Development of Integrated Nutritional Monitoring Application Utilizing Machine Learning and Artificial Intelligence for Child Growth Assessment

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***Abstract*—Stunting, defined as a condition characterized by nutritional deficiencies during the critical growth and development stages of early childhood, poses significant long-term consequences for affected individuals. This issue remains a pressing public health challenge for children in Indonesia. In response to the alarming rates of stunting in the country, this study aims to develop an integrated nutritional monitoring application that leverages machine learning and artificial intelligence (AI) to monitor child growth and prevent stunting. Employing a Research and Development (R&D) approach utilizing the 4D model (Define, Design, Develop, Disseminate), the application is specifically designed to assist parents and healthcare providers in effectively monitoring children's growth. Key features of the application include dietary pattern recognition, an AI-based nutritional calculator, personalized intake menus, virtual nutritionist consultations, and a directory of nearby nutritionists. The implementation of this application took place in the Special Region of Yogyakarta, involving collaborations with community health centers (puskesmas), integrated health service posts (posyandu), and early childhood education institutions. The evaluation of the application was conducted using the System Usability Scale (SUS), with 38 respondents yielding a usability score of 82.5%, indicating a high level of acceptance and ease of use. The results of this study demonstrate that the application is effective in providing accurate and personalized nutritional information, facilitating the monitoring of child growth, and enhancing parental awareness regarding stunting prevention. This application has the potential to serve as a valuable tool in efforts to reduce the prevalence of stunting in Indonesia, particularly in areas with limited access to conventional healthcare services.**

Keywords*—*Artificial Intelligence, Child Growth, Healthcare, Machine Learning, Nutrition Monitoring, Stunting Prevention.

I. Introduction

Stunting remains a significant public health issue affecting children in Indonesia [1]. According to the 2021 Indonesia Nutritional Status Study (SSGI), the stunting prevalence in Indonesia is 24.4%, surpassing the 20% threshold recommended by the World Health Organization (WHO) [2-3]. This condition not only impedes physical growth but also poses serious risks to brain development and cognitive function [4]. Stunting is defined as a state of nutritional deficiency during the critical periods of early growth and development, with profound long-term consequences [5-6].

The causes of stunting are multifactorial, involving complex interactions between various aspects of a child's life and environment [7]. Key contributing factors include nutritional inadequacies, suboptimal parenting practices, poor sanitation, and limited access to healthcare services [8-9]. A lack of adequate nutrition during pregnancy and early childhood is a central issue, often compounded by limited maternal knowledge about proper nutrition [10-11]. For instance, in Yogyakarta, the prevalence of stunting reaches 17.3% [12]. This regional challenge is primarily driven by a combination of factors such as malnutrition, inappropriate complementary feeding, and inadequate caregiving practices. The complexity of stunting's underlying causes highlights the necessity for an integrated approach in prevention and intervention efforts, which must encompass not only the health sector but also the education, social, and economic dimensions [13].

As awareness increases regarding the severe impacts of stunting on child development and the nation's future, technological innovations offer promising new solutions. In this context, advances in Machine Learning and Artificial Intelligence (AI) present new opportunities for stunting prevention and management [14]. These technologies enable real-time, precise monitoring of child growth and the provision of personalized nutritional education tailored to individual needs. For example, AI systems can analyze child growth data and health histories to deliver specific nutritional recommendations. Additionally, these technologies facilitate more efficient resource planning and allocation, allowing for more targeted and effective large-scale interventions.

This study aims to develop an innovative application as a solution to address the challenges of stunting in young children. The application is designed as an integrated platform that leverages AI and Machine Learning technologies to provide a more personalized and effective approach to stunting prevention. The research has resulted in an interactive, accessible stunting education application, which delivers comprehensive, individualized information on stunting prevention and offers a concrete solution for the government of the Special Region of Yogyakarta in efforts to reduce stunting prevalence. By integrating child health data and dietary patterns, the application is expected to be a valuable tool in supporting targeted and sustainable stunting prevention policies and programs.

II. Literature Review

Similar studies have explored the use of digital technology in healthcare, particularly artificial intelligence (AI) and mobile applications, within the fields of nutrition and health. This review covers various aspects, from the application of AI in biomedical, clinical, and epidemiological nutrition research to the use of mobile applications and wearable devices in clinical nutrition management.

The first study examines the use of artificial intelligence (AI) in nutrition research, focusing on three primary areas: biomedical, clinical, and epidemiological nutrition. The findings indicate that artificial neural networks (ANNs) are predominantly used in studies related to food composition, while machine learning algorithms are widely applied to understand the effects of nutrition on health [15].

