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RESEARCH ARTICLE

A Marine Knowledge System for Ocean Affairs: Integrating Data, Evaluating Usage, and Enabling Sustainable Marine Management

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Abstract

This study presents the evolution and assessment of the Marine Knowledge Education System (MKES), designed to improve user acceptance among students in professional marine science courses in Taiwan. The MKES leverages real-world maritime cases from the General Coast Guard Administration and is built upon existing technologies like cloud services, social networks, and data analysis tools. The technology acceptance model (TAM) provides the theoretical underpinning for the assessment of user confidence. Data was collected from 190 participants through purposive sampling. Path analysis confirmed all hypothesized relationships within the TAM with statistical significance ($p < 0.001$). Additionally, paired-sample t-tests revealed a significant increase in student acceptance of the MKES after integrating it into the marine science curriculum. These findings underscore the capacity of the MKES as a digital learning tool to enrich course pedagogy and improve student learning outcomes, thereby offering valuable support in advancing the education of professional marine managers.

Keywords: Information system, Marine management, Sustainability

1. Introduction

Although Taiwan has made commendable progress in integrating marine education into school curricula since 2011, and teaching materials on marine concepts are becoming increasingly available, a critical gap persists in the availability of resources that effectively facilitate the implementation of marine education. In particular, there is a dearth of comprehensive, interactive digital platforms designed to engage students and enhance their learning experiences in this multidisciplinary field encompassing marine science, environment, history, culture, and politics. Despite governmental efforts to promote marine education, this lack of robust digital tools hinders the holistic and immersive learning experiences necessary to foster a deep understanding and appreciation of the marine domain among students. The Marine Knowledge Education System (MKES) aims to address this gap by providing a comprehensive and interactive learning environment that leverages real-world maritime cases and the technology acceptance model (TAM) to enhance student engagement and knowledge acquisition.

More and more countries worldwide are emphasizing the importance of exploring and utilizing marine resources [1]. Developed nations such as America, Japan, Canada, and Australia have all devised marine development strategies accordingly [2,3]. Regarding marine education, a report issued by the United Nations in 1988 highlighted its importance for both specialized marine professionals and the general public. The United Nations General Assembly passed Resolution No. 111 on December 5th, 2008, designating June 8th as

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World Ocean Day starting from 2009. It is hoped that every country will show respect for this vital oceanic resource and continue to promote the theme of marine conservation globally.

Worldwide, Taiwan holds a prominent advantage in industries such as shipping, shipbuilding, and fishing [4]. The Marine Policy White Book notes that Taiwan has historically been influenced by the cultural ideology of island thinking rather than embracing a mentality of coexistence with the ocean. “Island thinking” refers to the cultural ideology that historically shaped Taiwan's perception of the ocean primarily as a barrier or resource to be exploited, rather than as an integral part of the nation's identity and well-being. This mindset has influenced various aspects of Taiwanese society, including policies, economic development, and cultural practices. As highlighted in the Marine Policy White Book, this traditional perspective has sometimes hindered the development of a more sustainable and harmonious relationship with the marine environment. Recognizing this, recent efforts have sought to shift towards a “blue economy” approach, emphasizing the importance of ocean conservation and sustainable utilization of marine resources. However, as the importance of the ocean began to be emphasized globally by the end of the 20th century, with many countries outlining marine strategies for future development [5], Taiwan published its first Marine White Book in 2001. This document identified Taiwan as a maritime nation, positioning the country within the ocean and signaling a shift towards ocean-centric development, thereby creating opportunities for blue growth. In 2004, the government released the “National Oceans Policy Guidelines” as a framework for the nation's marine policy, proposing initiatives to stabilize the marine environment, promote oceanic engagement, and cultivate ocean awareness and culture [8]. Following the establishment of these policies, the 2006 Marine Policy White Paper provided comprehensive guidelines for their implementation. Governments at all levels aligned their ocean-related policies with the strategies outlined in the White Paper, aiming to foster sustainable marine development while promoting economic growth and environmental protection. In 2007, the Marine Education Policy White Book was formally published, establishing objectives and strategies for the future development of marine education in Taiwan [10]. Over the years, Taiwan has developed its own unique marine education system [6], with a focus on enhancing the maritime education quality across all levels of schools and cultivating high-quality talent to meet industry demands.

