Advance Sustainable Science, Engineering and Technology (ASSET)
Vol. 7, No.2, April 2025, pp. 0250209-01 ~ 0250209-014
ISSN: 2715-4211 DOI: https://doi.org/10.26877/asset.v7i2.1117

Advancing Adaptive and Personalized E-Learning Systems: A Systematic Literature Review

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Abstract. With the rise of Information and Communication Technologies (ICTs), adaptive e-learning has become a promising method for enhancing educational practices. This study reviews current research on personalized adaptive e-learning systems and proposes a mobile-based design to addressing the requirements toward Industry 4.0 and Society 5.0. Using a systematic literature review methodology by Kitchenham and Charters, 28 studies were analyzed further. The findings suggest a necessity for clearer definitions of "personalized" and "adaptive" learning and categorize adaptive e-learning designs into four models: learning materials, learner characteristics, pedagogical approaches, and learning structure systems. The findings show there is still a lack of clarity in the definitions of "personalised" and "adaptive" learning, emphasizing the importance of more standardized terminology. The proposed system dynamically customized learning content material based on user preferences, cognitive abilities, and performance metrics, demonstrating the potential for increased students' engagement and their learning outcomes. This study focusses on the possibilities of blockchain-based open educational resources, artificial intelligence, and gamification as for more engaging personalized student test to improve adaptive learning environments. Future study should confirm the suggested paradigm using empirical investigations and assess its usefulness in promoting lifelong learning.

Keywords: Adaptive e-Learning, Learning Innovation Models, Personalized Learning Strategies, Systemmatic Literature Review, Technology-Driven Education

(Received 2024-10-06, Accepted 2025-01-02, Available Online by 2025-04-27)

1. Introduction

The challenge for higher education institutions in preparing for the industry 4.0 and society 5.0 eras lies in internalizing lifelong learning and independent learning culture within students [1]. These attributes are essential for students, as knowledge workers, to succeed and prosper in their professional context in global competitiveness. The proper learning environment is required to support the student's needs through an immersive and suitable personalized experience [2]. Distance education has emerged as an education that utilizing technology to deliver courses to students. This method is already being applied, especially during the COVID-19 epidemic, when students inevitably must study in distance mode [3]. A strategy to achieve the global standard of inclusive education involve addressing students' diversity to accommodate different learning styles approach and increase their learning engagement [4]. A smart learning environment is a system that tailors itself to the needs, abilities, interests, and learning styles of learners to facilitate successful and efficient strategic learning experiences [5]. This concept cultivates skills like problem solving and creativity, preparing students to become lifelong learners.

Previous study indicates that out of 69 case studies with a global scope, 41 (59%) demonstrated that tailoring educational approach to individual students' learning styles and adapting based on their learning progress could improve their academics outcomes [6]. Given this context, smart learning environment plays a pivotal role in fostering a lifelong learning culture, aligning with Indonesia's strategic goals for workforce development and global competitiveness. Building a smart learning environment incoporates advanced technologies such as artificial intelligence (AI), machine learning (ML), data mining, and big data. The adoption of artificial intelligence has been widely implemented across different industries such as general information services through chatbot system in online retail and education, as well as diagnostic tools for diseases in healthcare [7-9]. Within the context of smart learning environment, these technologies enable personalized recommendation, adaptive learning activities, students' progress tracking, or learning analytics [10][11].

To underscore the novelty of this research, it is essential to conduct a thorough review of prior studies regarding systematic literature reviews in the development of personalized adaptive e-learning technology. Nevertheless, the current studies reveal gaps that warrant further exploration. While numerous reviews have examined aspects such as learning styles, learner characteristics, and system elements, their conclusions are disjointed to be a comprehensive unified architecture system. For instance, prior studies finding the most least commonly used e-learning platform, which learning style model is being used, and which learning support is being provided in the system [12]. Additionally, one study identifies and categorizes prior development based on six domains of critical learner characteristics and their impacts [13], while others focus on adaptive learning system components, such as the adapted objects, criteria, parameters, and algorithms [14].

