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Technology Integration and Ocean Literacy in Vocational Tourism Education: A Study in the Context of the Sustainable Development Goals (SDGs)

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A B S T R A C T

This study examines the integration of ocean literacy and digital technology in vocational tourism education in Indonesia. Using a descriptive quantitative approach, the research explored students' familiarity with digital learning tools and their understanding of marine concepts. While many students indicated the use of mobile applications and online platforms for learning, their exposure to ocean environments was limited, particularly for those living in inland areas. This creates challenges for marine education because direct experience is often essential for building conceptual understanding. However, technology-based learning may serve as an alternative because it enables virtual exposure to coastal systems. The Technology Acceptance Model was applied to examine how students respond to educational technologies. Findings are discussed in relation to the Sustainable Development Goals, particularly in areas concerning education, environment, and tourism. Vocational tourism education is considered in this context because it connects career preparation with sustainable practices, including the need to link tourism activities with marine awareness through accessible and adaptable learning methods.

1. INTRODUCTION

Ocean literacy (defined as the understanding of the ocean's influence on people and people's influence on the ocean) has become a cornerstone of contemporary environmental education. Many reports regarding ocean literacy have been well-documented [1-4]. Its significance is increasingly recognized in response to escalating threats to marine ecosystems, such as rising sea temperatures, ocean acidification, and biodiversity loss. Global efforts, including the UN Decade of Ocean Science for Sustainable Development (2021-2030), have emphasized the need for embedding ocean literacy into formal education systems. The strategic target for 2025 is to have ocean literacy integrated into national curricula in at least 70% of countries [5]. This initiative positions ocean literacy not only as a scientific imperative but also as a critical dimension of sustainability education across all educational levels.

Despite its importance, ocean literacy remains underdeveloped, particularly among students in non-coastal and vocational contexts. Studies indicate that learners in K-12 and vocational tracks often exhibit only moderate understanding of ocean systems due to factors such as limited access to marine environments, overloaded curricula, and insufficient teacher training [6]. This gap is especially troubling in the tourism sector, which directly depends on healthy marine ecosystems while simultaneously contributing to their degradation. Vocational education, which plays a vital role in preparing the tourism workforce, must address this issue by integrating ocean literacy into its learning frameworks [7].

At the same time, the digital transformation of tourism has opened new avenues for promoting sustainable practices through the use of technology. Technological innovations such as mobile applications, virtual reality (VR), augmented reality (AR), and smart tourism platforms offer powerful tools to bridge gaps in ocean literacy, especially for students with limited coastal access [8,9]. Countries like Thailand, Fiji, and Palau have demonstrated successful implementation of technology-enhanced sustainable tourism models, including carbon-neutral tourism initiatives aligned with the Bio-Circular-Green (BCG) economy [10,11]. However, the integration of these technologies into education (particularly vocational tourism education) remains fragmented and lacks systematic frameworks.

Given the urgent need to address marine environmental degradation and the increasing demand for digitally literate tourism professionals, a comprehensive educational model is needed; one that merges ocean literacy, sustainable tourism, and technology-based learning within vocational contexts. This study aims to develop and test such a model for achieving sustainable tourism technology integration through ocean literacy education. It addresses critical gaps in theory and practice by exploring how digital tools can be used to improve students' ocean awareness and environmental responsibility. Ultimately, the study contributes to advancing Sustainable Development Goals (SDGs) (particularly SDG 4 (Quality Education), SDG 8 (Decent Work), SDG 13 (Climate Action), and SDG 14 (Life Below Water)) through a digitally enhanced, sustainability-oriented vocational education framework.

2. METHODS

This study employed a cross-sectional quantitative survey design with a descriptive-analytic approach. The primary objective was to assess the levels of marine literacy, technological readiness, and understanding of sustainable tourism among vocational students in Indonesia's tourism sector. Additionally, the study aimed to identify the potential for integrating technology into marine literacy education within tourism-based vocational curricula.

The research population comprised students from vocational high schools specializing in tourism across Indonesia. The sample included 67 students, selected using a purposive sampling method that considered accessibility and representation of tourism-related majors. The respondents consisted of 71.6% female and 28.4% male students, with the majority aged between 16–17 years (84.4%). Based on specialization, 77.6% were enrolled in Culinary Arts, 16.4% in Hotel Accommodation, and 6% in Travel or Fashion Business. The class-level distribution included 10th grade (13.4%), 11th grade (62.7%), and 12th grade (23.9%).

The research instrument was a structured questionnaire comprising 80 items, developed based on the Marine Literacy Framework and the Technology Acceptance Model (TAM). It covered six key dimensions: (a) demographics, (b) ocean literacy, (c) readiness and attitudes toward technology, (d) understanding of sustainable tourism, (e) learning preferences, and (f) scenario-based problem-solving abilities. A 5-point Likert scale was used for most items, except for demographic questions and open-ended responses. The instrument underwent expert validation for content accuracy and demonstrated strong reliability (Cronbach's alpha > 0.70).

