Analysis of the Effectiveness of Digital Transformation in Maritime Context-Based Kinematics Learning

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Abstract
This study aims to determine the effectiveness of digital transformation in maritime context-based kinematics learning. The study used a quantitative method, with a pretest–posttest one-group design with eleventh-grade high school students as subjects. Learning was conducted using QR-code-based worksheets (LKPD) that directed students to various digital resources, such as learning videos, Google Maps, and the Encyclopedia Britannica, through problem-solving stages (problem orientation, investigation, presentation, and reflection). Data were obtained through learning outcome tests (pretest and posttest). The Shapiro–Wilk normality test showed normally distributed data (sig > 0.05), and the homogeneity test showed a homogeneity (sig = 0.464). The one-sample t-test showed a p-value of 0.000 (<0.05), with a posttest average of 76.57, which is higher than the minimum completeness criteria (KKM) of 70. The proportion test showed that more than 80% of students achieved learning mastery. This study has significantly demonstrated the effectiveness of digital transformation in maritime context-based kinematics learning.

Keywords*: effectiveness, kinematics, maritime context, digital transformation*

Abstrak
Penelitian ini bertujuan untuk mengetahui efektivitas transformasi digital dalam pembelajaran kinematika berbasis konteks maritim. Kajian ini menggunakan metode penelitian kuantitatif, dengan desain Pretest–Posttest One Group Design dengan subjek siswa kelas XI SMA. Pembelajaran dilaksanakan menggunakan LKPD berbasis QR-Code yang mengarahkan siswa menuju beragam sumber digital seperti video pembelajaran, Google Map, dan Ensiklopedia Britannica melalui tahapan problem solving (orientasi masalah, penyelidikan, presentasi, dan refleksi). Data diperoleh melalui tes hasil belajar (pretest dan posttest). Hasil uji normalitas Shapiro–Wilk menunjukkan data berdistribusi normal (sig > 0.05) dan uji homogenitas menunjukkan data homogen (sig = 0.464). Hasil One Sample t-Test menunjukkan nilai signifikansi 0.000 (< 0.05) dengan rata-rata posttest 76.57 lebih tinggi dari KKM 70. Uji proporsi menunjukkan lebih dari 80% siswa mencapai ketuntasan belajar. Penelitian yang dilakukan telah menunjukan secara signifikan bahwa transformasi digital dalam pembelajaran kinematika berbasis konteks maritim terbukti efektif digunakan.

Kata Kunci*: efektivitas, kinematika, konteks maritim, transformasi digital*

INTRODUCTION

The contemporary educational process in schools predominantly focuses on knowledge transmission, in which the educator serves as the primary source of information, while the student's role is largely confined to passive knowledge reception. This educational approach frequently results in pupil passivity, rendering learning devoid of significance. Consequently, the material provided is inapplicable to quotidian existence. Student disengagement in the educational process may lead to a superficial understanding of the subject matter and difficulties in relating scientific principles to practical applications. Evaluation of the Efficacy of Digital Transformation in Contextual Kinematics Education within the Maritime Sector.

The marine setting offers a diverse learning environment that can effectively connect science to reality. The marine environment serves as a foundation for contextual learning, especially in kinematics, including distance, speed, and journey time. By connecting learning to maritime phenomena, students not only comprehend concepts mathematically but also relate them to contemporary challenges such as energy efficiency and sustainable maritime transportation. The swift advancement of digital technology requires the educational sector to undergo a digital transformation to maintain the relevance of learning in contemporary society. Digital learning facilitates interactive, flexible, and autonomous education using many online resources. Digital learning promotes the acquisition of digital literacy, a key competency of the 21st century. A learning paradigm that prioritizes students in the learning process is essential for achieving meaningful, contextual learning. A pertinent methodology is Problem-Based Learning (PBL). This model prioritizes advanced cognitive processes by addressing real-world challenges.

