

Research Article

Development and Evaluation of a Gamified Mobile Application with Two-Dimensional Animation for MPASI Education to Support Stunting Prevention

Diny Anggriani Adnas^{1*}, Sri Arnilasari², and Milasari³

¹ Department of Informatics, Universitas Sulawesi Barat, Majene, Indonesia, 91411

² Department of Health Administration, Universitas Sulawesi Barat, Majene, Indonesia, 91411

³ Department of Informatics, Universitas Sulawesi Barat, Majene, Indonesia, 91411

*Corresponding Author: diny.anggriani@unsulbar.ac.id | Phone: +6285341402059

ABSTRACT

Inappropriate *Makanan Pendamping Air Susu Ibu (MPASI)* practices (complementary feeding) remain one of the major contributors to child malnutrition and stunting during the first 1,000 days of life. This study aimed to develop and evaluate a gamified mobile application incorporating two-dimensional (2D) animation as a nutrition education medium to improve mothers' knowledge and adherence to appropriate MPASI practices. A Research and Development (R&D) approach using the ADDIE model was employed. The application was developed using the Flutter framework and integrates educational modules, 2D animations, interactive quizzes, local food-based MPASI recipes, daily checklists, and gamification features. Its effectiveness was evaluated using a One-Group Pretest–Posttest design involving 30 mothers. Data were analyzed using descriptive statistics, the Shapiro–Wilk test, the Wilcoxon Signed-Rank Test, effect size analysis, and the USE Questionnaire. The results showed that the mean knowledge score increased from 8.93 to 9.97, while the adherence score improved from 27.53 to 30.53 after using the application. Significant improvements were observed for both variables ($p = 0.001$), with large effect sizes ($r = 0.61$ and $r = 0.62$). The application also achieved an excellent usability score (3.70) and high reliability (Cronbach's Alpha = 0.961). These findings indicate that the proposed application effectively improves mothers' knowledge and adherence regarding MPASI while providing an excellent user experience, demonstrating its potential as a digital nutrition education tool to support stunting prevention.

Keywords: 2D animation; gamification; MPASI; nutrition education; stunting

1. INTRODUCTION

Stunting remains one of the major public health challenges worldwide, particularly in developing countries. It is characterized by impaired linear growth resulting from chronic malnutrition over a prolonged period, which adversely affects cognitive development, productivity, and quality of life in adulthood (Anggryni et al., 2021). The World Health Organization (WHO) reports that millions of children worldwide continue to experience stunting, while Indonesia remains among the countries with a relatively high prevalence of stunting in Southeast Asia (*Perkiraan Gabungan Malnutrisi Anak (JME) (UNICEF-WHO-WB)*, n.d.; *Survei Kesehatan Indonesia (SKI) 2023 - Badan Kebijakan Pembangunan Kesehatan | BKKP Kemenkes*, n.d.). Consequently, accelerating stunting reduction has become one of Indonesia's national development priorities through various nutrition interventions focusing on the first 1,000 days of life (1000 HPK), from pregnancy until a child reaches two years of age. This period is widely recognized as the *window of opportunity* because it plays a crucial role in determining children's future growth and developmental outcomes (Mulyani et al., 2022).

One of the most important nutrition-specific interventions for stunting prevention is the appropriate provision of *Makanan Pendamping Air Susu Ibu (MPASI)* (Suryani et al., 2023). MPASI should not only be introduced at the appropriate age but should also fulfill the principles of adequate energy, protein, and micronutrient intake, age-appropriate food texture, feeding frequency, and dietary diversity. Inappropriate MPASI practices, such as introducing complementary foods too early, providing unsuitable food textures, and inadequate consumption of animal-source protein, have been associated with an increased risk of stunting and impaired child growth. Previous studies have shown that insufficient maternal knowledge regarding MPASI remains one of the primary factors contributing to suboptimal feeding practices among children aged 6–24 months (Aryanti et al., 2024).

Although MPASI education has been delivered through *Posyandu* (community health posts), primary healthcare centers (*Puskesmas*), and maternal education programs, educational activities are still predominantly conducted using lectures,

leaflets, and printed materials. While these approaches are relatively easy to implement, they have limited ability to maintain participants' attention and encourage active user engagement (Lee et al., 2022). Meanwhile, the increasing ownership of smartphones has created significant opportunities to utilize digital technology as a more flexible, interactive, and accessible medium for health education. The mobile health (mHealth) approach has been widely adopted to support health promotion, behavioral monitoring, and improve adherence to various healthcare interventions (Adnas & Rachmawan, n.d.; Aulia et al., 2022; Rachmawan & Adnas, 2022).

Several previous studies have developed mobile applications and digital media to support maternal and child health education. Study (Hastuty et al., 2025) developed an Android-based MPASI education application that successfully improved mothers' knowledge regarding complementary feeding; however, the application primarily presented educational content through text and images. Study (Hayati & Lisviarose, 2025)(Majumder, 2025; Zhang, 2023) utilized animated video media to improve maternal knowledge of child nutrition and reported positive learning outcomes following the intervention. Furthermore, studies (Adnas & Rachmawan, n.d.; Majumder, 2025; Zhang, 2023) applied gamification in health applications and demonstrated increased learning motivation and user engagement through point-based reward mechanisms. In addition, study (Putra et al., 2024) reported that two-dimensional (2D) animation significantly improved information retention compared with conventional learning media, while study (Rizal et al., 2020) evaluated application usability using the USE Questionnaire and reported a high level of user satisfaction. These findings indicate that digital media have considerable potential for supporting health education; however, their implementation in MPASI education remains limited.

