Elinvo (Electronics, Informatics, and Vocational Education)
Vol 9, No. 1, 2024, pp. 208-219
ISSN 2580-6424 (printed) | ISSN 2477-2399 (online)

Design and Development of Interactive Moodle using Design Thinking to Support Online Learning

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Article Info

Article history:
Received June 23, 2024
Revised September 19, 2024
Accepted Oktober 02, 2024

Keywords:
Design thinking; Moodle-based LMS; K-12 online learning; user-centered design; educational technology innovation

Abstract

Moodle is an open-source learning management system (LMS) or e-learning platform that is designed to help educators create online courses with various features to facilitate learning. Interest in this research area has increased significantly in recent years, leading to an increasing number of schools employing this LMS. In the early stages of the development process, schools need to gain insights into user needs and generate new ideas for designing and developing interactive LMS. In this light, Design Thinking (DT) is viewed as an important approach. This study aimed to design and develop an online learning system based on Moodle to facilitate online learning for elementary school students. The objectives were to (1) design a system diagram, system architecture, and functional structure for facilitating online learning and (2) develop an interactive LMS using Moodle. The research methodology was conducted following the DT process. An evaluation was made to assess the usability of the system using the Computer System Usability Questionnaire (CSUQ). Across dimensions such as system quality, information quality, and interface quality, scores ranged between 5 and 7, highlighting a positive user perception across various aspects of the evaluation. These findings, therefore, offer practical guidance for educational stakeholders in adopting and promoting Moodle-based LMS.

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INTRODUCTION

Currently, a significant number of learning technologies are being developed according to the needs of distance education practices [1, 2]. One of the distance learning applications needed to facilitate and manage distance learning activities is called the Learning Management System (LMS) [3–6]. LMSs have been widely adopted by current schools and institutions to facilitate the creation, design, and delivery of course content via mobile devices or websites. For general use, the application of LMS aimed to provide different learning objectives, such as providing complementary activities for conventional classes and classroom management. However, in a pandemic situation, LMS can completely replace physical presence among students, lecturers, and staff in terms of learning and teaching. LMS can facilitate online meetings, course management, course presentations, and learning assessments [7]. Several features facilitating distance learning can be provided through the LMs, such as online homework/assignments tools, assignment notification for students, automatic feedback, collaboration tools, individual learning tools, task scheduling, learning reports, and content management (images, documents, audio, links, and videos). Other features relate to online meeting platforms, quiz creation

ISSN 2580-6424 (printed) | ISSN 2477-2399 (online)

tools, attendance records, and forum discussions [8]. With the emergence of LMS, accessibility to learning materials becomes easier and more efficient. LMS allows teachers to upload learning materials, assignments, and other information centrally, making it easier for students to access them anytime and anywhere. This is especially important in the context of distance learning or blended learning [9]. LMS provides various types of learning content, ranging from text and images to audio and video, which enables educators to create interactive and engaging learning experiences.

The LMS also facilitates online assessment and feedback, allowing teachers to digitally assign assignments, exams, and quizzes and provide immediate feedback to students. This simplifies the process of evaluating and monitoring students' learning progress [10]. In addition, LMSs are often equipped with analytics features that allow teachers and administrators to track and analyze learning data, such as student participation rates, exam results, and attendance rates [11]. This analysis can help identify areas for improvement and devise more effective learning strategies for the future. An LMS plays a crucial role in facilitating online learning by providing the accessibility, flexibility, interactivity, assessment, and data analysis needed to create effective and powerful learning experiences for students and teachers in this digital age [12]. With the continuous development of technology, the role of LMS in online education is expected to be increasingly important and positively impact education in the future [13].

Moodle-LMS

Developing and managing an LMS is often hampered by several key issues that can make it expensive and difficult to implement. The development of modern educational technologies, especially e-learning platforms and learning applications, requires large investments in hardware, software, and qualified human resources. In addition, to ensure a rich and meaningful learning experience, high-quality content is required. Creating or acquiring content such as interactive videos, simulations, and reading materials requires a significant amount of funding. This is especially challenging for educational institutions with limited budgets [14]. Furthermore, several problems can occur during the integration of LMS into online learning, including 1) development of reliable and intuitive software requires expensive development resources, such as programmers and UI/UX designers; 2) developing an LMS that can be customized to individual needs requires complex custom programming and educational institutions often have different needs so that they need specific learning platform tailored to their needs; 3) the LMS must be designed to evolve as the number of users and functional needs increases; 4) teachers and educational staff need to be trained to use the LMS effectively. This training requires a lot of effort in terms of time and resources; 5) an effective LMS requires a robust technology infrastructure, including adequate servers, networks, and data storage, and not all regions or institutions have fast and stable internet access or adequate hardware; 6) furthermore, LMS implementation can lead to cultural and process changes within educational institutions and can also be a barrier to adopting new learning method systems. This can cause discomfort and resistance from the parties involved [15].