Marine education in Taiwan is structured across elementary, high school, and higher education levels, each with its own distinct educational objectives and programs [7]. To integrate marine educational knowledge into elementary and high school curricula, the Ministry of Education has incorporated five study areas into the Grade 1−9 Curriculum Guidelines, embedding marine-related content into various subjects. Additionally, efforts to enhance teachers' proficiency in marine knowledge and related lessons are supported through training centers. Consequently, schools are encouraged to offer marine subjects based on their specific expertise [8]. In secondary schools, marine education focuses on subjects such as ocean recreation, marine society, ocean culture, and ocean resources [9]. In senior high school, marine subjects vary according to grade level, with some being compulsory while others are elective. At the university level, institutions are responsible for offering marine education courses, either as specialized or general courses. The primary objective of general courses is to enhance individuals' understanding of marine concepts [10]. Overall, the key objectives of marine education in Taiwan are to strengthen individuals' foundational marine knowledge, promote ocean awareness and conservation nationwide, and cultivate talented professionals for the marine industry, thereby enhancing its competitiveness [11]. Although marine education is emphasized across educational institutions in Taiwan, from primary to tertiary levels, the integration of comprehensive, interactive digital platforms like the MKES to support this curriculum remains an ongoing process.

The MKES has been established, integrating resources and information from diverse databases across industries, educational institutions, government agencies, and not-for-profit organizations. The present study integrates ongoing marine resource conservation initiatives with governmental marine education policies, leveraging information technology to identify accessible resources and efficient methods for enhancing marine education via online platforms. We utilize advancements like cloud technology, online networks, geospatial data systems, and social media to establish a platform that facilitates exploration, collaboration, and administration within the MKES. Nevertheless, the effective integration of e-learning hinges on users' perceptions, as well as their proficiency and understanding in computer usage. Research indicates that these factors significantly impact users' initial receptivity to information and technology, as well as their behavior when engaging with e-learning systems [12,13]. The TAM stands as a prominent and highly

influential theoretical framework within the realm of technology adoption, asserting that the perceived utility and ease of operation constitute pivotal factors influencing user embracement of technological innovations [14,15]. The TAM has found widespread application across diverse contexts, encompassing domains such as e-learning, serving to elucidate and forecast the drivers behind user acceptance or resistance towards novel technological advancements. Therefore, we aim to explore university students' behavioral intentions towards the MKES as a learning tool. The level of acceptance is understood by using the TAM. This paper is structured as follows: Section 2 details the framework of the MKES, Section 3 reviews prior research on the TAM, and Section 4 presents the MKES functions and employs the TAM to analyze student acceptance of the system. Section 5 concludes.

2. Design of marine knowledge education system

To fulfill our objective of data delivery and operational integration, in our design we adopted service-oriented architecture (SOA), a software model centered on user requirements that comprises three main components: software components, services, and processes. The system's software components are delivered as services through object-oriented functionalities. The related processing steps, as defined by the service, are employed in designing and constructing the entire system. The MKES is built upon a structured database and employs cloud-based geospatial information services. It leverages Internet-based technology for information delivery to establish a network-based system facilitating seamless data exchange and immediate updates. The system showcases information in both a list format and via a geographic information system (GIS) interface, such as Google Maps/Earth. Fig. 1 illustrates the integration of cloud-based software solutions such as Google Maps API and Google Earth API in the construction of our geographical information service. In contrast, Google Maps is a robust cloud-based service platform providing global imagery and vector data along with cutting-edge street view functionalities. Our plan involves integrating data from the General Coast Guard Administration (GCGA) and harnessing widely-used technologies like AJAX and other web development tools to build the system.

