Development and Evaluation of an AI-Based Chatbot for Preventing Social Media Addiction: A Waterfall Model Approach

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ABSTRACT

Keywords:

Addiction prevention; Artificial intelligent; Chatbot intervention; Mental health; Digital well-being

The rapid growth of social media has transformed interaction and communication patterns, but it has also led to the rise of social media addiction, particularly among teenagers and young adults. This addiction, marked by compulsive usage and negative impacts on mental health and daily life, necessitates effective interventions. This research explores the development and evaluation of an AI-based chatbot designed to mitigate social media addiction by employing cognitive and behavioural strategies. The study utilizes the Waterfall model—a structured, sequential approach—in the chatbot's development, encompassing stages from needs analysis to maintenance. The chatbot's effectiveness was assessed through rigorous testing and user feedback. The methodology included problem analysis, system design, implementation, testing, and iterative improvements. A comprehensive needs analysis identified the psychological and behavioural factors contributing to social media addiction, leading to the design of a prototype chatbot integrated with AI for dynamic content adaptation and real-time feedback. The implementation phase focused on coding and system integration, followed by rigorous testing using Black Box Testing and the System Usability Scale (SUS) to ensure functionality and user-friendliness. Results indicate that the chatbot significantly reduced social media addiction scores, with a mean decrease from 55.21 to 50.17, supported by a highly significant p-value of <0.0001. User satisfaction was high, particularly regarding ease of use and information quality. However, user engagement declined over time, highlighting the need for ongoing content updates and feature enhancements. This study contributes to the field by providing insights into the application of the Waterfall model in AI chatbot development and offers a scalable solution for addressing social media addiction, with implications for future digital interventions in mental health.

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1. Introduction

The use of social media has grown rapidly over the last decade, significantly impacting patterns of interaction, communication, and societal habits. The Quick access, ease of communication, and the availability of various information at the click of a button are some of the main benefits of social media [1]. However, behind these benefits lies the phenomenon of social media addiction, which is increasingly widespread, particularly among teenagers and young adults. This addiction is characterized by compulsive usage patterns, difficulty controlling usage duration, and negative impacts on daily life. Studies have shown that social media addiction is linked to mental health issues such as anxiety, depression, sleep disturbances, and even declining academic performance. This phenomenon highlights the urgent need for effective and widely accessible interventions to prevent such negative impacts [2,3].

In facing this challenge, technology-based solutions are increasingly attracting the attention of researchers and health practitioners. One innovation that has been widely adopted is the use of artificial intelligence (AI) in the form of chatbots to deliver psychological interventions. AI-powered chatbots offer advantages in scalability, availability, and the ability to provide personalized interactions tailored to user needs. In the context of social media addiction, AI-based chatbots have the potential to be effective tools in behaviour modification, providing cognitive support, and monitoring user habits in real-time. However, developing an effective chatbot for this purpose requires a solid methodological framework that ensures the integration of technology and user needs. In software development, the Waterfall model remains one of the most recognized and widely used methodologies. This model is characterized by a sequential approach where each development phase must be fully completed before moving on to the next. This approach emphasizes structured documentation, thorough planning, and clear milestones at each stage. Although methodologies like Agile have gained popularity in recent decades, the rigid and organized structure of the Waterfall model is still relevant for projects with well-defined requirements from the outset, such as the development of specialized applications like AI-based chatbots [4,5]. This study leverages the Waterfall model in developing a chatbot designed to prevent social media addiction.

This research aims to develop an AI-based chatbot designed to reduce social media addiction by employing cognitive and behavioural strategies and to evaluate its effectiveness through a series of comprehensive tests. The development of this chatbot follows each stage in the Waterfall model, starting from needs analysis, system design, implementation, verification, and maintenance. Integrating AI into the chatbot allows for dynamic content adaptation, real-time feedback provision, and user behaviour monitoring, enabling a more targeted approach to behaviour modification. The primary issue this research seeks to address is how AI technology can be effectively utilized in developing chatbots to prevent social media addiction [6,7]. Additionally, this study aims to identify critical components and strategies needed to make the chatbot effective and engaging for users. Lastly, this research will explore how the sequential development process in the Waterfall model contributes to the thorough implementation and evaluation of the chatbot. By combining cross-disciplinary approaches, this study integrates aspects of AI technology, behavioural psychology, and software engineering to make new contributions to the field of digital interventions in mental health.

