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Design of Digital Learning for Preventing Human Error in Ship Accidents

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***Abstract*— Shipping safety is a main priority in all industries, including the shipping industry. The shipping industry must provide guarantee of the safety of people and cargoes in the shipping process. Ensuring shipping safety will support increased world trade. The development of the shipping industry has increased due to world trade, but this increase is not consistent with shipping safety standards. Shipping safety is low due to the quantity of ship accidents that have caused fatality and property loss. Humans error are one of the factors causing ship accidents. Inadequate skill and competence of ship crew is one of the indicators in human error that can cause ship accidents. Inadequate skill and competence of ship crew due to limited time and space to learn and improve their skills and competency. Purpose of this study is to develop maritime learning application prototype, that can be used crews to learn by ship and improve their competence and skills with flexible time and place. The name is application is Smart Shipping. The method used in this research is the waterfall method. The result of this research is an e-learning Prototype that was designed based on user's competence and subject expertise as well as the position on the ship. Material in this e-learning can be downloaded for offline learning. Furthermore, e-learning provides learning evaluation to measure user understanding through questions, exercises, and tests. The shipping industry can use this e-learning as a preventive action of ship accidents due to human error.**

Keywords— smart shipping, e-learning, ship crews, shipping safety, competency improvement, ship accidents.

I. INTRODUCTION

Sea transportation has been used for more than 80% of world trade. The increase in the volume of goods is in line with the development of world trade. Even though sea transportation is the primary means of trade, basically there are many accidents during voyage and the ship in port [1].

Sea transportation is critical to the global economy's development because it is the principal mode of cargo transportation. Sea transportation is commonly used because it is less expensive and more accessible. The smooth traffic flow of sea transportation must be supported by high shipping safety. Marine safety is related to protecting life and property through regulation, management, and technology development. Marine safety is directly tied to ship management and ship operation. Ship safety standards contribute to the threat of unsafe conditions.

Shipping safety is a significant issue, and the total loss caused by a ship accident is a nightmare for shipping industry [2]. Shipping safety is essential and has a central position in aspects of marine transportation. Neglected shipping safety will increase economic costs, pollution, medical costs, and inefficient energy. Furthermore, ship accidents can cause fatality, loss of property, loss of cargo, and pollution [3]. Currently, International Regulations applied to prevent ship accidents and control shipping safety. These regulations include SOLAS, ISM Code, STCW Manila Amendment, and ISPS Code. SOLAS regulates ship construction, stability, engine, electrical, safety equipment, radio communications, and navigation equipment. The ISM Code is an international convention that aims to ensure safety during ship operations and prevent pollution. STCW is an international treaty that ensures seafarers have the required competencies and abilities to perform their responsibilities safely and effectively on ships. The Convention aims to do this by defining minimum training and certification requirements that must be satisfied before a seafarer in a voyage.

Many factors cause ship accidents, and one of them is that is human error [4]. The human error occurs due to the lack competence of crew [5]. Human error, such as inadequate skills and supervision, was the most common causative factor that cause the ship to burn or explode [6] Inadequate crew competence is dominant factor of human error that has lead marine casualties [7]. Study found that the training of master and crew were more significant factors causing ship accidents than other human risk factors [8]. Willingness to learn, talent, training and education of seafarers will have an impact on safety and efficiency in sea transportation [9].

The most critical cause of accidents is the human factor, especially the crew. The crew's lack of discipline, skill, and unpreparedness of the crews in emergencies situation can lead to ship accidents [10]. The limited knowledge of crew has caused risks to shipping safety and has lead ship accidents [11]. Law crew skills can lead to ship accidents, and if not handled, will reduce shipping safety [12].

The number of ship accidents in Indonesia is caused by inadequate crew skills or competencies. Inadequate competency has a negative impact, consisting of fatalities and material losses. This condition is a very big problem in the shipping industry. The crew should have training to improve their skills and ensure shipping safety. Therefore, it is important to provide the crews with education and training systematically [13].

The inadequate crew competence because they have limited time and facility to learn and develop their competence. This limitation is because the learning media in maritime education and the shipping industry are offline learning.

E-Learning can be a solution to solve the problem of crews and cadets' inadequate competence, but there is no

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application in the maritime industry available for e-learning.

The aim of this study is to create a digital learning to improve crews and cadets' competence and skills that flexible time and place.