The GCGA serves as the executing body responsible for maintaining domestic maritime order and the environment. It comprehensively records and statistically estimates related maritime cases. This

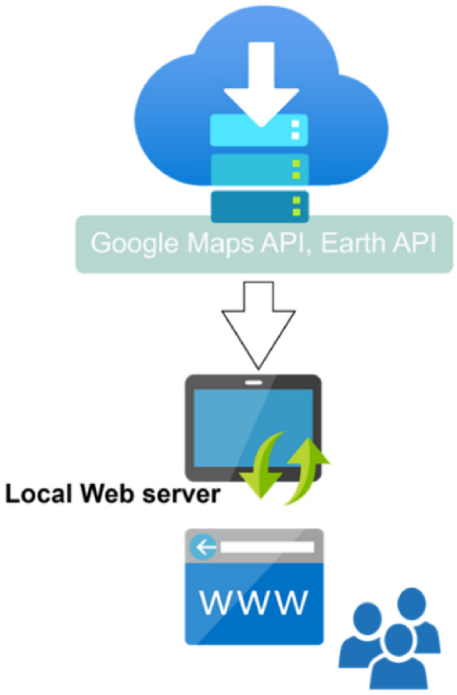

Fig. 1. Google cloud computing application.

study utilizes distributed heterogeneous technology to integrate data sourced from the GCGA for the development of the MKES. Focusing on system integration flexibility and future expansion, we propose a framework for seamless data transmission and operational integration, grounded in SOA. This framework aims to facilitate the exchange of critical data and support system adjustments. This approach promotes collaboration and streamlines resource sharing in cross-platform marine education. The distinctive functionalities of the system are depicted in Fig. 2, with the foundational layer representing the core data resources essential for platform construction. Following the organization and analysis process, the data is then stored within a relational database, where it is classified into seven discrete categories. These materials are

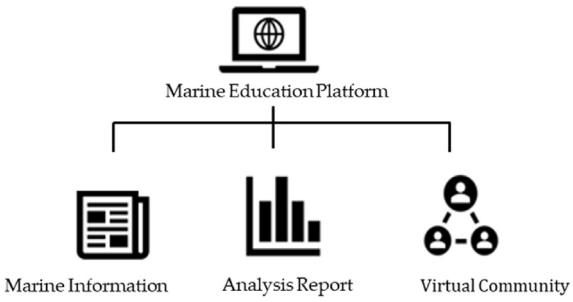

Fig. 2. MKES features.

characterized by their global, regional, scientific, and humanitarian qualities, enhancing convenience for system management, maintenance, and user interface information presentation. Users access information from the MKES using computers, mobile devices, or tablets, as depicted in Fig. 3.

3. Development of theoretical model and hypotheses

Building upon the theory of reasoned action (TRA) [17], the TAM [16] offers a valuable lens by which to examine technology adoption from a user perspective. The TAM underscores the pivotal role of two primary user perceptions—perceived usefulness (PU) and perceived ease of use (PEU)—in shaping technology adoption behaviors. Perceived usefulness denotes the user's conviction regarding the system's capacity to enhance their job efficacy, whereas perceived ease of use underscores the user's assessment of the system's ease and acquirability. The widespread application of the TAM in diverse fields such as education [18], marketing [19], and information technology [20] highlights its effectiveness in understanding user acceptance of technology.

The MKES is an innovative platform designed to revolutionize teaching practices and empower educators to deliver high-quality marine science courses. This study investigates university students' attitudes towards integrating the MKES into their marine science curriculum. We utilize the TAM to investigate the determinants shaping student acceptability of the MKES. Fig. 4 illustrates the research model, and subsequent sections delve deeper into each hypothesized relationship based on findings from the literature.

