

Development of a Web-Based E-Learning System Using the Waterfall Model to Support Learning in Junior High Schools

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Article Info

Article history:

Received Jun 19, 2026

Revised August 15, 2026

Accepted Sept 10, 2026

Online First Sept 21, 2026

Keywords:

E-Learning

Junior High School

Learning Management System

Waterfall Model

Web-Based System

ABSTRACT

Purpose of the study: This study aims to develop a web-based e-learning system using the Waterfall model to support learning activities at Muhammadiyah 1 Teluk Kuantan Junior High School. The system is intended to facilitate structured access to learning materials and online exercises while addressing difficulties in accessing learning resources through the previously used Google Classroom platform.

Methodology: This study employed a system development research design using the Waterfall model. Data were collected through literature study, direct observation, and interviews. System analysis and modeling used Unified Modeling Language (UML). The development environment included Windows 10, XAMPP, CodeIgniter, Firefox, Microsoft Visio, and Sublime Text. Functional testing was conducted to verify system operations.

Main Findings: The developed web-based e-learning system provides role-based access for administrators, teachers, and students. Administrators can manage teacher, student, class, and subject data. Teachers can upload learning materials and create online exercises, while students can view and download materials and complete exercises. Learning materials and exercise results are stored in the database, and functional testing verifies the operation of the developed system.

Novelty/Originality of this study: This study develops a school-oriented e-learning system specifically adapted to the learning needs of a junior secondary school. Its originality lies in integrating role-based access, learning-material distribution, material downloading, online exercises, and database storage within one platform. The system translates specific school learning problems into an integrated digital learning facility tailored to users' roles and needs.

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1. INTRODUCTION

The development of information and communication technology has brought significant changes to the implementation of education at various levels [1]. The use of technology is no longer limited to information delivery but can also support the provision of learning resources, material management, exercises, and broader

access to learning activities. The integration of information technology into education at the secondary school level has the potential to support access to learning resources, facilitate resource sharing, and provide greater flexibility in the learning process [2]. Therefore, the utilization of digital-based learning technology has become a relevant alternative for supporting learning activities that are not entirely dependent on face-to-face classroom instruction.

One form of technology utilization in education is e-learning. E-learning enables learning materials to be provided through digital systems so that students can access them according to their learning needs and conditions [3]. Previous studies on web-based e-learning have demonstrated that the integration of technology and pedagogy can support various forms of learning, including online learning, blended learning, and face-to-face learning, while providing benefits for both teachers and students [4]. However, the success of technology-based learning is not determined solely by the availability of a digital platform [5]. Infrastructure, technological readiness, and the suitability of the system to users' needs are also important factors in supporting the implementation of online learning [6]. Therefore, the development of an e-learning system needs to consider the actual needs of teachers and students so that the resulting technology can function effectively as a learning support facility [7], [8].

These needs are relevant to the learning process at Muhammadiyah 1 Teluk Kuantan Junior High School. Based on the problems identified in the initial research, limited instructional time resulted in learning materials not always being delivered according to the intended targets, which could affect students' understanding of the material. In addition, the use of Google Classroom created difficulties for students in obtaining learning materials, resulting in the learning process not being carried out optimally [9]. This condition indicates the need for an electronic learning system that can provide learning materials and exercises in a more structured manner and allow users to access learning resources according to their respective roles.

Previous studies have developed web-based e-learning systems as solutions for supporting learning activities. Aspriyono, for example, developed an e-learning system at Vocational High School Teknik PAL Surabaya using the Waterfall model and utilizing CodeIgniter and MySQL [10]. Another study at Vocational High School Strada 2 Jakarta developed a web-based e-learning application using the Waterfall SDLC to address limitations in learning material delivery [11]. In addition, research conducted at the Einstein educational institution in Purwokerto applied the Waterfall model to develop an e-learning system that integrated the requirements of administrators, teachers, and students and included functional system testing. These studies demonstrate that the Waterfall model can be systematically applied in the development of e-learning systems, particularly when system requirements can be identified during the early stages of development.