Digital learning provides an opportunity to increase knowledge in a flexible environment, and can help achieve a productive and diverse education. In addition, digital learning has a positive impact on the environment due to reduced carbon emissions [14]. E-Learning is an educational method using internet, participating in online, interacting digitally, and independent learning that is flexible in time and place.

In many countries, development of infrastucture, and strengthening foundations of technology and communication have been carried out to provide users to availability unlimited information via internet. This is intended to create online teaching and learning in general and in educational institutions.

The Covid 19 pandemic has changed people's of life. The order of life has changed in all sector, including education. Educational institutions are adapting quickly to use of digital media in teaching and learning. E-learning provides users with distance learning. This means that users can access it at any time and from any place. E-learning have implemented in schools and universities in Indonesia since 2019. Furthermore, developing states also take advantage of E-Learning when the COVID-19 pandemic until now. E-Learning can supports education and positively improves students' skills and competencies. Covid-19 prompted instructors to adopt e-learning for future learning [15]. E-learning provides satisfaction to students and reduces their anxiety related to covid-19 [16]. E-learning is a new method with no risks for student learning and can build student confidence [17]. Previous research found that medical students at the University of Jordan were satisfied in using e-learning and the knowledge they gained, so that satisfaction and knowledge had a significant relationship [18]. Another study discovered that students' long-term orientation influences the beneficial association between the use of e-learning systems and the benefits gained [19].

Research found that 95.5% advantages of e-learning is flexible in study [20]. In addition, study reveals that students in South Korea have positive intentions to use e-learning. It also mentions that the E-Learning is helpful for effective education [21]. A study also states that digital learning is an innovative technique to increase student success. The availability of e-modules in this system makes students more active in developing their learning [22]. E-education success in replacing classical learning for medical students in King Abdul Aziz University [23]. In line, the implementation of e-education in the Medical Physics Master program at the University of Malaya, conclude that study-from-home provide much flexibility and hopes that e-learning may apply in the future [24]. In addition, E-learning has much potential to develop university in Nigeria, and the use of E-learning positively impacts the educational process [25]. Furthermore, a study involving 171 psychology study program students shows that using e-learning positively impacts student academic achievement [26]. Study also found that the e-learning model provides independent learning facilities for students, and this method helps teachers and students develop computer skills and increase interactive skills [27].

Many previous researchers have investigated e-learning. However, its implementation is limited in formal education such as schools and universities. This research fills the gap by implementing e-learning in the broader environment, namely shipping industry. This study implements e-learning to crew and cadets of ships. This research creates an e-learning application titled "smart shipping," for cadets and crews. This e-learning provides the user with the video and module in the format of portable document format (PDF) containing scientific courses and national as well as international regulations in the maritime sector. Users can study these courses and regulations online or download them offline. There are also exercises of questions and answers to train and test users' competencies.

E-learning provides the questions with the available answer choices. If the user gives the wrong answer, the system will make corrections and display the correct answer. The material in these fields consists of 3 levels, consisting of Level 1 for Cadets, Level 2 for Third and Second officers, and level 3 for chief officers, Machinists, and Master.

This research contributes to maritime education and shipping industry. Implementation of this E-learning can improve the cadets and crews' competencies and skills. Since adequate cadets and crews' competence may prevent ship accidents, the use of E-learning is suitable for this sector.

II. METHOD

This research develops applications using the waterfall method. Waterfall develops software like flow pattern, each stage must be completed before moving on to the next. The waterfall method is a way of developing applications through a series of sequential stages. This can reduce the possibility of errors This method starts with the phases of analysis, design, implementation, and testing. The process of the waterfall method follows:

1. Analysis
   The Analysis Process begin by gathering information about user needs, the application's capabilities, functional and non-functional requirements, analyzing business processes, analyzing existing facilities in the application, creating requirement documents, and confirming requirement documents. Confirmation of requirement documents consists of designing specifications, developing applications, and testing.
2. Design.
   This phase is the software design. The stage consisting of system architecture design, user interface design, database design and application module design. Desain Process used Entity Relationship (ER) Diagram.

3. Application development
   This stage is developing the application. Application development is done through coding. The application is developed according to the design specifications. Application development used Data Flow Diagram (DFD)
4. Testing
   This phase is developed application modules. The tests performed include functional tests and performance tests. The software is tested to ensure that it works properly. Testing also corrects any faults in the application before it is released to users. This research used laboratory tests.