As an alternative to the limitation of LMS, Moodle (Modular Object-Oriented Dynamic Learning Environment) can be an alternative solution for educational institutions to provide a distance learning platform. Moodle was developed using website technology and open-source software for educational purposes in several teaching and learning industries. Using Moodle-based LMS has several advantages: a) as open source platform, Moodle is available for download and free for educational usage; b) flexible customization, Moodle's modular design allows users to customize the program's features, functionality, and appearance to meet institution’s unique needs; c) provide interactive and collaborative learning tools, Moodle offers some tools like chat, wikis, and discussion boards for collaboration activities that allow students to communicate with teachers and their peers; d) assignment and assessment management, Moodle facilitates online assignment distribution, collection of student work, and

provision of immediate feedback by the teachers; e) universal accessibility, Moodle was easy to access by students with various devices so that they can participate in online classes [16].

Design Thinking for Moodle

Various factors affect the implementation of e-learning through Moodle. Initially, several emerging challenges were identified, such as issues with content, interface design, and navigation [17]. Additionally, other sources indicate that computer anxiety can hinder significant improvements in learning outcomes [18]. Extensive research has proposed potential solutions to address these concerns. It's crucial to ensure that the Moodle system in use aligns with the users' needs [19], provides strong accessibility, and offers a robust virtual environment as its foundation [20].

To effectively address the challenges of Moodle's e-learning platform, such as content usability, interface design, and user engagement, the Design Thinking approach provides a powerful framework. Starting with the empathize phase, this step emphasizes understanding the unique needs and frustrations of users through direct observation and interviews, which are crucial in identifying problems like navigation difficulties or computer anxiety [21]. In the define phase, these insights are synthesized to establish a clear problem statement, focusing on aligning the platform's capabilities with users' expectations for better learning outcomes. During the ideation stage, collaborative brainstorming sessions encourage the generation of innovative solutions, such as improving the user interface or simplifying content navigation, which involves a multidisciplinary approach to ensure that diverse perspectives shape the design. In the subsequent prototype phase, rapid, low-cost models are created, allowing for early testing and user feedback before more extensive development. Finally, the testing phase validates the proposed solutions through iterative user testing, ensuring that the e-learning platform is optimized for accessibility, engagement, and improved learning outcomes [22]. This iterative, human-centered approach ensures that Moodle evolves to meet the dynamic needs of its users.

Research Objectives

Design Thinking, as a problem-solving approach, has gained traction in various fields, including education. However, its application in LMS development, particularly for K-12 education, remains underexplored. This study leverages DT to bridge this gap, focusing on user-driven innovation in educational technology. The innovation of this study lies in applying the Design Thinking methodology to Moodle-based LMS development, focusing on K-12 education. While Moodle has been widely adopted, integrating DT ensures a tailored, user-centered approach that addresses both student and teacher requirements, making this implementation distinct and practical. The goals were twofold: (1) to create a system diagram, architecture, and functional structure to facilitate online learning; (2) to develop an interactive Learning Management System (LMS) utilizing Moodle.

This study's main contribution is the structured application of Design Thinking in developing the LMS. The DT process, comprising the five stages, shaped every aspect of the system, ensuring that user needs and challenges were central to the final implementation. Therefore, these findings provide practical guidance for educational stakeholders in promoting a Moodle-based LMS.

METHODS

This research and development (RND) aimed to develop a Moodle-based LMS to support distance learning activities using the Design Thinking process. Design thinking encompasses understanding how individuals approach and reason through design challenges. It is often referred to as 'designedly ways of knowing, thinking, and acting' [23]. It embodies the unique cognitive processes and methodologies employed by designers. This process tries to expand the frame of the problem to capture its complexity and aims to create a specific solution to the problem [24]. The outcome of the design process is documentation, some kind of communicable representation of the design solution. Data collection for

the system design in this study followed a structured approach to develop a Moodle-based LMS supporting distance learning, leveraging the Design Thinking (DT) process that includes five steps i.e., empathizing, defining, ideating, prototyping, and testing [25].