Successful educational transformation in higher education can be achieved through the use of eLearning and bLearning modalities, which complement face-to-face methods (Galvis & Carvajal, 2022). Online learning for maritime subjects in vocational high schools in Indonesia is effective, with digital literacy and perceived effectiveness of online learning being key predictors of student understanding (Sulistyono et al., 2024). Digital transformation in maritime education, particularly in kinematics learning, has brought about a significant shift from traditional methods to technology-based approaches. The use of blended learning, AR, and VR consistently improves students' conceptual understanding, practical skills, and learning motivation. These technologies enable visualization and simulation of real-world situations at sea, thus bridging the gap between theory and practice. Transportation technology utilizes the principles of force to improve efficiency and safety. From land vehicles such as cars, sea vehicles such as ships, to air vehicles such as airplanes, the application of force is crucial in their design and operation. Teachers' digital competence significantly influences the adoption and effectiveness of technology in learning. Teachers' digital competencies positively influence technology adoption in maritime vocational education, leading to increased perceived usefulness, ease of use, behavioral intentions, and actual implementation (Widiatmaka et al., 2024). Teacher preparation for the digital era focuses on digital competencies, including general, instructional, and professional digital competencies (Starkey, 2020). Digital tools can enhance human resource development in the maritime sector, but challenges such as security, skills gaps, and regulatory compliance require a comprehensive strategy (Autsadee et al., 2023). Teachers' skills in designing teaching materials, adopting new technologies, and adapting to the full digital transformation are key factors in contemporary educational services. While it is known that offline learning has been contaminated by digital technologies, such as smartboards, projectors, internet access, and computers, students can quickly obtain necessary information and search for additional materials in real time (Iskandar et al., 2023). While 55% of junior high school science teachers in Tanjungpinang City, Riau Islands, Indonesia, have not integrated maritime contexts into their science instructional media, some have (Asikin et al., 2022). This prompted the authors to examine kinematics learning delivered through a maritime context.

The advancement of technology has profoundly influenced the education sector, especially with the emergence of e-learning, which offers a more adaptable and efficient teaching and learning experience. In the instruction and acquisition of physics, especially regarding intricate subjects like kinematics, e-learning possesses significant potential to address the constraints of conventional pedagogical methods, including restricted class duration and limited access to laboratory resources (Dewi et al., 2023). Kinematics material frequently poses difficulties for students because of its abstract characteristics and the requirement for profound conceptual comprehension (Buma et al., n.d.). The author's interest in examining kinematics

material was also stimulated by these issues within a nautical context. Technology is catalyzing substantial transformations in the education sector, serving as a crucial element in enhancing the efficacy of teaching and learning processes (Manek & Butar-Butar, 2024). The utilization of digital technology is essential in endeavors to reinvent teaching and learning practices to enhance the efficacy of classroom activities. Digital technology, including online educational platforms, interactive software, and artificial intelligence gadgets, positively influences the efficacy of teaching and learning activities. Technology can enhance student engagement, broaden access to educational resources, and facilitate teaching and learning methods tailored to individual need. Numerous interactive aspects in digital platforms have demonstrated efficacy in promoting active engagement and collaboration among students. Moreover, research has identified difficulties requiring attention, such as disparities in access to digital technology, inadequate infrastructure, and the necessity for teacher training to optimize technology use (Sari & Munir, 2024). The utilization of media and technologies, including video and animation, can enhance the efficacy of teaching and learning activities. Videos facilitate students' learning of material through increasingly interactive and engaging methods, hence enhancing understanding and information retention (Sari & Munir, 2024). Interactive e-learning enhances student engagement in educational activities, as participation can occur directly through accessible simulations and animations (Buma et al., n.d.). Maritime-themed interactive learning movies can enhance comprehension of the Pythagorean theorem (Deanto, 2023).

Multiple arguments have been presented concerning the ongoing evolution of digital transformation, emphasizing the necessity of including a maritime context to enable students to recognize the relevance of the challenges they encounter to their daily lives. The learning conducted in this study pertains to the kinematics sub-chapter. This study aims to assess the efficacy of digital transformation in the context of maritime kinematics education. This project aims to enhance the creation of creative teaching and learning strategies by incorporating digital technology, local context, and problem-solving methodologies to create meaningful and relevant education that addresses 21st-century concerns.