Nevertheless, previous studies still leave room for further development of e-learning systems based on the specific needs of junior secondary schools. A systematic review of information and communication technology integration in secondary education indicates that technology can support learning processes, curriculum coverage, access to learning resources, and more personalized learning, although its successful implementation remains dependent on the educational context and users' needs. Similarly, studies on web-based e-learning in schools emphasize the need to develop systems that are secure, aligned with the needs of students and teachers, and relevant to the characteristics of the educational environment. Thus, a gap remains between the general development of e-learning systems and the development of systems specifically designed to address difficulties in accessing learning materials and online exercises at the junior secondary school level.

This study offers novelty through the development of a web-based e-learning system specifically adapted to the learning needs of Muhammadiyah 1 Teluk Kuantan Junior High School using the Waterfall model. The developed system does not only provide access to learning materials but also integrates administrative data management, teacher-based material and exercise uploads, and student access to materials and online exercises [12]. These features are designed to provide a more integrated learning environment than the previous process, in which students depended on Google Classroom to obtain access to learning activities [12]. Within the developed system, teachers can upload learning materials in the form of files or videos, while students can access and download the materials. Students can also complete online exercises through the system, with the exercise results stored in the database.

Based on these problems and research gaps, the development of a web-based e-learning system is important as a supporting facility that can assist teachers in providing additional learning materials and exercises while giving students more flexible access to learning resources [13], [14]. Therefore, this study aims to develop a web-based e-learning system using the Waterfall model to support the learning process at Muhammadiyah 1 Teluk Kuantan Junior High School, particularly in providing learning materials and online exercises [15]. The developed system is expected to facilitate teachers in providing materials and exercises and enable students to access learning materials and complete exercises without depending on classroom codes from the previously used platform [16]. The results of the source study indicate that the system can function as a supporting learning facility that enables students to access and review learning materials and use the system at different times and locations, while e-learning remains a supporting facility rather than a replacement for face-to-face learning.

2. RESEARCH METHOD

2.1. Research Design

This study employed a system development research design to develop a web-based e-learning system for Muhammadiyah 1 Teluk Kuantan Junior High School. The research focused on identifying learning-process problems, determining system requirements, designing and developing the application, testing its functionality, and implementing the resulting system [17]. The development process adopted the Waterfall model, which was selected because the system requirements could be identified from the existing learning process before the development stages were conducted sequentially [18]. The research was conducted at Muhammadiyah 1 Teluk Kuantan Junior High School during the eighth semester of 2022. The research site was selected based on preliminary observations showing that the school used Google Classroom to support learning activities, particularly when teachers were unable to attend school. The study identified limitations in accessing learning materials and the limited instructional time available to deliver learning materials. The research design consisted of eight chronological stages: (1) problem formulation, (2) problem identification, (3) data and literature collection, (4) application design, (5) application development, (6) system testing, (7) implementation, and (8) reporting. These stages followed the research flow described in the source study [19].

2.2. Research Subject and Object

The research subject consisted of the users involved in the proposed e-learning system, namely the administrator, teachers, and students of Muhammadiyah 1 Teluk Kuantan Junior High School. These three user groups were determined according to the access rights and functions designed in the system [20]. The system scope in the source study explicitly limits access to administrators, teachers, and students. The research object was the development of a web-based e-learning system used to support the provision of learning materials and online exercises [21]. The system was designed to address difficulties in delivering learning materials and exercises through the previously used learning platform. Because this study focused on software development rather than estimating population parameters, no statistical sample-size calculation was applied. The users were treated as system stakeholders and sources of requirements rather than as a quantitative research sample.

2.3. Data Sources and Data Collection Techniques

The study used primary and secondary data. Primary data were obtained from direct observations of the learning process and interviews concerning the implementation of learning activities Muhammadiyah 1 Teluk Kuantan Junior High School. Secondary data were obtained through literature studies, including books, journals, previous research, and relevant information related to web-based e-learning development. These data were used as the basis for identifying system requirements and supporting the development process [22].