Data collection was conducted through a hybrid method: 70% via online surveys using Google Forms and 30% through printed questionnaires distributed in schools. This mixed approach was chosen to accommodate students in regions with limited internet access. The data collection process lasted for 10 weeks, including preparation, administration, and verification stages.

Data analysis was carried out using SPSS version 28.0. Descriptive statistics (such as frequency, percentage, mean, and standard deviation) were used to describe respondent characteristics and variable distributions. Pearson correlation was applied to examine relationships between variables, while t-tests and ANOVA were conducted to analyze differences across gender, specialization, and grade level. All statistical analyses were performed using a significance threshold of $p < 0.05$. This methodological approach enabled the study to provide an empirical overview of students' marine literacy, digital readiness, and sustainable tourism understanding, insights that are crucial for the development of technology-based vocational education strategies in Indonesia's marine tourism sector.

3. RESULTS AND DISCUSSION
3.1. Demographic Profile of Respondents

The study gathered responses from 67 vocational tourism students across Indonesia, offering meaningful insights into the current levels of ocean literacy and technological readiness among prospective tourism professionals. The demographic analysis revealed that the majority of respondents were female (71.6%, n = 48), with male participants comprising 28.4% (n = 19). This gender distribution reflects common trends observed in vocational tourism education, both nationally and globally. A comprehensive analysis [12] similarly identified a predominance of female enrollment in tourism-focused programs across multiple countries. Supporting this, other cross-cultural studies have reported a 55.5% female representation in tourism education, reinforcing the recurring pattern. Notably, gender plays a significant role in shaping students' career intentions within the hospitality and tourism sectors [13,14].

In terms of age, the majority of participants were 16 years old (52.2%, n = 35), followed by 17-year-olds (32.8%, n = 22), indicating that most of the sample consisted of mid-level vocational students. This pattern corresponds with the structure of Indonesia's vocational education system, where students typically enroll at 15-16 years of age and complete their programs by 18. This age group is particularly important in vocational education reform, as these students are digital natives capable of connecting traditional vocational skills with

evolving technological demands [15]. The transitional nature of this age phase has been identified as a crucial window for influencing students' attitudes and aspirations toward tourism careers.

Regarding specialization, a significant majority of students were enrolled in Culinary Arts programs (77.6%, n = 52), followed by Hotel Accommodation (16.4%, n = 11), while Travel Business and Fashion Design each accounted for just 3% (n = 2). Although this distribution appears imbalanced, it accurately reflects broader national enrolment trends in vocational institutions, where culinary programs consistently draw the highest number of students. This pattern is often attributed to perceptions of greater job market accessibility and cultural familiarity [16]. The concentration in culinary arts is also consistent with global tourism employment patterns, where the food and beverage sector represents the largest share of tourism-related jobs [17,18].

Geographically, the student sample was predominantly drawn from Java, which presents a notable limitation in terms of representativeness across Indonesia's archipelagic landscape. Java's dominance in vocational education infrastructure (hosting the majority of well-established tourism programs) accounts for this concentration. While this geographic skew may restrict the generalizability of findings to other regions, it is methodologically justifiable given Java's role as a national reference point for vocational education standards. Prior studies have emphasized that geographic distribution is a critical factor in educational research, as regional differences in curriculum delivery and resource allocation can significantly shape student outcomes [19]. Additionally, analysis from the Indonesian Ministry of Education confirms that Java-based vocational schools frequently serve as benchmarks for national curriculum development [20].

3.2. Ocean Literacy Assessment Results

The assessment of ocean literacy among vocational tourism students revealed a moderate level of understanding, with an average score of 3.37 out of 5.0 across core ocean knowledge indicators (**Figure 1**). This outcome aligns with global findings that suggest ocean literacy among K-12 learners is generally moderate to low [5]. The radar chart analysis (**Figure 1**) further illustrates the multidimensional aspects of ocean literacy, highlighting students' strongest performance in understanding ocean–weather relationships (3.8/5.0) and weakest comprehension of water cycle mechanisms (3.1/5.0).

When broken down into specific components, students demonstrated relatively strong familiarity with ocean-weather interactions, with 50.7% (n = 34) reporting that they "know" this topic and 7.5% (n = 5) indicating "very high" levels of understanding. However, significant knowledge gaps were found in areas such as ocean oxygen production, where 22.4% (n = 15) of students responded "do not know" and another 22.4% (n = 15) expressed a "neutral" level of understanding.

These findings are consistent with broader international trends in ocean literacy. For instance, a cross-cultural study in the Mediterranean region involving 1,004 elementary school students also reported moderate knowledge levels, particularly weak in understanding how the ocean produces oxygen [21]. The urgency of improving ocean literacy is further underscored by the State of the Ocean Report 2024, which notes that ocean warming has doubled over the past two decades, reinforcing the need for ocean literacy, especially for those pursuing careers in coastal and marine tourism. Moreover, a bibliometric analysis of research from 2005 to 2019 identified "Students' OL Improvement" and "Measuring and Evaluating Students and Teachers' OL" as dominant themes, indicating sustained global attention to this issue [22].