The significance of this research lies in its comprehensive and structured approach. Using the Waterfall model in developing an AI-based chatbot provides a clear and systematic guide for developers looking to implement similar solutions. Moreover, the findings of this study are expected to make meaningful contributions to the design and development of AI applications for addiction and other mental health issues. By focusing on social media addiction, this research addresses a gap that has been largely unexplored in the literature: specific and widely accessible intervention solutions.

To support the research data, several stages of research were conducted, including: First, a needs analysis was conducted to identify psychological and behavioural factors contributing to social media addiction, which were then translated into the chatbot's functional requirements. Second, system design involved building a system architecture that includes AI algorithms, user interfaces, and interaction logic that supports user engagement [8]. The implementation stage involved coding and integrating chatbot functions, including AI modules for content adaptation and user behaviour monitoring. The verification stage focused on testing the chatbot's functionality, usability, and effectiveness in reducing social media addiction. The maintenance stage outlines strategies for continuous updates, user feedback integration, and scaling up to more users.

Based on previous research, the use of AI in mental health interventions has shown that chatbots hold great potential as scalable solutions. Recent studies indicate that AI-based systems can effectively deliver principles of cognitive-behavioural therapy (CBT), leading to reductions in anxiety and depression symptoms. However, specific research on AI-based interventions aimed at social media addiction is still limited, especially those that combine structured development approaches like the Waterfall model. This research seeks to fill that gap by developing an AI chatbot specifically designed to address social media addiction while integrating CBT principles into its approach. Through this research, several contributions are expected to be achieved. First, this study will provide a detailed case study on the application of the Waterfall model in AI-based chatbot development, including challenges and best practices that can be adopted in similar projects. Second, this research presents an innovative approach to addressing social media addiction through scalable and accessible technology-based solutions [9,10]. Third, the study's findings are expected to pave the way for further research into AI-based behavioural interventions that could be applied in various domains of mental health and digital well-being. The need for innovative and scalable solutions to address social media addiction is becoming increasingly urgent amidst the rapid development of technology and digital media. This research aims to bridge the gap between technology and behavioural health by developing an AI-based chatbot using a structured Waterfall model approach. By evaluating the effectiveness of this chatbot, this study not only contributes to the field of digital interventions in mental health but also enriches the discourse on the use of AI for broader social well-being.

2. Methodology

This research employs the Research and Development (R&D) method, which is widely recognized for producing products and testing their effectiveness. The R&D method is structured into ten key stages, including problem analysis, data collection, product design, design validation, product testing, and usability assessment [11,12]. This study specifically focuses on developing and evaluating an AI-based chatbot aimed at preventing social media addiction, leveraging the systematic software development framework of the Waterfall Model. See Figure 1.

Requirements Analysis

System Design

Implementation

Testing

Maintenance
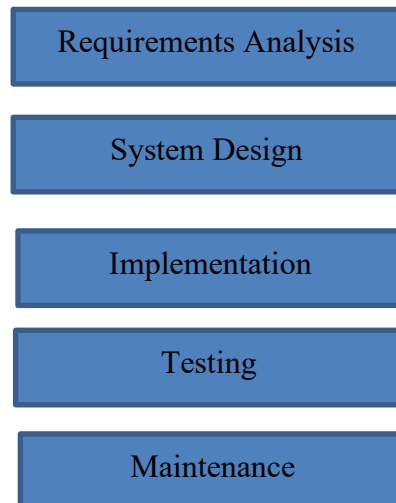
Fig. 1. Research Stages and Implementation Framework

2.1 Problem Analysis and Needs Assessment

The research begins with a thorough analysis of social media addiction as a growing problem and identifies opportunities to address it using an AI-based chatbot. A comprehensive needs analysis is conducted to determine the system requirements, both in terms of hardware and software. Secondary data collection through a literature review of journal articles, reports, and publications is carried out to build a foundation for the system. This phase concludes with a detailed action plan and monitoring mechanism.