Specific reviews on adaptive content recommenders in personalized learning to analyze what is the most used and least frequently used of learner parameters, recommendation techniques for content such as ontological and content-based filtering, machine learning techniques to implement more accurate content suggestions, evaluation metrics to measure the effectiveness of recommender systems, and usability testing [15]. The findings in usability testing studies, however, still lack in-depth in real-world cases. Some reviews focus on the implementation of AI/ML algorithms to enable personalized adaptive e-learning systems, such as which machine learning techniques are being used for identifying students' learning styles or which evaluation method to evaluate the effectiveness [12][16-19]. Also, some reviews focus on the terminology of personalized e-learning and adaptive e-learning itself from previous studies until 2020, and the result is still a lack of clear distinctions between these terms [20].

Recent systematic literature review on personalized adaptive e-learning emphasizes the application of AI or ML methods within one specific model on the system architecture [21][22]. Personalized adaptive e-learning architecture system consists of several model such as the learner model and the learning content model [23]. Designing comprehensive systems and it user interfaces require to conduct systematic literature review on the development of adaptive and personalize e-learning architecture system based on prior studies until 2024. This review aims to provide insights and categorize its development into four design components: the learning material contents, learner, pedagogical strategies

module, and learning structure system [23-25]. Also, the terminology of “personalized” and “adaptive” e-learnig system remained unclear until 2020. Furthermore, the lack of clear distinctions between "personalized" and "adaptive" e-learning necessitates a reevaluation of these concepts to ensure clarity and consistency in system design.

Based on this consideration, this research aims to analyze design requirements derived from prior studies, with the objective of developing a comprehensible adaptive and personalized e-learning system tailored to each student’s needs. The study aims to accomplish two specific objectives: (1) Define and differentiate the concepts of "personalized" and "adaptive" within the framework of e-learning systems, (2) Classify and synthesize findings from prior studies to guide the development of a cohesive and thorough system architecture.

2. Research Methods

This research employs the systematic literature review (SLR) method proposed Kitchenham and Charters [26] on academic search engines, Mendeley database. This method was selected due to the prevalent use of Kitchenham and Charters’ SLR in software engineering topic. The steps of SLR are outlined in detail below.

Determine the research questions for the browsing process. For this research, the research questions are as followed:

a) What are the existing definitions and concepts of "personalized" and "adaptive" in e-learning systems?
b) What models and design components have been proposed for adaptive and personalized e-learning systems?
c) How can personalized adaptive e-learning systems be tailored to meet user needs effectively?

Determine the keywords: “Personalized Adaptive E-learning”.
After the papers have been retrieved, the papers are filtered with below parameters:

a) Search filtration phase: published in a journal or conference between 2013 until 2024 and using English or Indonesian language.
b) Title and Abstract filtration phase: include the summary of the adaptive and personalized learning system implementation and the results. This phase also removes duplicate papers in the exclusion process. The meet criteria are based on the research questions that have been defined before.
c) Content filtration phase: include the detail about the adaptive and personalized learning system implementation and design result based on the meet criteria in the research questions.

The remaining papers will be scored when the papers are filtered. If the criteria are fulfilled more than half of the conditions in Table 1, the paper would be included in the next step.

Table 1. Quality Criteria Checklist

Quality Criteria Checklist	Checklist Condition
C1	Does the article clearly describe the research objectives?
C2	Does the article include a literature review, background, and research context?
C3	Does the article present related work from previous research to show the main contribution of the research?
C4	Does the article describe the proposed design, or the methodology used?
C5	Does the article have research results?
C6	Does the article present a conclusion that is relevant to the research objective/problem?

C7	Does the article recommend future work or future improvements?
C8	Is the article Scopus Indexed (Q1/Q2/Q3/Q4)?

Based on the SLR Process illustrated in Figure 1, 71 results were identified from Mendeley database. During the title and abstract filtration phase, 53 papers remain for further processing after the removal of duplicates due to similar titles, abstracts, and authors across different years. One paper could not be accessed due to a technical issue on the website, preventing its progression to the content filtration phase. A total of 28 papers were obtained from the content filtration phase and are deemed suitable for further analysis.