Previous studies further support these findings, highlighting that while ocean literacy principles have been embedded in educational curricula in many countries, implementation remains inconsistent. Their review of 43 studies (2012–2022) showed that project-based, problem-based, and inquiry-based learning methods were most effective in conveying marine and coastal biodiversity knowledge; yet knowledge retention remains moderate. A related study in Portugal, which introduced a pedagogical model of ocean citizenship, reported gains in knowledge and skills but noted that critical thinking and environmental activism were still underdeveloped outcomes [23].

Further complicating the issue is the disconnect between scientific knowledge and public understanding, which Evans and colleagues identified as a barrier to effective societal uptake of marine science. This gap is particularly relevant for vocational tourism students, who may act as translators between scientific insight and public experience [24]. Additionally, traditional educational methods often fail to establish meaningful connections between students and ocean systems, limiting emotional engagement and deeper learning [25].

Recent literature calls for a reconceptualization of ocean literacy as a multidimensional construct; one that integrates not only knowledge, but also emotional connection, attitudes, and behaviors. These dimensions evolve at different rates and require diverse, context-sensitive educational approaches to be effectively developed [26]. For vocational students preparing for marine-related tourism careers, fostering this comprehensive form of literacy is essential to ensuring sustainable ocean use and stewardship.
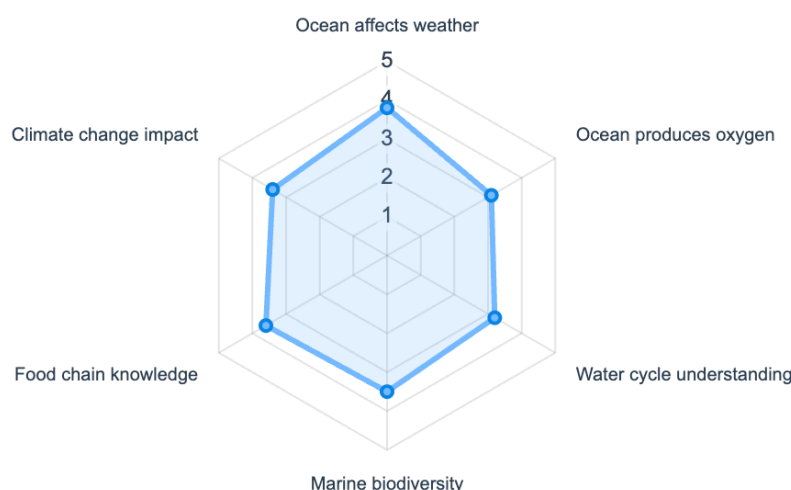

Figure 1. Ocean literacy knowledge assessment.

3.3. Geographic and Experiential Factors

Geographic proximity to coastal environments plays a significant role in shaping students' exposure to the ocean and may directly influence the development of their ocean literacy (**Figure 2**). The analysis revealed that 47.8% of respondents (n = 32) reported living more than 50 kilometers from the coast, while 31.3% (n = 21) were uncertain of their proximity to marine areas. This lack of geographic connection was reflected in their ocean visitation patterns: 43.3% (n = 29) reported rarely visiting coastal areas (less than once in a lifetime), while 34.3% (n = 23) indicated visiting only once per year. Only 10.4% (n = 7) of students reported frequent coastal visits. These findings suggest that the majority of respondents had limited direct

experiences with marine environments, which may hinder the development of ocean literacy through experiential learning.

The relationship between proximity to the coast and marine knowledge has been extensively discussed in international research. A study on coastal residents in Oregon found that individuals living near the ocean exhibited higher awareness of marine reserves and demonstrated greater support for conservation efforts [27]. A similar pattern was observed in a Mediterranean cross-cultural study, which confirmed that geographic closeness to the sea generally improved ocean literacy, although some inland students outperformed coastal peers in specific contexts, highlighting the complexity of this relationship [28].

These geographic and experiential limitations present notable challenges for ocean literacy development, especially given that first-hand interaction with marine environments is crucial for fostering meaningful and lasting connections with ocean systems. Research shows that contact with nature enhances not only knowledge but also health, wellbeing, and pro-environmental attitudes, underscoring the broader impacts of limited coastal access [29]. Therefore, ocean literacy education must address these constraints by creating alternative pathways to ocean engagement, particularly for inland learners who may never have substantial exposure to marine settings [30].

Evidence from residential marine field-course programs supports this approach. One study demonstrated that even short-term, immersive coastal learning experiences significantly enhanced students' understanding of marine ecosystems and conservation values, especially among those with limited prior exposure [31]. These findings underscore the value of structured experiential learning as a compensatory strategy for geographic limitations. Further research highlights that effective ocean literacy programs must be designed to overcome such spatial barriers through innovative pedagogical approaches.