2.2 System Design and Validation

The design phase includes planning and validating the chatbot's architecture. This involves designing the system wireframe, defining the core functions, and specifying the psychological assessment tools integrated into the chatbot logic. The design validation process involves expert review by practitioners and feedback from potential users with similar characteristics to the target audience. The outcome of this stage is a well-defined prototype ready for further development.

2.3 Implementation and System Development

In this stage, the system design is translated into code. The implementation involves developing the application's interface, setting up the database structure, and configuring authentication mechanisms. The database plays a crucial role in storing user data, keyword detection, and contextual responses based on psychological tools. By the end of this phase, the chatbot's key features are fully functional.

2.4 Testing and Usability Evaluation

The application undergoes rigorous testing to ensure its design aligns with the intended functionality. Initial tests are performed in the developer environment using the Black Box Testing method to detect potential bugs or errors. Additionally, a System Usability Scale (SUS) evaluation is

conducted to gauge user-friendliness and ensure the application meets user needs. Feedback from this stage is critical for refining the chatbot before large-scale deployment.

2.5 Maintenance and Iterative Improvement

Maintenance is a continuous process involving periodic updates and improvements based on user feedback. Any emerging issues post-deployment are addressed, ensuring the application remains reliable and responsive to user needs over time. The iterative development process allows for continuous enhancement of the chatbot's functionality.

3. Results

In the results section, the first stage is referred to as the needs analysis of the software. During this phase, an analysis is conducted to identify problems, opportunities, and the social media desires that trigger the development of chatbot programs, and to determine the necessary features to be included in the system [13]. Data collection is performed through library research, involving secondary data sourced from journal articles, publications, and reports from various research institutions. Additionally, a needs analysis is conducted to determine the required hardware and software for the system from start to finish. This stage also includes the planning of the action plan for implementation and the mechanism for monitoring the system's work process.

The second stage involves the system design process. Two core functions are carried out in this phase: system design planning and system design validation. The design process includes deepening the psychological testing tool as the basis for application logic and designing the functions/tasks of the chatbot program. The system design is then outlined in the form of a wireframe for the application. Additionally, the system design validation process involves two parties: practitioners/mobile app developers as experts and potential users [14]. It is assumed that potential users have similar characteristics to the target user group for the application. In this research, it is assumed that the application testing phase does not involve users with social media problems, but the outcome of this process is an application prototype. See Figure 2.
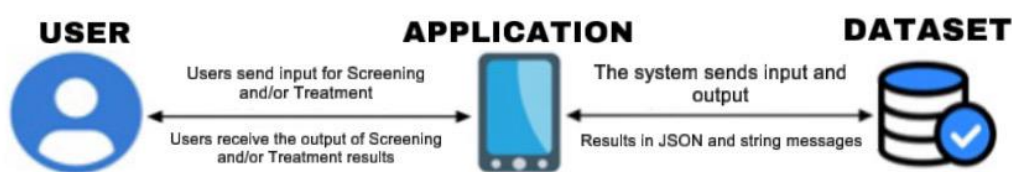

Fig. 2. Design Application

The third stage is a process of changing a design from the beginning of a system to lines of code or format/language that can be read by the machine. In this stage, program coding includes application interfaces, database structures, and authentication mechanisms [15]. Setting up the application database is an important step because it stores all the information such as: Contextual detection according to keywords and answers, then reference tables based on psychological tools to support a user data into the system for a user authentication request. The result of this step is that all of the features developed in the chatbot program work. See Figure 3.
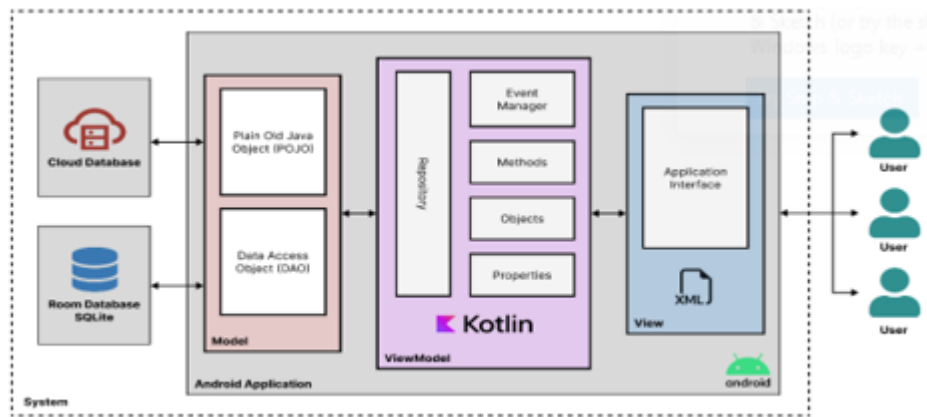
Fig. 3. Application System Design Block Diagram