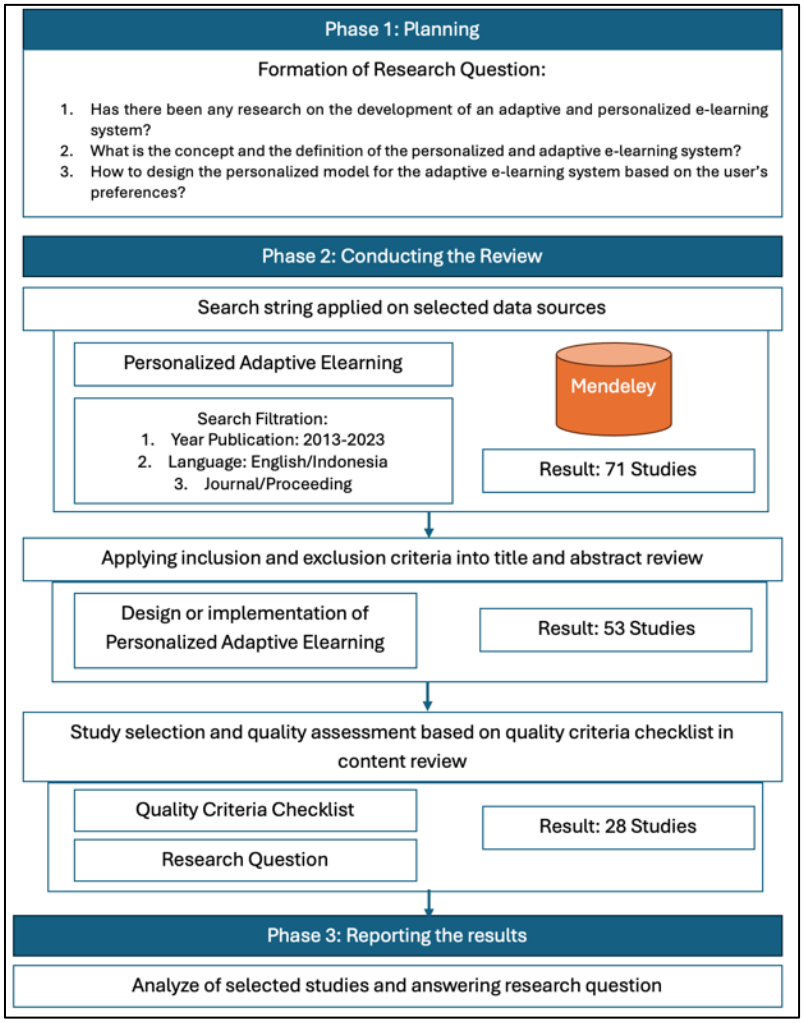

Figure 1. SLR Process

While the SLR provides a structured approach, analyzing of merely 28 studies may limit the generalizability of the findings. This limitation arises due to lack of diversity of journal paper database and its quality and scope of included studies based on only one database sources, potential bias in study selection related to database access permissions or employed a limited keyword search strategy, and limited representation of non-English and non-Indonesian studies, which may overlook significant contributions in other countries. Future studies should consider expanding the search to include grey literature, incorporate a wider range of languages, and evaluating more diverse e-learning implementations to ensure a comprehensive understanding of personalized adaptive e-learning systems.

3. Results and Discussion

Several discussions exist concerning the analysis of 28 prior studies on personalized and adaptive e-learning systems. this paper will present the results divided into two subsections. To clarify for requirements analysis of personalized adaptive e-learning system, the definitions of “adaptive” and “personalized” in the context of e-learning system based on previous study will be first be examined.

3.1. The Definition of ‘Adaptive’ and ‘Personalized’ in E-Learning System

An “adaptive” e-learning system refers to online pedagogical system that can adapt to indivisual student learning style, based on their activities and their prior knowledge [27]. This adaptability aims to enhance the effectivenes of the learning process and promotes metacognitive evaluation of learning objectives. This also being supported by [28] which stated that the “adaptive” aspect in e-learning system should be based on the learner preferences, such as learning style, learning strategy, and the learner’s knowledge level. According to [29], the preparation for adaptive e-learning involves seven steps: (1) content selection, (2) content division, (3) content outline and adaptivity of learning path, (4) select image, (5) design assessment and interactivity, (6) assembly the course content, (7) and the last is design an evaluation and feedback mechanism for continuous learner improvement.

