Development of an E-Commerce Platform Using Extreme Programming Methodology

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Article Info	ABSTRACT
	The rapid advancement of information technology has significantly influenced human activities, particularly in shopping behavior. Andalas Store, a bookstore in Lampung, has faced a decline in customer visits, primarily due to the shift towards online shopping. This research addresses the issue by developing an e-commerce platform for the Andalas Store using the Extreme Programming (XP) methodology and the MERN Stack technology. The platform aims to enhance the store's online presence and improve customer reach. The e-commerce system was developed through iterative cycles, following XP's structured phases of planning, design, coding, and testing. Key testing methods employed include unit testing, black box testing, and Google Lighthouse, alongside usability evaluation using the System Usability Scale (SUS). The results demonstrate the platform's high performance in terms of speed, accessibility, SEO, and user satisfaction, with a SUS score of 75.375. This project not only successfully addresses the identified business problem but also offers a robust, scalable solution for expanding the store's market through e-commerce. Further work is suggested to integrate additional features such as advanced analytics and AI-driven recommendations.

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1.   INTRODUCTION

According to a survey by the Indonesian Internet Service Providers Association (APJII), internet users in Indonesia reached a remarkable number in 2023 [1]. The survey revealed that approximately 215.63 million individuals out of the total Indonesian population of 275.773.901 were internet users [1]. This figure reflects a strong growth trend, indicating an increase of 2.67% compared to the previous period, which recorded around 210 million internet users [1]. This growth trend is attributed to the convenience of conducting daily activities through the Internet, including online shopping. Electronic commerce, or e-commerce, is the activity of buying and selling goods and services carried out online via the Internet [2].

Andalas store is a bookstore located at Jalan Kota Raja No.27, Gn. Sari, Engal, Bandar Lampung City. The store offers a wide variety of books, including textbooks from preschool to college level, dictionaries, Islamic books, and the Quran. The results of interviews indicate that the number of walk-in customers needs to be higher. The book sales process at Toko Andalas still uses conventional methods, such as WhatsApp, to disseminate information about the products sold. WhatsApp sales currently account for most of the customers. However, this media can only be used if customers know the store owner's WhatsApp number. The current system has great potential to utilize e-commerce technology. The developed e-commerce can also open up opportunities to expand reach. By adopting e-commerce, bookstores can reach customers from various

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geographical areas, even outside the physical store's location. Through e-commerce, customers can easily find the books they want and make online transactions.

In a previous study conducted by Muhammad Iqbal Fauzi and Yono Cahyono in 2021, a website-based e-commerce platform was developed for LP3ES Bookstore [3]. This website aimed to provide efficiency in sales and report recording at LP3ES Bookstore [3]. The study was developed using the PHP programming language and resulted in the LP3ES website, which was used in the researcher's competitor analysis, along with the Gramedia and Bukukita.com websites. The second research conducted by Nasri and Agustiawan in 2021 aimed to build a system to manage transaction processes, data collection, and online sales to increase sales and reduce data loss [4]. This research uses a payment gateway, the researcher's reference, namely Midtrans [4]. In application development, this research uses extreme programming methods, modeling using UML, and producing the expected software [4]. The programming language used in this development is the PHP programming language, with a MySQL database, and for payments using the Midtrans application programming interface [4].

The third research conducted by Siama Mary et al. in 2023 aims to develop a web-based information system using mixed methods for data collection and an extreme programming system development model [5]. In its implementation, it uses unit testing, which is the researcher's reference for testing program code [5]. Karishma Arora et al.'s research in 2023 aims to develop a web application that can help freelancers find projects and businesses find freelancers who suit their needs [6]. The resulting application uses MERN stack technology, namely MongoDB, Express.js, React.js, and Node.js [6]. The fifth research conducted by Welda et al. aimed to analyze Website Usability Testing Using the System Usability Scale (SUS) Method [7]. Welda's research used a descriptive method involving 30 respondents. The data collection techniques used were interviews, observation, and questionnaires [7]. In the research that the researchers will carry out, they will use the SUS method and several data collection techniques from Welda's research as references.