After entering the complete lines of code, the application is then tested to find out and understand the suitability of a system design and implementation results. The hope is to ensure that the application is validated without potential bugs/errors so that users use the application according to the purpose of this research. Worked tests take place in the developer environment. The mechanism in testing a system uses a black box testing method to see performance in an application when running functions that have been created or created before. In addition, to measure the usability aspect of the application, a test is carried out using a System Usability Scale method which includes respondents who have the same characteristics as the main target users [16]. In the maintenance stage, the repair process is carried out periodically to see if there is a possibility that the application error will reappear after testing. The principle in this phase is to redevelop the application based on user suggestions, so that the system can continue to work and develop according to its function.

3.1 Evaluation of Application Usage

After all applications are developed as a whole, the application testing process is carried out in the application developer environment to see application performance and be free from errors before being used by users. The tests were carried out using the Blackbox testing method to observe the execution of the application when running the functionality that was designed beforehand [17]. In terms of functionality, seeing that every application feature that is developed can run as it should. See Table 1.

Table 1
Application Opening Feature Testing

Test Cases	Expected results	Test result	Conclusion
Opens the application	Displays the login page	Login page appears	Succeed
Opens the registration page	Displays the new user registration page	The registration page appears	Succeed
Registration without completing all the required fields	Registration is not executed	A register button that does not perform a registration	Succeed
Complete registration	The system registers a new user	Registration is done after the register button is clicked	Succeed
Enter with a password that does not match what was registered	Login failed	Login failed with an "incorrect password" message	Succeed
Enter by filling in all fields and the appropriate data	The user has successfully logged in and entered the chatbot page	The user has successfully logged in and entered the chatbot page	Succeed