METHOD

This study employs a quantitative research methodology that utilizes numerical data to assess variables and evaluate theories or hypotheses. The primary aim is to empirically test hypotheses, assess correlations among variables, or objectively evaluate the efficacy of an intervention, allowing for retesting. This research is a quasi-experimental study with a single-group design without a control group (Arikunto, 2013). This study evaluates the efficacy of digital transformation in maritime context-based kinematics learning using a pretest-posttest one-group design, a pre-experimental framework that includes a pretest (administered prior to treatment) and a posttest (administered following treatment) within a single group (Sugiyono, 2013). The research subjects were divided into two groups, each comprising 30 pupils. Subject randomization was conducted using Cluster Random Sampling. This is due to the uniform characteristics of the research subjects. Both classes received instruction in Maritime Context-Based Kinematics Learning.

The effectiveness will be assessed using the outcomes of the pretest and posttest administered to both classes. Data analysis employing descriptive statistics: calculating the mean, standard deviation, minimum, and maximum values for pre-test and post-test data. Prerequisite Evaluation Examination: Shapiro-Wilk test for data normality. Due to the sample size being less than 100, the test is used to verify the data's normal distribution. Hypothesis testing is conducted using two methods: the one-sample t-test and the Proportion Test. The

one-sample T-test assesses whether the mean of a single sample is greater than or equal to 70, the minimum threshold for school completion, whereas the proportion test evaluates whether at least 80% of students attain a score of 70 on the post-test. Consequently, digital-based learning is deemed efficient if 80% of pupils attain a minimum score of 70.

DISCUSSION

The study's results demonstrate that Digital Transformation in Maritime Context-Based Kinematics Learning can markedly enhance student learning outcomes. The educational model employed is grounded in a problem-solving methodology, facilitated by QR-Code-integrated digital LKPD (Worksheets) that guide students to diverse learning resources, including instructional videos on social media, Google Sites, geographic data via Google Maps, and the Encyclopedia Britannica as a scholarly reference. The amalgamation of these many digital resources enhances the essence of 21st-century education, specifically collaborative, contextual, and digital literacy-focused learning.

The stages of problem-solving learning, encompassing problem orientation, inquiry, presentation, and reflection, were successful. During the issue orientation phase, students encountered a real-world scenario about a journey from Teluk Dalam Port (Nias) to Tamtave Port (Madagascar). This issue sparked students' interest and necessitated applying distance, speed, and time principles within the framework of sustainable maritime transportation. The investigation phase emerged as the central component of the scientific reasoning process, as students employed digital technology to acquire geographic coordinate data from Google Maps and compute distances utilizing the haversine formula. Students subsequently computed flight time utilizing fundamental kinematics equations. This procedure concurrently enhanced numeracy, digital, and scientific literacy skills. Subsequently, during the presenting phase, students articulated their calculations and analyses through collaborative conversations. This phase promoted scientific discourse, analytical reasoning, and cooperation. The reflection stage was employed to examine conceptual inaccuracies and problem-solving methodologies, thereby enhancing comprehension of kinematic principles within a marine framework.

A fundamental assumption in parametric statistical analysis is that the data must exhibit a normal distribution. Consequently, the pretest and posttest data were initially analyzed to ascertain their distribution characteristics utilizing SPSS software. The outcomes of this normalcy assessment are detailed in the subsequent section to ascertain the suitability of employing parametric tests in the data analysis of this study.

Tabel 1. Normality Test

	Kolmogorov-Smirnov			Shapiro-Wilk		
Class	Statistic	df	Sig.	Statistic	df	Sig.
Pretest Kelas XI-6	0.175	30	0.019	0.961	30	0.328
Posttest Kelas XI-6	0.144	30	0.112	0.967	30	0.454
Pretest Kelas XI-7	0.131	30	0.197	0.972	30	0.591
Posttest Kelas XI-7	0.177	30	0.18	0.949	30	0.157

A normality test was performed utilizing the Shapiro–Wilk method, based on the pretest and posttest data. The test findings indicate that all data (pretest and posttest for classes XI-6 and XI-7) achieved a significance value over 0.05, signifying that the data were regularly distributed. Following the establishment of normal distribution of the data, a prerequisite for the subsequent parametric test, a homogeneity test was performed to ascertain whether the variances of the data from the two classes utilized as study subjects were equivalent. Table 2 presents the outcomes of the homogeneity test.

