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Log-Based Code Maniac E-Learning Web Development Model Utilizing Adaptive Web Development Techniques

Reko Syarif Hidayatullah *
Universitas Indraprasta PGRI, South Jakarta City, Special Capital Region of Jakarta, Indonesia.
Corresponding Email: rifkyjr@yahoo.co.id.

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Abstract: Education is a fundamental requirement for human civilization, particularly for children and adolescents. The recent pandemic has compelled the education sector to adopt online learning alternatives. Codemaniac is an e-learning tool developed with gamification techniques to enhance student motivation. However, Codemaniac still lacks adaptive features that optimize user engagement based on individual behaviors. To address this limitation, further development will incorporate adaptive features by utilizing recorded user behavior from log files. This behavioral data will be clustered using the fuzzy c-means algorithm, resulting in three distinct user groups, each receiving a tailored user interface. The system is developed following the SDLC waterfall model, with Python used for clustering implementation. The development process involves three user roles, five additional functional requirements, and one non-functional requirement. System testing employs white-box methods for unit testing and black-box methods for validation.

Keywords: Adaptive E-Learning; Log File; Fuzzy C-Means; Clustering.

1. Introduction

In today's digital era, the need for an adaptive and responsive online learning platform (e-learning) is increasingly urgent. Technology-based Education supports learning flexibility and improves accessibility and user experience. However, many e-learning platforms available today need to fully accommodate the individual needs of users, such as adaptability to learning styles, level of understanding, or user technology preferences. In adaptive web development, a more responsive and log-based approach is essential to provide users with a personalized and efficient experience [1]. Log-based systems leverage user interaction data to analyze patterns and behaviors, allowing for the development of more focused features on individual needs. Research that integrates adaptive web development techniques into models such as Log-Based CodeManiac can provide new solutions in improving the effectiveness of online learning [2]. Given the rapid adoption of e-learning due to the global pandemic and digital transformation, the urgency to develop more innovative and data-driven models is becoming increasingly important. Models like this provide a better learning experience and support educational inclusion globally [3].

In a news article published on BBC News, they launched information from UNESCO, which showed that in April 2020, there were 1.6 billion students who were on holiday from schools and universities as measures to reduce the spread of COVID-19. This figure is 90% of the entire student population in the world [4]. Our government has implemented social restrictions, better known as social distancing, which result in educational institutions having to conduct the online teaching and learning process or temporarily suspending their students [5]. Online Education is a teaching and learning process [6]. From this understanding, several

elements must be met, such as adequate hardware, a stable internet network, and a sufficient amount of internet quota to carry out the online learning process. Online learning can have various ways and models that can be used as long as it still applies the basics to support a quality teaching and learning process [5]. Online learning using e-learning benefits learners because it can be accessed anytime and anywhere [7]. Codemaniac is a web-based Java coding learning system that requires an internet connection to access it. Codemaniac was compiled by Dhanuari Bastari, a student of Filkom Ub, in 2017 by app,lwhonappliedcation techniques. The gratification technique comprises features such as challenging other users, reward features for certain conditions (badges), and level and experience features [8]. The use of this gamification technique is expected to increase the value of efficiency, effectiveness, motivation, and student involvement in e-learning [9].

The application of gamification alone is still proven to be insufficient to increase student learning motivation; for this reason, it is necessary to apply a player-centric approach that allows a system to adjust the gameplay to suit the user's learning style [10]. In order to maximize the behavior of each user, it is necessary to have adaptive learning that is based on the identification of individual learning styles, which is an essential feature to improve individual learning, especially in online learning [11][12]. To develop Codemaniac, an algorithm that can capture changes in the interests of users analyzed in a certain period is needed to create web personalization that can be used to create a user experience that is appropriate for each user [13]. The fuzzy means algorithm is used because it can be used to perform clustering by using data on user behavior recorded in log files. The data in the file log will then be divided into several clusters using the fuzzy means algorithm in the Python programming language; later, each cluster will have a different user interface. This development process will use Waterfall Life Cycle Development Software and object-oriented and procedural development methods [14].