Based on the five previous studies, the researcher's research aims to develop the Andalas Books e-commerce website using MERN Stack technology. MERN Stack was chosen for its novelty compared to three competing websites' technology, full-stack development capabilities for server and client sides, and the React framework for developing single-page applications (SPAs) and JavaScript-based web applications [8]. SPA is a web-based application that only uses one page; in other words, if the user switches menus, the URL will not show the page change [9]. MERN Stack was also chosen to create e-commerce websites with better performance than competitors, including accessibility, best practices, and good SEO optimization. Apart from that, this research will add a PWA or Progressive Web App feature, namely a web application designed to provide a user experience like a native application (an application that is downloaded and installed on a device).

Ability to Develop Systems	Structured Methodologies		RAD Methodologies			Agile Methodologies	
	Waterfall	Parallel	Phased	Prototyping	Throwaway Prototyping	XP	SCRUM
With Unclear User Requirements	Poor	Poor	Good	Excellent	Excellent	Excellent	Excellent
With Unfamiliar Technology	Poor	Poor	Good	Poor	Excellent	Good	Good
That Are Complex	Good	Good	Good	Poor	Excellent	Good	Good
That Are Reliable	Good	Good	Good	Poor	Excellent	Excellent	Excellent
With a Short Time Schedule	Poor	Good	Excellent	Excellent	Good	Excellent	Excellent
With Schedule Visibility	Poor	Poor	Excellent	Excellent	Good	Excellent	Excellent

Figure 1. Comparison of Software Development Methods [10]

Extreme programming (XP) was selected as the software development methodology due to its advantages over other methods and its alignment with the development requirements of an e-commerce website [11]. XP is an Agile methodology that encompasses the planning, design, coding, and testing phases [11]. In Figure 1 below, extreme programming is compared with other methods, thus making researchers choose extreme programming. Figure 1 compares the Extreme Programming method with other methods quoted from the book Systems Analysis Design UML 5th ed [10]. Based on the Figure 7 comparison of the XP method, this research uses the Extreme Programming (XP) development method for several reasons [10].

1) Unclear User Requirements: XP gets an "Excellent" rating when addressing unclear user needs. XP emphasizes constant communication with stakeholders (in this research, namely the Andalas bookstore), who can help or change requirements as time passes.
2) Unfamiliar Technology: XP gets a "Good" rating in handling unknown technology. This means that XP tends to use familiar technology, but XP also allows developers to learn and get used to new technology

effectively. In this research, the technology used is MERN Stack, which is a relatively new technology, but many large companies have used it, such as Tokopedia and the Goto Impact Foundation.

3) Complex Projects: XP received a "Good" rating in handling complex projects. With a focus on testing and long-term integration, XP can help manage project complexity.
4) Reliability: XP received an "Excellent" rating in terms of reliability. In this study, XP has various practices that can improve software reliability, such as continuous testing and improvements based on continuous feedback.
5) Short-Time Schedule: XP gets an "Excellent" rating when dealing with tight schedules. This method also makes it possible to develop applications with short deadlines. Hopefully, application development will be completed quickly, even with a tight schedule.
6) Schedule Visibility: XP received an "Excellent" rating regarding schedule visibility. Schedule Visibility refers to the extent to which the software development schedule can be seen by all parties involved. It also relates to the level of transparency and openness of information related to the project schedule, including stages, milestones, plans, and current developments.

In this research, the MERN website was created by one developer, assisted by two research colleagues, with changing project needs and a tight schedule. Therefore, the XP method is suitable because it is better than other methods for meeting researchers' needs. There are several reasons not to choose the throwaway Prototyping method and the Scrum method, which has an "excellent" value. Firstly, Throwaway Prototyping was not used because this research did not use a prototype model, so according to the researcher, it was not suitable to use this method. Throwaway Prototyping usually focuses more on concept exploration, while XP focuses more on producing ready-to-use software. XP can work well in small teams, even one person. While Throwaway Prototyping may be better suited to the initial exploration of an idea or concept, XP is more focused on developing ready-to-use software, usually better suited to one-person projects. Meanwhile, Scrum, which has the same value as XP, is not used for this research because Scrum is a software development methodology designed for larger teams to carry out sprint planning, daily scrum, sprint review, and retrospective and has different roles, such as a dedicated scrum master and project manager. In research developed by one person, the structure and rhythm implemented in Scrum are different from the needs of the research, and there are too many roles. Comparison of Software Development Methods

