 on simple harmonic motion for Grade 11 students through the OBEC Content Center; (2) to evaluate the efficiency and effectiveness of the developed media using the E1/E2 criterion of 75/75; (3) to compare students' physics learning achievement before and after learning with the developed media; and (4) to investigate students' satisfaction with the developed digital learning media. The findings are expected to provide empirical evidence concerning the integration of interactive simulation, theoretically grounded instructional design, and AI-assisted media development in upper-secondary physics education. In addition, the development approach may serve as a practical model for teachers and instructional developers

seeking to create high-quality digital learning resources more efficiently and disseminate them through national digital learning platforms for wider educational use.

Objectives

1. To develop digital technology learning media for Physics 3 on Simple Harmonic Motion using an interactive simulation for Grade 11 students via the OBEC Content Center.
2. To evaluate the efficiency and effectiveness of the developed digital technology learning media for Physics 3 on Simple Harmonic Motion using an interactive simulation for Grade 11 students via the OBEC Content Center.
3. To assess students' satisfaction with the developed digital technology learning media.

Hypotheses

1. The developed digital technology learning media for Physics 3 on Simple Harmonic Motion using an interactive simulation via the OBEC Content Center would meet the 75/75 efficiency criterion.
2. Students' post-test learning achievement would be higher than their pre-test achievement after learning with the developed digital media.
3. Students' satisfaction with the digital media would be at a high level or above, with a mean score of at least 4.00 out of 5.00.

Conceptual Framework

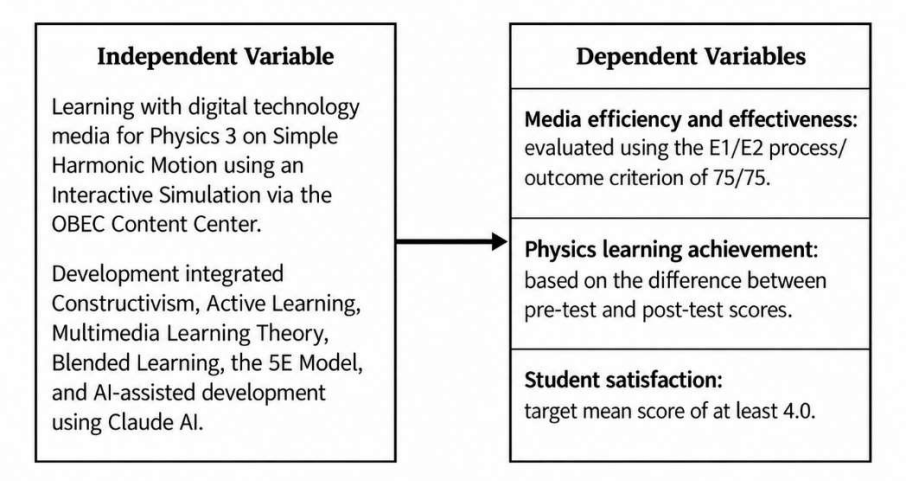


Figure 1. Conceptual framework of the study.

Methodology

The media development process was conducted in four phases, Phase 1, study and planning (2 weeks), Phase 2, media development (3 weeks), Phase 3, testing and revision (1 week), and Phase 4, implementation and evaluation (2 weeks). The process consisted of five sequential steps. Shown in Figure 2.

