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Digital-Based Chemistry Learning Innovation according to IMO Model Course 7.04 in Maritime Education

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Abstract: IMO Model Course 7.04 establishes training guidelines for officers in charge of an engineering watch, one of which is through chemistry courses. Innovation in chemistry learning at maritime universities is significant in meeting the competency needs of prospective seafaring students. Unfortunately, many students experience difficulty learning chemistry because chemistry concepts are abstract, and the allocation of learning time is negligible. Students also have difficulty finding chemical reference sources that comply with IMO Model Course 7.04 standards. The research analyzes the existing curriculum and develops innovative digital-based learning strategies by IMO Model Course 7.04 standards. Technology integration in learning includes using websites (e-modules), virtual laboratories, artificial intelligence, and edutainment applications/platforms. The evaluation results show that this innovation improves understanding of chemical concepts and the practical skills students need in the field. With real context through digital-based learning, students can understand the relevance of chemistry in various aspects of the maritime industry. It is hoped that these findings will become a reference for curriculum development in maritime universities and strengthen the contribution of higher education to the needs of the growing industry.

Keywords: Chemistry learning; Digital; IMO Model Course 7.04; Innovation; Maritime.

Introduction

Indonesia has a geographically strategic position and has an ocean area that is wider than land, so one of its visions is to become the world's maritime axis (Yakti & Susanto, 2018). Based on this, higher education in the marine sector is needed, which plays a vital role in preparing human resources (HR) to be competent and ready to face the demands of the global maritime industry. In this highly technical and high-risk industry, mastery of relevant science and technology is critical (Widodo & Bandono, 2021). Based on IMO Model Course 7.04, one of the fields of science that is a general subject, especially in the Engineering department, is chemistry (IMO, 2014). Chemistry learning in maritime higher education includes theory and practical application in the laboratory.

Chemistry is a science that studies the composition, structure, properties and changes of matter. In the provisions of IMO Model Course 7.04, chemistry is more specific regarding material related to the competence of Engineering or Ship Machinery Technology experts. However, chemistry is often faced with challenges, such as a lack of student interest, because the material is considered difficult and less applicable to maritime work (Chikendu, 2022). The time allocated for studying chemistry in maritime higher education is minimal, only 45 hours (IMO, 2014). Most of the chemical material is also abstract, so media tools are required to help visualize (Dela Cruz et al., 2014). Of course, these accumulated challenges will not be resolved if we still use conventional learning methods. This requires chemistry lecturers to have learning strategies relevant to these situations.

On the other hand, Gen Z students like the world of technology and have good digital skills. Student activities will always be close to gadgets, laptops, and smartphones (Wohlfart et al., 2023).

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They only need the internet to explore various things anywhere and anytime. Therefore, lecturers need references for technological innovation that can be integrated into chemistry learning according to the needs and characteristics of the students.

Educational activities require curriculum, strategies, techniques and methods to help the student learning process and achieve learning goals. A well-designed curriculum requires a systematic approach to information from the Maritime Education and Training vision, IMO Model Course, and national and international regulations (Wohlfart et al., 2023).

Specifically for maritime education, the International Maritime Organization (IMO) provides guidelines through several model courses to improve the quality of maritime education and training worldwide. IMO Model Course 7.04 is one of the relevant guides, one of which is on chemistry courses (industrial chemistry), specifically designed to ensure seafarers and maritime workers have an adequate understanding of the basics of chemistry and its application in ship operations and cargo handling (IMO, 2014). However, although this guide already exists, few chemical learning resources still comply with the IMO Model Course 7.04 guide, so learning in maritime higher education is not yet optimal.

Based on previous research, various research studies and developments of various learning media have been carried out. Various innovations in learning methods have been carried out, such as competency-based approaches and contextual learning, which can increase student motivation and understanding (Haryadi & Nurmala, 2021). Competency-based learning focuses on achieving specific skills relevant to industry demands, while contextual learning links theory with real situations that students will face in the world of work. These various approaches will be easy to do with digital-based learning media (Wohlfart et al., 2023). The integration of technology into maritime vocational education in Indonesia through scientific literacy can be an opportunity to create competent graduates (Mustain, 2020).

Based on the results of observations and interviews with chemistry learning practitioners at the Politeknik Maritim Negeri Indonesia, students still use the TCL (Teacher Centered Learning) approach and have not implemented SCL (Student Centered Learning). As a result, student learning is only limited to space and time. Lecturers are still looking for the best learning media to apply to chemistry courses, especially those whose material is by IMO Model Course 7.04. When conducting observations, lecturers and students were enthusiastic about various innovations in digital-based chemistry learning media, which could be a learning resource in maritime education (Sarjito, 2024). This research aims to explore digital-based chemistry learning according to IMO Model course 7.04 in maritime education through a qualitative approach. This approach is hoped to contribute to developing more relevant and effective learning methods in maritime universities, especially chemistry courses, to increase student understanding.