In the empathizing stage, an interview was conducted to gather insights about students, teachers, and other stakeholders' needs and their expectations for a distance learning platform. Observations of users interacting with current LMS platforms were carried out to identify common challenges and areas for improvement. Detailed personas/roles were created to represent different user types and their specific needs. During the defining stage, the collected data was analyzed to identify key themes and problems that needed to be addressed in the new LMS design. Clear problem statements were formulated based on the data to guide the design process. In the ideation stage, brainstorming sessions were conducted with designers, developers, and educators to generate a wide range of ideas and potential solutions. Mind mapping was used to organize these ideas and explore connections between different concepts. In the prototyping stage, wireframes and mockups of the LMS were developed to visualize potential designs and functionalities. Finally, the testing stage involves a complete software assessment to verify that it can meet the specified requirements. The overall process for DT is illustrated in Figure 1.

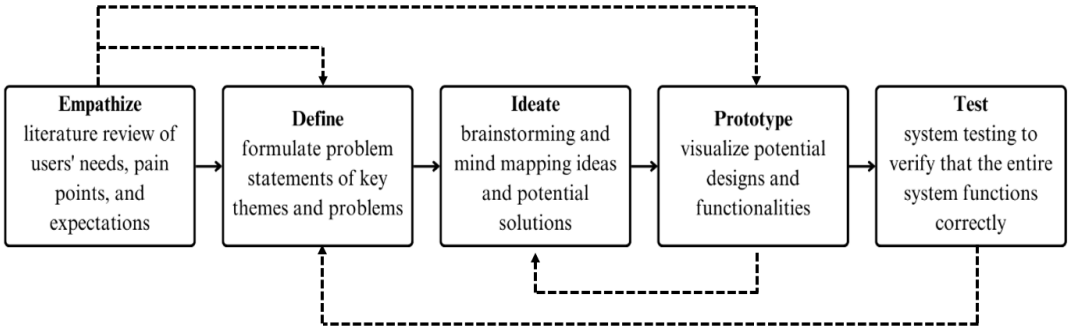

Figure 1. Design Thinking Process

RESULT AND DISCUSSION

Empathize, Define, and Ideation Stage

In the context of developing a Moodle-based LMS, in the first three stages, we focus on deeply understanding the needs and motivations of the different stakeholders involved, such as students and instructors, and then generating a wide range of potential solutions to the problem identified. Empathize stages resulted in a clear understanding that Moodle needs to become more intuitive, user-friendly, and mobile-optimized. Each user group's challenges were identified, such as avoiding complex user interfaces, easily navigating the different courses, and tracking assignments. Based on interviews, students and teachers express the need for an easy-to-use app that doesn't feel like a chore or adds to their stress. Some students mentioned frustration with complex Moodle-based LMS interfaces that make it harder to stick to a classroom routine. Design solutions could be tailored to meet those specific needs. This insight laid the foundation for the subsequent stages of development, such as designing the system and prototyping. By deeply understanding the functional needs of the users, the development team can ensure that Moodle becomes a more effective, engaging, and accessible platform.

Prototyping Stage

In this study, we design an online learning system to improve elementary student's cognitive abilities based on interview results and a literature review. The system diagram is shown in Figure 2. The following is the definition of defined actors with its description in the developed system. There are three different types of users or actors in general: (1) Teachers, who are responsible for managing overall activity in online classes. They are capable of doing modifications to the course content, documents of learning, worksheets, etc. In addition, related to student management in the course, the teacher's role

can to monitoring activities, reviewing their work, and assessing the student's project through the system; (2) Students, they are specific actors who doing learning activity, receive educational scaffoldings, and present some learning performances. They also can do collaborative work such as project-based learning, discussing with their team member, and giving/receiving peer assessment. (3) Administrator, this actor has special roles in the learning management system because they can manage overall activity performed through the developed Moodle-based LMS. This special role can do system upgrades, manage plugins, integrate with other systems, etc. The Moodle-based LMS activities, including course management, user management, and site management, can be done with a site administrator role. The differences among all users' roles are presented in Table 1. We also present an illustration of the proposed use case of the system in Figure 2. Using these use case diagrams, users can understand the expected functionality of the proposed Moodle-based LMS.