E-learning benefits learners because it can be accessed online without time and place restrictions. Unfortunately, however, traditional e-learning is still easy to find. In this case, e-learning has yet to provide a more personalized learning model for each student, so some students are unsuitable for e-learning. Based on these problems, this study provides a detailed introduction to an adaptive e-learning environment and its components so that each student can choose the learning method that best suits him. In this study, it is also explained that an adaptive system is a system formed from a combination of intelligent guidance and machine learning [15]. The application of gamification alone is still proven to be lacking in increasing student learning motivation; for this reason, it is necessary to apply a player-centric approach that allows a system to adjust the gameplay to suit the learning style of its users. Development of a cutting-edge web personalization system that can capture changes in the interests of analyzed users in a given vulnerable time. Web personalization can be used to create a user experience that is appropriate for each user. To create the web personalization system, this study uses a splay tree, an adaptive independent data structure, to track changes [16].

Online learning, absorbing, is a distance teaching and learning activity carried out in and with t of an internet network [17]. With this flexibility, e-learning is very beneficial for learners because it can be accessed online without restrictions on place and time [18]. However, the e-learning system still needs to consider every student not as an individual but as a homogeneous group [15]. Along with the times, in the last two decades, education or learning activities through and with the help of internet technology or online learning have been growing (Prof. Ir. Tian Belawati, 2020). One of the current developments in e-learning is the development of a more personalized learning model, and students can choose the most suitable learning method for themselves so that the learner feels suitable for the learning system provided [14]. As we can understand, a website is a collection of web pages interconnected between pages, usually located on the same server and containing data sets provided for specific purposes. Technological advances that have developed rapidly have affected many elements, including in terms of Education; the education system that used to be offline is starting to develop online thanks to the internet, one of which is by using a website co, commonly known as e-learnin [17]. The ability of a web to be adaptive is essential. It increases significantly in the context of the Future Internet (FI), which requires the web to adapt independently to changes in the provision of services, the availability of goods and content, computing resources, and network connectivity [19]. Such as in an adaptive search system that promotes an item in the search results list that is considered more relevant to the user according to the interests and needs of the user [20].

In this study, user behavior is the activity users perform in the Codemaniac learning system. To develop an adaptive e-learning system, the system needs to dig up information to display the user's learning type by looking at user behavior [20], learning objectives, learning patterns, user knowledge level, and talent [17]. This study uses user behavior stored in a log file in which various kinds of user behavior information have been recorded, as seen in Table 2.1. The system will record each time a user clicks on one of the behaviors in Table 2.1, the number of clicks on each, and each user will be counted as a value that can be used for clustering using the fuzzy means algorithm. The number of clicks only consists of HTTP(S) requests that correspond to the features clicked by the user but can directly indicate the user's concerns, intentions, and actions [21]. Judging from the explanation from Roger S. Pressman, software engineering is a technology that is composed, as in Figure 2.1, engineering approaches (including software engineering) begin by building a

foundation on a focus on quality, then focus on the process layer that has the function of defining the framework that must be established which contains the basis for controlling software project management, The next layer is a method that contains technical instructions about software creation, and the last layer is a tool that provides semi-automatic or full-automatic support for the process and method layer [22].