Three data collection techniques were employed:

1. Literature study

Literature study was conducted by examining books, theses, journals, and relevant information available on the internet. The collected literature was used to establish the theoretical and methodological basis for analyzing the identified problems and developing the system.

2. Observation

Observation was conducted directly at the research site to examine the existing learning process and identify information and system requirements needed for the development of the e-learning application. The observation was also used to understand the use of Google Classroom in the learning process.

3. Interview

Interviews were conducted with relevant sources at the school to obtain information about the teaching and learning process. The interview results were used to identify problems experienced by teachers and students and to determine the functions required in the proposed system.

2.4. Research Instrument

The research instruments consisted of observation guidelines, interview guidelines, literature documentation, and system requirement specifications. The instruments were used to collect information concerning the existing learning process, identify system requirements, and verify whether the developed functions corresponded to the needs of the intended users. The main system requirements identified from the research process are presented in Table 1.

Table 1. System Requirements and User Functions

No.	User	Required Function	System Output
1	Administrator	Manage teacher data	Teacher data are stored and managed in the system
2	Administrator	Manage student data	Student data are stored and managed in the system
3	Administrator	Manage class data	Class information is available in the system

4	Administrator	Manage subject data	Subject information is available in the system
5	Teacher	Upload learning materials	Learning materials are stored in the database
6	Teacher	Upload online exercises	Online exercises are stored in the database
7	Student	Access learning materials	Students can view/download available materials
8	Student	Complete online exercises	Student answers and exercise results are stored in the database
9	All users	Login using username and password	Users access the system according to their roles

The functional requirements in Table 1 were derived from the system design in the source study. The administrator manages teacher, student, class, and subject data, while teachers provide learning materials and exercises and students access materials and complete online exercises. The system also uses role-based login in which the username and password are validated against the database before the user enters the main menu. The research instrument was therefore not a questionnaire-based measurement instrument. Instead, the instruments were used to collect qualitative requirements and functional specifications that became the basis for software development.

2.5. Data Analysis Technique

The collected data were analyzed descriptively and functionally. The analysis consisted of three main activities: data completeness checking, data review, and data quality checking [23], [24]. First, the collected information was checked to ensure that the required data were available. Second, the data obtained from literature and field activities were reviewed and categorized according to their relevance to the system development process. Third, the quality and suitability of the information obtained from the research sources were examined before being used as the basis for system development [25].

In addition to analyzing the collected information, functional analysis was conducted to determine the relationship between users, system processes, inputs, outputs, and database storage. The analysis was represented using system modeling tools, including Unified Modeling Language (UML). The developed system included activity diagrams, sequence diagrams, and class diagrams to describe user activities, interactions between system objects, and the structure of the system. For example, the sequence design describes login validation, teacher data entry, material uploading, material downloading, and online exercise completion. The final analysis was performed through functional system testing. The purpose of testing was to determine whether the developed system elements functioned according to the specified requirements and to minimize errors before implementation.

2.6. Research Procedure

The research procedure followed the Waterfall-based development process and was organized into sequential stages. The procedure began with identifying the learning problems and ended with system implementation and reporting.

Stage 1 – Problem Formulation

The research began by formulating the main problem concerning the learning process and the need for a web-based e-learning system. The research question focused on how to develop a web-based e-learning system that could function as an alternative to the previously used Google Classroom platform.

Stage 2 – Problem Identification

The problems observed in the learning process were identified and analyzed. The main problems included limited instructional time and difficulties experienced by students in obtaining learning materials through Google Classroom.

Stage 3 – Data and Literature Collection

Data were collected through literature study, observation, and interviews. The information obtained was used to determine the needs of the proposed system and provide a theoretical basis for development.

Stage 4 – System Design

The system was designed based on the identified requirements. The design included input and output structures, database design, user access, and UML models. The system was structured around three main user roles: administrator, teacher, and student. Teachers were provided with functions for uploading materials and exercises, while students were provided with functions for accessing materials and completing exercises.