2.   METHOD
This research stage involves three main steps: data collection, and extreme programming methods to develop the system. It can be seen in Figure 1 below:
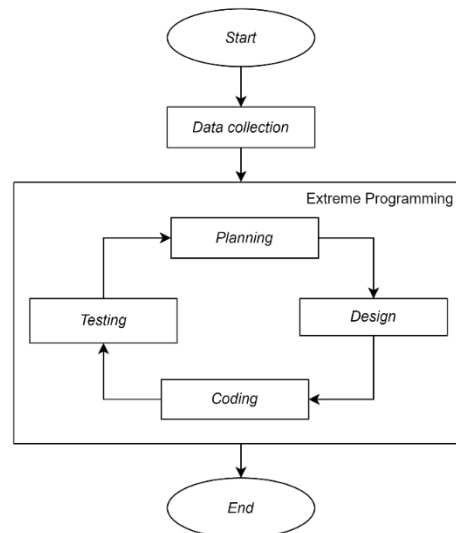

Figure 2. Research stages

2.1   Significance of XP and MERN Stack Implementation
The implementation of Extreme Programming (XP) and MERN Stack in developing the Andalas Books e-commerce platform holds substantial methodological and technological significance. The adoption of Extreme Programming (XP) in this research presents several notable advantages in the context of e-commerce development. XP's iterative and incremental approach facilitates rapid adaptation to the dynamic requirements

inherent in e-commerce ecosystems. This agility is particularly crucial in responding to evolving market trends and customer preferences. The short development cycles characteristic of XP enable frequent stakeholder feedback, allowing for continuous refinement of features to align with the bookstore's specific needs [12].

Moreover, XP's emphasis on continuous integration and testing is instrumental in maintaining high code quality and reducing the likelihood of critical errors in the e-commerce platform. This is especially pertinent in an online retail environment where system reliability directly impacts user trust and sales performance. The pair programming practice intrinsic to XP not only enhances code quality but also promotes knowledge transfer among developers, which is vital in building and maintaining a complex e-commerce system [13].

The selection of the MERN (MongoDB, Express.js, React.js, Node.js) Stack for this e-commerce project offers significant technological advantages. This full-stack JavaScript framework provides a unified development environment, streamlining the development process and facilitating easier maintenance. MongoDB, as a NoSQL database, offers the flexibility required to handle the complex and varied data structures typical in e-commerce applications, such as product catalogs and user transactions [14]. Its schema-less nature allows for agile adaptation to changing data requirements, a crucial factor in the evolving e-commerce landscape.

React.js, utilized for frontend development, enables the creation of a responsive and dynamic user interface. This is particularly significant in e-commerce, where user experience directly influences conversion rates and customer retention. The component-based architecture of React.js facilitates the development of reusable UI elements, enhancing consistency across the platform and improving development efficiency[15]. Node.js, employed on the server side, provides high performance and scalability, critical factors in managing the variable traffic loads characteristic of e-commerce platforms [16]. Its event-driven, non-blocking I/O model is particularly advantageous in handling multiple concurrent connections, a common scenario in online retail environments. The synergy between XP methodology and MERN Stack technology in this research provides a robust framework for developing a scalable, maintainable, and user-centric e-commerce platform for Andalas Books.

2.2 Data Collection

Data collection in this study involved the following steps:
1) Observation and Interview

At this stage, direct observations were made of the Andalas Bookstore and through one of the respondents, the owner of the Andalas Bookstore. This Observation aimed to provide an initial picture of operations and customer interactions in the store. The next stage was an interview with the Andalas Bookstore manager as the respondent. This involved meeting with the manager of the Andalas Bookstore owner. This Interview aimed to obtain information related to the needs of the system to be built. The following is a list of questions asked to the owner of the Andalas Bookstore, Mrs. Arni.