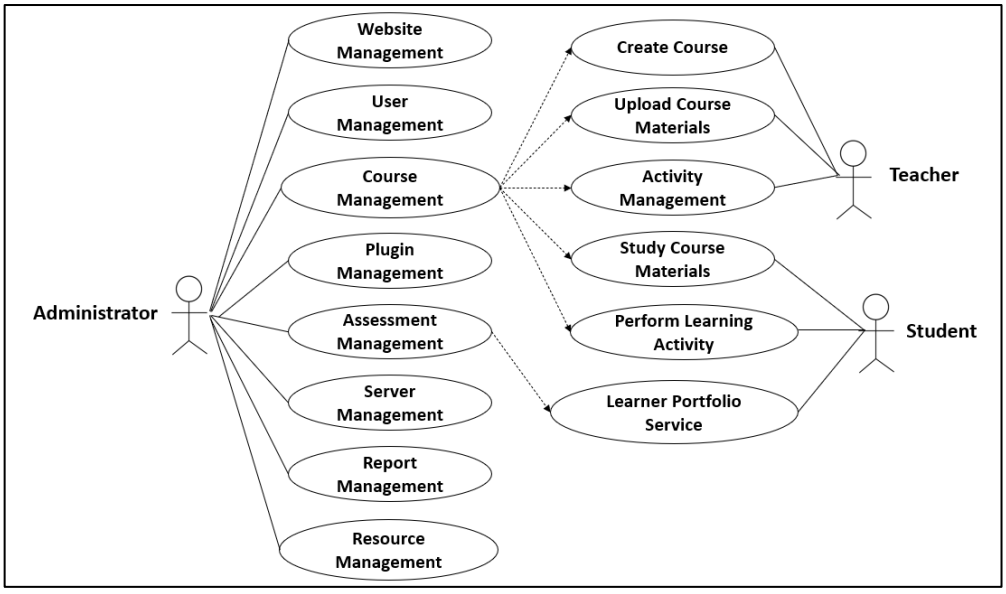

Figure 2. Use Case Diagram of The Developed System

Table 1. Defined The User's Role and The Features

Role	Description	Features
Administrator	Site administrators have the highest permissions to do anything, including assigning roles to other users.	Side administration, setting up the theme, managing courses, managing users and roles, scheduling reports, resting calendar events, secure authentication, managing plugins, security updates, details reporting, and logs.
Instructor or teacher	In the course, management tools, instructors, or teachers have a wide range of capabilities, such as modifying learning activities and assessing students' work. Typically, they can also designate other users as non-editing teachers or students.	Selecting the user's role, managing the instructor's role in the course management, assigning students, granting and revoking access and permissions, class management, course management, grading and scoring, notification, tracking learning progress, file management, and managing class activities.
Student	A user with a student role can see available courses and participate in course activities. They can access learning resources or view the class gradebook but they are not permissible to modify them. They are able to see their own grades if the teacher has granted permission.	View dashboard, managing site features like calendar and messages, course participation, resources and activities, and assessment.

Table 2. Moodle Architecture

ISSN 2580-6424 (printed) | ISSN 2477-2399 (online)

Module name	Module elements	Brief description
Interaction and communication	Forum	The Forum activity enables students and teachers to share ideas by posting comments within a 'thread'.
	Chat	The chat activity enables course participants to engage in a real-time discussion within a course of Moodle-based LMS.
	Mind map	The mind map is a visual tool that enables users to create and save mind maps directly within Moodle.
	Video conferencing	A video conferencing plugin for Moodle is a software tool that enables users to have video and audio conversations with each other.
Collaborative learning	Wiki	The Moodle Wiki activity enables students to build a webpage collaboratively. While anyone can edit it, the instructor can track the edit history. With a wiki, you can collectively create a document incorporating multimedia files.
	Workshop	The Workshop activity is a robust peer assessment tool where students submit their work, which is then evaluated by their peers using a grading scale defined by the teacher.
Learning resources	Book	A multi-page resource presented in a book-like format with chapters and subchapters. Books can include media files and text, making them ideal for displaying extensive information.
	File	A simple method for teachers to present materials to their students, which may include files like word-processed documents or slideshow presentations.
	Database	It enables teachers and/or students to create, display, and search data on any topic. These entries can be highly versatile, incorporating images, files, URLs, numbers, and text, among other elements.
	URL	The URL resource allows you to link directly to an external website/resource while also offering the functionality for you to search various sources online.
	Blog	It enables the creation of blogs within a Moodle course, separate from the core Moodle blog system. These can be course-wide blogs (where everyone in the course posts to the same blog), group blogs, or individual blogs.
	Interactive content	It can easily generate and integrate diverse, high-quality content into your LMS at no cost. This includes Interactive Videos, Quizzes, Collages, and Timeline functionalities.
Presentation	Online presentation	A content type for interactive presentations allows the display of multimedia slide shows and presentations in users' website browsers.
Motivation	Grading	An assignment, tasks, and/or manual grades are automatically compiled into a single score and piece of feedback in the Moodle Gradebook. Students can check their grades in personalized reports that safeguard student privacy.
	Badge	A good way of celebrating achievement and showing progress.
	Level-up	A gamification plugin on Moodle. For example, it calculates a student's total points based on their progress.
Assessment or evaluation	Grading	Calculating and presenting the final grades to students for submissions, evaluations, and delivering feedback to users.
	Checklist	Allows teachers to create a checklist/to-do list/task list for their students to work through. The academics can monitor all the students' progress as they tick off each of the items in the list.