Materials and Methods

This research uses a qualitative approach with conceptual design (Sharp, 2003), namely the initial stage of the design process, where general ideas about the product, system, or service to be developed begin to be formed. At this stage, the researcher has not yet gone into technical details but instead focuses on the big picture of function (what the product or system should do) and form (how the product or system will look or operate in general). This process includes interaction design, experience, process, and strategy. Some essential elements of this conceptual approach include identifying needs and problems, defining primary functions, explaining general forms, and exploring alternative solutions.

This approach was chosen because it allows researchers to explore lecturers' and students' perceptions, experiences and responses to the learning methods applied. This approach is hoped to support chemistry learning according to IMO Model Course 7.04 by integrating existing technology. This concept requires review by related parties in the education sector, especially maritime education, to encourage innovation by implementing the latest technology so that the chemistry learning process runs effectively and efficiently. Researchers also collected various supporting documents, such as syllabi, learning modules, and the IMO Model Course 7.04 guide used by lecturers in teaching. This documentation helps provide more apparent context regarding the teaching materials used and how international standards are integrated into the local curriculum.

Results and Discussion

This research aims to develop digital-based chemistry learning innovations adapted to IMO Model Course 7.04 in maritime education. Based on a qualitative approach with conceptual design, this research produces several significant findings regarding the effectiveness and relevance of implementing digital-based chemistry learning innovations in maritime educational institutions. The first finding shows that chemistry learning material in maritime education must be aligned with the IMO Model Course 7.04 standard, which covers the competencies required in Marine Engineering.

Discussion

This research's results align with previous research findings, which show that an industrial context-based learning approach can increase student engagement and the relevance of learning material. IMO Model Course 7.04 in teaching chemistry at maritime universities provides a more applicable approach, encouraging students to understand how the chemical concepts they learn can be applied in real situations in the maritime industry.

The chemical materials consist of 5 chapters, namely Fundamentals (6 hours), acidity/alkalinity (3 hours), corrosion (2 hours), Water Testing and Treatment (12 hours), and Introduction to Fuels and Lubricants (12 hours). Instructors and subject experts state that this material meets the technical and non-technical competencies expected of seafarers and marine engineers. Unfortunately, the allocation of learning time is minimal, so it is necessary to implement a learning strategy based on student-centered Learning, which is not limited to space and time. Therefore, one solution is to integrate chemistry material through digital-based learning innovation. Digital-based learning platforms often offer various interactive features, such as simulations, learning videos, visualizations and integrated game-based quizzes. Much research has been into the development of educational and entertainment (edutainment) learning media. Usually, these features are designed to improve students' understanding of chemical concepts.

1. Website

The chemistry learning website is a digital platform designed to help lecturers and students understand chemical concepts more effectively and in-depth. Various studies have been carried out on the development of website-based teaching materials, and these studies show that student learning outcomes using web-based interactive teaching materials are higher than those of existing teaching materials, with material limited to the subject of thermochemistry (Matondang et al., 2022). Apart from that, research into interactive multimedia development has been carried out using Adobe Flash software containing material about the human respiratory system. This Website is declared valid and suitable for biology learning (Sadikin et al., 2020). Interactive multimedia with a maritime context has also been developed using reaction rate material (Wijayati et al., 2021).

Integrating ICT in learning with the right strategy will help students understand the material more effectively and productively. However, as with the two studies, learning websites are usually limited to one subject. In addition, some lecturers have difficulty adapting their learning modules to comply with IMO standards without reducing the essence of important chemistry material. Based on this, it is necessary to have a chemistry learning website whose material complies with the provisions of IMO Model Course 7.04 (Kurniawan et al., 2024). References to the industrial chemistry website are accessed via the link https://bit.ly/kimindustri. The Website provides chemistry content, including interactive simulations, quizzes, and learning instruments for introductory chemistry, acid-base, corrosion, water testing and treatment, and oils and lubricants.

2. Virtual Laboratory

Some chemical experiments relevant to IMO Model Course 7.04 material require special equipment not always available in the laboratory. Students also stated that Learning would be more effective if it were accompanied by more practical practicums in the field or simulations related to chemical theory. One student said, "The theory is good, but we need more practicum to understand. If there were more complete facilities, maybe the Learning would be even more effective." Unfortunately, chemistry laboratories at maritime universities usually do not have the tools and materials students need. Due to these limitations, some practicums use virtual laboratory-based learning media.

Virtual laboratory is an interactive simulation platform that allows users to conduct chemical experiments online without needing physical laboratory equipment (Hao et al., 2021). The following are details of some of the materials that can be studied in the virtual laboratory, such as in the Basic Chemistry chapters (chemical reaction simulations, interactive periodic table, and gas laws), Acids and Bases (pH determination, neutralization reactions, and acid-base titrations), Corrosion (metal corrosion simulations and corrosion prevention), Water Testing and Treatment (water quality testing, water treatment, and desalination), Oil and Lubricant (physical properties of oil and lubricants, oil composition analysis, and lubricant quality testing).