Table 1. Interview Questions

No.	Interview Questions
1.	How long has it been since Andalas Bookstore was founded?
2.	What products or goods are sold at the Andalas shop?
3.	How does the buying and selling process at the Andalas store take place?
4.	How many transactions usually occur at the Andalas store daily?
5.	Are there any obstacles or challenges in the Andalas store sales business, such as a limited number of customers or other problems?
6.	Is Andalas shop interested in developing its business into E-Commerce or online sales?

2) Competitor Analysis

The competitor analysis analyzed the e-commerce websites Gramedia, BukuKita, and GaleriBuku LP3ES. This Analysis is used as a reference for e-commerce development regarding competitors' strengths and weaknesses. Opportunities for improvement obtained from competitors will be implemented in e-commerce development to give the website advantages.

3) Requirement Analysis

At this stage, an analysis of functional and non-functional requirements is carried out. Functional requirements include the features required for e-commerce needs. Meanwhile, non-functional requirements describe attributes such as security and usability to support e-commerce performance.

2.3 Software Development Method

The software development method used is Extreme Programming (XP), which includes several stages: planning, design, coding, and testing.
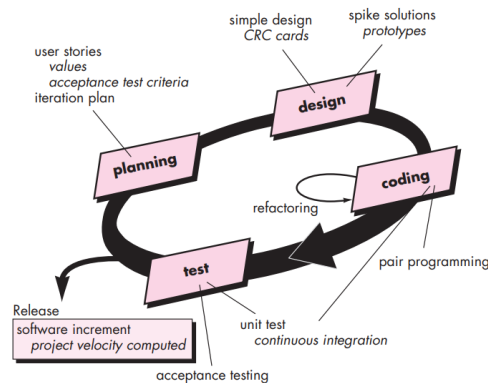

Figure 3. Extreme programming [11]

1) Planning

Based on the results of the requirement analysis which produces functional and non-functional requirements, user stories, acceptance criteria, and values are determined (using the MoSCoW method). After determining these three values is complete, the implementation schedule (iteration planning) is carried out. In the Extreme Programming method, determining the priority of the task stories that must be completed is the user stories with the highest value and then re-determining the priority values (high, medium, and low). The duration of 1 iteration in the extreme programming method is 1-2 weeks. However, the duration of this iteration can be adjusted to suit project needs.

2) Design

After the planning stage, the next step is to design the system to be built. The system's design includes case diagrams, activity diagrams, CRC cards, class diagrams, and spike solution prototypes. Use cases describe activity patterns or habits in a designed portal system [17]. Activity diagrams are needed to describe the workflow or sequence of use cases that have been created. Class diagrams describe a system by defining each class designed to create the system [17]. Before creating a class diagram, create a CRC card first. CRC cards are obtained from classes relevant to the e-commerce system. These classes involve responsibilities and collaborators necessary to fulfill these responsibilities [10]. Next, a spike solution prototype was created using a mid-fidelity interface design. The design was created using draw.io and Figma tools.

3) Coding

The program code is implemented using the JavaScript programming language (MERN) at the coding stage. Apart from that, it also utilizes CSS frameworks such as Tailwind and Bootstrap. Coding is done with the Visual Studio Code editor, which includes backend and frontend creation. At this stage, pair programming is used (collaboration with fellow developers). Pair programming is carried out with one backend partner and one QA tester. Next, there is continuous integration using GitHub to store source code and to collaborate remotely. Finally, there is refactoring (improving code quality) to meet core practices in the extreme programming method.

4) Testing

In the testing phase, four testing methods will be carried out: unit testing, black box, lighthouse, and system usability scale. Unit testing is carried out using the jest library to test the functionality of the program code. Testing was also carried out using the User Acceptance Test (UAT) methodology, which utilizes the alpha testing method with a black box approach [18]. The black box method can be used to determine the design's suitability and the system development results [17]. The choice of this method is based on the need to test the system from the end user's perspective, thereby allowing better identification of the suitability between the system being developed and the user's needs and expectations. This testing was carried out by researchers, fellow quality engineers, and three respondents who can test website functionality. The Google Lighthouse test assesses four aspects: performance, accessibility, best practices, and SEO (search engine optimization) [19]. The system usability scale is carried out in the final iteration to obtain the usability value of the application from the perspective of the last user or end user [7]. The respondents in this test were 20, and 1 person was from the Andalas Bookstore.