2.1. Entity Relationship (ER) Diagram

This study uses an entity relationship (ER) diagram to create a database and represent the connection between entities and their attributes in detail in the design stage. ER is a model used to explain related data. The components of the ER diagram are entities and attributes. The entities in ER are users, knowledge areas and learning materials. Attributes consist of name and address user, user competence level, learning material content and test questions. The ER diagram also defines the relationship between entities and attributes.
ER Diagrams aims to plan the data structure, design new model databases, and ensure it identifies any logic or design flaws before implementation. Entity Relationship Diagram of this application shows in Fig 1.

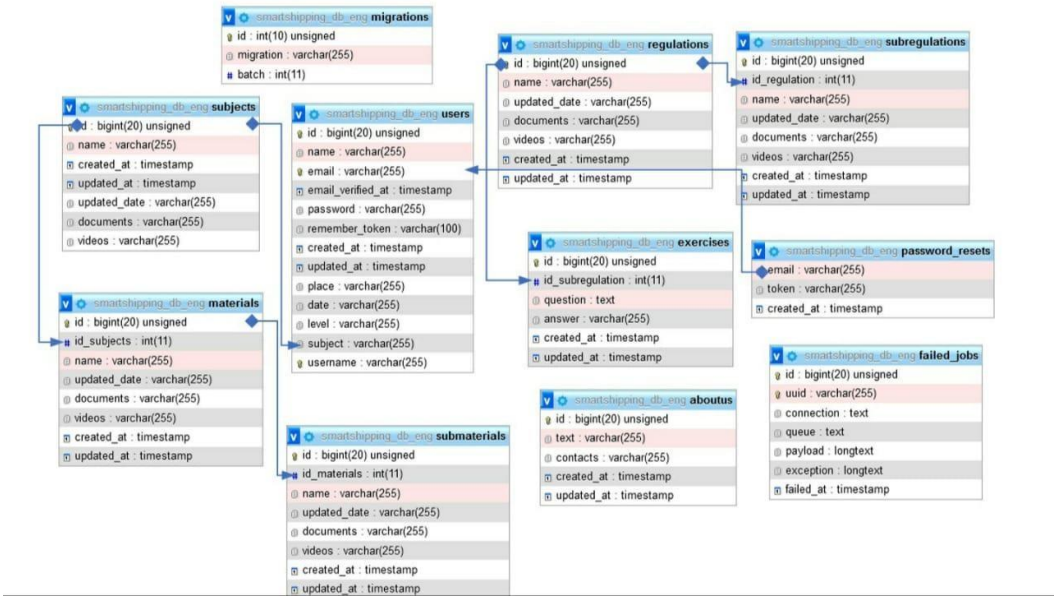


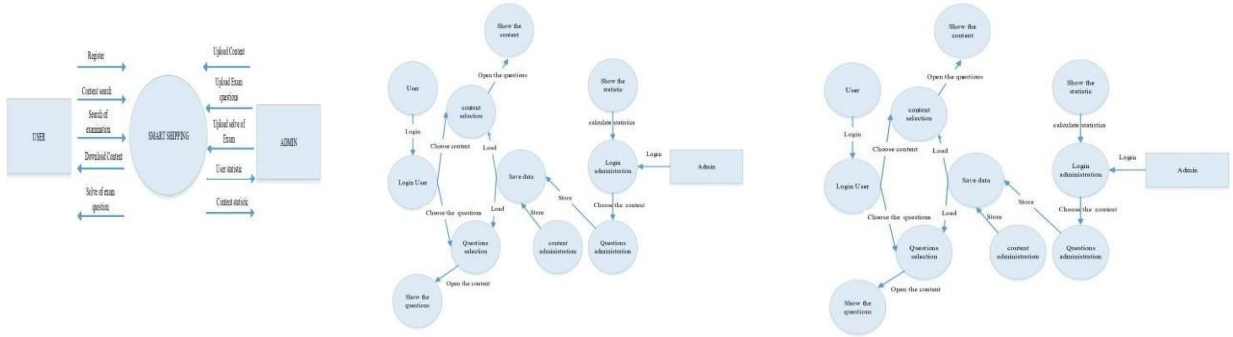
Figure 1 Entity Relationship Diagram

The entities used in this application are Crew, Cadets, Courses and their competency levels. The attributes are crew or cadet name and birthplace, email, username, password, knowledge area, course type and crew or cadet competency level.