The term “personalized” in an e-learning system refers to the system that allow learners to tailor their learning process or environment according to their exisiting knowledge, cultural background, condition, learning styles, behaviors, personalities, and preferences [27]. This results in each learner having a unique experience and access to the contents. According to [30], personalization allows learners to customize their environment, contents, media of contents, and learning paths. The parameters have been mentioned to provide a suggestion to the learner: the case problem, learning style, knowledge level, learning object, path, and the result score or performance from the evaluation test. Another definition of personalization indicates that the e-learning system should comprehend learner preferences, needs, and “what they are looking for,” which can be encapsulated in the navigation path feature [31].

Based on the above definitions, "Adaptive and Personalized" e-learning system involves continuous assessment of each learner's real-time performance. This approach utilized a platform to enhance the learner's satisfaction, identify the potential learning obstacles, and optimize learning efficiency. The technology platform has improved, particularly following the COVID-19 pandemic, however, it remains a significant challenge within the current educational system due to the complex and time-consuming processes involved. However, if the adaptive and personalized e-learning system is implemented effectively, it will lead to cost reductions by substituting traditional instructor-led teaching, enhance the quality of content delivery, and offer greater time flexibility for students [27][28][30][31].

3.2. The Design of Adaptive and Personalized E-Learning System

Based on the result of SLR, some adaptive and personalized e-learning system designs have been suggested. Four models are classified as components of personalized adaptive e-learning design: learning material contents, learner, pedagogical, and learning structure systems. The previous studies indicate the possibility for the inclusion of two or more component designs.

3.2.1. Learning Material Contents Model

This model emphasizes the personalization and adaptability of learning materials and content for learners, as proposed in various prior studies. There is a proposed model to break down learning material using Content Chunking Method, when the learning material is being reduced into manageable chunks such as topics, modules, content type (information, test, quiz, or assessment), make a smaller content units into learning objects (description, theory, practices, evaluation) or frame-layer method to establish the sequence of each layer (the beginning of lesson, instruction, exercise, evaluation, and completion) [27] [32-34]. Another proposed model involves segmenting learning material according to subject-specific context that contain numerous challenging terms or concepts, particularly in language subject which includes translation, glossaries, and specialized terminology [35]. Lastly, there is a model that categorizes learning resources according to specific parameters, such as: media presentation (text based,

image, video, audio), difficulty level, and knowledge type (basic, supplementary, and reinforcement) [28][30][36][37].

Although the module division methods of these models are varied, the metadata design are similar. Ot encompasses domain knowledge, structure, and sequence along with the relationship between the chunks of learning material or the information [32][34]. This is achieved using semantic web or ontology, which enabling the relationship between learning object or content and establish the hierarchy for various advanced techniques, including knowledge engineering, artificial Intelligence (AI), Natural Language Processing (NLP), and its new emerging fields like the Semantic Web for E-learning (SWEL) [38-43] or using adaptive hypermedia system [44]. Alia et al. [9] stated that "artificial Intelligence (AI) technology with the Natural Language Processing (NLP) method is an attractive option". The design of the open corpus of learning material is discussed in several papers, highlighting the process of retrieving online material sources or data collection from external digital libraries, blogs, and educational websites through crawling or Natural Language Processing (NLP) [38][45]. One paper indicated that supplementary features could be incorporated to enhance learning materials, including the recording of learners' opinions and the sharing of their preferences through notes, comments, or expressions of likes and dislikes. This aims to develop a human-centric system that enhances the agility of the e-learning framework to incorporate learner feedback, accommodate learner preferences, and allow instructors to monitor learner activities and respond appropriately [46].

3.2.2. Learner Model

This model focuses on describing the identification of learner characteristics to become a feature of how e-learning system will be adaptive and personalized that cater to individual need. The stored data can include learner's performance or competency indicators (pretest, posttest, quiz, or assignment submission) [28][29][34][37][47], learner's knowledge or cognitive levels [31][32][34][39][48], learner preferences (learning strategy, learning style, learner sequences) or learner characteristic derived from questionnaire [28][31][34][39][49], and logs of activities or learning behaviors recorded in the database or system (such as eContent) that contain the time spent related to learning process, user history of website access, access learning materials, and the participation in discussion, etc. [31][32][45][47].