5) Release

The launch stage is carried out after the functionality of the e-commerce website has been thoroughly tested. The website's launch in this research was only for environmental staging. For the record, staging or

staging environment is an artificial environment similar to the production environment (the live website environment that users access).

3. RESULTS AND DISCUSSION
3.1 Data Collection
1) Observation and Interview

Observation results can be obtained in Andalas bookstore operations using conventional methods and WhatsApp. Apart from that, researchers have found a need for more visitors to the Andalas bookstore. The solution to overcome this problem is to expand the reach of buyers and book enthusiasts through e-commerce that will be built.

Table 2. Interview Results

No.	Answer
1.	Andalas Shop was founded in 1995 and has been running for approximately 25 years. This shop started its own business after previously following its brother's business.
2.	This shop sells various books, including textbooks for preschool to tertiary levels, School Alper, APE Paud, dictionaries, Islamic books, and the Al-Qur'an.
3.	The buying and selling transaction process at the Andalas store uses conventional methods and WhatsApp media. WhatsApp numbers can only be obtained through shops and by word of mouth.
4.	When there are many visitors, the Andalas shop can attract 20 people, but that number needs to include buyers. Meanwhile, when it is quiet, the Andalas shop can only attract approximately five people who come.
5.	The first factor is that children, especially students, do not like reading books and tend to prefer their gadgets, so interest in buying books is now very much reduced. Meanwhile, according to him, the heyday of book sales occurred in the 2000s, when he managed to sell hundreds of books. At that time, many students were looking for books for their lectures.
6.	According to Mrs Arni, the manager of the Andalas Store, she is interested in e-commerce or online stores, which are offered to expand market reach and help overcome the current generation's lack of interest in reading books.

2) Competitor Analysis

Figure 4. Competitor Analysis

The results of the analysis using the lighthouse tool for three bookstore websites (Gramedia, BukuKita, and LP3ES) show that Gramedia has a lower performance rating among the three websites tested, which can affect user experience. However, it has a better score for the SEO aspect, getting a score of 92, and accessibility, getting a score of 72. If the SEO of this website is searched on Google search, it is ranked first with the search keyword "online bookstore." Meanwhile, the BukuKita website has better performance than the Gramedia website. Apart from that, the accessibility value of 89 outperforms the other three websites. Even though it has a lower SEO score than the Gramedia website, this is not a problem because there is still room for improvement. This website is ranked fourth in Google searches with the search keyword "online bookstore." LP3ES has the best performance of the three websites tested. This is because the website has a simple appearance, and there are not too many additional trinkets that make the website heavy. LP3ES outperformed the Gramedia and Bukukita websites by scoring 78 for performance and 91 for best practice. The accessibility is quite good, and the SEO score can still be improved to get better results on Google searches.

3) Requirements Specification

Table 3. Functional Requirement

ID	Functional Requirement
KF-01	The system provides authentication features (register, login, and logout).
KF-02	The system allows users to access the home page of a website.
KF-03	The system can provide features to search for products.
KF-04	The system can provide a basket feature before purchasing the product.
KF-05	The system can provide features to view product types or categories.
KF-06	The system allows users to view order information.
KF-07	The system allows users to provide reviews
KF-08	The system allows users to manage profile accounts.
KF-09	The system allows users to access contact persons
KF-10	The system can provide a wishlist feature to save the products you like
KF-11	The system can provide features to manage products.
KF-12	The system can provide features to manage orders
KF-13	The system can provide features to manage users.
KF-14	The system can provide features to manage reports.