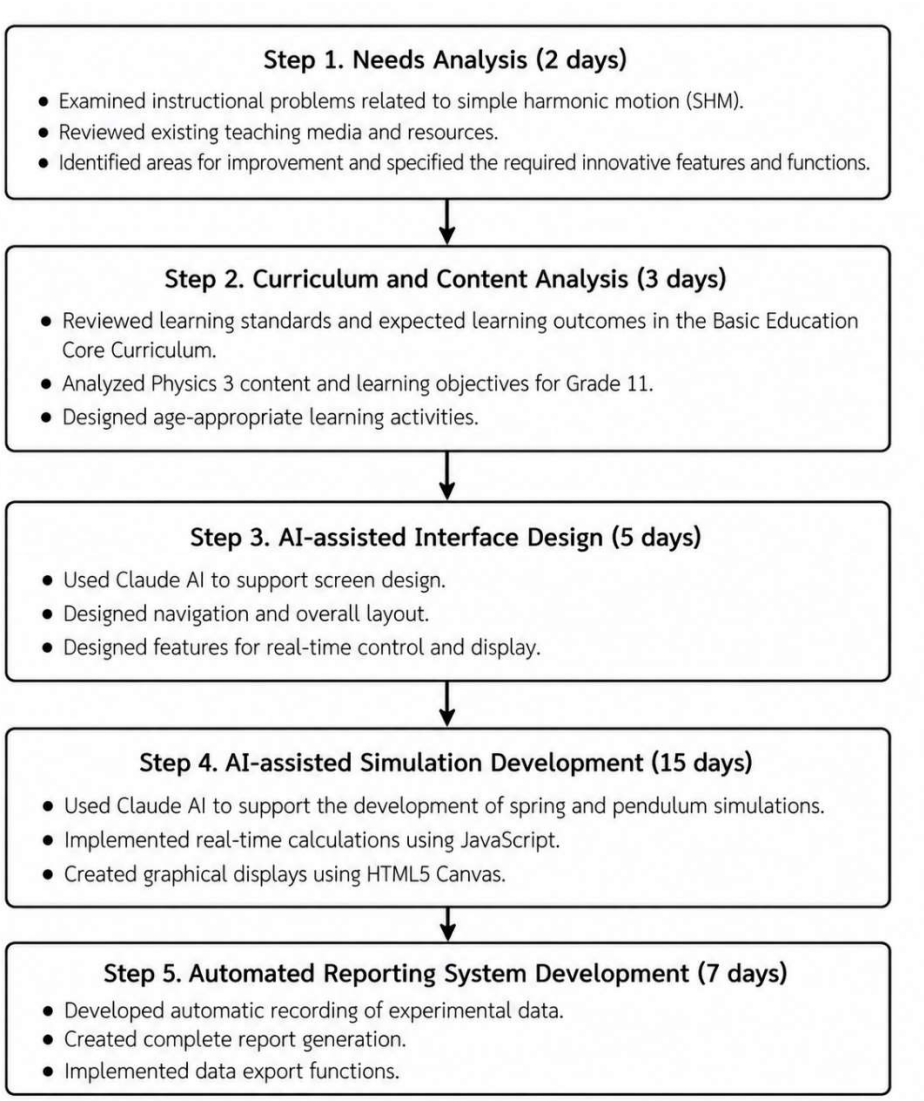


Figure 2. Flowchart of SHM Learning Media Development Process.

The media were then prepared for publication on the OBEC Content Center. This process included preparing a clear media description, cover and preview images, and an infographic user guide, registering and uploading the media files and supporting documents, entering complete and accurate metadata, and undergoing system and expert review. Revisions were made as needed before approval for publication.

The simulation was developed to align with the Basic Education Core Curriculum B.E. 2551 (A.D. 2008), revised in B.E. 2560 (A.D. 2017). The content covered the characteristics of simple harmonic motion,

displacement, velocity, acceleration, a mass-spring system, a simple pendulum, natural frequency, and resonance. The media were designed for upper-secondary students aged 16–18 years. Design considerations included the learners' level of abstract thinking, supported by graphical representations, interest in technology, supported by a modern and user-friendly interface, and the need for learner autonomy, supported by self-directed control of learning.

The media design was guided by User Experience (UX) principles, including ease of use, a low learning curve, clear organization, and appropriate use of colors and fonts. Real-time feedback was provided so that changes were displayed immediately when users adjusted parameters, giving clear and useful feedback. Scaffolding was used to organize learning tasks from basic to more complex levels, with guidance and examples provided as needed.