A global review of ocean literacy initiatives identified geographic accessibility as a persistent barrier in marine education and emphasized the success of programs targeting inland populations [32]. These programs have developed strategies such as virtual coastal experiences, mobile marine laboratories, and partnerships with coastal institutions; all of which acknowledge that traditional classroom instruction is insufficient to replicate the cognitive and affective impact of real-world marine encounters.

This inclusive perspective is echoed in the strategic vision of the UN Decade of Ocean Science for Sustainable Development, which advocates that ocean literacy should be equally accessible to all populations, regardless of their geographic location [33]. Inland communities, despite their distance from the sea, contribute to marine degradation through watershed pollution, plastic waste, and consumption patterns, making their inclusion in ocean education initiatives both urgent and essential. For Indonesian vocational tourism students, this is particularly relevant, as many inland tourism destinations increasingly include marine-themed attractions and ecotourism elements that demand ocean knowledge and environmental sensitivity.

The implications of geographic disconnection extend beyond knowledge deficits to impact career readiness and professional competence. A study of pre-service teachers found that limited coastal exposure resulted in lower confidence when teaching ocean-related content, suggesting that spatial limitations can have long-term effects on instructional quality and content delivery (Hartley et al., 2018). The same applies to vocational tourism students, who may enter the workforce underprepared for roles in marine tourism, ecotourism planning, and sustainable destination management if they lack sufficient exposure and understanding of marine environments.
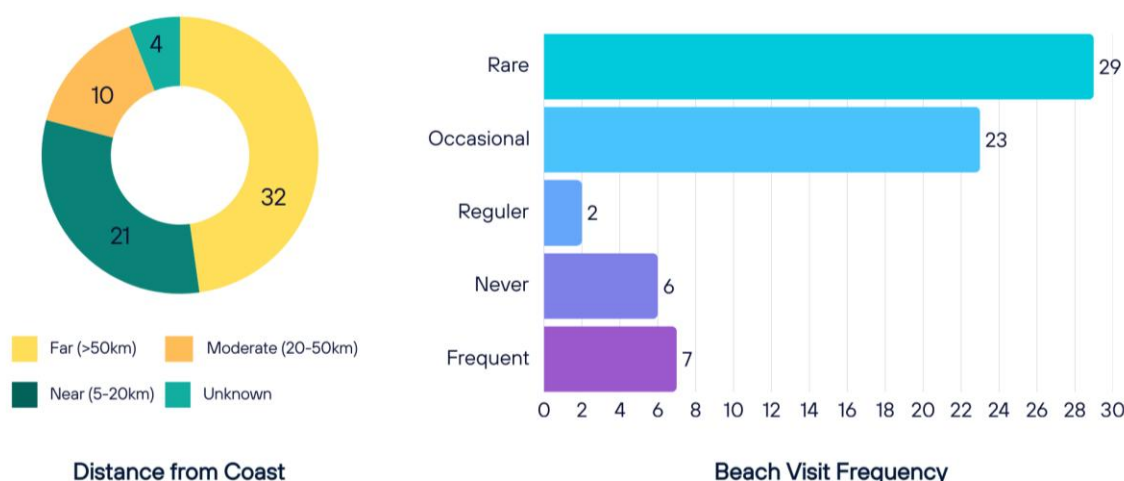
Figure 2. Geographic and ocean access patterns.

3.4. Technology Readiness and Digital Access

The assessment of students' technology readiness revealed generally positive attitudes toward the use of digital tools for learning, particularly in the context of vocational tourism education (**Figure 3**). A majority of students (50.7%, n = 34) reported that they "know" how to enjoy learning with new technology, while 32.8% (n = 22) indicated "very high" levels of comfort in adopting technology. Additionally, 53.7% (n = 36) agreed that technology makes learning easier, with 23.9% (n = 16) strongly agreeing. These results indicate that students already possess a receptive mindset toward technology-enhanced learning, providing a strong foundation for introducing digital ocean literacy programs.

These findings are consistent with broader research on technology acceptance in education, particularly in vocational settings. A systematic review of digital competence among teachers found that technology readiness significantly influences adoption behavior, and vocational students often show higher acceptance levels compared to those in traditional academic environments [34]. This is attributed to vocational learners' pragmatic orientation, viewing technology primarily as a tool for skill development and real-world application.

The study also assessed digital infrastructure and internet access, revealing that 65.7% of students had good to excellent internet quality (49.3% good, 16.4% perfect) (**Figure 3**). Daily internet use patterns showed high digital engagement: 25.4% of students reported using the internet for 5–8 hours per day, while another 25.4% used it for more than 8 hours daily. These usage patterns suggest that students are already embedded in digitally mediated environments. However, 11.9% (n = 8) reported poor internet quality, highlighting a digital divide that must be addressed for equitable access to technology-enhanced education. High-frequency internet use has been associated with increased motivation and knowledge gains in digital learning settings [35].