2.2. Data Flow Diagrams (DFD)

DFD provides an overview of the data flow of a process and presents information about the inputs and outputs of each process. The study uses data circulation diagrams to represent the flow of data in each process in the application. DFD is a picture of the flow of information through the input process to produce output. DFD focuses on information flow, data origin, destination, and data storage. In the software development process, DFD is a tool for describing and analyzing an information system. Creating a DFD will facilitate the process of conveying information with a simple visual display to make it easier for users to understand this application. In addition, the DFD can effectively explain the workflow, and the DFD structure can describe the workflow in detail.

DFD in this application consists of DFD level 0, DFD level 1, and DFD level 2. DFD level 0 is a basic diagram that provides an overview of interactions with external parties In DFD 0, the data flow is directed directly to the system, so no data information is stored in the data memory. DFD level 1 is the process of elaborating information after passing through DFD level 0. Information on DFD level 1 design to be easier to understand and information is broken down into smaller units. DFD level 2 is a data flow diagram which is a detailed process of DFD level 1. This function describes the processes that exist within the scope of the system. Data flow diagrams show in Figure 2.



(a) (b) (c)

Figure 2 Data Flow Diagram (a) DFD level 0 (b) DFD level 1 (c) DFD level

III. RESULTS AND DISCUSSION

3.1. Smart Shipping application

The Covid 19 pandemic has changed the way of human life. The majority of people carry out their social interactions virtually and more sectors are switching to digital platforms. One of them is the education sector. Online learning is an alternative choice for teaching and learning activities.

The positive impact of online learning are independence in study, more flexible, and low cost. The development of communication technology and increasingly widespread internet networks has made online learning affordable for all regions. The digital era has encouraged the development of online learning applications. These applications can make it easier for users to obtain learning materials.

The use of applications as online learning media has been widely adopted in the education sector, especially in schools and universities. However, the use of e-learning in the industrial sector is still lacking. The maritime industry is an industry with a high level of risk. Many ship accidents occur in the shipping industry. One of the causes of accidents is inadequate crew skills and competence. Crew skills and competencies are inadequate due to the limited time they have to improve their skills and competencies. It is therefore important that the shipping industry is supported by a more flexible learning system to improve crew skills and competencies. The online learning system is a solution to problems that occur in the shipping industry, but until now the shipping industry has not been supported by an online learning system. This research has created an application to be used by shipping industry as an online learning media. The application is named Smart Shipping.

Smart Shipping is a learning application for the maritime industry that can be used by ship crews and cadets as an online learning. Smart Shipping was created based on previous research that found the factor causing ship accidents in Indonesian waters is inadequate crew skills and competence. The competency of ship crew is inadequate because the shipping industry has not supported learning media to develop crews' competence while they are in voyage [28].

Smart shipping is a web-based digital learning. Web-based digital learning is a learning technology development that can complement conventional learning models. The use of the application can help the learning system to be more efficient. Crews and cadets can use the application as a learning medium to improve their competencies and skills without being limited time and place. As a digital learning media, the variety of technologies that can be selected is very diverse, however, The difference between the Smart Shipping application and other digital learning is that smart shipping uses in the shipping industry and the material contained in the application can be downloaded for offline learning. Smart Shipping users cannot always connect to the internet or have sufficient internet speed, therefore, hybrid technology is chosen as one of the aspects of strengthening the solution so that it can be used better. The smart shipping application will provide offline and online services for use with high mobility and minimal internet services.

There are differences between smart shipping and the other online learning applications. The differences are: 1) the material, questions and discussions focus on the maritime education, including the division of learning materials and questions according to regulations and areas of competence. This is different from other e-learning with general materials, 2) arrangements can be made for learning materials that can be downloaded and studied offline, and 3) the process of purchasing learning materials can be added in further development.

Smart shipping can be accessed after user has an account in this application. To be able to have an account, users can register in a smart shipping account. The first step to use this application is that the user accesses the smart shipping web as seen in Figure 3.