Media quality was evaluated through functional testing, usability testing, and content validation. Functional testing examined the operation of all features and the accuracy of calculations. Usability testing involved trial use by sample students, collection of feedback, and subsequent revision. Content validation focused on academic accuracy and review by expert teachers. Key innovative features included one-click automated experiment reports, real-time display of position, velocity, and acceleration, data export, dual simulations of both spring and pendulum systems within one platform, AI-assisted development using Claude AI for coding and troubleshooting, and accurate parameter control. Unlike conventional media that mainly display information, this system provides complete data management and reporting functions that can be used for assessment in and outside the classroom. The media were evaluated by five experts and revised before implementation with the target group.

Results

The quality evaluation showed that the developed digital technology learning media for Physics 3 on Simple Harmonic Motion using an interactive simulation via the OBEC Content Center achieved a validity score of 1.0, indicating that the media were suitable for use. Key expert recommendations included adding a real-time displacement graph to strengthen students' understanding of SHM equations, providing additional physics explanations within the experimental display, and improving the arrangement of control buttons for practical use. The efficiency and effectiveness of the developed media were evaluated according to established criteria, as shown in Table 1.

Table 1. Comparison of process efficiency and outcome efficiency.

N	During learning				Post-test				E1/E2
	Full score	$\bar{x}$	SD	E1	Full score	$\bar{x}$	SD	E2	
72	10	8	0.95	80	10	7.9	1.15	79	80/79

Interpretation: The innovation achieved an efficiency (process/outcome) of 80/79.

As shown in Table 1, the developed simulation achieved process and outcome efficiencies (E1/E2) of 80/79, exceeding the required 75/75 criterion. This result may be attributed to the integration of Constructivism, Active Learning, and the 5E model, which encouraged students to construct knowledge through hands-on interaction with the media. The real-time feedback system also displayed changes immediately after parameter adjustments, allowing students to receive clear feedback during learning. Thai studies by likewise reported that PhET simulations can improve conceptual understanding in physics and reduce misconceptions.

The efficiency of the developed digital learning media was evaluated using the E1/E2 criterion, whereas its effectiveness was evaluated using the Effectiveness Index (E.I.). The obtained efficiency value was E1/E2 = 80/79, which exceeded the predetermined criterion of 75/75. The E1 value of 80 indicates that students achieved an average score of 80% during the learning process, including learning activities, exercises, and formative tasks, while the E2 value of 79 indicates that students achieved an average score of 79% on the post-learning assessment. These results demonstrate that the developed media were efficient in supporting both the learning process and the resulting learning outcomes.

Table 2. Percentage of students who passed and did not pass the post-test criterion.

N	Full score	Below criterion		At/above criterion	
		Number	Percentage	Number	Percentage
72	10	0	0	72	100

Interpretation: 100% of students met the criterion after using the innovation.

As shown in Table 2, all 72 students (100%) met the post-test criterion after using the media. This result suggests that interactive simulations can effectively support learning of abstract physics content involving complex mathematical equations. By transforming abstract concepts into real-time graphical representations that students can visualize and control, the simulation helped overcome some limitations of traditional laboratory experiments. As shown in Table 3, the standard deviation decreased from 1.85 before learning to 1.15 after learning, indicating that post-test scores were more consistent. This suggests that the simulation may help reduce differences in learning outcomes and support broader access to effective learning, consistent with the goals of the OBEC Content Center.

Table 3. Distribution of pre-test and post-test scores.

N	Full score	Below criterion		At/above criterion	
		$\overline{x}$	SD	$\overline{x}$	SD
72	10	4.8	1.85	7.9	1.15

Table 4. Comparison of pre-test and post-test scores.

N	Mean score		Effectiveness index	t-test
	Pre-test	Post-test		
72	4.8	7.9	0.6458	15.236*

Critical t at the .05 level, df = 71, is 1.697, the result is statistically significant.