Tabel 2. Homogeneity Test

	Levene Statistic	df1	df2	Sig.
Based on Mean	0.861	3	116	0.464
Based on Median	0.931	3	116	0.428
Based on Median and with adjusted df	0.931	3	114.689	0.428
Based on trimmed mean	0.878	3	116	0.454

The homogeneity test, yielding a significant value of 0.464 (>0.05), demonstrates that the data from both groups are homogeneous, hence permitting parametric analysis.

Following the fulfillment of preparatory tests, parametric tests were administered. The initial assessment was a one-sample t-test. The outcomes are as follows:

Tabel 3. *One-Sample Test*

One-Sample Statistic						
	N	Mean	Std.Deviation		Std.Error Mean	
Hasil Posttest	60	76.57	10.913		1,409	
One-Sample Test						
	t	df	Sig.(2-tailed)	Mean Difference	Lower	Upper
Hasil Posttest	4.661	59	0.000	6.567	3.75	9.39

A One Sample t-Test was subsequently performed with a test value of 70, representing the Minimum Completion Criteria. The findings indicated a significant value (2-tailed) of 0.000 (<0.05) and a posttest mean of 76.57. Consequently, H_0 was dismissed and H_1 was affirmed, signifying that the mean student learning results were markedly distinct and exceeded 70. This illustrates that digital learning enhances student outcomes in kinematics.

The second parametric analysis conducted was the proportion test. This proportion test was performed to ascertain that 80% of the total study subjects attained scores exceeding the Minimum Completion Criteria (KKM). Table 4 displays the results of the proportion test.

Tabel 4. Proportion Test

Descriptive Statistic						
	N	Mean	Std.Deviation	Minimum		Maximum
Hasil Posttest	60	76.57	10.913	45		98
Binommial Test						
		Category	N	Observed Prop.	Test Prop.	Exact Sig. (1-tailed)
Hasil Posttest	Group1	≤ 70	16	0.3	0.2	0.131
	Group2	> 70	44	0.7		
	Total		60	60		

This conclusion was substantiated by a percentage test, yielding a one-tailed significance value of 0.131 (> 0.05), signifying that over 80% of students attained a score exceeding the Minimum Competency (KKM) of 70. This indicates that the classical learning completion standard has been attained. The results affirm that the incorporation of digital media within marine situations in education might enhance comprehension of kinematics concepts.

The efficacy of digital learning in this study was attributed to numerous significant elements. The implementation of QR-Code-based worksheets offers pupils the autonomy to

autonomously access diverse and credible learning resources. This reinforces the notion of student-centered learning and enhances active student participation in the educational process. The marine context enhances the significance of learning by providing students with direct exposure to real phenomena pertinent to life and Indonesia's geographical potential as a maritime nation. This context corresponds with the approach of contextual learning that links scientific principles to daily life. The integration of digital learning and problem-solving cultivates advanced cognitive skills, including data interpretation, application of physics principles, and methodical problem-solving.

The findings of a pertinent study by Sulistyo, incorporating various prior research, indicate that online education for marine subjects in Indonesian vocational high schools is effective, with digital literacy and perceived effectiveness of online learning serving as the primary predictors of student comprehension (Sulistyono et al., 2024). The learning of kinematics is organized through digital transformation and has demonstrated efficacy.

This study pertains to the research by Manek and Sari, which asserts that technology is instigating substantial transformations in the education sector and is a crucial element in enhancing the efficacy of teaching and learning activities (Manek & Butar-Butar, 2024). The utilization of digital technology is essential for innovating teaching and learning activities to enhance the efficacy of classroom endeavors. Digital technology, including online educational platforms, interactive software, and artificial intelligence gadgets, positively influences the efficacy of teaching and learning activities. The utilization of media and technology, including video and animation, can enhance the efficacy of teaching and learning activities (Sari & Munir, 2024). The implementation of technology in maritime kinematics education has demonstrated efficacy in digital transformation.