3.2.3. Pedagogical Model

This model focuses on how methods or practices related to teaching to be implemented in personalized adaptive e-learning. For example, classifying the learning material based on certain learning style such as visual-auditory-kinesthetic (VAK), Felder-Silverman model and adaptive mobile learning (AMOL) system that support visual-verbal preference, and apprentice-incidental-inductive-deductive-discovery (AIIDD) [30][36][50]; determining appropiate learning method and pedagogical method such as case based reasoning, constructivist, collaborative, inquiry-based, integrative, reflective, objectivist, and competency-based [30][51]; identifying utilized learning strategies that have been use such as instructional system design [31]; establishing evaluation criteria through self-assessment tools like "Rubrics" [48], employing custom rule-based assessments based on learning design outcomes to pinpoint a remedial or additional assessments [29]; assessing outcomes for each topic or learning material via quizzes [37]; providing a feedback, suggestions, or recommendations based on predetermined evaluation criteria [28][29][37][49][52].

3.2.4. Learning Structure System Model

This model focuses on designing the the learner-centered learning structure, interface system, learning path, or course module. To ascertain learner's preferences regarding learning styles and other criterias, the system can utilize a questionnaire, filled form, or quiz [31][47][53]. This model encompasses a dynamic learning course structure, learning sequence path, various learning activities, learning material, learning content, suggestion or recommendation system based on learner's activities or the learner preferences in pedagogical model and learning style, as well as plagiarism check [31][32][36][40][43][45][50][51][53][54]. It includes an assessment and evaluation focused on indivual learning

[29][37][48][49]; dynamic interface system, and contents presentation position and customized navigation menu based on pedagogical model or learning style that reflect the learner preferences or performance [36][38].

3.3. Discussion

Table 2 summarizes the categorization of prior studies based on the design component model. Previous research in the design of components or models for personalized and adaptive e-learning has primarily concentrated on the learning material component, followed by the learning structure system. Learning material component is the smallest unit from the other components, but also the most complex and the most challenging to implement into a real case. Since the learning material can be subject to change because it must adapt with the state-of-the-art of the knowledge itself or there is a revision that must follow the curriculum. Especially if the course subject is heavily dependent on the novelty of the adoption like Information Technology (IT) or digital related. Moreover, the learning environment needs to be simplified and emerge the output of learning process into fun and inspiring for students [55]. There is also a challenge to designing an open corpus domain knowledge because in the 21st century learning, students can search their supplement material from Google to be more understanding about the topic that still confusing for them. But the quality of supplement material itself should be reviewed by the teacher to ensure that student will get a credible knowledge source.

Table 2. List of previous studies groupings based on design components

Design Component	**Previous Study**
Learning Material Model	[27] [28] [30] [32] [33] [34] [35] [36] [37] [38] [39] [40] [41] [42] [43] [44] [45] [46]
Learner Model	[28] [29] [31] [32] [34] [37] [39] [45] [47] [48] [49]
Pedagogical Model	[28] [29] [30] [31] [36] [37] [48] [49] [50] [51] [52]
Learning Structure System Model	[29] [31] [32] [36] [37] [38] [40] [43] [45] [47] [48] [49] [50] [51] [53] [54]

The design of personalized adaptive e-learning system has been categorized into four (4) models in the previous section. This section will discuss the detail of the adaptive and personalized e-learning system interface design and elaborate on the Learning Structure System Model based on previous research papers. The last part will show the brief interface design of personalized and adaptive testing. There are several methods to get the learner's characteristic data:

1. Using a pretest to know their current knowledge toward the subject.
2. Using a questionnaire when the learner accesses the e-learning system for the first time to know their preferences.
3. Using the record of the log activities in the database system to understand their updated knowledge and preferences.

The method also can be implemented as a single method or combined with others. However, the best implementation step of the method is the system could actively ask about the learner's needs before they take the course or begin to learn. This information can determine the learning path structure or the interface of the system itself.