ISSN 2580-6424 (printed) | ISSN 2477-2399 (online)

The architecture of the online learning system is presented in Table 2. As an open-source-based learning management system (LMS), our proposed system provides a robust and flexible framework that supports various educational needs. Its architecture is designed to be modular, scalable, and interoperable, ensuring that it can be adapted to various learning environments. Below is an in-depth look at the key modules within our developed Moodle system architecture, focusing on their roles, interactions, and functionalities. The developed architecture of the proposed system includes six unique modules.

First, the main purpose of the interaction and communication module is to facilitate communication and interaction among students, teachers, and administrators. In general, this module consists of six components such as forums that enable threaded discussions where users can post and reply to messages, messaging that provides real-time private messaging and group chat functionalities, announcements that allow instructors to broadcast important messages to students, user interface which is accessible via the main dashboard and course pages, notifications that integrated with email and mobile notifications to alert users of new messages or posts and plugin which is extensible with additional communication tools such as video conferencing integrations (e.g., Zoom, BigBlueButton).

The second module is called the collaborative learning module. This module supports collaborative activities and peer learning through the system. Some components included are Wikis that allow students to collaboratively create and edit content, Workshops for peer assessment activities where students can submit work and review each other's submissions, and Groups that organize students into groups for collaborative projects and discussions. Instructors or teachers can create and manage groups within courses and control the permission over who can edit and view collaborative content. In a workshop activity, students submit their work, which is then randomly assigned to peers for review. The system tracks submissions and reviews, ensuring anonymity and fairness in peer assessments.

The third module is the Learning Resources Module. The purpose of this module is to manage and deliver educational content and resources. For example, File Management can facilitate the process of uploading and organizing various file types, including documents, videos, and presentations, Resource Linking for embedding links to external resources and multimedia, and Content Delivery for sequentially delivering content using tools like Lessons and Books. In this module, teachers are facilitated to upload a series of lecture videos and reading materials, organize them into weekly modules, and track which students have accessed the resources. Some interaction activities can also be done using this module, such as repository integration to connect with external repositories (e.g., Google Drive, OneDrive) for seamless content import, resource tracking for logs of student access and interaction with learning materials, and content versioning for maintaining versions of resources to manage updates and revisions.

The fourth module is called the presentation module. It can enhance content delivery with dynamic and engaging presentations. Some components of this module included Slideshows for creating and presenting slides directly within Moodle, Multimedia Embedding for incorporating videos, audio, and interactive content into presentations, and Interactive Activities for the inclusion of quizzes and polls within presentations to engage learners. Instructors can monitor student participation and engagement with presentations using activity tracking and gather real-time feedback from students during presentations using feedback collection tools. During online learning, a teacher can present slides that include embedded videos and interactive polls. Students participate in polls, and their responses are displayed in real-time.

The following two modules are the motivation module and the assessment module. These two modules are responsible for encouraging students to engage through rewards and recognition and supporting the assessment and evaluation process of student performance, respectively. In assessment modules, some functions can be used to engage students in learning activities, such as Quizzes for creating and administering online quizzes with various question types, Assignments to manage assignment submissions and grading, and Gradebook, which is used to facilitate comprehensive tools

for recording and calculating grades. Whereas, teachers can use Badges for achievements and milestones to acknowledge and celebrate an individual's or a group's accomplishments. In addition, they can visualize students' progress through course activities using the Progress Bar.