The second study addresses the application of digital technology in clinical nutrition, including the use of mobile applications and wearable devices. The results demonstrate that mobile applications enable the real-time collection of nutritional data, while machine learning enhances data analysis. Although these technologies are still in their early stages, their potential for improving nutrition management is highly promising, offering opportunities for better patient interaction and more effective health monitoring beyond traditional healthcare settings [16].

The third study further investigates the use of digital applications in clinical nutrition, including mobile apps and wearable technology. The results show that these applications facilitate real-time nutritional data collection and complex analysis using machine learning [17]. The use of digital applications in the health sector, particularly in nutrition management, shows significant promise for improving healthcare quality and clinical outcomes. As innovations in this field continue to advance, the future of nutrition management and digital health appears very promising, with the potential to transform the healthcare paradigm towards a more proactive, personalized, and efficient approach.

III. Research Method

This research employs the Research and Development (R&D) approach to design, create, and test a research-based product [18]. The application that was developed in this study was named *NutriGuard*. In this study, the specific R&D method utilized is a software development methodology that adopts the 4D model (Four-D), developed by Thiagarajan and Semmel [19-20]. The 4D model encompasses four primary stages: Define, Design, Develop, and Disseminate [21-22].

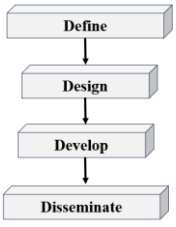


Fig 1. R&D Research Stage in 4D model

The 4D (Four-D) Research and Development model, depicted in Fig. 1, guides the systematic development of the *NutriGuard* application through four stages, such as define, design, develop, and disseminate.

The Define stage involves a comprehensive analysis of needs, identifying problems, and setting development goals, supported by a literature review, user analysis, and product specifications that shape the application's design.

In the design stage, a prototype is created, including user interface design, system architecture, and technology selection, to ensure a user-friendly and functional application.

The application prototype is further refined in the Develop stage, where coding, feature integration, and rigorous testing are conducted to guarantee quality and functionality while addressing any bugs and ensuring the application meets requirements. *NutriGuard* was built using the Flutter framework and programmed in the Dart language. The development process utilized Visual Studio Code as the primary integrated development environment (IDE), with application testing and execution conducted through the Android Studio emulator.

The final stage, Disseminate, focuses on distributing the application to end-users, implementing it in real-world environments, and assessing its impact. This stage facilitates user feedback for ongoing improvements.

Data collection methods include a literature review, questionnaires, and direct observation involving mothers with children aged 0-36 months, pregnant women, and community health volunteers in Yogyakarta's community health centers from March to August 2024. The System Usability Scale (SUS) was employed for evaluating usability, focusing on system functionality, bug testing, and user-friendliness.

Development tools comprised computers, mobile devices, and anthropometric sensors, with machine learning and AI libraries incorporated for personalized nutritional recommendations. *NutriGuard* emphasizes ease of use, featuring anthropometric data input, growth monitoring through visualizations, educational content, and consultation options with healthcare professionals. This application available on the Google Play Store for Android Mobile, *NutriGuard* offers a practical solution for supporting child health and addressing nutritional challenges. In addition, not only through the Google Play Store, *NutriGuard* can also be downloaded via the link: https://play.google.com/store/apps/details?id=id.nutri.guard or https://bit.ly/nutriguardapp. The appearance of the application on the Google Play Store can be seen in Fig. 2.

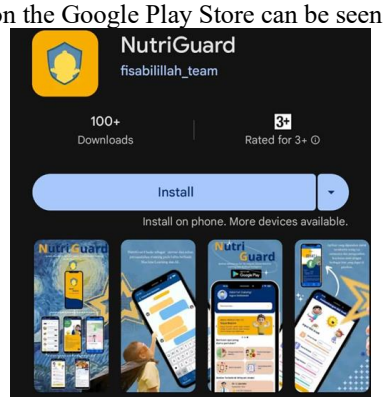


Fig 2. *NutriGuard* Application in Google Play Store

IV. Results and Discussion

A. Application Design and Concept

The *NutriGuard* application offers several key features, including a home page, Nutrify, AI integration, tips & tricks, profile, dietary pattern introduction, nutritional development tracking, baby food menus, and consultations with nutrition experts. Designed to provide fast, accurate, and integrated information on children's nutritional status, *NutriGuard* aims to deliver evidence-based data to support better decision-making by parents and caregivers regarding children's dietary intake and care.