Based on the review of previous studies, several research gaps remain. First, most existing MPASI education applications focus primarily on information delivery and have not integrated 2D animation, gamification, interactive quizzes, behavioral checklists, and local food-based recipes within a single platform. Second, previous studies generally evaluated improvements in users' knowledge, whereas changes in maternal adherence to appropriate MPASI practices have rarely been assessed simultaneously.

To address these gaps, this study developed a gamified MPASI education mobile application incorporating two-dimensional animation using the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model. The application integrates animation-based educational modules, Mandar local food-based MPASI recipes, interactive quizzes, a point system, badges, and daily checklists to encourage positive behavioral change. Unlike previous studies, this research not only evaluates the application's usability but also examines its effectiveness in improving maternal nutrition knowledge and adherence to recommended MPASI practices using a one-group pretest–posttest design. Therefore, this study is expected to contribute to the development of more interactive, contextually relevant, and effective digital health education media to support stunting prevention efforts in Indonesia.

2. RESEARCH METHOD

2.1 Research Design

This study employed a Research and Development (R&D) approach using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) to develop a gamified MPASI education mobile application incorporating two-dimensional (2D) animation. The ADDIE model was selected because it provides a systematic development framework, beginning with user needs identification and ending with product effectiveness evaluation (SANCHEZ-GARCÍA et al., 2023). During the Analysis phase, a literature review, observations of *Posyandu* (community health post) activities, questionnaires, and interviews with mothers of children aged 6–24 months were conducted to identify user requirements for an MPASI education medium. The Design phase included the preparation of the User Requirement Document (URD), application flow design, wireframes, user interface (UI), user experience (UX), animation storyboards, gamification mechanisms, and database structure. During the Development phase, the application was built using the Flutter Framework, accompanied by the creation of two-dimensional animation assets, integration of educational content, implementation of gamification features, and internal (alpha) testing (Adnas & Melisa, 2025). The Implementation phase consisted of application trials involving the research participants, while the Evaluation phase assessed both application usability and its effectiveness in improving mothers' knowledge and adherence to recommended MPASI practices. Product effectiveness was evaluated using a One-Group Pretest–Posttest design, in which participants completed a pretest before using the application and a posttest after completing all learning activities.

2.2 Application Development

The MPASI education application was developed using the Flutter Framework and the Dart programming language for the Android platform. Flutter was selected because it supports cross-platform mobile application development with high performance, responsive user interfaces, and efficient development through a single codebase architecture (Maulana et al., 2023)(Maarif et al., 2017). Local data storage was implemented using SQLite, allowing most application features to function without an internet connection. The educational content was developed based on the complementary feeding guidelines issued by the Indonesian Ministry of Health and validated by a nutrition expert before being integrated into the application. Learning materials were presented through two-dimensional animations, concise learning summaries, interactive quizzes,

MPASI recipes based on local foods from Majene Regency, and daily checklists to monitor complementary feeding practices.

The application consists of five learning modules covering (1) the appropriate timing of MPASI introduction, (2) age-appropriate food textures, (3) the importance of protein and iron intake, (4) balanced MPASI menu planning, and (5) common mistakes in complementary feeding practices. To enhance user engagement, the application incorporates gamification elements, including a point system, badges, levels, a progress tracker, and achievement rewards obtained after users complete learning activities.

Table 1. Application Specifications

Components	Specification
Platform	Android
Framework	Flutter
Programming Language	Dart
Database	SQLite
Development Model	ADDIE
Educational Content	2D Animation, MPASI Learning Modules, Learning Summaries
Supporting Features	MPASI Recipes, Interactive Quizzes, Daily Checklists
Gamification	Points, Badges, Levels, Progress Tracker
Target Users	Mothers with children aged 6–24 months

2.3 Research Site and Participants

The study was conducted in Galung Village, Majene Regency, West Sulawesi Province, involving mothers recruited from several *Posyandu* in Majene Regency. Participants were selected using a purposive sampling technique based on predefined inclusion criteria. Eligible participants were mothers who (1) had children aged 6–24 months, (2) owned an Android smartphone, (3) agreed to participate throughout the study, and (4) signed an informed consent form. Participants who did not complete all stages of the study were excluded from the final data analysis. During data collection, five participants had children aged 25–26 months. These participants were retained because their children were still within the transition period of complementary feeding practices at the time of data collection and remained consistent with the study objective of evaluating maternal knowledge and adherence regarding MPASI practices. A total of **30 participants** completed the study and were included in the final analysis.

2.4 Research Instruments

Three research instruments were employed: a knowledge test, an adherence questionnaire, and a usability questionnaire. The knowledge test consisted of 10 multiple-choice questions designed to measure mothers' understanding of recommended MPASI practices. The adherence questionnaire measured the frequency with which mothers applied appropriate complementary feeding practices using a four-point Likert scale ranging from Never (1) to Always (4). Application usability was evaluated using the USE Questionnaire, which measures four dimensions: Usefulness, Ease of Use, Ease of Learning, and Satisfaction. Each item was rated using a four-point Likert scale. Prior to data collection, all instruments underwent content validation through expert judgment involving both a media expert and a nutrition expert. The reliability of the usability questionnaire was subsequently evaluated using Cronbach's Alpha.