The assessment of the learner's cognitive level and the learner's input will relate to their preferences to fit their need to enhance their learning process. On this research's proposed design, the cognitive level assessment will be used as a parameter for the adaptive learning structure path, system interface, and learning material. The learning path structure must provide the learning process in a specific subject. For example, before starting the course, the learner will assess their pre-knowledge using a pretest. Then, if the assessment shows that this learner still does not understand the basic knowledge of the subject course, the system will show the learning material that covers basic knowledge. On the other hand, if

the learner has basic knowledge but there are some misconceptions about several important topics, the system will reinforce the knowledge that needs improvement for learner itself.

The presentation of the content and the features itself will be shown as the navigation menu or link that can be adaptive based on learning style or learner preferences (should it be hidden, disabled, or to be delivered). For example, if student A is a visual learner, the system will provide an image or video format over a text-based one. For the sequential learner, the navigation and link in the learning material will be designed to follow the path in linear and logical order. For the global learner, the navigation and link will be developed from the big picture (overview) of the subject, and they can get into the detail at their own will. To provide it, the learning material will be managed into smaller parts of the unit and categorized based on the difficulty level, media presentation, knowledge type, and objective of unit learning. The other way is the learning material could be designed into a corpus of knowledge, should it be an open corpus with the consequences of ensuring the quality and the standardization of the metadata on the crawling process, or in private corpus form. This flexibility in the content presentation and features should be essential to implementing the adaptive e-learning environment and learning structure.

This section will discuss about what is the design of the personalized adaptive e-learning system development that have been proposed by previous study. The brief interface design of personalized adaptive e-learning system will be determined. The requirement from the previous study also will be elaborated to provide a simple interface design as an illustration of the system's blueprint in mobile application. Based on the design mentioned on the previous research, most research will divide the system into more than one module such as student and teacher or author modules. The content itself will be personalized based on the decided parameters and is suggested to divide the content to understandable parts. Some research studies also have already applied the advance machine learning [38][41], On this research's proposed design, the decided design for mobile based personalized adaptive e-learning system can be seen on Figure 2.

First, the system will ensure the user logs in before accessing the modules. When the learner does the login process for the first time, the survey will be shown using persuasive speech and a fun tone to make the learner feel unforce to do what they're not like. The audio on the interface will also help the learner that hasn't been able to read such as toddlers. The learner also can retake the survey if they want to know if there is a change in their learning since humans' feelings are dynamic and tend to change. Based on the previous research, the learners can have different preferences around the next six months, one year, two years, or never change since the time range for their preferences changes will be various between people. But this research's proposed design will evaluate and calibrate the survey based on the learner's log activities. After the learner clicks the button to take a survey, the system will proceed to the survey's questions that have to be answered by the learner.

After the learner takes the survey and receives the result, the learner can go through the course. Before the learner starts a lesson, they need to take a pre-test to evaluate their pre-knowledge (See Figure 3). The question in the pre-test will depend on the goal of the course per chapter or sub-topics in the learning material and the supported media material. It must be carefully designed to know the fundamentals of the course subject so that the learning path can be customized based on that information and enable the instructor to monitor accordingly. When the learner does the pre-test, the system will also log their answer's pattern and the time spent answering the question. This log will be sent to the instructor so that the instructor can give the appropriate feedback for the learner.