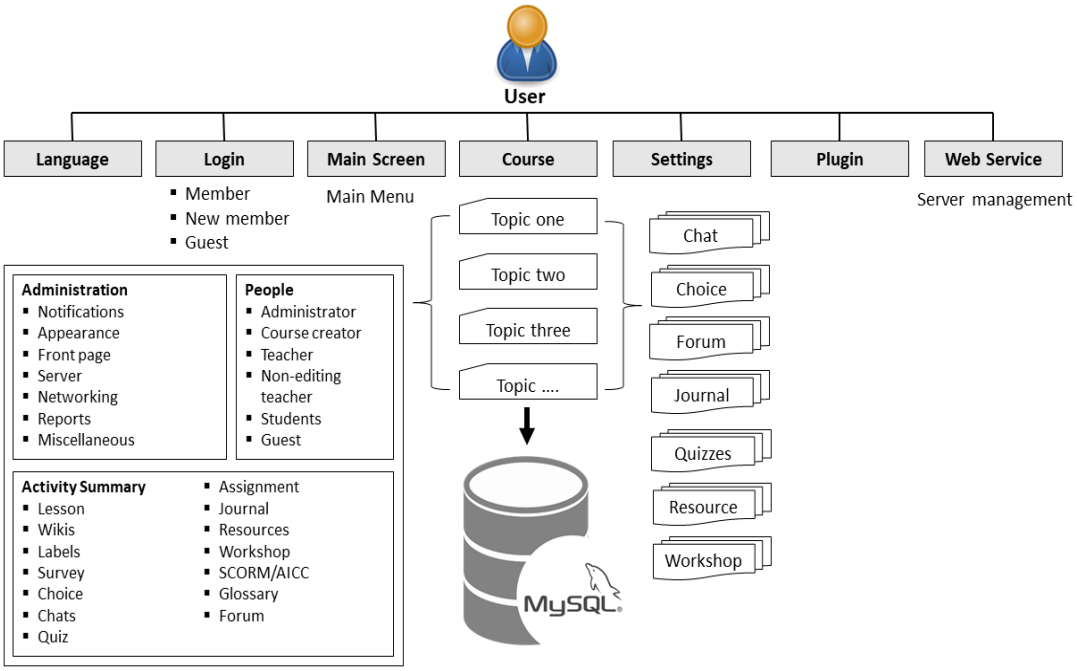

Figure 3. System Development Architecture

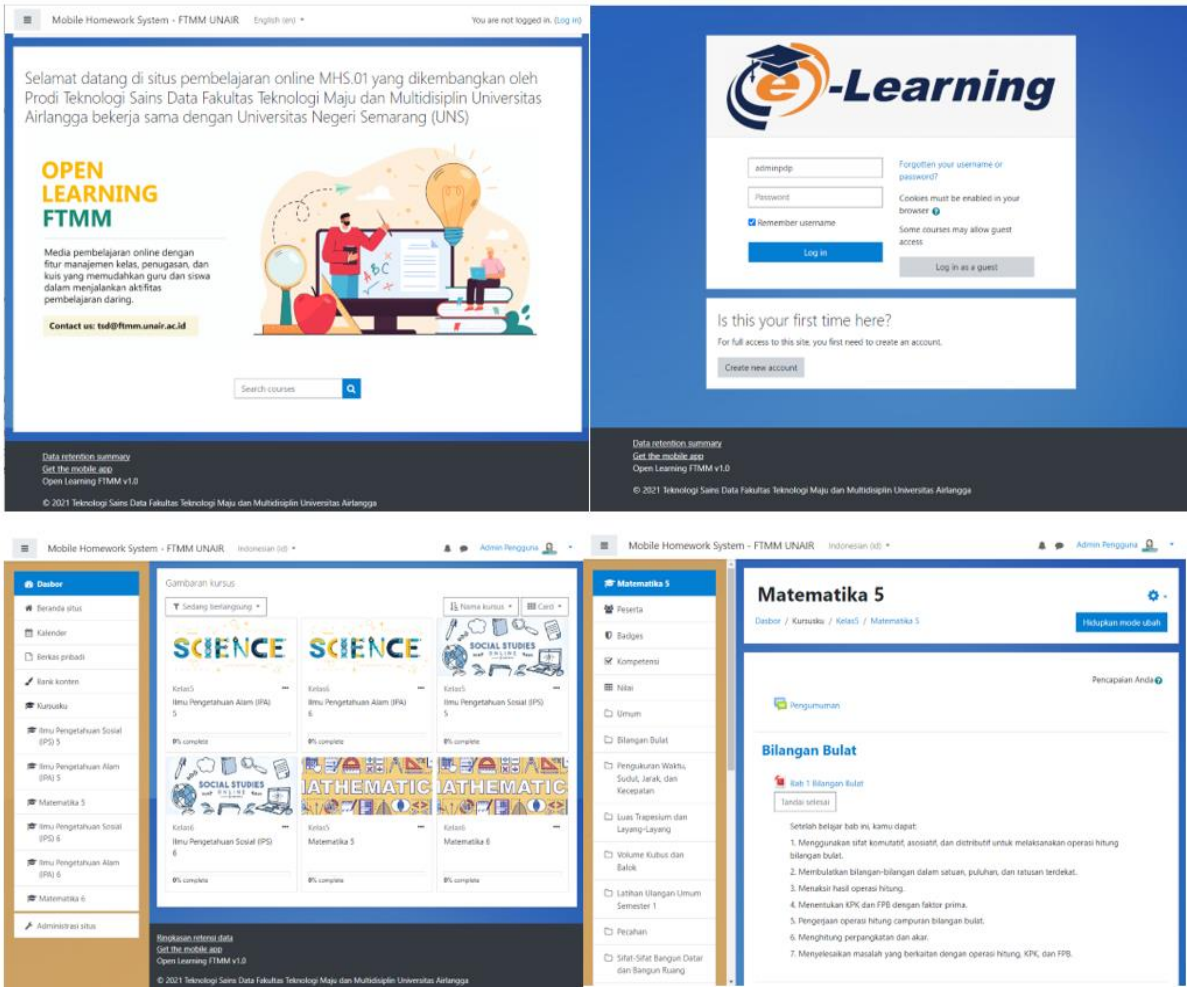

Figure 4. Moodle User Interface

ISSN 2580-6424 (printed) | ISSN 2477-2399 (online)

In terms of system development, the proposed LMS created by Moodle is developed using a web application and hosted on a Virtual Private Server (VPS). It is built utilizing the PHP scripting language alongside a MySQL database for robust functionality and efficient data management. The users of our proposed system can access any resources on the system via their browsers. The software is structured into three primary sections: Server, which manages backend operations and data storage; Learning Management System (LMS), which facilitates course delivery and student interaction; and URL, which handles external links and resources, ensuring comprehensive organization and efficient utilization of its components. The Database server, responsible for storing and organizing diverse datasets, and the Web server, which hosts and manages multiple application modules across the system, collaborate seamlessly to ensure efficient data management and robust functionality within each component of the LMS. Figure 3 presents the system architecture for the development phase and Figure 4 shows a user interface of the developed Moodle-based LMS.

Testing Stage

After completing the design and development phases, the researcher rigorously evaluated the system's suitability through comprehensive assessments and tests to verify its practical applicability and effectiveness in real-world scenarios. An evaluation was made to assess the usability of the system. The sample consisted of 30 elementary school teachers with teaching experience of more than 5 years who completed the training programs. In this study, we used purposive random sampling, where the researcher selects the sample based on specific criteria or characteristics that are important to the study. We employed standard and widely recognized questionnaires based on the Computer System Usability Questionnaire (CSUQ) version 3, featuring a total of 24 statement items rated on a 7-point scale, to ensure a comprehensive and detailed evaluation of user experience and satisfaction with the system. CSUQ has obtained widespread adoption as a reliable tool for assessing and investigating usability aspects across various software products, providing valuable insights into user interaction and satisfaction. It is noteworthy