Stage 5 – System Development

The application was developed based on the completed system design. The implementation environment included Windows 10, XAMPP, CodeIgniter, Firefox, Microsoft Visio, and Sublime Text. The hardware used included a laptop with an Intel N4000 processor and 2 GB RAM.

Stage 6 – System Testing

The developed system was tested to determine whether the system elements and functions operated according to the specified requirements. Testing covered the login function, administrator menu, teacher menu, student menu, learning-material functions, and online-exercise functions. The testing stage was intended to minimize errors and verify the accuracy of the developed software.

Stage 7 – Implementation

After the system had been tested, it was implemented as a web-based learning support facility. The implementation provided separate functions for administrators, teachers, and students. Teachers could upload learning materials and exercises, while students could access learning materials and complete online exercises.

Stage 8 – Reporting

The final stage consisted of documenting the development process, system implementation, and test results in the research report. The source study identifies reporting as the final stage after the system has been completed and considered ready for reporting. The chronological research procedure can be summarized as follows:

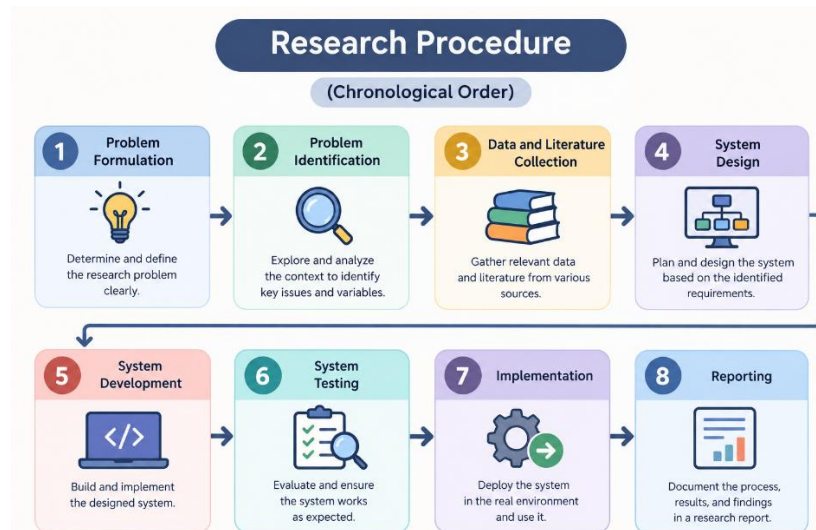


Figure 1. Chronological Research Procedure from Problem Formulation to Reporting

2.7. System Development Model

The Waterfall model was used as the software development model. Its implementation in this study followed a sequential process in which the system was first analyzed and designed before being developed, tested, and implemented. This approach was consistent with the source study, which explicitly identified Waterfall as the development method for the web-based e-learning system. The developed system consists of three principal user roles. The administrator manages teacher, student, class, and subject data. Teachers manage learning materials and online exercises, whereas students access the available materials and complete online exercises. Learning materials can be uploaded in file or video form, while exercise results are stored in the database.



Figure 2. Web-Based E-Learning Development Procedure (Waterfall Model)

Figure 2 illustrates the development procedure of the web-based e-learning system using the Waterfall model. The process consists of sequential stages, starting from research initiation and problem formulation, followed by problem identification, data collection, analysis, system design, development, testing, revision, implementation, and documentation until the research is completed.

3. RESULTS AND DISCUSSION

The development process resulted in a web-based e-learning system designed to support learning activities at Muhammadiyah 1 Teluk Kuantan Junior High School. The initial analysis identified two major problems in the existing learning process: limited instructional time, which made it difficult for teachers to deliver all learning materials according to the intended targets, and difficulties experienced by students in obtaining learning materials through Google Classroom. The existing learning process required teachers to prepare a Google Classroom code and distribute it to students before students could access the learning materials or assignments. The proposed system was therefore developed as a school-based learning platform in which users could access learning activities through individual usernames and passwords.