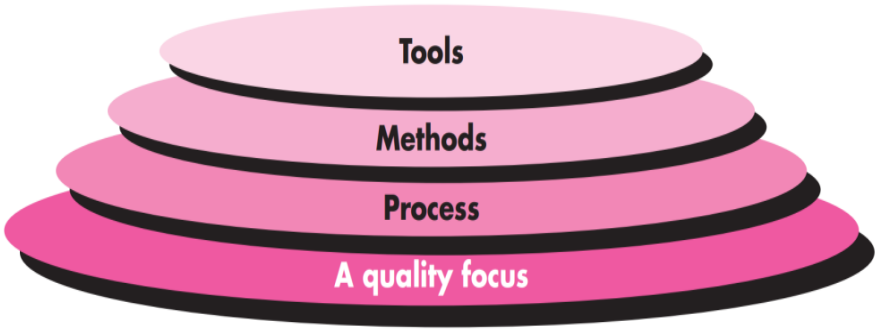

Figure 1. Layers on Software Engineering

The initial software development was just the programmer's job: writing program code to dismantle problems. With time, the need for the system increases, and the environment requires extra positions, such as designers, analysts, programmers, and users, to build a system. In order to run well, various system approaches were developed to improve the system, which can be known as the System Development Life Cycle (SDLC) [21][23]. Although much research has been done regarding e-learning and adaptive web development, there are some significant gaps, namely, a Lack of Integration between Log-Based Systems and Adaptive Web Development. Today's e-learning platforms still need to fully utilize user log data to develop adaptive learning interfaces and content. Previous research focused more on descriptive log analysis without adequate integration with the development of adaptive technology based on real-time user needs. Lack of Focus on User Experience (UX) in Adaptive E-Learning [24].

While there are efforts to improve content adaptation based on user preferences, few studies explicitly explore the impact of adaptive development on the overall user experience. Poor UX can reduce the effectiveness of e-learning platforms, regardless of how advanced the technology is applied. Lack of a Specific Model for Web Development Learning Learning about web development requires a unique approach due to its technical and complex nature. Many generic e-learning platforms need to meet the specific needs of students or developers studying web development, such as debugging, code management, and applying best practices in software development. Difficulties in Measuring the Effectiveness of Adaptive Platforms: There needs to be more consensus regarding the metrics used to evaluate the success of adaptive techniques-based e-learning. Previous research often needed to provide a systematic evaluation framework for measuring how log-based adaptations affect learning outcomes and user satisfaction [24][25][26].

2. Related Work

The development of web-based and adaptive learning platforms has been widely explored to enhance the quality and accessibility of education. Muchlis *et al*. (2021) demonstrated that web-based worksheets, especially when integrated with project-based learning models and interactive tools such as GeoGebra, can improve students' engagement and understanding in mathematics education [1]. Similarly, Panggabean *et al*. (2022) and Origenes (2022) developed web-based learning media for chemistry, highlighting the effectiveness of interactive and accessible platforms in supporting science education at various levels [4][5].

Log-based analysis is essential for understanding user behavior and improving the adaptability of e-learning systems. Adedeji *et al*. (2022) proposed a process-driven model for extracting user behavioral patterns from web access log files, which allows for the identification of learning trends and the personalization of content based on real-time user interactions [2]. This approach aligns with the findings of Abiodun and Justina (2022), who developed an adaptive web-based inventory control system for universities, demonstrating how adaptive systems can respond to user needs by leveraging behavioral data [6]. The implementation of adaptive interfaces has also been addressed by Mukhitova *et al*. (2023), who developed a model for adaptive graphic web interfaces, enabling more personalized and efficient user experiences in editing structured data [12]. In addition, Yang *et al*. (2022) utilized machine learning and adaptive testing models in web-based applications, showing that adaptive techniques can enhance both usability and accuracy in assessment systems [8].

Gamification and interactive features remain crucial in increasing motivation and engagement in web-based learning environments. Ahmad (2022) highlighted the potential of web-based games to foster active participation and sustained interest among learners [7]. Wibowo (2022) and Sujatmiko & Saputra (2023) further supported this by developing web application-based learning models and interactive e-modules, respectively, both of which incorporate gamified and project-based approaches to improve student outcomes in language and technical skills [9][10]. The application of effective development methodologies is also significant in ensuring the success of web-based learning systems. Sari and Zulkifli (2022) and Madiah *et al*. (2024) emphasized the use of the Waterfall model and project-based learning for systematic web application development, ensuring that user requirements are met at each stage of the process [11][23].