2.5 Research Procedure

The study began with coordination with local *Posyandu* to determine the implementation schedule and recruit eligible participants. Participants were informed about the objectives of the study and asked to provide written informed consent. Initially, participants completed a demographic questionnaire followed by a pretest assessing their knowledge and adherence regarding MPASI practices before using the application. The researchers then assisted participants in installing the Android application and provided a brief demonstration of its main features, including the learning modules, MPASI recipes, interactive quizzes, daily checklists, and the point and badge system. Participants subsequently used the application throughout the intervention period by completing all educational modules, quizzes, recipe activities, and daily checklists. Upon completion of the intervention, participants completed the posttest and the usability questionnaire to evaluate the application's usefulness, ease of use, ease of learning, and user satisfaction.

2.6 Data Analysis

Data were analyzed using IBM SPSS Statistics version 32. Descriptive statistics were used to summarize participant characteristics as well as the mean scores for knowledge, adherence, and application usability. Prior to hypothesis testing, data normality was assessed using the Shapiro–Wilk test because the sample size was fewer than 50 participants. Since the data were not normally distributed, differences between pretest and posttest scores were analyzed using the Wilcoxon

Signed-Rank Test with a significance level of $\alpha = 0.05$. The magnitude of the intervention effect on maternal knowledge and adherence was determined using effect size (r). In addition, the reliability of the usability questionnaire was evaluated using Cronbach's Alpha, while usability outcomes were analyzed descriptively using the mean scores of the four USE Questionnaire dimensions: Usefulness, Ease of Use, Ease of Learning, and Satisfaction.

3. RESULTS AND DISCUSSION

3.1 Implementation of the MPASI Education Application

This study resulted in the development of an Android-based MPASI education mobile application using the Flutter Framework. The application was designed as a digital learning medium to support mothers with children aged 6–24 months in independently learning appropriate MPASI practices. All educational content was developed based on the Indonesian Ministry of Health's complementary feeding guidelines and validated by a nutrition expert prior to implementation. The application consists of five main learning modules covering the appropriate timing of MPASI introduction, age-appropriate food texture, the importance of protein and iron intake, balanced MPASI menu planning, and common mistakes in complementary feeding practices. In addition to the educational modules, the application provides local food-based MPASI recipes, a daily checklist, and a user progress page to facilitate continuous learning and self-monitoring. To enhance user engagement, the application incorporates gamification through a point system, badges, levels, and a progress tracker. Users earn points by completing learning activities such as studying educational modules, answering interactive quizzes, and filling out daily checklists. Accumulated points contribute to users' level progression and unlock achievement badges, encouraging sustained participation and reinforcing positive MPASI practices.