Research has conclusively shown that digital revolution in maritime kinematics education is successful. This can enhance learning by offering diverse educational media through the integration of technology aligned with contemporary advancements. The study of physics, particularly kinematics, can be more diverse and engaging due to the incorporation of animated visual media, which may captivate students and enhance their motivation to learn. The kinematics material is connected to the nautical context, enabling students to perceive that the challenges provided extend beyond broad scenarios to include everyday living with marine subtleties. This presents a broader array of kinematics challenges that can be addressed, enhancing realism. Motivation will subsequently enhance the learning outcomes achieved. This also demonstrates to educators the necessity of adapting to technology and the diverse teaching and learning media employed, as they constitute a significant external element influencing the attainment of learning objectives. The school's internet facility can also incorporate input from external sources outside educators. This will enhance collaboration between internal factors (students) and external factors (educators, schools), leading to optimal learning results.

The incorporation of digital technology, including simulations, augmented reality (AR), virtual reality (VR), and online platforms, markedly improves the efficacy of maritime education. Digital simulations and technological applications have demonstrated their efficacy in augmenting the learning experience, refining practical skills, and equipping students to confront real-world difficulties in the maritime sector. The utilization of AR/VR facilitates a deeper and more participatory comprehension of kinematics ideas within a maritime framework for pupils. The utilization of digital media, including Learning Management Systems (LMS), Android applications, Virtual Reality (VR), and digital material (e.g., e-books, videos, websites), markedly enhances accessibility, flexibility, and educational outcomes for maritime students. A Moodle-based LMS has demonstrated enhancements in learning outcomes, improved access to materials, and reduced time and paper consumption for lecturers. The

advancement of VR media is regarded as highly effective, enhancing student interest and comprehension of marine environments. Students typically evaluate the development and utilization of digital content in project-based learning favorably, notwithstanding limitations such as restricted vocabulary and digital competencies. Metacognitive methods and collaborative teamwork facilitate the surmounting of these challenges. Maritime lecturers are regarded as proficient in digital media utilization, although they require enhancement in problem-solving skills inside online contexts. Digital learning media has demonstrated efficacy in marine lectures, enhancing student learning results, motivation, and engagement. Effective utilization necessitates digital training, interactive pedagogical approaches, and suitable media selection.

The study revealed that digital transformation has been implemented in the learning of kinematics sub-chapters through the integration of QR-Code-based LKPD, instructional videos, Google Maps, and the Encyclopedia Britannica. The integration of LKPD with QR-Code facilitates access to materials, assignments, and instructional films. Google Maps facilitates the accessibility of areas that require resolution in LKPD. The Encyclopedia Britannica website features resources and videos pertaining to the geographic coordinate system. The integration of various media constitutes a collaboration among mathematics, physics, and geography, which can be associated with daily living within a marine framework. This is essential for pupils to attain significant learning objectives. Students are not confined to problem-based learning; rather, there is a clear correlation to real-life situations in their daily experiences. The marine context is examined due to the ongoing deficiency of educators who connect real-world issues in maritime affairs to daily living. This reveals that kinematics, pertaining to motion, may be utilized in diverse contexts, including marine matters. Simulated kinematics principles may facilitate learning more effectively than traditional oral lectures.

Educators must innovate to enhance student learning results while also contemplating the significance of the learning process. Significant learning can initiate the formation of knowledge that requires interpretation rather than memorization. Thus, if students encounter various difficulties, they can resolve them utilizing the concepts and laws of physics previously studied. This will facilitate students' comprehension of kinematics, which has been seen as challenging to master. The research indicates the efficacy of digital transformation in the study of kinematics within a maritime context. This exemplifies how employing diverse learning material in conjunction with the maritime setting can serve as an alternative for instructors to attain significant learning objectives for pupils.

CONCLUSION

The use of technology in maritime kinematics education has demonstrated efficacy in enhancing student learning outcomes. The incorporation of QR code-based worksheets, instructional videos, Google Maps, and the Encyclopedia Britannica enhances the learning experience by providing greater context and significance.

The one-sample t-test indicates a significant p-value of 0.000 (<0.05) with a mean of 76.57, surpassing the Minimum Competency (KKM) of 70. Moreover, the proportion test indicates that over 80% of students have successfully completed the learning. Consequently, digital transformation learning media efficiently enhance students' conceptual understanding, critical thinking, and digital literacy, while concurrently fostering awareness of sustainable maritime transportation.

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