The TAM offers a useful framework for interpreting these results. A study combining TAM with the Technology Readiness Index (TRI) in Indian higher education found that technology readiness strongly predicted students' behavioral intention to adopt mobile learning platforms [36]. In line with this, the current findings suggest that Indonesian vocational tourism students demonstrate similar characteristics that facilitate technology acceptance in educational contexts. A meta-analysis on TAM applications further confirmed that perceived usefulness and ease of use, influenced by readiness, are among the most significant predictors of technology adoption across cultures.

Recent research on digital competence in vocational students adds depth to this perspective. A study involving 872 Chinese vocational students proposed a five-factor model of Vocational Digital Learning Competence (V-DLC), emphasizing that vocational learners require industry-aligned technological integration frameworks, distinct from traditional academic models [37]. This implies that digital readiness among tourism students must be harnessed through structured frameworks that bridge classroom learning and workplace digital requirements.

Further validation comes from network analyses of teacher technology acceptance, which identified technology readiness as a central node linking perceived usefulness and behavioral intention in educational innovation [38]. Likewise, research on Learning Management System (LMS) use among undergraduates found that technology readiness significantly predicted both system utilization and learner satisfaction [39].

The implications of high digital readiness extend beyond adoption to include learning outcomes and engagement quality. In one study, students with high readiness demonstrated greater academic achievement and satisfaction in online learning, with technology readiness acting as a mediating factor between digital platform features and success [40]. A related systematic review emphasized that technology readiness is central to student engagement and is a key determinant of successful digital learning [41].

However, the digital divide identified (where 11.9% of students reported inadequate internet quality) raises concerns about technology equity in educational access. Research in this area confirms that infrastructure limitations, particularly internet quality, significantly impact both engagement and learning effectiveness [42]. These findings suggest that targeted interventions are necessary to ensure that all students (regardless of digital access) can benefit equitably from technology-enhanced ocean literacy education.
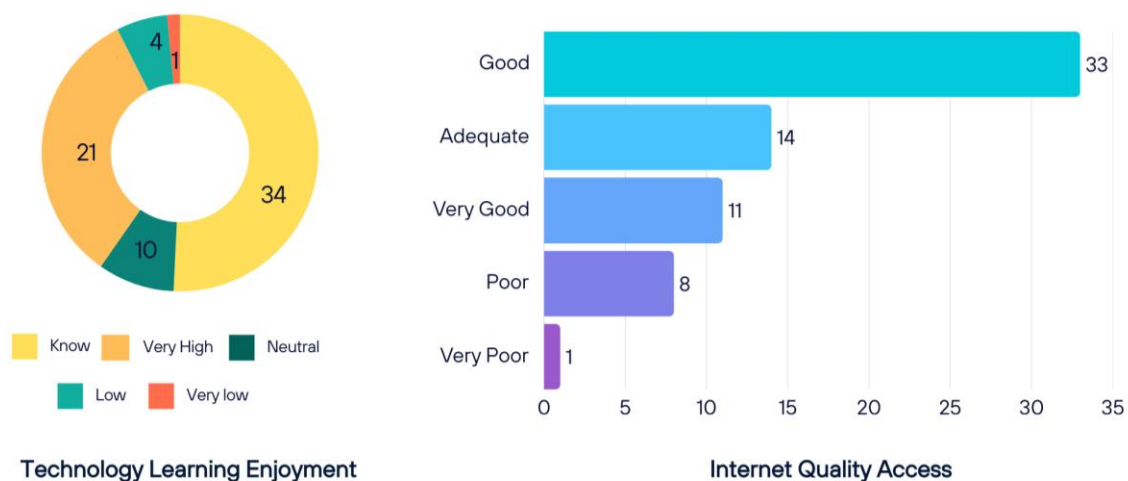

Figure 3. Technology readiness and digital access.

3.5. Sustainable Tourism Understanding

Students' understanding of sustainable tourism concepts reflected mixed levels of awareness and engagement. When asked about the importance of ecotourism, responses varied: 26.9% (n = 18) indicated moderate knowledge, 31.3% (n = 21) held neutral positions, and 16.4% (n = 11) reported low awareness. However, students demonstrated more confidence in the role of technology in supporting sustainable tourism, with 53.7% (n = 36) agreeing and 37.3% (n = 25) strongly agreeing that technology can aid sustainable practices.

The overall acceptance of technology integration was notably high, with 90.4% of respondents expressing positive attitudes toward the use of technology to support sustainable tourism education. Specifically, mobile applications for ocean learning received very high approval (85.1% positive response), while virtual reality applications garnered moderate acceptance at 49.3%. Meanwhile, when asked whether hotels and marine tourism providers should actively protect ocean environments, students showed moderate understanding, with 25.4% (n = 17) agreeing and 40.3% (n = 27) remaining neutral. These findings indicate an opportunity to strengthen connections between sustainable tourism concepts and environmental conservation responsibilities in educational content.