Table 4. Non-Functional Requirement

ID	Non-Functional Requirement	
KNF-01	Security	The system must use appropriate protocols, such as HTTPS and SSL. The system must be safe from hacker attacks and malware.
KNF-02	System Performance	The system must be able to load content quickly.
KNF-03	Usability	The system must use a user-friendly design and provide users with the features.
KNF-04	Accessibility	The system must be accessible to users with disabilities.

Determining the features used ten respondents who could use the website and one from the bookstore. Respondents were given a questionnaire containing a list of website features using the Moscow method. Respondents were allowed to determine feature priorities based on four criteria: must have, should have, could have, and will not have. Respondents can also provide recommendations for features that are not yet available in the list of features provided

3.2 Software Development and Testing Outcomes

At this stage, user stories are created based on the features that have been defined and sorted based on work priorities. Determining work priorities uses the Moscow method obtained from previous user respondent questionnaires. Furthermore, priorities with a must-have value will take priority in the initial iteration compared to should have and could have. If the time target has been met in the first iteration, work on the user story will be moved to the next iteration. The time for one iteration is two weeks or 80 working hours with a working duration of 8 hours per day. Calculation of work estimates based on the number of story points. The estimated work for one story point is eight working hours. The following is a table 5 that shows iteration planning.

Table 5. Iteration Planning

No Story	User Story	Value	Story Point	Estimation (Hours)
	Iteration 1			
US-01	As a new user, I would like to register an account so that I can access all of the website's features.	Must have	3	24 hours
US-02	As a customer, I want to log in to my registered account so that I do not have to create an account again to get all the website features.	Must have	4	32 hours
US-03	As a customer, I want to be able to log out of my account on the e-commerce website so that I can maintain account security or log in to another account.	Must have	3	24 hours
	Total			80 hours
	Iteration 2			

US-04	As an admin, I would like to be able to manage the products available in the store so that I can easily add, edit, or delete products as needed.	Must have	3	24 hours
US-05	As an admin, I would like to be able to manage a list of customer accounts registered in the store so that I can manage customer information, troubleshoot account issues, and better understand customer behavior.	Must have	3	24 hours
US-06	As an admin, I would like to be able to manage customer orders so that I can monitor order status, manage shipping, and provide effective customer support.	Must have	2	16 hours
US-07	As an admin, I would like to be able to manage customer reviews of products in the store so that I can monitor customer feedback, respond to reviews, and maintain the store's overall reputation.	Must have	2	16 hours
	Total			80 hours
	Iteration 3			
US-08	As a customer, I would like to see a list of books on the home page so that I can explore various types of books and get a general idea of the book collection offered.	Must have	2	16 hours
US-09	As a customer who wants to find a particular book or explore options relevant to my interests, I want to have a practical search feature in an online bookstore to find the book I am looking for easily.	Must have	2	16 hours
US-10	As a customer who wants to buy the books I choose, I want to have a feature to add books to the shopping cart to see a purchase summary, set the number of items I want to buy, and continue the checkout process to complete purchases quickly.	Must have	2	16 hours
US-11	As a customer who wants to purchase a book, I would like to have the option to add a shipping address at checkout so that the shipping price can be determined accurately before I complete the purchase.	Must have	2	16 hours
US-12	US-12 F-16 As a customer who wants to purchase books, I want to have the option to use various payment methods so that I can be more flexible in making payments according to my preferences and needs.	Must have	2	16 hours
	Total			80 hours
	Iteration 4			
US-13	As a customer using an e-commerce website, I would like to have access to my order history to manage my orders by monitoring them, updating order status, or deleting transaction details that I have made.	Must have	3	24 hours
US-14	As a customer, I would like to have the ability to manage my profile account so that I can view and organize personal information and perform account-related actions efficiently.	Must have	3	24 hours
US-15	As a customer using an e-commerce website, I would like to have access to a list of all available product categories so that I can easily	Must have	2	16 hours

	navigate and find products that match my interests or needs.				
US-16	As a customer who has completed a purchase on an e-commerce website, I would like to have the option to provide a review and rating for the product I have purchased so that others can see my review and make better purchasing decisions.	Should have	2	16 hours
	Total				80 hours