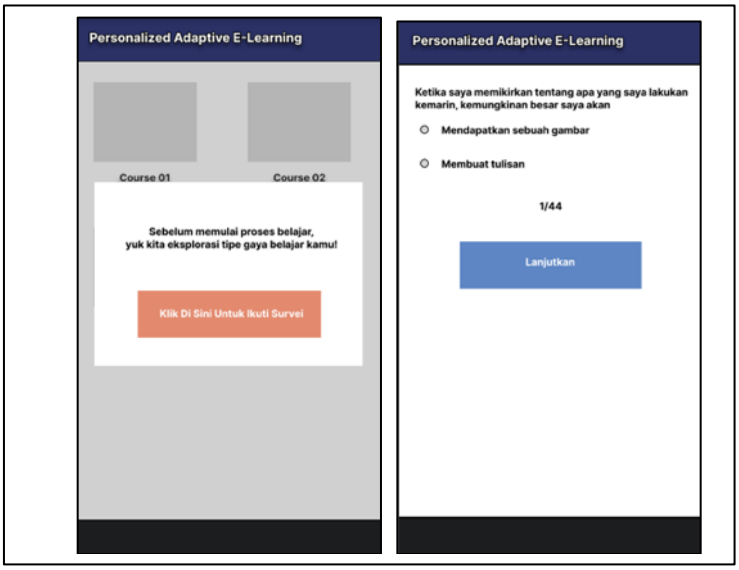

Figure 2. Interface Design to Take a Survey after First Time Login

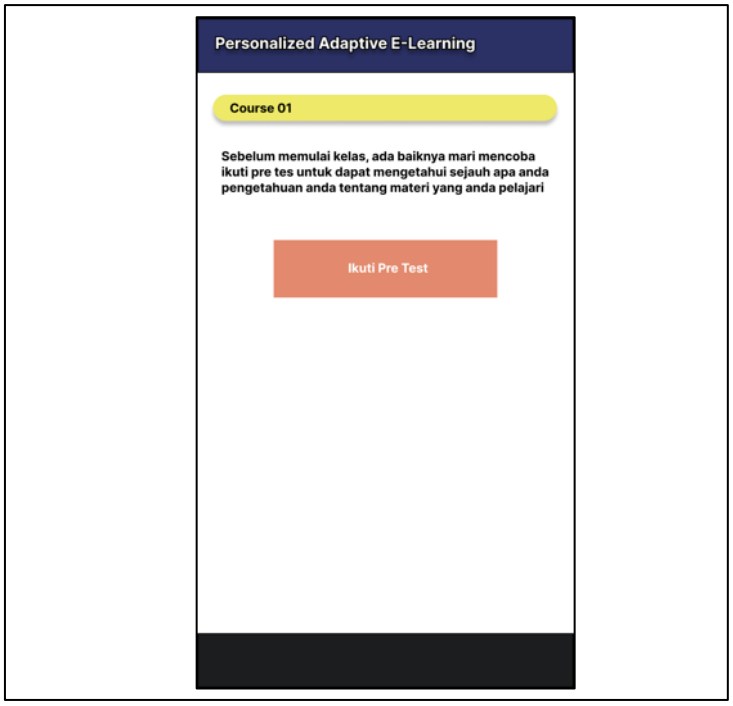

Figure 3. Interface Design of First Time Pre-Test

After the learner finishes the survey and the pre-test, the system will be personalized based on the survey and the pre-test answer. The system will also recommend the learner's learning path automatically. For example, if the learner has the condition such as need to improve the fundamental of the course subject, prefer learning in sequential order, and desire to learn by text over visually, the system will choose the sequential order of the learning path and highlight what they must learn first on the menu with the interface design. The design for this learner's condition is shown in Figure 4. But if the learner already has the fundamental knowledge, the learning material navigation menu and button would be ordered by the reinforcement topic that has to be learned first. The learner can also open all the learning material chapters and sub-chapters in the navigation menu with the configuration setting feature. However, the learning path recommendation for the learner will still order the navigation button

in the bottom right. When the learner finishes learning all the topics in the session, they will take a quiz to evaluate their knowledge acquisition. Lastly, if the learner retakes the survey that was done when the learner does the first login process, then the learning path and the navigation button will be personalized based on the updated survey's answers.