that all statements within the CSUQ framework are formulated in a positive tone, aiming to capture perspectives on user experience and perception effectively. The evaluation of the usability of the proposed Moodle-based Learning Management System (LMS) encompassed comprehensive assessments across several dimensions, including system quality, information quality, interface quality, and an overall score, ensuring a thorough analysis of its effectiveness and user-friendliness. The results of the usability test, which include detailed values of the CSUQ ratings and comprehensive descriptive statistics of the CSUQ scores, are presented in Table 3, offering a clear and quantitative overview of user feedback and satisfaction levels. The mean score of each CSUQ statement consistently surpassed a score of 5 on the 7-point scale, where 7 denotes strong agreement. Across dimensions such as system quality, information quality, and interface quality, scores ranged between 5 and 7, highlighting robust performance and positive user perceptions across various aspects of the evaluation. This result indicated that teachers perceived positive responses regarding system quality, information quality, and interface quality, reflecting their satisfaction with the functionality, reliability, and usability of the system's components. However, we identified the moderate value of the questionnaire in terms of online course design and user interface design. By this result, we suggested improving it by addressing multiple aspects to ensure an engaging, effective, and learner-centered experience. For example, before creating the course, consider the target audience, such as identifying the learners' goals, skill levels, and challenges. In addition, learning content should be broken down topics into smaller, manageable sections to avoid cognitive overload. It is also needed to deliver content in a way that keeps learners interested and helps them retain information such as using a variety of learning formats (text, videos, infographics, podcasts, and animations) to improve student’s learning motivation. Regarding the user interface design, this study suggested simplifying the page navigation and organizing LMS menus logically and consistently. Furthermore, to provide personalization, the

system should allow users (students and instructors) to personalize their dashboards by adding or removing widgets (e.g., calendar, upcoming assignments). The evaluation result is presented in Table 3.