These trends align with recent research examining the integration of AI and digital technology in sustainable tourism, which highlights both its potential and complexity. A systematic review of 148 publications from 2019 to 2024 revealed optimism in academic literature but also emphasized that real-world implementation of sustainable tourism technology is riddled with trade-offs, ambiguity, and contextual constraints, all of which require more nuanced educational frameworks [43]. This may help explain the moderate awareness observed in this study, where students recognize the promise of technology but lack clarity on its operationalization.

Further insight is offered by a review of IoT applications in ecotourism, which identified the roles of technology in enabling sustainability, while also emphasizing the obstacles posed by policy gaps and limited coordination among stakeholders [44]. The neutral responses by many students in this study may reflect this complexity, underscoring the fact that sustainable tourism education must prepare learners not just to adopt technology, but to engage in multi-stakeholder collaboration.

The four-stage model of ICT adoption (opportunity, disruption, immersion, and usurpation) provides a useful lens to interpret students' responses [45]. This framework suggests that the process of integrating technology into tourism is evolutionary and often non-linear. Students' tentative perspectives may reflect an intuitive recognition of these complexities, even if they have not yet been exposed to them conceptually.

Research on sustainable tourism education frameworks further confirms that students often understand individual dimensions (environmental, economic, or social), but struggle to integrate these into cohesive practice [46]. This fragmented understanding likely contributes to the inconsistent awareness levels found in this study, where sustainable tourism principles are encountered but not deeply synthesized within the curriculum.

Findings from recent work on sustainable tourism pedagogy in higher education reinforce this conclusion. Although students frequently express support for sustainability principles, they demonstrate limited ability to translate values into strategies or career applications [47]. This disconnect mirrors our findings, where acceptance of technology integration outpaces the ability to apply sustainability frameworks in real-world tourism contexts.

Another contributing factor is the lack of explicit connection between tourism activities and marine ecosystem health in existing curricula. A study on ocean literacy promotion in schools found that students often perceive tourism and environmental conservation as separate domains, requiring targeted interventions to promote integrated thinking [48]. This perspective may explain why many students in this study were neutral about the environmental responsibilities of hotels and marine tourism operators.

The implications of this partial understanding extend into future career development. A longitudinal study on sustainable tourism certification and education found that professionals with stronger foundations in sustainability reported greater career advancement and job satisfaction [49]. These findings highlight the urgency of embedding comprehensive

sustainable tourism education in vocational contexts, where students' current moderate awareness may otherwise limit their professional competency and long-term career outcomes.

3.6. Learning Preferences and Platform Utilization

The analysis of learning preferences among vocational tourism students revealed a diverse range of approaches to information seeking and knowledge acquisition. While a strong preference for practical, hands-on learning was evident, students also demonstrated a clear openness to digital platforms as learning tools. Utilization patterns indicated that students were highly familiar with social media and digital communication platforms, which they commonly used to support learning. These habits suggest that technology-enhanced ocean literacy education can be more effective if it integrates with students' existing digital behaviors. This aligns with contemporary research emphasizing multimodal learning approaches, particularly within vocational education, where the development of practical and applied skills is essential.

Integrating ocean literacy content into platforms that students already use and trust may increase both engagement and knowledge retention. Recent research on university students' preferences in foreign language learning found that learners preferred integrated digital approaches that combined several platforms, rather than relying on a single tool [50]. Conducted across the Czech Republic, Taiwan, and Iraq, the study showed that platform diversity supports vocabulary acquisition and skills development through flexibility, personalization, and interactive features.

A systematic review examining student engagement with digital technologies similarly highlighted the importance of platform integration [51]. The analysis of studies from 2010 to 2020 found that engagement is more effective when digital tools are used coherently across multiple platforms, rather than being applied in isolation. This finding supports the observed diversity in platform preferences among Indonesian vocational tourism students and suggests that ocean literacy programs should utilize multiple digital channels to optimize engagement.

Further evidence comes from a review of platform features and student satisfaction, which found that tools incorporating gamification, real-time feedback, and social interaction produced significantly better outcomes than traditional learning management systems. These findings suggest that interactive and socially engaging digital features are particularly effective in enhancing motivation and learning among vocational students.

Research examining online learning platform success factors revealed eleven key variables that impact academic achievement and satisfaction, including student autonomy, collaborative interaction, background experience, and engagement with content [40]. These factors reinforce the importance of aligning platform design with student preferences and experiences, particularly in vocational contexts where learning is often application-driven.

A separate study investigating the relationship between digital platform utilization and learning outcomes found that students' interaction with online learning tools positively correlates with motivation and knowledge development [35]. The study emphasized that interactive learning components significantly enhance learner engagement and confidence, especially when students feel a sense of self-efficacy in navigating digital environments.

The value of personalized learning paths in digital education has also been affirmed by a recent review of AI-enabled learning technologies [52]. Their systematic analysis of 78 articles concluded that tailored digital experiences aligned with students' individual preferences significantly enhance engagement and retention, emphasizing the importance of offering diverse platform options in ocean literacy education.