It is crucial to understand the factors influencing technology adoption. Drawing upon established research [21], this study explored the interrelationships among PEU, PU, and behavioral intention (BI) in relation to system usage. The results align with previous findings, demonstrating a positive relationship between PU and attitude toward use (ATU) [22], which emphasizes the importance of PU in fostering system adoption. Additionally, studies have demonstrated the importance of PEU in e-learning adoption [23–25]. Although ATU's role as a mediating variable has been proposed [26], further investigation is needed. To address this gap, this study proposes hypotheses examining the relationships among these variables.

H1. PEU positively influences students' ATU toward the marine knowledge education platform.

H2. PU positively influences students' ATU toward the marine knowledge education platform.

The targeted behavior of an individual is characterized by their attitude, which can be either positive or negative. Studies indicate that the

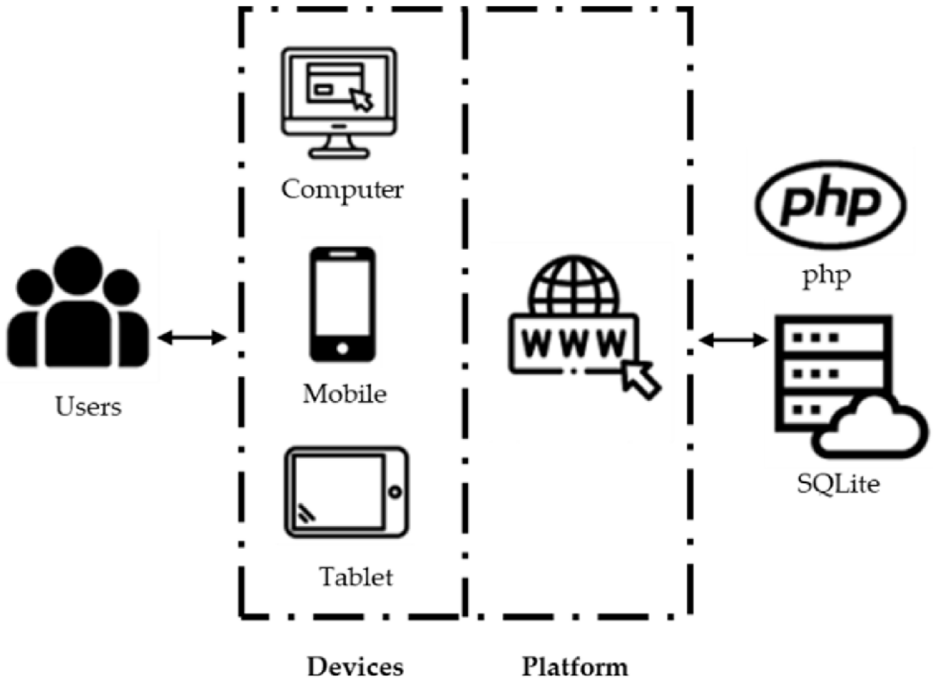

Fig. 3. MKES architecture.

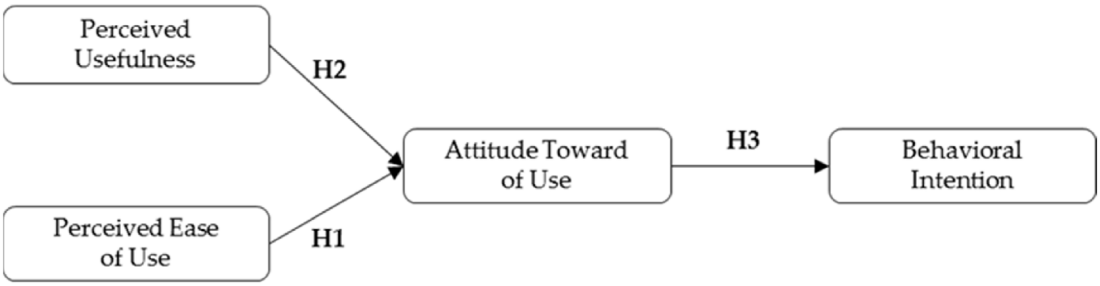

Fig. 4. Research model for marine education platform.

acceptance of technology is driven by a favorable ATU and BI [18,27,28]. Furthermore, research suggests that a positive attitude toward adopting new technology correlates with a higher intention to use it [18,21]. Therefore, the following hypotheses are postulated:

H3. ATU influences students' BI to use the marine knowledge education platform.