The second finding concerns the identification of user roles and functional requirements. The developed system consists of three main user roles: administrator, teacher, and student. The administrator is responsible for managing teacher data, student data, classes, and subjects. The teacher is provided with functions for managing learning materials and online exercises, while the student is provided with functions for accessing learning materials and completing online exercises. This role-based structure was developed to organize access according to the responsibilities of each user and to ensure that the learning process could be managed through an integrated system. The system design also included separate class diagrams for the administrator, teacher, and student, indicating that each user group has distinct system interactions and functions.

The third finding is the implementation of the core learning functions. Teachers can upload learning materials in the form of files or videos through the material-input function, and the uploaded materials are stored in the system database. Students can subsequently select the material menu and download the available learning materials. In addition, teachers can create online exercises through the exercise-input function, while students can access the exercise list and complete the exercises directly through the system. The results of completed exercises are stored in the database. These functions demonstrate that the developed system does not merely provide a web interface but integrates material distribution and online exercise activities into a single learning environment.

The fourth finding relates to system implementation and functional testing. The developed application was implemented using a web-based environment supported by XAMPP, CodeIgniter, a web browser, Microsoft Visio, and Sublime Text. The implementation included a login page, an administrator dashboard, a teacher dashboard, and a student dashboard. The administrator dashboard provides access to teacher, student, class, subject, and reporting functions; the teacher dashboard provides material, material-upload, and exercise functions; and the student dashboard provides material and online-exercise functions. System testing was conducted to determine whether the developed software components operated according to the expected functions and to minimize errors before implementation.

Table 2. Main Results of the Developed E-Learning System

No.	Development Component	Result
1	User authentication	Users can access the system through username and password
2	Administrator management	Teacher, student, class, and subject data can be managed
3	Learning-material management	Teachers can upload learning materials
4	Material access	Students can view and download learning materials
5	Online exercise management	Teachers can create and manage online exercises
6	Online exercise access	Students can access and complete online exercises
7	Database storage	Materials and exercise results are stored in the database
8	Role-based access	Administrator, teacher, and student have different functions
9	Functional testing	System functions were tested before implementation

Table 2 shows that the developed system provides an integrated set of functions corresponding to the identified problems and user requirements. The system provides a more structured mechanism for delivering learning materials and online exercises compared with the previously used process. The source study reports that the system was developed as a learning support facility that allows teachers to provide additional materials and exercises and enables students to access and review learning materials through the web-based system.

First discussion concerns the suitability of the developed system for addressing the problems identified at the beginning of the research. The findings indicate that the system directly responds to the limitations of the previous learning process, particularly the difficulty of obtaining learning materials and the limited time available for face-to-face instruction [26]. Instead of requiring students to wait for a classroom code before accessing the learning environment, the developed system provides individual authentication through usernames and passwords. Consequently, learning materials and exercises are organized within a school-specific platform. This result is consistent with the broader finding of Purnama, Wilujeng, and Abdul Jabar that web-based e-learning integrates technology and pedagogy and can support learning activities in different learning settings.

Second discussion relates to the use of the Waterfall model. The findings demonstrate that the sequential development process was appropriate for a system whose basic requirements could be identified from the existing learning process [27]. The stages of problem identification, requirement analysis, system design, development, testing, and implementation enabled the researchers to translate the identified educational problems into specific system functions [28]. This finding is in line with previous research by Sulistiono, Adha, and Shafira, which used the Waterfall method to develop a web-based e-learning application and reported that the resulting system could facilitate learning activities and provide more flexible access to learning. Similar findings were reported by Sani et al. in the development of a web-based e-learning application at State Senior High School 5 Batanghari, where observation, interviews, and literature review were used to identify system requirements before development using the Waterfall model [29].