Table 3. Usability evaluation result

Dimension	Sub-dimension	Mean	Std. Deviation
System quality (SQ)	Overall, I am satisfied with how easy it is to use this system.	5.93	1.015
	It is simple to use this system	6.10	0.885
	I am able to complete my work quickly using this system	5.80	1.064
	I feel comfortable using this system.	5.90	0.995
	It was easy to learn to use this system.	6.00	0.947
	I believe I became productive quickly using this system.	5.63	1.098
	The system gives error messages that clearly tell me how to fix problems.	5.60	0.968
	Whenever I make a mistake using the system, I recover easily and quickly.	5.33	0.922
Information quality (IFQ)	The information (such as online help, on-screen messages, and other documentation) provided with this system is clear.	6.07	0.828
	It was easy to find the information I needed.	6.03	0.850
	The information provided with the system is effective in helping me complete my work.	5.77	1.040
	The organization of information on the system screens is clear.	6.03	0.890
Interface quality (INQ)	The interface of this system is pleasant.	5.63	0.999
	I like using the interface of this system.	5.77	0.971
	This system has all the functions and capabilities I expect it to have.	5.63	0.765
	Overall, I am satisfied with this system.	5.83	0.913
Online Course Design (OCD)	The course content is interesting for my students	4.23	0.773
	The course content meets my student's needs	4.26	0.784
	In general, I am satisfied with the design of the course content	4.30	0.749
	In general, I am satisfied with the course content quality	4.40	0.723
	The layout design of the system makes the content easy to read	4.20	0.714
User Interface Design (UID)	The font style and color of the interface make the content comfortable for me to read	4.40	0.563
	I can use the navigation of the system easily	4.33	0.660
	In general, I am satisfied with the design of the interface	4.43	0.568

CONCLUSION

This study conceptualized and implemented an e-learning platform utilizing the design thinking methodology and the Moodle framework to foster online learning in elementary school students. The research identified four crucial stages in the development of this online learning system: (1) conceptual design, (2) architectural planning, (3) system implementation, and (4) comprehensive evaluation. The designed platform enables students to collaborate on projects, facilitating knowledge sharing and creation within their teams. This approach allows students to learn flexibly and enhance their cognitive abilities through online methods. The system is grounded in innovative knowledge creation theory allowing researchers to expand this system into an innovation ecosystem within schools' institutions, bridging the gap between student creativity and business networks, thereby contributing significantly to the nation's value creation. In analyzing the CSUQ survey responses from teachers, our findings indicated that our proposed system demonstrates commendable system quality, interface quality, and interaction quality, which effectively support distance learning initiatives. These outcomes serve as compelling evidence that a Moodle-based LMS can be effectively utilized by elementary school teachers to create a conducive learning environment for students. By offering suitable facilities and fostering a positive teaching and learning atmosphere, Moodle-based LMS enhances educational practices and facilitates effective pedagogy. The positive evaluations of system quality, interface quality, and

interaction quality as highlighted in the CSUQ survey responses suggest significant implications for educational research and practice. Specifically, the findings underscore the viability of implementing Moodle-based LMS in elementary schools to foster an effective and supportive learning environment. By leveraging these platforms, educators can enhance their teaching strategies and facilitate engaging and interactive learning experiences for students, thereby promoting overall academic success and student engagement in distance learning settings. This research provides valuable insights into the potential benefits of integrating technology-enhanced learning tools like Moodle-based LMS into educational frameworks, encouraging further exploration and adoption in diverse educational contexts.

ACKNOWLEDGMENT

This research is funded by the Faculty of Social and Political Sciences at Universitas Negeri Semarang, Indonesia. The support is provided under contract number 65.5.6/UN37/PPK.03/2023, as outlined in the Budget Implementation Document (DPA) of the Faculty of Social and Political Sciences (FISIP), Universitas Negeri Semarang (UNNES), with DPA Number DPA 023.17.2.690645/2023.03, Revision 6.

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