In addition, a bibliometric analysis of digital literacy in higher education during the COVID-19 pandemic confirmed that students are more likely to succeed with platforms that combine familiar communication tools—such as messaging apps and social networks—with structured educational content [53]. This aligns with the familiarity that Indonesian vocational students have with social media-based learning environments.

Research specific to vocational education further supports the relevance of aligning platform choices with career preparation needs. One study found that vocational students are more responsive to platforms that clearly demonstrate connections between digital learning activities and real-world applications [54]. This suggests that ocean literacy platforms for tourism students should include industry-relevant content, such as virtual tours of marine ecotourism sites, simulations, and interactive sustainability assessments.

Finally, the implications of these diverse learning preferences extend to pedagogical design. A comparative study of blended learning in vocational higher education revealed that platform diversity and flexible learning pathways significantly improve satisfaction and achievement [55]. Programs that offer multiple platform options and allow for individualized learning experiences are more likely to succeed in engaging students and fostering long-term knowledge retention.

3.7. Technology Integration for Ocean Literacy Enhancement

The intersection of moderate ocean literacy, high technology readiness, and diverse learning preferences among vocational tourism students presents a strategic opportunity for the implementation of technology-enhanced ocean literacy education. Findings from this study indicate that while students are highly receptive to digital tools and platforms, notable gaps persist in their foundational understanding of marine ecosystems. These knowledge gaps could be effectively addressed through immersive, interactive, and contextually relevant digital learning strategies. Tools such as VR simulations for underwater exploration, mobile applications for marine species identification, and gamified platforms for sustainable tourism training offer promising solutions for enriching ocean-related knowledge and promoting environmentally responsible behaviors.

Students' acknowledgment of technology's role in sustainable tourism practices further reinforces the potential of integrated learning approaches. This awareness lays the groundwork for the development of comprehensive curricula that blend ocean literacy content with digital literacy and sustainability principles. Such integration aligns with contemporary trends in educational technology research, which advocate for context-driven, industry-relevant, and practically applicable learning models, particularly in vocational education where skill transfer to the workplace is a primary objective.

The implications of these findings are substantial for both curriculum development and instructional design in vocational tourism education. The identification of moderate ocean literacy levels among students preparing for careers in tourism signals an urgent need to embed systematic ocean literacy instruction within existing vocational programs. Given Indonesia's archipelagic geography and the nation's dependence on marine-based tourism, this educational gap presents a critical obstacle to the cultivation of a sustainability-oriented tourism workforce.

The readiness of students to engage with technology provides a key leverage point for addressing this gap. Integrating ocean literacy modules with digital competencies (such as data interpretation, digital navigation, and content creation) can generate synergistic learning outcomes, equipping students not only with marine knowledge but also with career-relevant digital skills. This integration would support emerging professional pathways in marine

ecotourism, blue economy initiatives, and sustainable tourism management, which increasingly require a combination of environmental awareness and technological fluency.

Additionally, the geographic constraints experienced by many inland students, as identified in this study, highlight the critical need for technology-mediated access to marine learning experiences. Innovations such as VR-based underwater tours, AR marine ecosystem overlays, and interactive dashboards for ocean monitoring and conservation can democratize access to marine education regardless of students' physical proximity to coastal areas. By simulating real-world marine experiences through digital means, these technologies can foster deeper engagement, curiosity, and cognitive connection to ocean systems among students who otherwise lack direct exposure.

In conclusion, the integration of technology into ocean literacy education in vocational tourism settings is not only feasible but essential. It provides a pathway to elevate both environmental understanding and workforce readiness, ensuring that future tourism professionals are equipped to support sustainable practices in one of the world's most marine-dependent industries.

3.8. Vocational Education and The SDGs

Vocational education plays a critical role in advancing the SDGs by equipping learners with practical skills, technological competencies, and sustainability-oriented mindsets essential for 21st-century careers. In the context of Indonesia's tourism sector (particularly within its archipelagic and marine-dependent economy), vocational education serves as a frontline mechanism for preparing a workforce capable of balancing economic growth with environmental stewardship.

This study emphasizes that vocational tourism students are not only receptive to technology-enhanced learning but also positioned to become agents of sustainable change. By integrating ocean literacy, digital competencies, and sustainable tourism principles into vocational curricula, educational institutions can directly contribute to several SDGs:
(i)   SDG 4 (Quality Education): Promoting relevant, skill-based education that fosters environmental and technological literacy.
(ii) SDG 8 (Decent Work and Economic Growth): Enhancing youth employability in green tourism sectors and supporting lifelong learning.
(iii) SDG 13 (Climate Action) and SDG 14 (Life Below Water): Preparing students to understand, respect, and protect marine ecosystems through tourism practices.
(iv) SDG 12 (Responsible Consumption and Production): Encouraging responsible behaviors in hospitality, food services, and travel operations within tourism education.