The application incorporates functionalities such as a nutrition calculator, nutritious menu guides, and growth monitoring tools to present relevant information effectively. These features aim to serve as educational resources that help parents comprehend the significance of balanced nutrition and the need for early intervention in preventing stunting. The integrated approach ensures that the information provided is not only comprehensive but also practical for promoting healthy growth and development in children.

NutriGuard's capabilities are specifically geared toward facilitating more informed and proactive nutritional management. Through real-time data and tailored recommendations, the app functions as a valuable tool for enhancing parental understanding of nutritional needs and enabling timely measures to address potential issues, thus contributing to better health outcomes.

Fig. 3 illustrates the process of developing the application by integrating User Interface (UI) and User Experience (UX) to meet user needs. The UI is designed with Figma, a tool for creating visually appealing and intuitive interfaces. Meanwhile, the UX is implemented using Flutter, a versatile framework for cross-platform development and optimal performance. This approach ensures the application is both aesthetically pleasing and provides a seamless, efficient user experience.

In detail, Fig. 3(a) illustrates the layout and user interface elements being created for the app, showcasing the visual design aspects, including menus, buttons, and overall interface structure. Then, Fig, 3(b) reveals the coding environment where the app is being built, it displays snippets of code that contribute to the app's functionality, reflecting the technical aspects of app development.

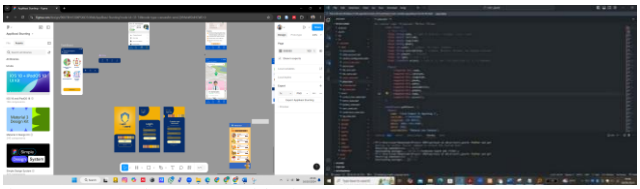
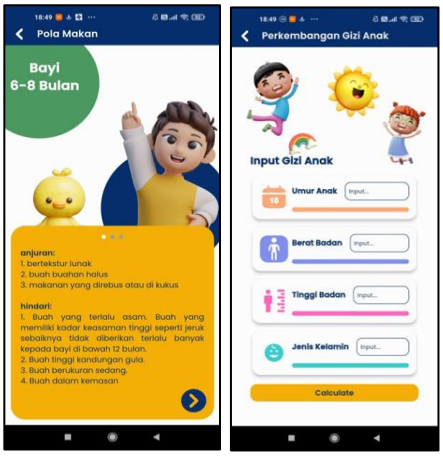


Fig 3. (a). Designing an app with Figma (b). Building an App on Flutter

B. *Application Features*

The application offers a range of innovative features specifically designed to assist parents in monitoring and improving their children's nutrition while preventing stunting. Each feature is developed with a user-centric approach and is supported by cutting-edge technology, ensuring that the application meets the needs of its users effectively.



(a) (b)

Fig 4. (a) Diet Recognition Feature; (b) Nutrition Development Feature

Fig. 4(a) represents the dietary guidance feature within this application, designed to provide brief educational insights on age-appropriate nutrition for infants and toddlers, segmented into three age groups: 6-8 months, 9-11 months, and 12-23 months. This feature offers recommendations on suitable foods and beverages, as well as items best avoided, enabling parents to make informed choices that support their child's optimal growth.

Meanwhile, Fig. 4(b) highlights the nutritional development feature, functioning as a nutrition calculator that leverages anthropometric data to assess child growth. Users can input a child's age, weight, height, and gender. Based on this information, the AI-powered calculator provides nutritional status, growth indicators, and relevant analyses, equipping parents with tools to effectively monitor and evaluate their child's nutritional health.

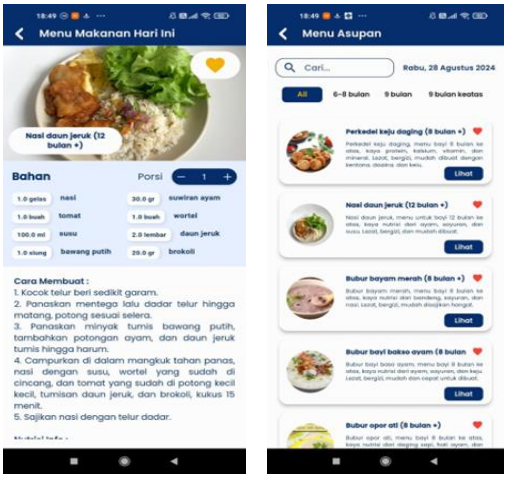
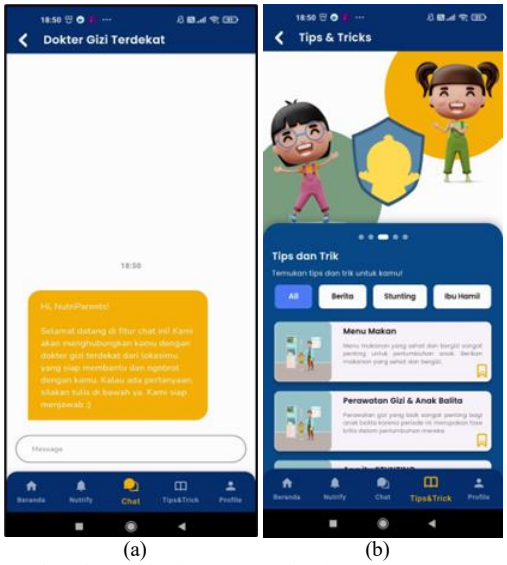