Figure 1. Splash Screen

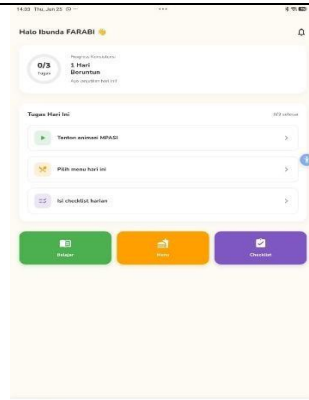


Figure 2. Home Screen

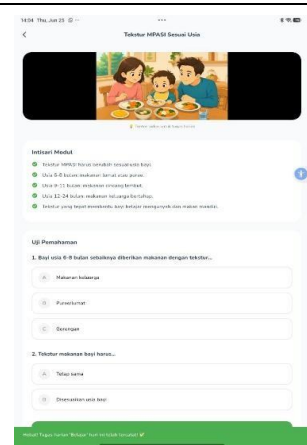


Figure 3. Learning Module, Quiz, and 2D Animation Features

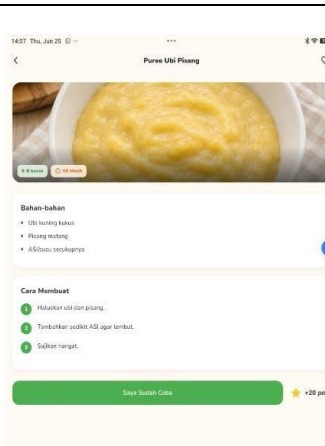


Figure 4. Local Food-Based MPASI Recipe Feature

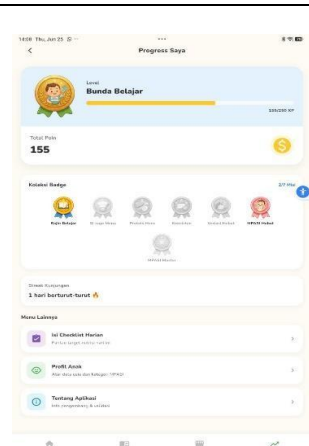


Figure 5. User Progress Feature

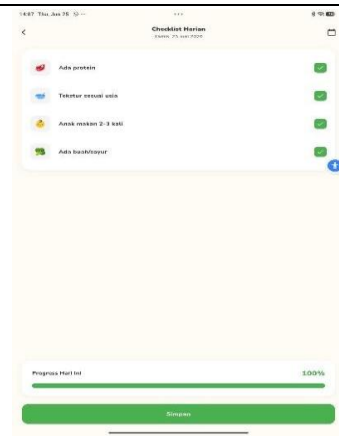


Figure 6. Daily Checklist Feature

Figures 1–6 illustrate the main interfaces of the developed application. The Splash Screen serves as the initial display when the application is launched, while the Home Screen provides access to all core features. The learning module integrates educational materials, two-dimensional (2D) animations, and interactive quizzes to facilitate knowledge acquisition. Additional features include local food-based MPASI recipes to assist mothers in preparing nutritious complementary meals, a progress page to monitor learning achievements, and a daily checklist to encourage consistent implementation of recommended MPASI practices. Collectively, these features provide an interactive learning experience while promoting behavioral change through gamification mechanisms.

3.2 Respondent Characteristics

A total of 30 mothers participated in this study. Respondent characteristics were analyzed based on maternal educational level, maternal age, and children's age to provide a comprehensive overview of the study population. Understanding respondents' demographic characteristics is important because these factors may influence mothers' knowledge, learning experiences, and complementary feeding (MPASI) practices. The distribution of respondents is presented in **Table 2**.

Table 2. Characteristics of Respondents

Characteristics	Category	Frequency (n)	Percentage (%)
Mother's Education	SD/SMP	10	33,3
	SMA	9	30,0
	Diploma/S1	11	36,7
Mother's Age (Years)	17–25	5	16,7
	26–35	13	43,3
	36–45	8	26,7
	>45	4	13,3
Child's Age (Months)	6–8	8	26,7
	9–11	2	6,7
	12–24	15	50,0
	25–26	5	16,7

Based on educational level, 11 respondents (36.7%) had completed a diploma or bachelor's degree, representing the largest proportion of participants. Meanwhile, 10 respondents (33.3%) had completed elementary or junior high school, and 9 respondents (30.0%) had completed senior high school. This distribution indicates that the study involved mothers with diverse educational backgrounds, enabling the application to be evaluated across users with varying levels of educational attainment. Regarding maternal age, the majority of respondents (43.3%) were between 26 and 35 years old, followed by 36–45 years (26.7%), 17–25 years (16.7%), and over 45 years (13.3%). These findings indicate that most participants were within the productive reproductive age, a period generally associated with active childcare responsibilities and greater exposure to health information. With respect to children's age, most respondents had children aged 12–24 months (50.0%), followed by 6–8 months (26.7%), 25–26 months (16.7%), and 9–11 months (6.7%). Although the study primarily targeted children aged 6–24 months, respondents with children aged 25–26 months were retained because they were still within the transition period of complementary feeding during data collection. Their inclusion remained consistent with the study objective of evaluating maternal knowledge and adherence regarding recommended MPASI practices. Overall, the respondent characteristics demonstrate that the developed application was evaluated by mothers with varying educational backgrounds and age groups, thereby providing a broader representation of the target users. This diversity strengthens the applicability of the findings in assessing the effectiveness and usability of the proposed MPASI education application.

3.3 Effectiveness of the MPASI Education Application

The effectiveness of the developed MPASI education application was evaluated by comparing respondents' knowledge and adherence scores before and after the intervention. The evaluation was conducted using a One-Group Pretest–Posttest design involving 30 respondents. Data analysis included descriptive statistics, normality testing using the Shapiro–Wilk test, hypothesis testing using the Wilcoxon Signed-Rank Test, and effect size analysis to determine the practical magnitude of the intervention. This analytical approach provides comprehensive evidence regarding the effectiveness of the developed application in improving maternal knowledge and adherence to recommended MPASI practices.

3.3.1 Descriptive Statistics

Descriptive statistics were first calculated to provide an overview of respondents' knowledge and adherence scores before and after using the application. The analysis included the mean and standard deviation (SD) for each variable.

Table 3. Descriptive Statistics of Knowledge and Compliance Scores Before and After the Intervention

Variables	Stage	n	Mean	SD
Knowledge	Pretest	30	8,93	1,413
	Posttest	30	9,97	0,183
Compliance	Pretest	30	27,53	3,401
	Posttest	30	30,53	2,063

As presented in **Table 3**, improvements were observed in both outcome variables following the intervention. The mean knowledge score increased from 8.93 (SD = 1.413) during the pretest to 9.97 (SD = 0.183) during the posttest. Similarly, the mean adherence score increased from 27.53 (SD = 3.401) to 30.53 (SD = 2.063) after respondents completed all learning activities within the application. In addition to the increase in mean scores, the standard deviation decreased for both variables, indicating that respondents' posttest scores became more homogeneous than their pretest scores. This finding suggests that the intervention not only improved overall performance but also reduced variability among respondents. Overall, the descriptive statistics provide preliminary evidence that the developed application positively influenced mothers' knowledge and adherence regarding recommended MPASI practices.

3.3.2 Normality Test

Prior to hypothesis testing, the distribution of the data was examined using the Shapiro–Wilk normality test, which is recommended for studies involving fewer than 50 observations.