Moreover, the focus on digital learning and equitable access in this study addresses SDG 10 (Reduced Inequalities) by proposing solutions that overcome geographic and infrastructural barriers through technology. Vocational education, when designed with sustainability and inclusivity at its core, has the potential to serve as a transformational platform for national development and environmental resilience.

Aligning vocational education with the SDGs is not merely an educational reform; it is a strategic imperative for building a tourism workforce that is future-ready, environmentally conscious, and globally responsible. This study adds new information regarding vocational education and SDGs, as shown in **Table 1 and 2**, respectively.

Table 1. Previous studies on vocational education.

No	Title	Ref.
1	Competency index of technical vocational education and training (TVET) instructors for 4.0 industrial revolution	[56]
2	Gender, region, and field of expertise in vocational education: A map of inequality among vocational high school students	[57]
3	Dataset on the number of schools, teachers, and students in Sulawesi, Indonesia: Kindergarten, primary, junior, senior high, vocational, and Islamic boarding schools with educational access, quality, and cultural implications to solve challenges and strategies in education management and support Sustainable Development Goals (SDGs)	[58]
4	Methodology for investigating competency index of technical vocational education and training (TVET) instructors for 4.0 industrial revolution	[59]
5	Literature review: Technical and vocational education and training (TVET) in Malaysia	[60]
6	How to make a cognitive assessment instrument in the Merdeka curriculum for vocational high school students: A case study of generating device materials about the Stirling engine	[61]
7	Industrial engineering students' readiness towards industrial revolution 4.0 at technical and vocational university: Literature review	[62]
8	Adaptive strategies for technical and vocational education and training (TVET) science educators: Navigating online home-based learning	[63]
9	Bibliometric analysis on artificial intelligence research in Indonesia vocational education	[64]
10	The urgency of online learning media during the Covid-19 pandemic at the vocational school in Indonesia	[65]
11	Ergo design of mentoring in the national ecosystem of vocational education in the period of the 10th technological order	[66]
12	Sustainable global economy through technical and vocational education and training for skilled workforce in achieving good governance	[67]
13	Teaching of the production and acceptance analysis of instant urap seasoning in the vocational school	[68]
14	Portfolio-based assessment in research methodology course students in vocational education	[69]
15	Measurement of the level of digital competence of vocational teachers in learning development	[70]
16	Vocational education curriculum: Between vocational education and industrial needs	[71]
17	Curriculum development in science education in vocational school	[72]
18	Barriers limiting the use of Google Classroom for learning vocational and entrepreneurship courses	[73]
19	A bibliometric analysis of vocational school keywords using VOSviewer	[74]
20	Current issue in the technical vocational education and training (TVET) instructor	[75]
21	Interactive multimedia design of motion graphics using a project-based learning approach for vocational education students: Experiments in cooking Taliwang chicken	[76]
22	The relationship of vocational education skills in agribusiness processing agricultural products in achieving sustainable development goals (SDGs)	[77]
23	Understanding vocational students' perception of video animation "physical activity and dietary behavior"	[78]

Table 2. Previous studies on SDGs in education.

No	Title	Ref.
1	Smart learning as transformative impact of technology: A paradigm for accomplishing sustainable development goals (SDGs) in education	[79]
2	Analysis of student's awareness of sustainable diet in reducing carbon footprint to support sustainable development goals (SDGs) 2030	[80]
3	Safe food treatment technology: The key to realizing the sustainable development goals (SDGs) zero hunger and optimal health	[81]
4	Analysis of the application of mediterranean diet patterns on sustainability to support the achievement of sustainable development goals (SDGs): Zero hunger, good health and well beings, responsible consumption, and production	[82]
5	Efforts to improve sustainable development goals (SDGs) through education on diversification of food using infographic: Animal and vegetable protein	[83]
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4. CONCLUSION

This study highlights the strong potential for implementing technology-enhanced ocean literacy education within Indonesia's vocational tourism sector. Students demonstrated moderate ocean literacy (3.37/5.0) and high technology readiness (83.6%), with 90.4% supporting the use of technology for sustainable tourism, despite limited direct ocean exposure among nearly half of the participants. The widespread digital engagement and platform diversity offer promising pathways for delivering marine education through virtual experiences, mobile applications, and interactive platforms. The findings support the integration of the TAM frameworks into ocean literacy initiatives, offering a robust approach to evaluating readiness and designing targeted interventions. However, the study's limitations (including geographic concentration in Java, culinary arts specialization bias, and cross-sectional design) suggest the need for broader, longitudinal, and experimental research to assess long-term impacts. Future studies should explore technology-mediated interventions, evaluate platform effectiveness (e.g., VR, mobile apps, gamification), and compare implementation across diverse regions. Ultimately, this research provides a foundation for scalable, inclusive, and industry-relevant ocean literacy education aimed at preparing vocational tourism students for careers in sustainable marine tourisms.

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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