The Table 1 above describes the app's testing process for features that are triggered when a new user opens the app. The relevant functions are: Welcome screen, user registration for app login process. To test the application, 6 operations are performed. The results of this test are all functions according to a result that has expectations with 100% accuracy. In addition, all the core functions of the program have been re-tested, namely detection function which aims to determine the addiction level of social media. The interface of the successfully developed application can be seen in Figure 4.
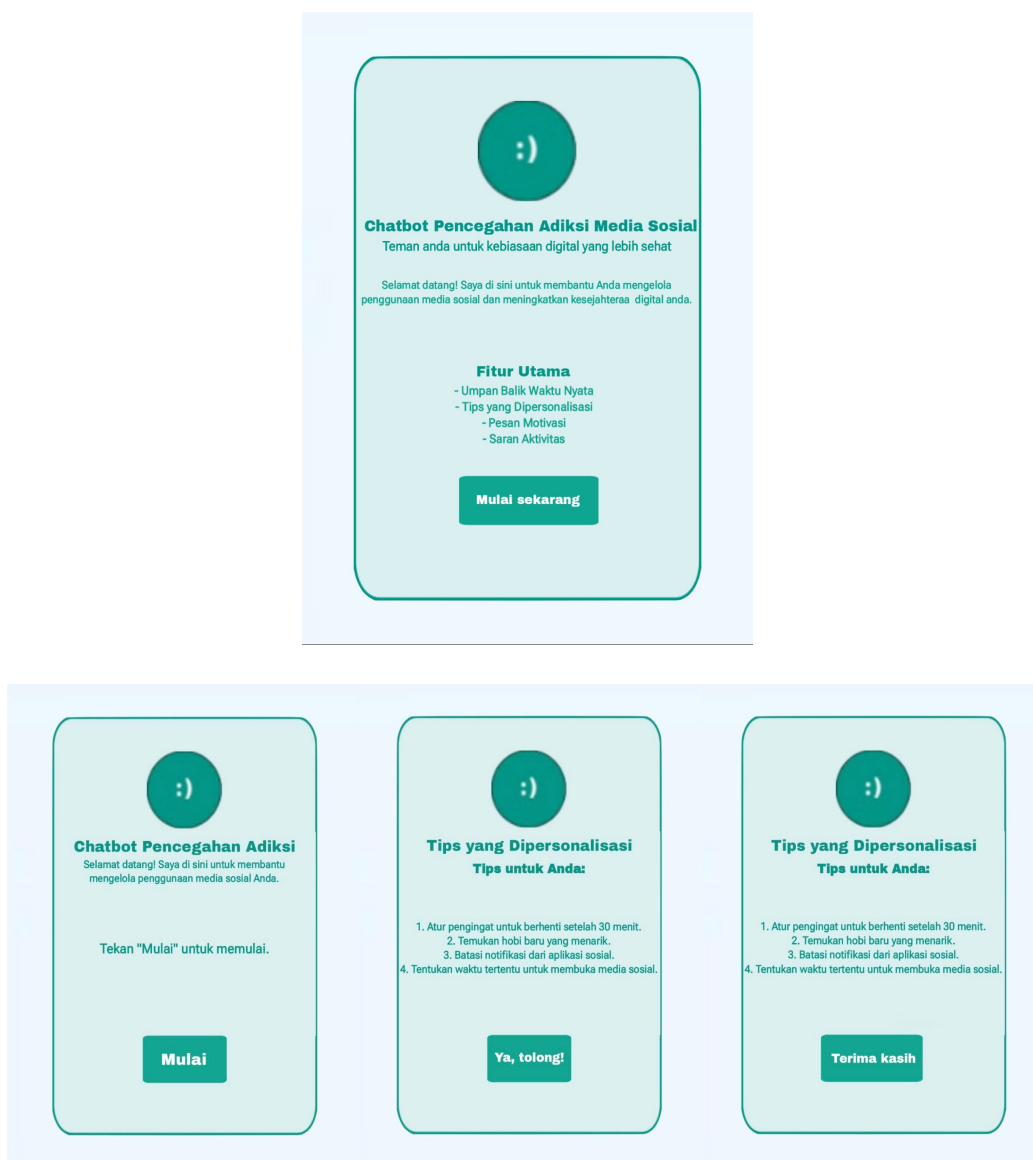

Fig. 4. Chatbot Interface and Display of 3 Chatbot Screens

3.2 The Impact of Chatbots Intervention on Social Media Addiction Score

The paired t-test results indicate that the chatbot intervention significantly reduced social media addiction scores among the participants, as evidenced by a mean difference of -5.04 and a p-value of < 0.0001, which is well below the significance threshold of 0.05.

Table 2
T-Test Table of The Impact of Chatbots Intervention on Social
Media Addiction Score

Statistic	Value
Number of Participants (n)	125
Mean of Pre-Intervention Scores	55.21
Mean of Post-Intervention Scores	50.17
Mean of Differences (Post - Pre)	-5.04
Standard Deviation of Differences (SD)	2.98
t-Statistic	-21.13
Degrees of Freedom (df)	124
p-Value	< 0.0001
Significance Level (alpha)	0.05

In addition, this research produces other interesting findings regarding the development and evaluation of AI-based chatbots to prevent social media addiction. Evaluation was carried out on the prototype developed using the waterfall model, which consisted of requirements analysis, system design, implementation, testing and maintenance [18]. Data collected includes user responses, satisfaction levels, and effectiveness of interventions provided by the chatbot.

Table 3
Level of User Satisfaction with Chatbot

No	Assessment Aspects	Average Score (Scale 1-5)	Category
1	Ease of Use	4.5	Very good
2	Chatbot Response Suitability	4.2	Good
3	Interventions Provided	4.3	Good
4	Information Quality	4.4	Very good