Iteration 5

US-17	As a customer, I want to have access to contact information so that if a problem occurs, I can easily contact the relevant party to get help or a solution.	Should Have	2	16 hours
US-18	As a customer, I would like access to the bookstore profile to find information about the bookstore and see its reputation and related reviews.	Should have	1	8 hours
US-19	As a customer, I want to have a feature to save products that I want to buy later into a wish list to find and buy these products easily.	Could Have	2	16 hours
US-20	As a customer, I would like access to the FAQ (Frequently Asked Questions) page to find a list of frequently asked questions and get appropriate answers.	Could Have	1	8 hours
US-21	As a customer, I would like to receive a discount when purchasing certain books to save money and get added value from my purchase.	Could Have	3	24hours
US-22	As a customer, I want to be able to track the location of the book package I ordered to monitor the delivery status and estimated arrival time more accurately.	Could Have	1	8hours
	Total				80 hours

Table 6. Table of Iterative Development Process for Andalas Books

Iteration	Period	Development Focus	User Stories	Testing Results & Revisions	Involved CRC Classes
Iteration 1	Week 1 – 2, January 2024	UML system design, login feature implementation using MERN stack	3	Passed; no revisions	C_User, M_User
Iteration 2	Week 3 – 4, January 2024	Admin feature implementation	4	Improved login validation, added show/hide password feature	C_Product, M_Product, C_Order, M_Order, C_User (with added responsibilities)
Iteration 3	Week 1 – 2, February 2024	Homepage, book search, cart, shipping page, checkout features	5	Passed; no revisions	C_Product, C_Order, C_Payment, C_Songkir
Iteration 4	Week 3 – 4, February 2024	Adding responsibilities to CRC classes from previous iterations	4	Passed; no revisions	C_User, C_Order, C_Product (with additional responsibilities)
Iteration 5	Week 1 – 2, March 2024	Adding FAQs, a footer with contact info, and a wishlist feature	6	Passed; no revisions; C_Product updated with wishlist responsibilities	C_Product (with additional responsibilities)

3.3 Platform Performance Evaluation Using Specific Metrics

Comprehensive testing was carried out using two primary metrics tools: Google Lighthouse and the System Usability Scale (SUS). These tools were chosen to evaluate key performance indicators—such as website responsiveness, accessibility, adherence to best practices, SEO performance, and usability.

The Lighthouse tool produced favorable results across 13 tested pages, as shown in Table 7. The Andalas Books platform achieved an average performance score of 94.38, 100 for accessibility, 93.69 for best practices, and 99.31 for SEO. These high scores reflect the effectiveness of the MERN Stack architecture in enabling a Single Page Application (SPA) model, which facilitates faster load times and smooth transitions between different sections of the website.

Additionally, Progressive Web App (PWA) optimization played a significant role in achieving these results. PWA ensures the platform delivers a native app-like user experience by supporting offline access and enhancing page responsiveness. This feature directly impacts user satisfaction, particularly in areas with inconsistent internet connectivity. Table 7 below shows the results of the lighthouse test for 13 pages of the Andalas Books website.

Table 7. Result Lighthouse Testing

Page	Performance	Matrix Accessibility	Best practices	SEO	PWA
Home	94	100	95	100	✓
Login	96	100	91	100	✓
Register	91	100	91	100	✓
Forgot Password	97	100	91	100	✓
Category	94	100	95	100	✓
Book Details	94	100	95	100	✓
Profile	96	100	95	100	✓
Edit Profile	94	100	91	100	✓
Cart	94	100	95	100	✓
Wishlist	94	100	95	100	✓
Delivery	96	100	95	100	✓
My Order	92	100	95	91	✓
About	81	100	95	100	✓

Table 8. Result in System Usability Scale Testing

SUS Score	Adjective Ratings	Grade Scale	Acceptability
75.375	Excellent	C	Acceptable