Table 4. Results of the Shapiro–Wilk Normality Test

Variable	Sig.	Notes
Knowledge Pretest	0,000	Abnormal
Knowledge Posttest	0,000	Abnormal
Compliance Pretest	0,009	Abnormal
Compliance Posttest	0,000	Abnormal

The results of the Shapiro–Wilk test indicated that the significance values for all pretest and posttest variables were below 0.05, demonstrating that the data were not normally distributed. Consequently, the assumption of normality was not satisfied, and a non-parametric statistical test was selected for subsequent analysis. Based on these findings, differences between pretest and posttest scores were analyzed using the Wilcoxon Signed-Rank Test.

3.3.3 Wilcoxon Signed-Rank Test

The Wilcoxon Signed-Rank Test was conducted to determine whether significant differences existed between respondents' pretest and posttest scores after using the MPASI education application.

Table 5. Results of the Wilcoxon Signed-Rank Test

Variabel	Z	Sig. (2-tailed)	Keputusan
Knowledge	-3,334	0,001	Signifikan
Compliance	-3,379	0,001	Signifikan

As shown in **Table 5**, the knowledge variable produced a Z value of -3.334 with a significance value of 0.001, while the adherence variable produced a Z value of -3.379 with a significance value of 0.001. Since both significance values were lower than the significance threshold of 0.05, the null hypothesis was rejected. These findings indicate statistically significant improvements in both maternal knowledge and adherence following the intervention. The results demonstrate that the developed MPASI education application effectively improved respondents' understanding of complementary feeding as well as their adherence to recommended MPASI practices.

3.3.4 Effect Size Analysis

Although statistical significance indicates whether an intervention is effective, it does not describe the magnitude of its impact. Therefore, effect size (r) was calculated to determine the practical significance of the intervention.

Table 6. Effect Size Analysis

Variable	Effect Size (r)	Interpretation
Knowledge	0,61	Efek besar (<i>Large Effect</i>)
Compliance	0,62	Efek besar (<i>Large Effect</i>)

The analysis showed an effect size of 0.61 for the knowledge variable and 0.62 for the adherence variable. According to Cohen's interpretation, both values fall within the large effect category, indicating that the intervention produced substantial practical improvements in maternal knowledge and adherence. These findings demonstrate that the developed application not only achieved statistical significance but also generated meaningful educational benefits for its users. Therefore, the integration of educational modules, two-dimensional animation, interactive quizzes, gamification features, and daily behavioral monitoring has considerable potential to support digital nutrition education and promote appropriate MPASI practices among mothers.

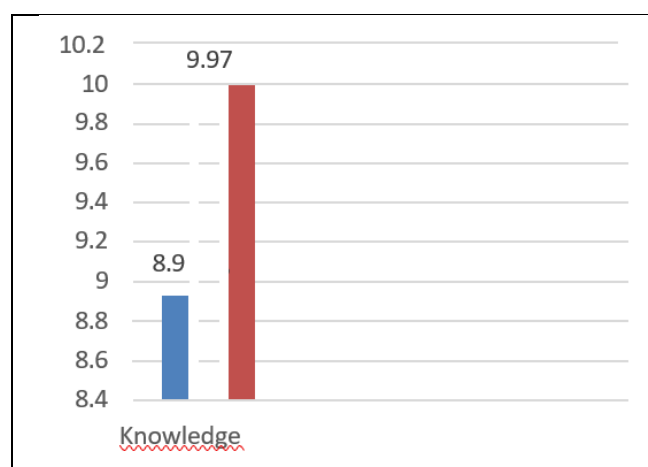
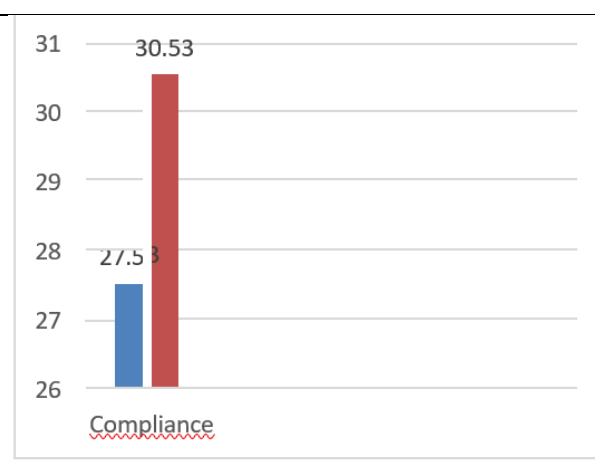
**Figure 7.** Comparison of Mean Knowledge Scores Before and After the Intervention**Figure 8.** Comparison of Mean Compliance Scores Before and After the Intervention

Figure 7 and **Figure 8** provide a visual comparison of respondents' mean scores before and after using the application. **Figure 7** illustrates an increase in the mean knowledge score from 8.93 during the pretest to 9.97 during the posttest. Likewise, **Figure 8** shows an improvement in the mean adherence score from 27.53 to 30.53 following the intervention. The graphical presentation clearly supports the descriptive and inferential statistical findings, confirming that respondents demonstrated higher levels of knowledge and better adherence to recommended MPASI practices after completing all learning activities within the application. These visual findings further reinforce the effectiveness of the developed mobile application as a digital nutrition education tool.

3.4 Application Usability Evaluation

In addition to evaluating the effectiveness of the intervention, the usability of the developed MPASI education application was assessed using the USE Questionnaire, which measures four dimensions: Usefulness, Ease of Use, Ease of Learning, and Satisfaction. The evaluation was conducted after respondents completed all learning modules and intervention activities. Descriptive statistics were used to determine users' perceptions of the application, while Cronbach's Alpha was calculated to assess the internal consistency of the questionnaire.