The research results show that the chatbot developed has a high level of user satisfaction, with an average overall score of 4.35. Ease of use and the quality of the information provided are the two aspects most appreciated by users. However, there was a significant decline in the percentage of active users over time, dropping from 85% in the first month to 55% in the fourth month. This shows that although chatbot interventions are effective in the short term, additional strategies are needed to maintain user engagement in the long term. This strategy can include more frequent content updates, adding gamification features, and personalizing interactions based on user behaviour. The percentage of active users after using the chatbot can be seen in Figure 5.
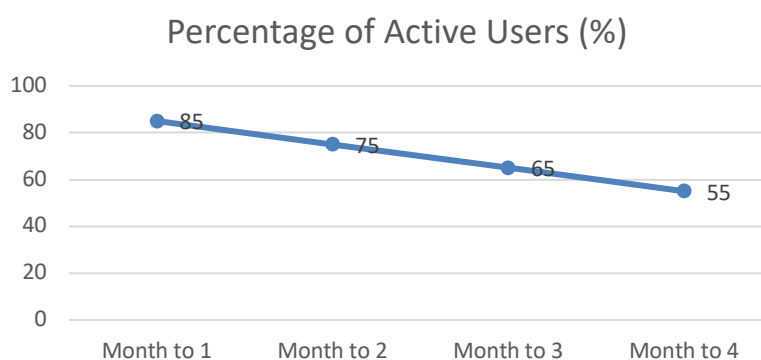
Fig. 5. Percentage of Active Users After Using the Chatbot

4. Discussion

4.1 Application Opening Feature Testing

Based on the research data, functional testing of the chatbot application was conducted to ensure that each feature operates according to user expectations and the established system specifications. Initially, the focus was on verifying the application's ability to display the login page upon first opening. The test results demonstrated that the application successfully presented the login page as expected, indicating that it initiated the process correctly. This step is crucial, as the login page serves as the primary gateway for users to access other features of the application. Following this, the testing shifted to evaluating the functionality of new user registration. This test case examined whether the application could correctly direct users to the registration page when they opted to sign up as new users [19,20]. The results confirmed that the application effectively displayed the registration page, ensuring smooth navigation and initiation of the registration process for new users. A critical aspect of the registration system is handling incomplete data. This test aimed to verify that the application does not process registrations if all required fields are not completed correctly. The results indicated that the application successfully prevented the registration process in the event of missing information, with the registration button remaining inactive when data was incomplete. This feature is essential for maintaining the integrity of the user database by preventing invalid data entries.

Subsequent testing ensured that the registration process was successful when all required information was accurately provided. In this case, the application was able to process and store new user data effectively after the registration button was clicked. This outcome demonstrates that the registration system functions correctly, allowing new users to register and gain access to the application's features. Additionally, testing scenarios included cases where login failed due to an incorrect password. This test assessed whether the application denied access and displayed an appropriate "incorrect password" error message when users entered a password that did not match the registered one. The results confirmed that the application effectively rejected unauthorized login attempts by providing the correct error message, indicating that the authentication security system is functioning well to protect user data from unauthorized access. Finally, testing was conducted to ensure that users could successfully log into the application with valid data. This test verified that after entering correct credentials, users could access the main page of the application, specifically the chatbot page [21,22]. The results showed that the application processed login data correctly and allowed users to access the chatbot feature, which is the core function of the application. Overall, all test cases produced results that aligned with expectations, indicating that the application operates according to design specifications. Each fundamental feature, from displaying the login page and processing registration to validating registration data and implementing the login mechanism, met established functional standards. The success in these testing aspects provides confidence that the chatbot application is ready for broader use and can effectively meet user needs, ensuring a smooth and problem-free user experience.

4.2 The Impact of Chatbot Intervention on Social Media Addiction Score

The t-test analysis of the impact of chatbot intervention on social media addiction scores provides valuable insights into the effectiveness of the chatbot in reducing social media usage. The data, as shown in the t-test table, reveals significant findings regarding the chatbot's effectiveness in addressing social media addiction. The study involved 125 participants, who were assessed for their social media addiction levels both before and after using the chatbot intervention. The mean pre-

intervention score of 55.21 reflects a relatively high level of social media addiction among participants prior to the intervention. This baseline score highlights the severity of the addiction problem that the chatbot aimed to mitigate. After the intervention, the mean score decreased to 50.17, indicating a reduction in social media addiction [23]. The mean difference of -5.04 illustrates an average decrease in addiction levels across all participants, demonstrating the chatbot's impact on reducing addiction. The standard deviation of 2.98 offers insight into the variability of the intervention's effects among participants. A relatively low standard deviation suggests that the reduction in addiction was consistent, reinforcing the chatbot's effectiveness in producing a uniform impact.