Based on Table 8, it can be concluded that the Andalas Books e-commerce site obtained a usability score acceptable to users, as shown by the SUS assessment standards, where the final score between 70 and 100 falls into the "Acceptable" category. The System Usability Scale (SUS) calculations show the final total value is 1507.5, which, after dividing by 20 respondents, produces a final figure of 75.375. The superior performance of the Andalas Books platform can be attributed to several critical design and development choices. The use of the MERN Stack allowed the creation of a dynamic SPA that optimizes load speeds by reducing the need for full-page reloads. This design decision was key in achieving high performance and accessibility scores. The platform adhered to SEO best practices, ensuring better visibility in search engine results. Furthermore, the Extreme Programming (XP) approach allowed continuous refinement through feedback loops, where each iteration improved upon previous results. Adjustments to the login feature, such as adding error messages and password visibility options, improved the usability experience, directly contributing to a higher SUS score.

Usability testing revealed that while the final SUS score of 75.375 falls within the "acceptable" range, it received a "C" grade scale, suggesting room for further improvements. Positive experiences were noted, with many respondents rating usability aspects such as intuitive navigation and ease of use highly. However, lower scores on some questions suggest that minor interface adjustments could enhance responsiveness and clarity. This SUS score reflects that iterative refinements through testing had a meaningful impact on the

platform's overall usability. Future efforts should focus on refining interface responsiveness and enhancing feature clarity to improve the platform's standing within the B or A grade scale.

Table 9. Comparison of Website Performance (MERN Stack vs. Competitors)

Measured Aspect	Andalas Books	Gramedia	BukuKita	LP3ES
Page Load (GTMetrix)	6.7 s	12.3 s	8.9 s	36.1 s
Responsive	Yes	Yes	Yes	Yes
Performance (Lighthouse)	94.38	59	71	78
Accessibility (Lighthouse)	100	72	89	79
Best Practices (Lighthouse)	93.69	64	64	91
SEO (Lighthouse)	99.31	92	82	80
PWA	Yes	Yes	No	No

4.   CONCLUSION

The research demonstrates that the Andalas Books e-commerce platform was successfully developed using the MERN Stack and met the expected time targets, with five iterations completed within 400 working hours (10 weeks). Testing of 22 user stories produced 63 acceptance criteria, all of which were successfully validated by five testers, confirming the platform's functional compliance with user expectations.

Performance analysis using Google Lighthouse revealed superior results across 13 tested pages, with average scores of 94.38 for performance, 100 for accessibility, 93.69 for best practices, and 99.31 for SEO. These results are attributed to the MERN Stack's Single Page Application (SPA) model, which minimizes page reloads and enhances load speed. Furthermore, the Progressive Web App (PWA) optimization ensures offline access and smooth user interaction, providing a native app-like experience, which is particularly beneficial for users in regions with unstable internet connectivity. The System Usability Scale (SUS) evaluation scored 75.375, classified as "Excellent" in terms of user experience but within the "C" grade scale, indicating room for improvement. User feedback highlighted intuitive navigation and ease of use, although minor interface adjustments could enhance responsiveness and clarity, potentially improving the platform's usability to the B or A grade scale in future iterations.

A comparative analysis between Andalas Books and three competitors—Gramedia, BukuKita, and LP3ES—highlights the platform's competitive edge. Andalas Books outperformed its rivals with a performance score of 94.38, compared to 59 for Gramedia, 71 for BukuKita, and 78 for LP3ES. The platform also achieved perfect scores in accessibility (100) and SEO (99.31), outperforming its competitors in these metrics. Unlike BukuKita and LP3ES, Andalas Books supports PWA, offering enhanced user interaction and offline access. Moreover, page load speed tests showed Andalas Books loading in 6.7 seconds, significantly faster than Gramedia (12.3 s), BukuKita (8.9 s), and LP3ES (36.1 s).

In summary, the use of the MERN Stack architecture has proven critical to achieving high performance, accessibility, and best practices adherence. Future developments could further improve user experience by integrating personalized recommendations based on user behavior, enhancing search functionalities, and conducting longitudinal studies to monitor user engagement over time. The introduction of machine learning algorithms for data-driven insights and predictions would also enhance the platform's capability to offer a more tailored shopping experience. These future directions will ensure the continuous development and competitiveness of the Andalas Books e-commerce platform.

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