3.4.1 Reliability Test

Before interpreting respondents' perceptions, the reliability of the USE Questionnaire was examined using Cronbach's Alpha.

Table 7. Reliability Test Results

Instrument	Cronbach's Alpha	Category
USE Questionnaire	0,961	Very Reliabel

The reliability analysis yielded a Cronbach's Alpha coefficient of 0.961, indicating excellent internal consistency. According to commonly accepted reliability criteria, a Cronbach's Alpha value greater than 0.90 reflects outstanding reliability,

demonstrating that the questionnaire items consistently measured users' perceptions of the application. Therefore, the USE Questionnaire was considered reliable for evaluating the usability of the developed MPASI education application.

3.4.2 Usability Evaluation Results

Following the reliability assessment, respondents' perceptions were analyzed descriptively based on the four dimensions of the USE Questionnaire.

Table 8. Results of the USE Questionnaire

Dimensions	Mean	Category
Usefulness	3,74	Very Good
Ease of Use	3,67	Very Good
Ease of Learning	3,69	Very Good
Satisfaction	3,70	Very Good
Mean	3,70	Very Good

The results showed that the overall usability score of the application was 3.70, which falls within the excellent category. Among the four evaluated dimensions, Ease of Learning obtained the highest mean score, indicating that respondents found the application easy to learn and understand. Likewise, the Ease of Use dimension received a high rating, demonstrating that users experienced minimal difficulty when navigating the application and accessing its features. The Usefulness dimension also achieved a high score, suggesting that respondents perceived the application as beneficial in improving their understanding of MPASI practices. Furthermore, the Satisfaction dimension indicated that respondents were generally satisfied with the application's interface, educational content, and interactive learning experience. These findings demonstrate that the developed application successfully combines educational effectiveness with a positive user experience.

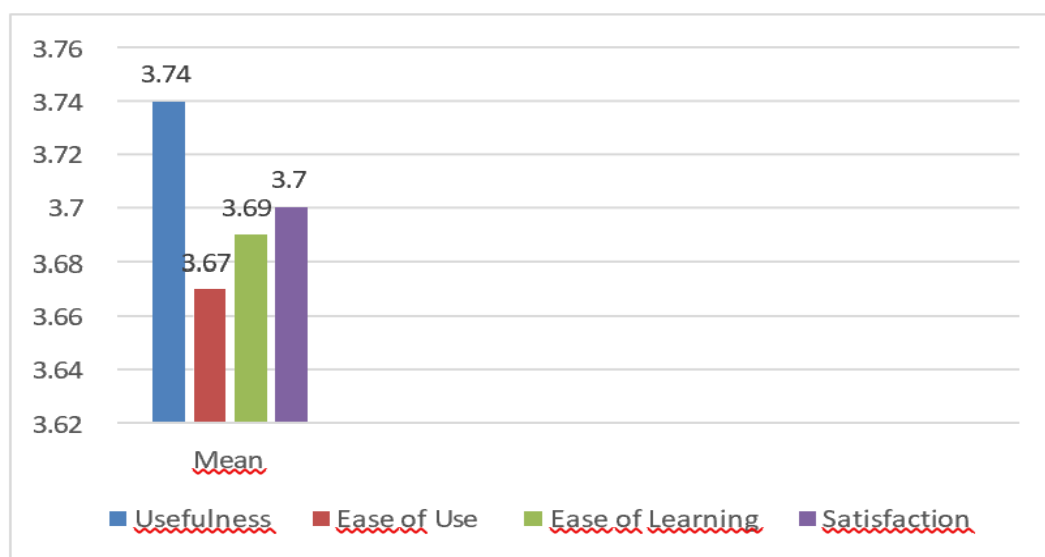


Figure 9. Mean Scores of the Four USE Questionnaire Dimensions

Figure 9 illustrates the mean scores for the four usability dimensions. The consistently high scores across all dimensions indicate that respondents positively perceived the application's usefulness, usability, learnability, and overall user satisfaction. These findings complement the effectiveness evaluation, suggesting that improvements in knowledge and adherence were supported by an application that was both easy to use and engaging for its target users.

3.5 Discussion

The findings of this study demonstrate that the developed MPASI education mobile application effectively improved mothers' knowledge and adherence regarding recommended complementary feeding practices. This conclusion is supported by significant differences between the pretest and posttest scores for both variables, as confirmed by the Wilcoxon Signed-Rank Test. In addition, the calculated effect sizes indicated a large practical effect, suggesting that the intervention not only achieved statistical significance but also produced meaningful educational benefits for the participants. These findings indicate that integrating digital learning media with gamification and two-dimensional (2D) animation can serve as an effective strategy for promoting appropriate MPASI practices among mothers.

The improvement in maternal knowledge observed in this study may be attributed to the application's combination of concise educational materials, visual animations, and interactive quizzes. Compared with conventional educational media such as printed leaflets or lecture-based counseling, multimedia learning facilitates better understanding by presenting information through multiple forms of representation. Animated visualizations simplify complex concepts related to complementary feeding, while interactive quizzes provide immediate feedback that reinforces learning and improves information retention. These findings are consistent with previous studies reporting that multimedia-based nutrition education significantly enhances maternal knowledge and learning outcomes (Hastuty et al., 2025; Hayati & Lisviarose, 2025; Putra et al., 2024).