Third discussion highlights the research gap and novelty of the present study. Previous studies have demonstrated the feasibility of developing web-based e-learning systems using Waterfall, but many have focused on general learning platforms or different educational contexts. For example, previous work has developed e-learning applications for higher education and senior/vocational secondary education, while systematic literature evidence emphasizes that the design of school-based e-learning should remain aligned with the needs of teachers and students. The present study extends these findings by developing a system specifically for a junior secondary school context, with functions tailored to the identified problems at Muhammadiyah 1 Teluk Kuantan Junior High School. Its novelty lies not simply in using a web-based platform or the Waterfall model, but in translating the school's specific learning problems into an integrated role-based system that combines material distribution, material downloading, online exercises, and database storage within one school-oriented platform.

The fourth discussion concerns the implications and limitations of the findings. Practically, the developed system has implications for teachers because it provides a dedicated mechanism for distributing learning materials and online exercises, while students can access and review learning materials without relying entirely on face-to-face classroom meetings. The findings therefore support the view that web-based e-learning can function as a learning-support facility that extends access to learning resources beyond the physical classroom [30]. However, the findings should not be interpreted as evidence that the system directly improves students' academic achievement or learning outcomes because the study did not employ an experimental design or quantitative measurement of learning achievement. The main limitation is therefore the absence of empirical evaluation involving larger numbers of teachers and students, usability measurement, learning-outcome comparison, and long-term system effectiveness. In addition, the source study itself positions the developed e-learning system as a supporting facility rather than a replacement for face-to-face learning. Thus, future research should evaluate usability, user satisfaction, system quality, and its potential effects on learning outcomes using empirical and comparative designs.

4. CONCLUSION

The development of a web-based e-learning system using the Waterfall model successfully produced an online learning platform designed to support learning activities at Muhammadiyah 1 Teluk Kuantan Junior High School. The system was developed in response to problems identified in the existing learning process, particularly limited instructional time and difficulties experienced in accessing learning materials and exercises through Google Classroom. The developed system provides structured access to learning activities through administrator, teacher, and student roles. Teachers can upload learning materials and videos and create online exercises, while students can access and download learning materials and complete exercises through the system. Thus, the research objective stated in the Introduction was achieved through the development of a web-based e-learning system that supports learning activities beyond the physical classroom. The main implication of this development is the availability of a more centralized school-based learning facility for managing supplementary learning materials and online exercises. The system can help teachers organize and distribute learning resources while providing students with more flexible access to materials and exercises. From an institutional perspective, the system also provides a platform that can be managed according to the needs of the school and its users. However, the developed e-learning system should be positioned as a supporting learning facility rather than a replacement for face-to-face instruction. Its effectiveness in supporting learning remains dependent on the availability of internet access, electricity, appropriate devices, and users' ability to operate the system.

This study has several limitations. First, the research focused primarily on the development and functional implementation of the e-learning system and did not employ an experimental design to quantitatively measure its effect on students' academic achievement or learning outcomes. Second, the study did not conduct a large-scale evaluation of user satisfaction, usability, or technology acceptance among teachers and students. Third, the system was developed for the specific needs and context of Muhammadiyah 1 Teluk Kuantan Junior High School; therefore, its implementation in other schools may require adjustments to user requirements, learning processes, and institutional conditions. In addition, the system remains dependent on stable internet and electricity infrastructure. Future research is recommended to evaluate the developed system using usability, user

satisfaction, and technology acceptance measures involving a larger number of teachers and students. Further studies may also employ experimental or quasi-experimental approaches to examine whether the use of the system contributes to improvements in student learning outcomes, engagement, or learning effectiveness compared with conventional or other existing e-learning platforms. The system can also be further developed by incorporating additional features such as discussion forums, automated assessment, learning progress monitoring, notifications, and integration with other educational services. Such developments would allow the platform to evolve from a supplementary learning facility into a more comprehensive learning management system while remaining aligned with the needs of the school and its users.

ACKNOWLEDGEMENTS

The author would like to express sincere gratitude to the principal, teachers, and students of Muhammadiyah 1 Teluk Kuantan Junior High School for their support, cooperation, and participation during the research and development process. The author also acknowledges the support and guidance provided by the academic supervisors and all parties who contributed to the completion of this research. The author gratefully acknowledges the assistance received throughout the study and confirms that this research did not receive any specific financial support or sponsorship.

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