4. Results

4.1. System display

The MKES comprises three distinct features: First, it provides research information. Second, the analysis report service offers performance analysis results of marine data. Third, the virtual community service enables students to share or discuss information. Users utilize the search service to locate marine affairs information and display it in either list or graphical format following analysis, as illustrated in Fig. 5. The sharing of marine knowledge empowers managers to publish articles online (Fig. 6(a)), leveraging community engagement to promote marine education and share experiences in utilizing marine education teaching resources. Within the article publishing feature, users can input details such as the article title, author's name, email address, date, and article content. Collaborative tools are incorporated into each information segment, enabling users to distribute pertinent content with others via social channels (Fig. 6(b)) and participate in extended exchanges.

4.2. Data analyses

Descriptive analysis was conducted on the demographic sample. Of the 190 samples, 31.1% were male students and 68.9% were females. All students reported a habit of searching for information on the Internet. Approximately 116 students (61.1%) reported daily Internet use, with 30.5% reporting usage between 5 and 6 times per week, and 8.4% reporting usage between 3 and 4 times per week. Additional demographic data of the participants is outlined in Table 1. Curiously, more than half of the students (57.9%) expressed a lack of comprehension regarding marine education. However, more than half of the students (56.3%) expressed an interest in marine issues. Among these, 26.8% stated that they obtained marine education knowledge from extracurricular reading, 23.7% from school teachers, 17.4% from TV or the Internet, 16.3% from textbooks, and 15.8% from newspapers and magazines.

Focusing on a southern Taiwanese university campus, this case study explored how university students enrolled in professional marine courses utilize information technology (IT) within the MKES. To investigate the research hypotheses established within the framework, participants were recruited through purposive sampling. This study investigated the relationships among PEU, PU, ATU, and BI in the context of technology adoption. The findings indicate that these constructs are important determinants of individuals' intentions to use a particular technology. A 21-item questionnaire adapted from Davis's work [29] was used to measure these constructs. Data collection involved the use of a five-point Likert scale, where participants indicated their responses on a scale of “strongly agree” (5) to “strongly disagree” (1). The data was subsequently analyzed using SPSS Statistics 20.0. This analysis included (1) Cronbach's alpha for internal consistency, (2) path analysis to explore hypothesized relationships, and (3) paired-sample t-tests for further investigation.

The questionnaire underwent scrutiny to determine Cronbach's alpha values, ensuring the questionnaire's precision and coherence. A Cronbach's alpha exceeding 0.7 is generally deemed satisfactory for all items within a variable, suggesting

Fig. 5. The MKES provides locate marine affairs information and displays it either as a list or in graphical format.

homogeneity and consistent measurement of the construct. Table 2 exhibits the reliability values for the constructs, all surpassing 0.7, signifying strong reliability.

The research model analysis yields statistically significant relationships between all the investigated variables, thus supporting all the proposed hypotheses. BI is influenced by both actual ATU and

Fig. 6. (a) Marine information sharing interface; (b) Marine information sharing integrated with social service functions.

Table 1. Statistical analysis of basic data of research participants.

Items/Criteria	Options	Participants	Percentage (%)
Gender	Male	59	31.1
	Female	131	68.9
Habit of searching for information on Internet	Yes	190	100
	No	0	0
Times Internet used per week	3–4 Times	16	8.4
	5–6 Times	58	30.5
	Daily	116	61.1
Understanding towards marine education	Yes	80	42.1
	No	110	57.9
Sources of marine education knowledge	Textbooks	31	16.3
	Extracurricular reading	51	26.8
	Newspapers and magazines	30	15.8
	TV or Internet	33	17.4
	School teachers	45	23.7
Displays interest in marine issues	Yes	107	56.3
	No	83	43.7

Table 2. Construct reliability.