In addition to improving knowledge, the application significantly increased mothers' adherence to recommended MPASI practices. This finding suggests that the intervention successfully influenced not only cognitive outcomes but also behavioral implementation. One possible explanation is the integration of daily checklists, which encouraged respondents to consistently apply recommended feeding practices during the intervention period. Furthermore, the incorporation of gamification elements, including points, badges, levels, and progress tracking, likely enhanced user motivation and sustained engagement throughout the learning process. Similar findings have been reported in previous studies, which demonstrated that gamification can increase user participation, encourage behavioral change, and improve adherence in digital health interventions (Majumder, 2025; Rachmawan & Adnas, 2022; Zhang, 2023).

Another important finding of this study is the excellent usability of the developed application. The overall usability score indicated that respondents perceived the application as useful, easy to use, easy to learn, and satisfying. Moreover, the Cronbach's Alpha coefficient of 0.961 demonstrated excellent internal consistency of the USE Questionnaire, indicating that respondents' evaluations were highly reliable. High usability is particularly important for health education applications because positive user experiences increase the likelihood of continuous application use, thereby supporting long-term behavioral change. Similar observations have been reported in previous usability studies of mobile health applications, which identified usability as a key determinant of user acceptance and sustained engagement (Rizal et al., 2020).

The novelty of this study lies in the integration of several educational components within a single mobile application. Unlike previous MPASI education applications that primarily focused on information delivery, the proposed application combines two-dimensional animation, gamification, interactive quizzes, local food-based MPASI recipes, and daily behavioral monitoring into one comprehensive learning platform. This integrated approach not only facilitates knowledge acquisition but also promotes practical implementation of recommended complementary feeding practices. The inclusion of Mandar local food-based recipes further enhances the contextual relevance of the application by encouraging mothers to utilize locally available food resources in preparing nutritious MPASI meals.

Despite these promising findings, several limitations should be acknowledged. First, the study employed a One-Group Pretest–Posttest design without a control group, limiting the ability to attribute observed improvements exclusively to the intervention. Second, the sample size was relatively small and recruited from a single geographical area, which may limit the generalizability of the findings. Third, the intervention was evaluated over a relatively short period; therefore, the long-term sustainability of behavioral changes could not be assessed. Future studies should consider randomized controlled trials involving larger and more diverse populations, as well as longer follow-up periods, to further validate the effectiveness of the application. Overall, the findings demonstrate that the proposed MPASI education application represents a promising digital health intervention for improving maternal knowledge and adherence regarding complementary feeding practices. By integrating evidence-based educational content with gamification and interactive multimedia, the application offers an innovative and practical approach to supporting nutrition education and stunting prevention during the first 1,000 days of life.

4. CONCLUSION

This study successfully developed and evaluated a gamified mobile application incorporating two-dimensional (2D) animation for MPASI education using the ADDIE development model. The application integrates educational modules, interactive quizzes, local food-based MPASI recipes, daily checklists, and gamification features, including points, badges, levels, and progress tracking, to provide an engaging and interactive learning experience for mothers. The evaluation results demonstrated that the application effectively improved mothers' knowledge and adherence regarding recommended MPASI practices. Significant differences were observed between pretest and posttest scores for both variables ($p < 0.05$), with large effect sizes, indicating substantial educational benefits. Furthermore, the application achieved excellent usability, supported by high scores across all USE Questionnaire dimensions and excellent questionnaire reliability. These findings suggest that the developed application has strong potential as a digital nutrition education tool to support appropriate complementary feeding practices and contribute to stunting prevention during the first 1,000 days of life. Future studies are recommended to evaluate the application using larger and more diverse populations, include a control group, and assess long-term behavioral outcomes to further strengthen the evidence regarding its effectiveness and scalability.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the Directorate of Research, Technology, and Community Service (DRTPM), Ministry of Higher Education, Science, and Technology of the Republic of Indonesia, for funding this research through the BIMA Research Grant Program, Fiscal Year 2026. The authors also extend their appreciation to the Majene District Health Office, the participating primary healthcare centers (Puskesmas) and Posyandu, as well as all mothers who generously participated in this study. Their valuable support, cooperation, and active involvement were essential to the successful completion of this research.