Virtual Laboratory platforms that can be used include PhET Interactive Simulations – Developed by the University of Colorado Boulder, which provides simulations for a variety of basic chemistry concepts, including acid-base and Corrosion; ChemCollective – Which provides virtual experiments for introductory chemistry, including acid-base titration simulations and chemical reaction experiments; Virtual Chemistry Lab by Late Nite Labs – Simulation laboratory for various organic, inorganic, and physical chemistry experiments; Labster – This platform has a variety of simulations related to industrial chemistry, such as water treatment, environmental chemistry, and oil and lubricant applications. Students can conduct various experiments safely and comfortably through this virtual platform and gain an in-depth understanding of materials necessary for introductory chemistry and industrial applications. Based on previous research, students responded positively to PhET Simulations as a virtual laboratory (Mashami et al., 2023).

Figure 1. PhET Simulation for Acid-Base material (pH determination)

3. Artificial Intelligence

Artificial Intelligence (AI) in chemistry has become a revolutionary tool to accelerate research and innovation (Baum et al., 2021). AI can be used to predict the results of chemical reactions, design new molecules, and speed up drug discovery (Brown et al., 2020). With sophisticated data analysis, AI can process vast amounts of information from chemical experiments (Choudhary et al., 2021) and scientific literature to discover complex patterns for humans to see. In industry, AI helps optimize chemical manufacturing processes, water treatment, and the development of new materials such as lubricants and anti-corrosion compounds. AI in virtual laboratory simulations also makes it easier for students to learn chemistry concepts interactively, opening up new opportunities in science learning in the digital era. Each type of AI can help address learning and research challenges in these various subfields of chemistry, making the learning process more interactive, predictive, and adaptive.

Table 1. Artificial Intelligence in Chemistry Learning.

Chapter	Artificial Intelligent Tools and Platform
Basic Chemistry	PhET Simulations, DeepChem, ChemDraw, ChemDoodle, ALEKS, Wolfram Alpha, SciFinder.
Acid-Base	PhET Simulations (Acid-Base Reactions), IBM RXN for Chemistry, Wolfram Alpha (untuk kalkulasi pH dan titrasi).
Corrosion	Corrosion Prediction Software, Finite Element Analysis (FEA) untuk simulasi korosi, AI Predictive Maintenance.
Water Testing and Treatment	AIQ Water, AI-based IoT Systems, Water Quality Monitoring AI.
Oil and Lubricants	TriboAI, Oil Intelligence, Predictive Analytics for Lubrication.

4. Edutainment Applications/Platforms

Edutainment (education and entertainment) applications combine elements of education and entertainment to make learning more interactive and fun. For introductory chemistry, acid-base, Corrosion, water testing and treatment, and oil and lubricants, several applications and platforms can help understand these concepts more interestingly. The following are examples of edutainment applications that are relevant to chemistry: ChemCaper, Kahoot!, Periodic Table 2023, Happy Atoms, Virtual Chemistry Lab by MEL Science, Water Cycle by Toca Lab, and Corrosion Game by NACE International. These applications make learning chemistry more interesting through games, simulations and interactions that are entertaining but still educational. Suitable for a wide range of ages, from children to adults, they help simplify complex concepts in chemistry in a fun way.

Apart from that, digital comics are one of the media currently popular with Gen Z through the power of their illustrations and storylines. Several development studies have used the CET (chemo edutainment) approach to increase creativity and student learning outcomes from cognitive, affective and psychomotor aspects (Nugraha, 2020). Usually, researchers use the webtoon application as an online comic platform to disseminate works, such as physics comics, which are assisted by the webtoon application (Aliifah et al., 2023; M. Arsyad et al., 2022). A chemical comic that can be used as an edutainment medium whose material is by IMO Model Course 7.04 is ChemicoMine (Nafillah et al., 2024). The comic can be accessed via the link https://www.webtoons.com/id/canvas/chemicomine/list?title_no=966301.

The results of interviews with lecturers and students showed that the majority of participants responded positively to this innovation. They consider that digital-based learning methods make complex chemical material more accessible through concept visualization and interactive simulations. This digital-based chemistry learning innovation is a strategic step in improving maritime education's quality in accordance with international standards' demands (IMO Model Course 7.04). This research shows that digital-based learning has advantages, such as flexibility and accessibility, efficiency, and SCL (Student Centered Learning) based learning, which is attractive to students. Several challenges include the availability of equipment and technology, limited laboratory facilities and the need for material adaptation. Educational institutions must invest in adequate digital infrastructure and train educators in managing digital-based learning.

Overall, this research shows that digital-based chemistry learning innovations that comply with IMO Model Course 7.04 have great potential to improve the quality of chemistry education in maritime universities and produce graduates who are better prepared to face challenges in the world of work. However, the long-term success of this innovation will depend heavily on the institution's ability to overcome existing challenges and continue to improve the quality of learning by seafarer competencies and adaptation to international curricula.

Conclusions

Chemistry is a general introductory course in maritime higher education, especially in the

Engineering department, the material of which must be by IMO Model Course 7.04, but has little allocation of learning time. Students need learning that has high flexibility and accessibility through technology implementation. This research explores digital-based chemistry learning innovations according to IMO Model Course 7.04 for maritime education. Some innovation options are using learning platforms and combining existing technology such as interactive websites, virtual laboratories, artificial intelligence, and edutainment applications/media. Hopefully, this research can become a reference in learning and be helpful in the world of education, especially in the maritime sector.

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