Furthermore, the integration of advanced techniques such as machine learning, data mining, and adaptive clustering has been shown to support more intelligent and personalized web-based learning systems. Zheng (2024) designed a smart classroom model utilizing data mining technology, enabling the system to adapt to students' individual learning needs and preferences [27]. Shan (2024) also introduced a web front-end development training platform based on generative artificial intelligence and low-code development, demonstrating the growing role of AI in automating and personalizing educational content [32]. Despite these advancements, research by Abouzeid *et al*. (2022) found that the success of online discussion forums and web-based platforms depends not only on technological innovation but also on the effective design of interaction models and user support systems [3]. This highlights the need for a holistic approach that combines adaptive technologies, user behavior analysis, gamification, and sound pedagogical principles to maximize the effectiveness of e-learning environments.

3. Research Method

This section discusses the methodology and the steps used in the development of the Code Maniac e-learning web platform.

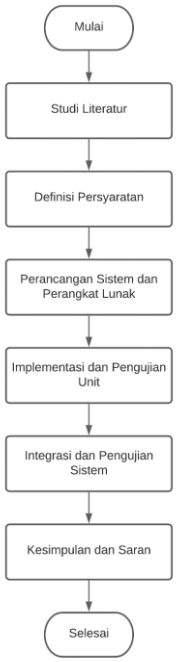

Figure 2. Flow Diagram of Research Methods

At the needs analysis stage, stakeholders conduct a survey to identify the list of requirements to be developed. These requirements are then modeled, and a use case diagram is created based on the collected needs. The needs analysis stage can be repeated if there are discrepancies between the stakeholders' goals and the gathered requirements. This repetition helps improve the system and ensures alignment with the expected objectives. In the system design stage, the system is designed based on the results obtained from the needs analysis phase. At this stage, a design model is defined using Unified Modelling Language (UML) for an object-oriented approach. The object-oriented design produces sequence and class diagrams, which are then used as a basis for user interface design. All design results serve as references for implementation. Additionally, this study employs a procedural approach to produce data flow diagrams. The system implementation is carried out using both object-oriented and procedural approaches. The Code Maniac e-learning web will include

additional features as identified during the requirements definition process. System testing is conducted to ensure that the implemented system operates according to the design and requirements. The testing process utilizes both white-box and black-box testing techniques. The developed program is tested to ensure that all system units function properly as an integrated whole, and that the resulting system meets the needs analysis conducted at the beginning. If any deficiencies or changes in functionality or features are found, they can be recorded and corrected in subsequent development stages.

4. Result and Discussion

4.1 Results

Codemaniac is an engaging online learning tool for Java programming designed to enhance the interest and knowledge of FILKOM UB students in Java programming (Bastari *et al.*, 2017). The system offers various practice questions from multiple topics and features challenges for users. It also implements gamification techniques by awarding experience points, activity points, and badges based on user activity. This research aims to make Codemaniac more adaptive by recording each user's behavior in a log file within the database. The data is then grouped into three clusters using the fuzzy means algorithm, implemented with Python. Each cluster receives a different interface according to system settings. The system design stage is closely related to the needs analysis process, using the output of the needs analysis as the foundation for design. The Codemaniac system design is divided into several parts: architecture design, component design, data design, and interface design.

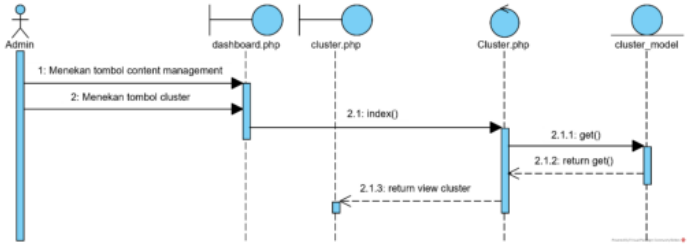

Figure 3. Sequence Diagram for Viewing the Cluster List

This figure shows the sequence diagram for displaying the cluster list. The diagram consists of four main notations: the actor (Admin), two boundaries (dashboard.php and cluster.php), a controller (Cluster.php), and an entity (cluster_model). To view the cluster list, the Admin starts on the dashboard page, selects the content management and cluster menus, which calls the index method on the Cluster.php controller. The controller retrieves data from the cluster_model entity and displays it on the cluster.php page.