REFERENCES

- Adnas, D. A., & Melisa. (2025). *Design and Development of the 2D Android-Based Game "Let's Sort It" Using the Game Development Life Cycle* (Vol. 5, Number 1). <https://journal.uib.ac.id/index.php/conescintech>
- Adnas, D. A., & Rachmawan. (n.d.). *Develop Video Games As Therapeutic Media For Depression Using Research And Development Method*.
- Anggryni, M., Mardiah, W., Hermayanti, Y., Rakhmawati, W., Ramdhanie, G. G., & Mediani, H. S. (2021). Faktor Pemberian Nutrisi Masa Golden Age dengan Kejadian Stunting pada Balita di Negara Berkembang. *Jurnal Obsesi: Jurnal Pendidikan Anak Usia Dini*, 5(2), 1764–1776. <https://doi.org/10.31004/OBSESI.V5I2.967>
- Aryanti, N., Sari, D., & Kalsum, U. (2024). Edukasi dan Pelatihan Pemberian Makan Bayi dan Anak dari Bahan Lokal bagi Ibu Balita dan Ibu Hamil. *Jurnal Abmas Negeri (JAGRI)*, 5(2), 453–460. <https://doi.org/10.36590/jagri.v5i2.1319>
- Aulia, S. P., Syarif, S., & Usman, A. N. (2022). Audio Visual Educational Food Complementary Breastfeeding to Mothers Against Improvement of Baby's Nutritional Status. *JKM (Jurnal Kebidanan Malahayati)*, 8(4), 691–697. <https://doi.org/10.33024/jkm.v8i4.7473>
- Hastuty, A., Febiola, A., & Wahyuddin, W. (2025). Mpasi Dan Cemilan Sehat Berbahan Dasar Lokal. *Jurnal Sintaks Logika*, 5(1), 1–11. <https://doi.org/10.31850/jsilog.v5i1.3501>
- Hayati, N., & Lisviarose, L. (2025). *Efektivitas Media Audio Visual Terhadap Pengetahuan Ibu tentang Gizi Balita di Desa Penyaguan Kabupaten Indragiri Hulu*. <https://doi.org/10.55382/jurnalpustakakeperawatan.v4i1.1451>
- Lee, D., Frey, G. C., Cothran, D. J., Harezlak, J., & Shih, P. C. (2022). Effects of a Gamified, Behavior Change Technique–Based Mobile App on Increasing Physical Activity and Reducing Anxiety in Adults With Autism Spectrum Disorder: Feasibility Randomized Controlled Trial. *Jmir Formative Research*, 6(7), e35701. <https://doi.org/10.2196/35701>
- Maarif, V., Widodo, A. E., & Wibowo, D. Y. (2017). *Aplikasi Tes IQ Berbasis Android*. 3(2). <https://doi.org/10.31294/IJSE.V3I2.2820>
- Majumder, N. N. (2025). *Motivational Digital Health App Design for Behavioral Change*. 105–134. <https://doi.org/10.4018/979-8-3693-7210-4.ch004>
- Maulana, R., Andrianto, R., Nasution, A. H., Hasibuan, H. A., Siregar, A. R. R., & Hasibuan, A. H. (2023). Penerapan Flutter Dalam Pengembangan Aplikasi Mobile Resep Kue Indonesia. *Deleted Journal*, 1(3), 103–110. <https://doi.org/10.54066/jptis.v1i3.819>
- Mulyani, N. S., Fitriyaningsih, E., Rahmad, A. H. Al, & Hadi, A. (2022). Peningkatan Pengetahuan Dan Sikap Ibu Untuk Pencegahan Stunting Di Kabupaten Aceh Besar. *Jurnal Pade Pengabdian & Edukasi*, 4(1), 28. <https://doi.org/10.30867/pade.v4i1.810>
- Perkiraan gabungan malnutrisi anak (JME) (UNICEF-WHO-WB). (n.d.). Retrieved November 14, 2025, from <https://www.who.int/data/gho/data/themes/topics/joint-child-malnutrition-estimates-unicef-who-wb>
- Putra, I. N. A. S., Sustiwati, N. L., Udayana, A. A. G. B., & Suardana, I. W. (2024). Integrating Learning Management System and Clasification Learning Media Based On Two Dimension Animation. *IJCCS*, 18(2). <https://doi.org/10.22146/ijccs.94981>
- Rachmawan, R., & Adnas, D. A. (2022). Perancangan dan Pengembangan Video Game sebagai Media Terapi Depresi. *Computer Based Information System Journal*, 10(1), 62–71. <https://doi.org/10.33884/cbis.v10i1.5443>
- Rizal, M. F., Widodo, A., Adi, K., Riyanto, D. E., & Nurhayati, O. D. (2020). *Usability testing mozita application based on use questionnaire model*. 1524(1), 12104. <https://doi.org/10.1088/1742-6596/1524/1/012104>
- Sanchez-García, J. R., Galeana-Victoria, L. G., Flores-Azcanio, N. P., & Sánchez-Vázquez, E. (2023). Addie model as a methodology for the design of distance courses. *Revista de Tecnología Informática*. <https://doi.org/10.35429/jit.2023.30.10.16.26>
- Survei Kesehatan Indonesia (SKI) 2023 - Badan Kebijakan Pembangunan Kesehatan | BKKPK Kemenkes. (n.d.). Retrieved November 14, 2025, from <https://www.badankebijakan.kemkes.go.id/hasil-ski-2023/>

- Suryani, D., Krisnasary, A., Kusdalinah, K., & Wahyu, T. (2023). Peningkatan Keterampilan Ibu Balita Dalam Pemenuhan Gizi Balita di Desa Panca Mukti Kecamatan Pondok Kelapa Kabupaten Bengkulu Utara. *Jurnal Kreativitas Pengabdian Kepada Masyarakat (Pkm)*, 6(4), 1670–1678. <https://doi.org/10.33024/jkpm.v6i4.8848>
- Zhang, X. (2023). A Literature Review and an Investigation on Gamified Mobile Apps in Health and Fitness. *Springer Proceedings in Business and Economics*, 227–234. https://doi.org/10.1007/978-3-031-24294-6_24