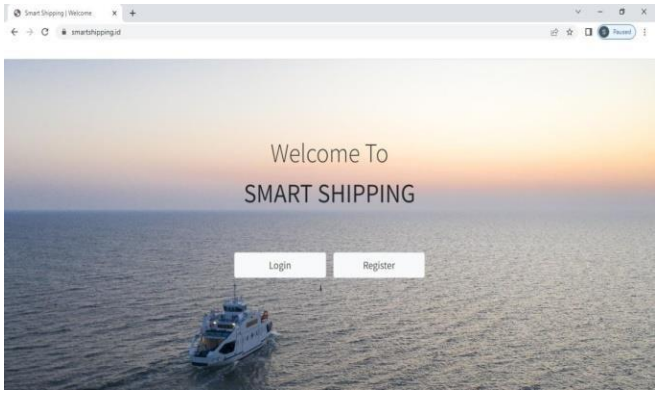


Figure 3 Initial menu

Ship crew as a user, register by inputting personal data, namely name, place and date of birth, level of Certificate of Competency, competency field, email, username, and password to the account registration. Users can use the account to login and access the application. The account registration menu shows in Figure 4.

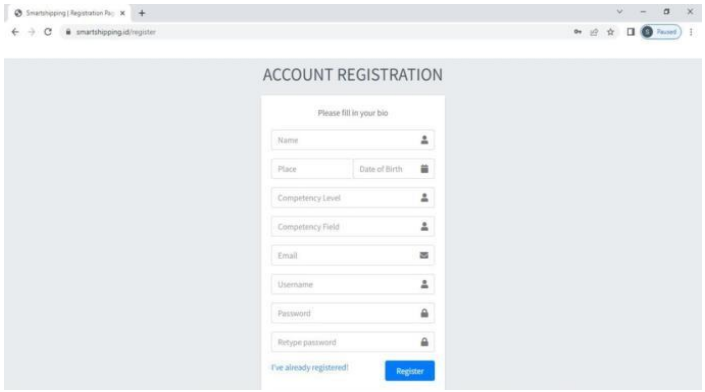


Figure 4 Account of registration menu

Figure 4 shows registration menu to access the application. The purpose of inputting data about level and competency fields is that users can use this application according to their field and level of competency. The system in this application will store personal data entered by user in the memory of this application. In addition, the confidentiality of the user's data is guaranteed and will not be published. After the user registers, the admin sends a letter of registration confirmation to the user's email. Users can access this application after registering. Users can log in to this application using the registered username and password. The login menu as shown in Figure 5.

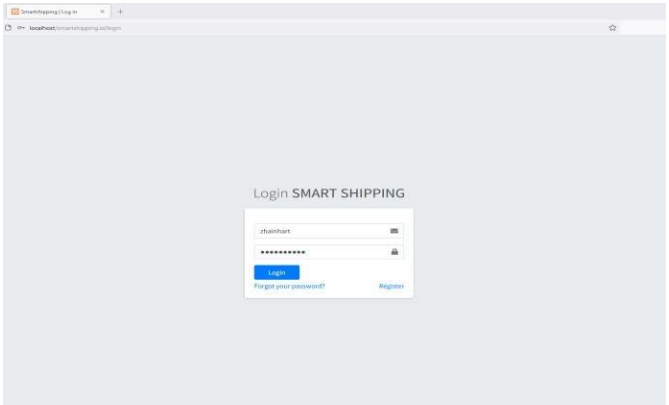


Figure 5. Login menu

In the login menu, users input their name and password to enter the application. If the user forgets the password, the user can use the Forgot Password feature and then change the password. If the user does not have a username and password, the user can use the Register feature.

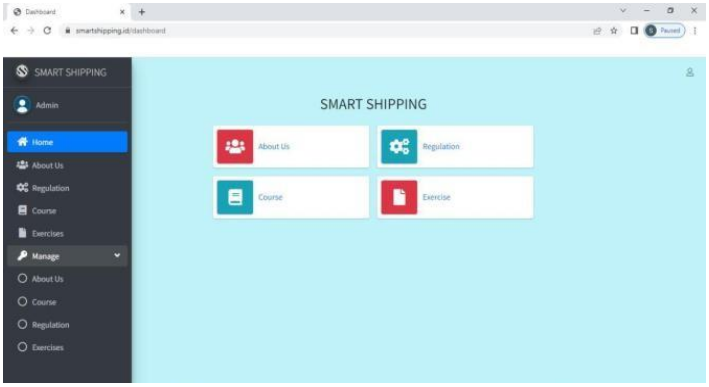


Figure.6. Smart shipping menu

Figure 6 shows the home page of this application. The home page displays the features of the application. These features are About Us, Courses, Rules and Exercises. About Us contains information about the application, including the administrator's smartphone number and email. The Courses menu contains learning material on nautical, engineering, port and shipping. The Regulations menu contains international conventions and national regulations related to shipping, navigation, safety and port. The exercise menu contains questions related to the learning material based on each field and level.