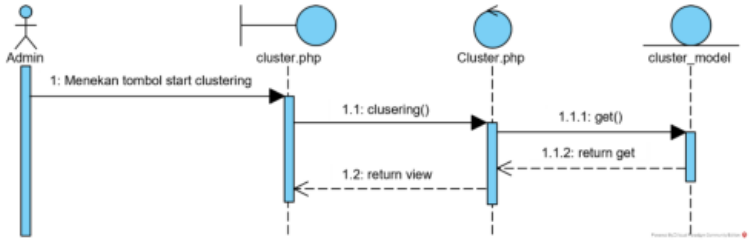

Figure 4. Sequence Diagram for Clustering

The clustering process involves the Admin on the cluster.php page pressing the start clustering button, which triggers the clustering method in Cluster.php. This method executes the fuzzy means clustering, requests data from cluster_model, and displays the result on the cluster.php page.

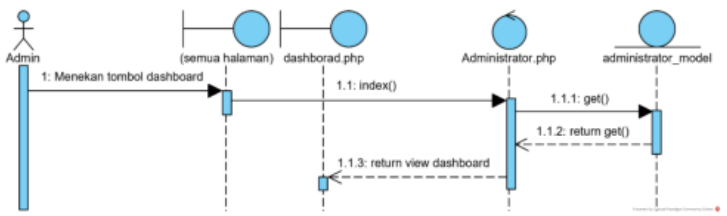

Figure 5. Sequence Diagram for Displaying the Dashboard

This diagram describes how the dashboard is displayed. The Admin, after logging in, accesses dashboard.php via the Administrator.php controller, which retrieves data from the administrator_model entity and displays it on the dashboard.php page.

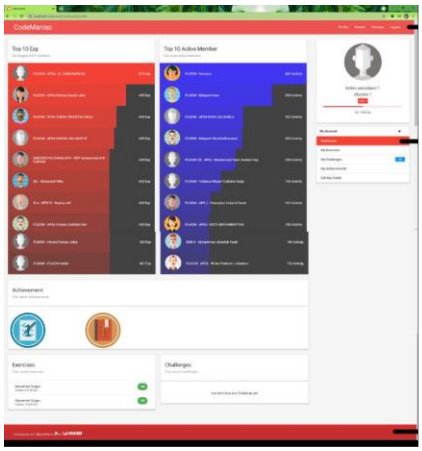

Figure 6. User Interface Design for Interface Changes

The interface color changes in three areas: header, sidebar, and footer. Members in cluster one see red, those in cluster two see blue, and those in cluster three or unclustered see green. These changes are applied to all accessible pages.

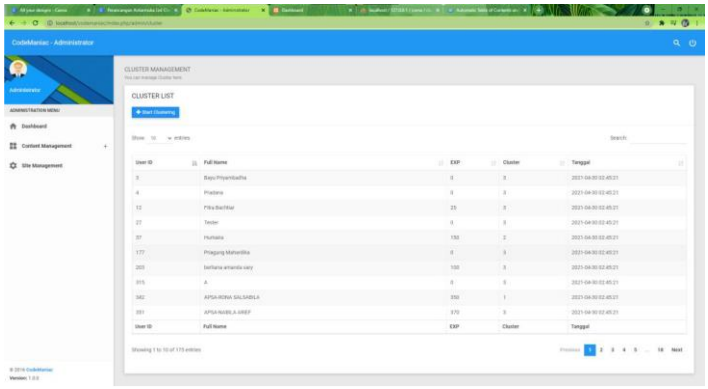

Figure 7. Cluster Interface Implementation

This page has three main sections: header (system name, search, logout), sidebar (accessible menus), and body (start clustering button, clustering result table, and page controls).