Construct	Items	Cronbach's alpha
PU	6	0.737
PEU	6	0.850
ATU	5	0.848
BI	6	0.867

subjective factors, with ATU representing an individual's overarching sentiment towards employing a specific technology. Note that this is shaped by factors including the individual's perception of PU and PEU, where PU refers to an individual's conviction that the technology will enhance their job performance and PEU denotes their perception regarding the technology's ease of learning and usability. Finally, attitude represents an individual's overall disposition towards a specific behavior, encompassing both positive and negative evaluations.

Path analysis (Fig. 7) reveals significant relationships among the studied variables, supporting all three hypotheses. Both PEU and PU significantly predict ATU, with PU having a stronger influence ($\beta = 0.235$ and 0.560, respectively; $p < 0.001$). Combined, these factors explain nearly half (44.6%) of the variation in ATU ($R^2 = 0.446$). Moreover, ATU

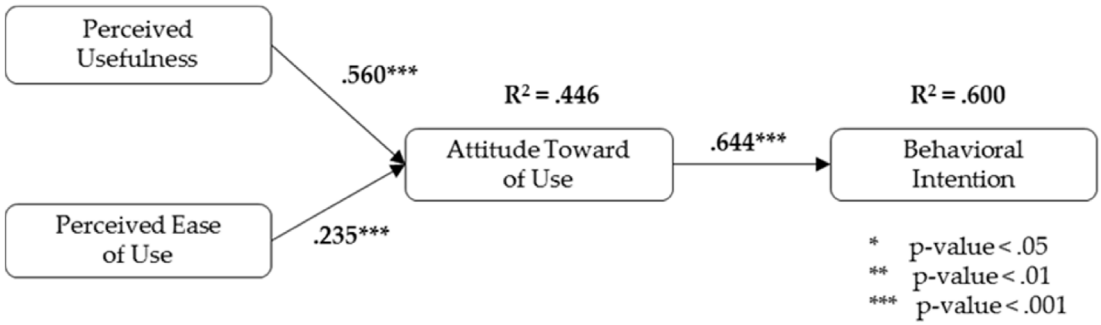

Fig. 7. Path analysis results based on all valid samples.

exerts a substantial positive effect on BI ($\beta = 0.644$, $p < 0.001$), explaining a remarkable 60% of its variance ($R^2 = 0.600$). The R-squared value, representing the determination coefficient for endogenous constructs, serves as an indicator of the variance explained by the model. Chin [32] suggests a categorization where 0.67 indicates a substantial effect, 0.33 a moderate effect, and 0.19 a weak effect. Based on the guidelines proposed by Chin, we maintain that the R-squared value is acceptable for the TAM model in this context. The outcomes of this investigation hold considerable implications for the development and deployment of novel technologies. By understanding the factors that influence users' behavioral intentions, organizations can develop technologies more likely to be adopted by users. For instance, organizations have the opportunity to devise user-friendly technologies that offer utility to users within their professional endeavors. Additionally, organizations can offer training and support services to facilitate users in acquiring proficiency with the technology and maximizing its utility.

To gauge student acceptance of the marine knowledge education platform, we employed a paired-sample t-test to evaluate changes in perceptions towards using the platform (ATU) and behavioral intentions (BI). Behavioral intention is known to be shaped by an individual's affective disposition (attitude toward use) towards a specific behavior, alongside their perceived instrumentality (subjective criteria) regarding its benefits. A one-month gap was strategically implemented between the two tests to capture any potential shift in student sentiment.

The present study revealed a significant increase in students' ATU and BI toward the marine knowledge education platform after one month of continuous use. This finding suggests a positive shift in student perception, characterized by both an improved disposition and a heightened willingness to integrate the platform into their regular learning routines. These results provide evidence for the successful user acceptance of the platform, highlighting its potential as a valuable tool to augment student learning experiences within professional marine science courses.