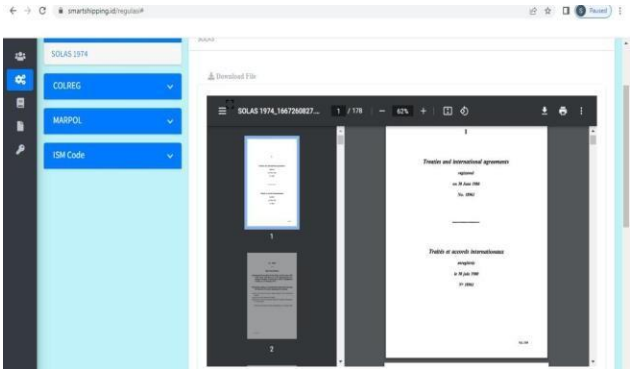
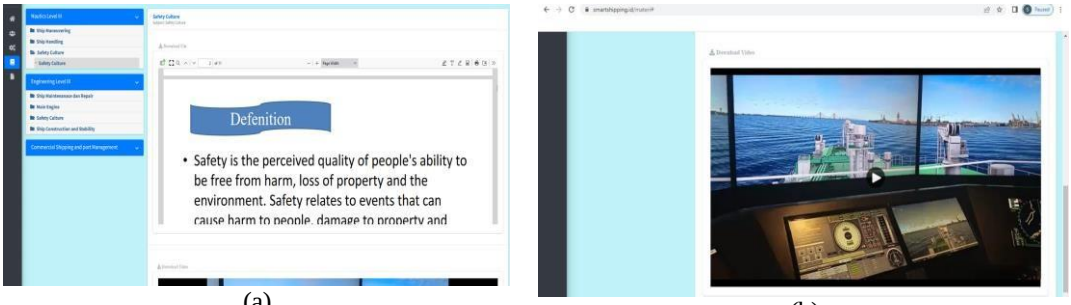


Figure.7. International Convention menu and international convention material

Figure 7 shows a menu of international conventions related to shipping and maritime safety regulations. These regulations consist of international regulations and national regulations. International regulations include regulations or conventions issued by the IMO and national regulations issued by the Government of the Republic of Indonesia. International regulations namely SOLAS, COLREG, MARPOL, ISM Code and ISPS Code. Government of the Republic of Indonesia regulations namely Shipping Law No. 17 of 2008 on Shipping, PM 39 of 2016 on Loading Lines, and PM 115 of 2016 on Transportation of Vehicles on Board Ships. Admin will enter new conventions or regulations issued by IMO and Government of Indonesia, so that users can read and know the latest conventions and regulations. Users can study the regulations or conventions online. Users can also download them for offline study. In addition, users can access learning materials based on their field and competency level.



(a) (b)

Figure.8. Learning materials in PDF (a), Learning Material in Video (b)

Figure 8 shows the learning materials based on the field and level of competence. The learning materials in this application are the nautical field level 3, level 2, level 1, engineering field level 3, level 2 and level 1, field of safety at sea, ship management and port management. The learning material in the nautical field consists of electronic navigation, watchkeeping, ship stability, cargo handling, marine safety, leadership and teamwork on board. The engineering material consists of ship engine operation, engine maintenance and repair, watchkeeping, electricity, marine safety, leadership and teamwork on board. Courses in shipping management namely shipping company operations, ship agency, cargo management, transport costs and safety management. Port Management courses namely port operations, ship management, ship services and transportation costs. Learning materials are presented in PDF as shown in Figure 8a and in Video as shown in Figure 8b. Learning materials in the form of videos contain theories, work procedures, and simulations of handling emergencies on board. Learning materials are presented based on the field and level of competence of the user. Learning materials in the form of PDF and video can be accessed online and can be downloaded for offline learning. Learning materials will continue to be added and updated in accordance with scientific developments.