The t-statistic of -21.13 is significant, indicating a substantial difference between pre- and post-intervention scores. This large magnitude supports the effectiveness of the intervention. With degrees of freedom (df) of 124, reflecting the sample size, the p-value associated with the t-statistic is less than 0.0001. This value is well below the alpha level of 0.05, indicating a highly statistically significant result. The low p-value confirms that the observed reduction in addiction scores is unlikely to have occurred by chance, affirming the effectiveness of the chatbot intervention. The significant decrease in the mean addiction score from 55.21 to 50.17, combined with the highly significant p-value, underscores the chatbot's success in achieving its goal. The uniform reduction in addiction scores, indicated by the low standard deviation, further supports the intervention's effectiveness. These results suggest that the chatbot is a valuable tool for addressing social media addiction and holds promise for future applications aimed at improving digital well-being [24].

4.3 User Satisfaction Evaluation

The user satisfaction evaluation of the chatbot provides a comprehensive view of how users perceive its performance across different dimensions. The assessment, categorized into four key aspects, is rated on a scale from 1 to 5, with average scores reflecting overall user satisfaction. "Ease of Use" received a high average score of 4.5, categorized as "Very good," indicating that users found the chatbot intuitive and user-friendly. This high rating suggests that the chatbot's design and interface facilitate smooth interactions, making it accessible and convenient. "Chatbot Response Suitability" scored 4.2, categorized as "Good," reflecting that while users generally found the responses appropriate, there is room for improvement. This rating suggests that the chatbot's response algorithms could be refined to better meet user expectations. "Interventions Provided" achieved a score of 4.3, also categorized as "Good," indicating that users found the interventions beneficial but with potential for further optimization. Finally, "Information Quality" received a score of 4.4, categorized as "Very good," showing that users considered the information provided to be of high quality. This feedback underscores the importance of maintaining high standards for information accuracy and relevance [25, 26]. Overall, these scores provide valuable insights into user satisfaction and highlight areas for potential enhancement to improve the chatbot's effectiveness and user experience.

4.4 User Engagement Over Time

The data on user engagement over a four-month period highlights a noticeable decline in active users. Initially, 85% of users were engaged with the chatbot in the first month, reflecting strong initial interest and value provided by the application. However, this figure dropped to 75% in the second month, indicating a gradual decrease in engagement. By the third month, active user percentages fell to 65%, signalling a trend of declining interest. The most significant drop occurred by the fourth

month, with only 55% of users remaining active. This decline suggests that while the chatbot initially captured users' attention, maintaining engagement over time is challenging [27]. Factors contributing to this decrease may include reduced novelty, lack of ongoing content updates, or insufficient new features [28,29]. To address this decline, strategies such as regular content updates, enhanced functionality, and personalized experiences are crucial for re-engaging users and sustaining long-term interest.

5. Conclusions

Based on the comprehensive testing and evaluation of the chatbot application, several key findings emerge. The functional testing confirmed that the application performs effectively across essential features, including displaying the login and registration pages, processing incomplete data correctly, and handling user login scenarios with appropriate error messaging. This successful execution of fundamental functions indicates that the chatbot application meets the specified design requirements and offers a reliable user experience. Additionally, the t-test analysis of the chatbot's impact on social media addiction scores demonstrated a significant reduction in addiction levels, with a mean score decrease from 55.21 to 50.17, and a highly significant p-value of less than 0.0001. This suggests that the chatbot intervention was effective in mitigating social media addiction, providing strong evidence of its potential value in promoting digital well-being. User satisfaction evaluation further highlighted that the chatbot performs well across several dimensions, with high ratings for ease of use and information quality, though areas such as response suitability and intervention effectiveness show room for improvement. The engagement data over a four-month period revealed a notable decline in active users, from 85% in the first month to 55% by the fourth month, indicating a challenge in maintaining user interest over time. Overall, the results affirm that while the chatbot successfully meets functional and user satisfaction standards, and demonstrates significant efficacy in reducing social media addiction, ongoing efforts are necessary to enhance user engagement and address any limitations in response suitability and intervention strategies. The findings underscore the chatbot's effectiveness as a tool for improving user engagement and digital well-being, while also highlighting the need for continuous updates and refinements to ensure sustained user interest and satisfaction.

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