Table 3 presents the findings of a paired-sample t-test analysis devised to evaluate the presence of a significant disparity in students' ATU scores following their initial and subsequent uses. The results reveal a significant increase in students' ATU scores ($p < 0.000$). The observed mean difference of −2.4926 suggests a positive change in student attitudes towards using the platform after one month. This finding implies that students developed a more favorable perception of the marine knowledge education platform.

Table 4 presents a paired-sample t-test analysis examining students' behavioral intention following their initial and subsequent uses. The analysis reveals a significant difference in BI scores (−2.2087, $p < 0.000$). Note that for BI scores, higher values indicate a greater willingness to use the platform. Consequently, this finding suggests a potential increase in students' propensity to integrate the

Table 3. Paired sample test on ATU.

	Paired difference					t	Degree of freedom	Significance (two-tailed)
	Mean	Standard deviation	Standard error of the mean	95% Confidence interval of difference				
				Lower limit	Upper limit			
Pair 1	−2.492	0.7105	0.0515	−2.594	−2.391	−48.358	189	0.000

Table 4. Paired sample test on BI.

	Paired difference					t	Degree of freedom	Significance (two-tailed)
	Mean	Standard deviation	Standard error of the mean	95% Confidence interval of difference				
				Lower limit	Upper limit			
Pair 1	−2.208	0.7093	0.0514	−2.310	−2.107	−42.919	189	0.000

platform into their learning routines following exposure. This implies a possible growth in student intention to utilize the platform over time.

5. Conclusions

In this study we develop and evaluate the Marine Knowledge Education System (MKES), which leverages real-world maritime cases from the General Coast Guard Administration. Moreover, we utilize the technology acceptance model (TAM) as the theoretical foundation of our research to delve into the factors affecting student acceptability of the MKES in the university environment. The findings of our study confirm that student perceptions of the MKES's usability and perceived usefulness (PU) significantly influence their attitudes towards using the platform for professional marine science learning. These findings not only demonstrate the successful development of a potentially valuable educational tool but also highlight the TAM's utility in understanding student technology acceptance in professional education contexts.

This study investigates the factors influencing students' attitude toward use (ATU) of the MKES. The findings indicate that PU and perceived ease of use (PEU) are significant predictors of ATU, corroborating prior studies [22] that highlight the importance of practicality in shaping users' attitudes towards technology. These findings suggest that student perceptions of the MKES's PU and PEU play a key role in determining their enthusiasm to adopt the platform for their professional marine science education.

As hypothesized in H3, ATU significantly influences behavioral intention (BI), aligning with previous research [18]. This implies that when college students possess a positive attitude toward using the network for marine knowledge learning, it positively influences their inclination towards web-based learning, fostering their willingness to utilize the network for educational purposes.

The results of the paired-sample t-test demonstrate that students' ATU and BI toward the MKES significantly increase after using the platform. This discovery aligns with prior studies [27,28] showing positive changes in user attitudes and intentions towards technology after experiencing its benefits. These findings suggest that the MKES may be able to serve as a valuable aid for augmenting student learning in the context of professional marine science education.

This study demonstrates that the MKES is an effective tool for supporting student learning in marine knowledge, as evidenced by participant willingness to continue utilizing the platform. However, to maximize student interest and academic achievement in marine knowledge subjects, it remains crucial to create a supportive learning environment through school resources. The study's generalizability is limited by its focus on students with prior experience with online information retrieval systems. Future research should explore the potential user experience disparities among learners with diverse technological backgrounds and learning styles, informing strategies for adapting the MKES to a wider range of students. Expanding the MKES content could incorporate diverse marine knowledge topics, interactive simulations, and emerging technologies like VR/AR to create immersive learning experiences. Additionally, future work could investigate corporate sustainability transitions within the growing maritime industries of Southeast Asia and explore solutions to enhance port state control efficacy in Taiwan [30], addressing personnel constraints and salary disparities [31].

Ethics Information

Ethical approval was not required for this study as it did not involve any human or animal subjects.

Conflicts of interest

The authors declare no conflict of interest.

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