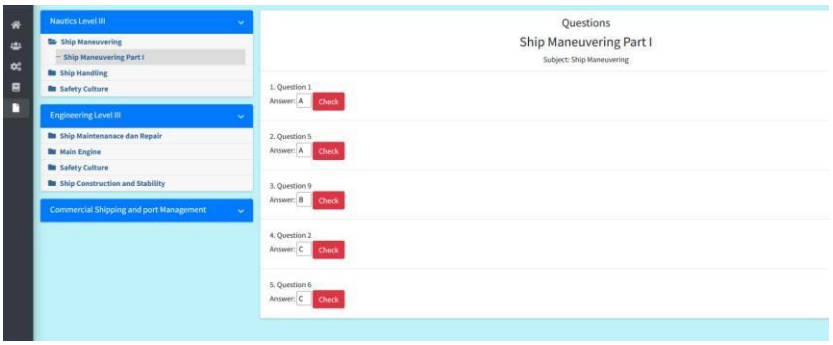


Figure. 9. Exercise menu

Figure 9 shows the exercise menu, which contains questions for each course based on level and competency fields. The questions are multiple choice. The questions change after the user has completed twenty-five questions. The advantage of this exercise menu is that the system checks the user's answer and makes corrections if the user's answer is wrong. If the user gives an incorrect answer, the system will display the correct answer. In the Exercise Menu, the time allowed to answer twenty-five questions is 30 minutes for theory and 60 minutes for calculation questions. The user's score is displayed after the user has answered twenty-five questions.

Laboratory testing

The researcher tested the Smart shipping E-learning using laboratory test. A test consisting of a functional test in the user registration and authentication process, a test for searching and displaying regulatory and competence materials, a test in the process of downloading material, a test in the process of searching and answering the exercises, a test in the process of adding, changing and deleting material, exercises and the answer.

In the registration process, if the username has been used, and user data is stored in the system there is a warning. The login page shows the error system if the users make a mistake in entering the username or password. The system proceeds to a menu's page if users log in successfully. The practice menu displays questions, answers, and a check answer feature. When the check answer feature is clicked, the system will make corrections and display the correct answer.

Technology, information, and scientific developments have made the education sector implement e-learning in the learning process. Likewise, the shipping sector requires e-learning to assist in producing ship crews who have good quality and competence. The *smart shipping* makes it easier for cadets and crews to

improve their competence. Good competency will guarantee the safety of passengers, goods, and ships.

Previous researchers have widely supported the implementation of e-learning because it has excellent benefits. The research consists of an efficient e-learning system that has an impact on learning outcomes. This system is easy to use, creates satisfaction, and improves performance. That is the hope that educational institutions can soon use it widely as a learning method [29], Students can enhance their knowledge in a flexible environment and resources by using online learning. The scope of e-learning now is more vital than ever. Due to its low cost, convenience, and availability, e-learning is becoming the dominant education in the world and a twenty-first-century force [30]. Flexible, economical, easy access, and can be updated regularly are the advantages of E-Learning as a modern technology. [31].

IV. CONCLUSION

Ship accidents are a big problem for the shipping industry. Inadequate competence and skill of crew are part of human error that can cause ship accidents. Therefore, a flexible learning method is needed for crew and cadets to improve their competence.

Smart shipping is a learning applicatioan prototype that can be used of ship crew to learn and improve their competency with more flexible. Smart Shipping suitable for implementation in the shipping industry and can be a solution to improve the competence and skill of ship crew. In addition to ship crew, cadets can also use this application to better prepare their competencies before becoming ship crew.

Learning material in application is in the maritime and shipping scope, namely Nautical, Engineering, Shipping safety, Shipping management, and Port management. The learning materials in this application consist of several levels, namely level 3, level 2, and level 1. Users can use the learning materials based on level of their certificate of competence. The learning materials in this application are in the PDF and Video, and these learning materials can be used online and can be downloaded for offline.

The implementation of *smart shipping* makes it easier for them to learn and develop their competencies. Ship crews and cadets with good competence can prevent ship accidents and provide safety guarantees for passengers and cargo.

This research created web based. The researcher hopes that the next research may develop it into Android-based and add features that are not available in this research yet.

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