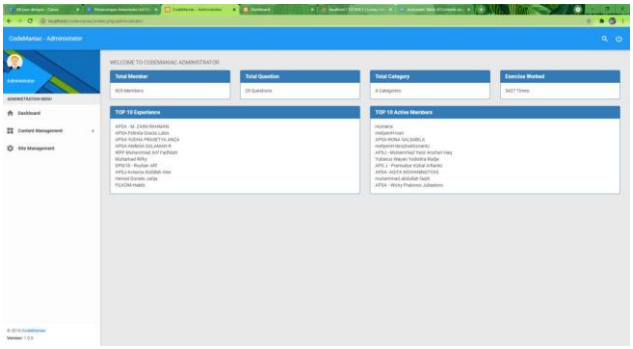

Figure 8. Dashboard Interface Implementation

The dashboard consists of header, sidebar, and body. The body contains several panels, each displaying different information. Unit testing was conducted for each minor unit added to the software using the white box testing method. This includes testing two methods of the CodeIgniter controller and a clustering function in the Python script, with test cases collected based on path testing.

4.2 Discussion

This study explores the potential of developing a Log-Based CodeManiac E-Learning Web Development model that utilizes adaptive web development techniques to enhance the effectiveness of online learning, especially in web development. The findings emphasize the importance of a log-based approach for understanding user behavior in real time and leveraging this data to create a more personalized, responsive, and relevant learning experience [27][28]. One of the main contributions of this study is the use of user data logs to identify individual learning patterns and preferences. By analyzing log data—such as interaction time, frequently visited pages, and common code errors—the platform can provide content recommendations tailored to users' needs. These findings support the theory that data-driven personalization can enhance learning effectiveness and user engagement, as noted by Kay *et al*. (2008), who found that personalization approaches help learners feel more supported and motivated [29][30].

The adaptive web development techniques in this model allow flexibility in customizing the interface and learning content based on user characteristics. The research demonstrates that adaptive approaches can improve user experience and accelerate learning by automatically providing relevant materials. This aligns with the view of [31], who emphasized that a robust adaptive system must be able to adjust in real time to changing user needs. This study also highlights the positive impact of the model on user experience. The adaptive interfaces proposed are designed to minimize complexity, improve navigation, and provide immediate feedback. Users find it easier to understand the material and feel more confident in mastering technical skills such as debugging and code development. This underscores the importance of integrating user-friendly interface design with adaptive technology to create an intuitive and immersive learning experience [32].

While the findings show many benefits, the study identifies several challenges, including the need for adequate technological infrastructure and advanced data analysis capabilities. Implementing log-based adaptive techniques requires processing large amounts of data in real time, which can be a bottleneck for institutions with limited resources. Additionally, user resistance to technological changes is another obstacle that must be addressed through digital competency training and development [21]. This model uniquely contributes to web development education by providing a learning environment that supports hands-on practice. Features such as automatic code error detection and data log-based remediation suggestions enable learners to understand web development concepts more deeply. The research also offers a holistic approach to improving technical learning competencies by emphasizing adaptation and personalization. This research aligns with the global trend toward technology-based education that prioritizes personalization and flexibility. Adopting this model can help bridge the gap between learner needs and traditional teaching methods, especially in fields that require a technical, practice-based approach such as web development.

5. Conclusion

The needs analysis process that has been carried out has resulted in five functional requirements and one non-functional requirement. A model containing case diagrams and scenarios was also produced in this process. The design process resulted in a system architecture that includes sequence diagrams and class diagrams for the object-oriented approach, as well as data flow diagrams for the procedural approach. This section also produced component mapping, database design, and interface design. The implementation process resulted in system specifications, system implementation, program code implementation, database implementation, and interface implementation, all of which follow the design results. Three-unit tests, five validation tests, and one compatibility test were conducted during the testing process.

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