As shown in Table 4, the mean post-test score (7.9) was significantly higher than the mean pre-test score (4.8) at the .05 level (t = 15.236). The effectiveness index was 0.6458, indicating clear learning improvement. These findings are consistent with Adams et al. (2008), who reported that interactive simulations increase engagement and support independent exploration, and with Podolefsky et al. (2010), who found that simulations promote deeper exploration of abstract concepts. that simulation-based multimedia improved learning efficiency and understanding. More broadly, Adams et al. (2008), Podolefsky et al. (2010), Rutten et al. (2012), and Smetana and Bell (2012) reported positive effects of simulations on learning, particularly for complex and abstract topics such as SHM. The Effectiveness Index of 0.6458 represents the degree of learning improvement achieved after using the developed media. This value indicates that students achieved approximately 64.58% of the maximum possible improvement from their pre-test performance toward the full score. Therefore, the E.I. reflects the effectiveness of the media in promoting students' learning progress, whereas the E1/E2 values reflect the efficiency of the instructional process and outcomes. Distinguishing these two indicators provides a clearer interpretation of the results and directly corresponds to the second research objective concerning the efficiency and effectiveness of the developed digital learning media.

Discussion

The media achieved an efficiency of E1/E2 = 80/79, which was higher than the required criterion. This result may be explained by the integration of Constructivism and the 5E learning model with interactive simulation technology. Real-time feedback allowed students to monitor their understanding and correct errors during the learning process (E1), which likely contributed to improved learning outcomes (E2). Multimedia learning research suggests that learners process information more effectively when images and text are appropriately integrated (Mayer, 2009, Clark & Mayer, 2016). In Thailand, reported that multimedia can improve learner understanding and satisfaction, while found a high level of satisfaction with digital media.

The significant improvement in learning achievement and the 100% post-test pass rate may be explained by the ability of the simulation to make the abstract and mathematically complex topic of SHM more visible and understandable. Students could observe displacement, velocity, and acceleration together with simulated spring and pendulum motion, helping them connect theory with real phenomena. This finding is consistent with Adams et al. (2008) and Podolefsky et al. (2010), who reported that interactive simulations increase engagement and promote deep learning in abstract topics. Active Learning has also been shown to improve academic achievement (Freeman et al., 2014), while Prince (2004) and Chi (2009) emphasized that

active learner engagement is important for knowledge construction. In the Thai context, reported that the 5E model and Active Learning improved students' thinking skills and achievement. Interactive and online learning have also shown positive effects on achievement (Hake, 1998, Means et al., 2013), while reported improved achievement and satisfaction from digital learning media.

Another notable finding was that post-test scores were less dispersed than pre-test scores. This may indicate that the interactive simulation supported more consistent learning outcomes by allowing students to learn at their own pace and according to their individual abilities. The system was designed to be easy to access and use, enabling lower-performing students to review the content as needed. This finding is consistent with the OBEC Content Center's goal of reducing educational inequality and improving access to quality learning resources. AI may also support personalized learning and improve learning efficiency (Holmes et al., 2019, Zawacki-Richter et al., 2019). reported that AI-assisted media development can improve efficiency and reduce development time.

Conclusion

This study developed and evaluated digital technology learning media for Physics 3 on Simple Harmonic Motion using an interactive simulation via the OBEC Content Center. The developed media achieved process and outcome efficiencies (E1/E2) of 80/79, exceeding the required 75/75 criterion. All students (100%) met the post-test criterion. The mean post-test score (7.9) was significantly higher than the mean pre-test score (4.8) at the .05 level ($t = 15.236$). The effectiveness index was 0.6458, indicating clear learning progress. The post-test score distribution was also lower ($SD = 1.15$) than that of the pre-test scores ($SD = 1.85$), suggesting more consistent understanding among students after using the media.

Recommendations

1. Recommendations for Practical Application

1.1 Teachers should ensure that devices and Internet connections are ready before using the media so that the interactive simulation and real-time feedback functions operate effectively.

1.2 Teachers should act as facilitators, use guiding questions, and allow students to adjust different parameters in accordance with the 5E learning model.

1.3 The media can be used for review or remedial instruction to improve students' understanding and increase learning opportunities.

2. Recommendations for Future Research

2.1 Future studies should develop simulation-based media for other physics topics, such as electrostatics, electromagnetism, and atomic physics.

2.2 Future research should examine additional outcomes, such as learning retention, analytical thinking, and problem-solving skills.

2.3 AI should be integrated to support personalized learning and provide feedback tailored to individual learners.

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