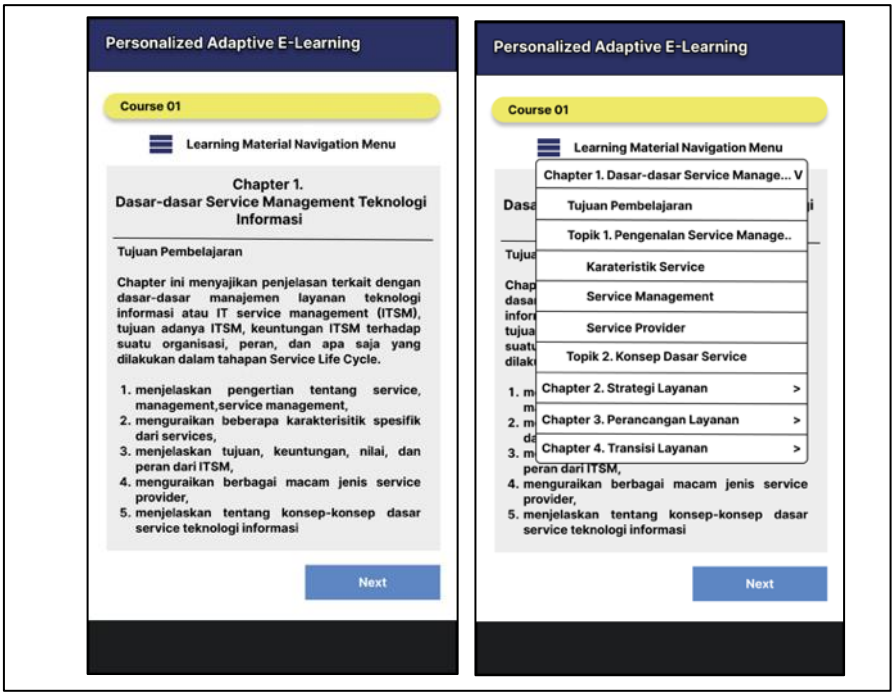

Figure 4. Interface Design of Reading a Learning Material for Sequential and Verbal Learner for Basic Learning Path

4. Conclusions

The challenge for higher education institutions to face industry 4.0 and society 5.0 era is to instill a culture of lifelong learning and independent learning. To utilize the application of this learning culture, a learning environment is needed that supports students while studying at institutions. Based on the previous research, the meaning of "adaptive" and "personalized" in e-learning is to "enable the learner to learn based on the learning style and strategy, learner knowledge level, environment, preferences, needs, and "what are they looking for". There are some designs mentioned in previous research. Most research will divide the system into more than one module, such as student and teacher or author modules, and the content itself will be personalized based on decided parameters and suggested to divide the content into understandable parts.

In this research, the learner module's design has been provided. In detail, the learner will need to log in to the system and take a survey to evaluate their initial knowledge. Then when the learner accesses the material, the material's content will be personalized based on the survey and the pre-test answers. Finally, the learner needs to take a quiz for evaluation after they learn. Although this research has provided the design of adaptive and personalized mobile e-learning, this design has not been tested yet because of the time limitation. Hence for the following research, the testing process and the evaluation should be done to know whether the system has been proven to be adaptive and personalized for the learner or still needs to be improved. It could also be possible to integrate the personalized adaptive test with gamification to give an enjoyable and positive learning experience and became a factor to encourage student learning motivation and student learning engagement [56]. On the pedagogical model, chatbot as virtual assistant teacher and helpdesk could help students by responding general and frequently question-answer related to material or general information to support student services [8].

Also, from our finding in previous research, Learning Material Model become a center of attention for designing a personalized and adaptive e-learning system. Implicitly, that adaptive and personalized learning system is mainly focused on learning resources such as material studied by students. Learning resources need to be designed in an adaptive and open manner, so they need to be developed towards an open educational resource (OER) which offers broad access, scalability, free use of content from various sources, and can reveal more quickly and efficiently in terms of costs. However, the challenges of OER itself are on ongoing maintenance related to the quality of the content that needs to be monitored and controlled, related to the copyright of the content itself, and a centralized OER system by centralized institutions. Blockchain technology may become an alternative solution to be adapted for meeting the challenges of future OER development.

To improve accessibility, policymakers and institutions should invest in infrastructure, encourage adaptable technology, and make use of open educational resources (OERs), especially in underprivileged areas. It is suggested that future research should focus on validating integrated models, investigating future technologies such as blockchain and AI, and addressing diverse learner requirements to ensure inclusivity. Furthermore, Practical implementations can begin with pilot programs, include real-time feedback mechanisms, and encourage stakeholder participation to improve adaptive systems. By increasing these criteria, adaptive e-learning systems can alter education and better prepare students to face global issues.

Acknowledgements

This work was supported by Universitas Terbuka under Skema Penelitian Dosen Pemula, LPPM UT under Grand number B/1006/UN31.LPPM/PT.01.03/2022.

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