Fig 5. Intake Menu Feature

Fig 5. is a feature of the intake menu, this feature provides a food menu, recipes, and serving methods according to the principles of 4 healthy 5 perfect for a certain age of children. The goal is to help parents plan and prepare healthy and nutritious meals, ensuring that each dish meets the nutritional needs for optimal health and development of the child.



(a) (b)

Fig 6. (a) AI-based Consultation Feature; (b) Literacy Feature

Fig. 6(a) showcases the AI-powered consultation feature, which enables users to receive answers to inquiries regarding child nutrition and dietary needs. This AI has been rigorously

trained and tested to ensure the accuracy of information provided. With unlimited response capacity, this feature offers ongoing support for parents in addressing the challenges of child nutrition.

Fig. 6(b) presents the E-Book Literacy and Tips & Tricks feature, offering a wealth of educational resources on child development, including YouTube videos for expectant mothers and the latest updates on stunting. The E-Book provides comprehensive information on stunting, meal planning guides, and nutritional care for young children, serving as a robust resource to support awareness and preventive actions against stunting.

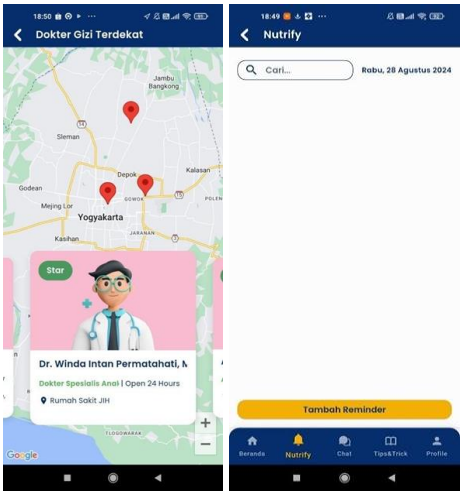


Fig 7. (a) Nearest Nutritionist Search Feature; (b) Nutrify Feature

Fig. 7(a) illustrates the nearby nutritionist search feature, designed to simplify parents' efforts in locating qualified nutrition specialists within their vicinity. Upon receiving location permissions, the application employs Machine Learning technology to identify nearby nutritionists, ensuring convenient access to healthcare services and facilitating proper monitoring of child growth. This feature is especially beneficial for parents who may struggle to find nutritional experts, thus supporting easier access to specialized care for children's development.

Fig. 7(b) highlights the Nutrify feature, which assists parents in tracking essential health aspects for their children, such as check-up schedules, medication reminders, and nutrition assessments through a built-in nutrition calculator. This tool is ideal for parents who may occasionally overlook routine care schedules. With timely notifications, Nutrify ensures consistent health monitoring, allowing for proactive stunting prevention and supporting balanced nutrition for healthy growth.

C. *Utilizing Machine Learning and AI in Application*

Machine learning, in the context of stunting risk identification, can play a pivotal role in stunting prevention through precise data analysis provided by parents of young children. It enables the prediction of stunting risks based on observed factors, delivering targeted information, real-time growth monitoring through data input by parents or healthcare workers, and offering customized nutritional reminders and guidance tailored to each child's needs. Additionally, it can identify geographic regions vulnerable to stunting, aiding in the design of targeted intervention programs.

The application offers features such as nutritional tracking for young children and AI-driven consultations for parents with nutrition experts. These AI consultations use accurate data embedded during app development and updated inputs from parents, providing tailored advice that aligns with each child's nutritional needs. Thus, the application not only supports routine monitoring but also offers integrated, data-driven guidance to ensure every child receives personalized nutritional support.

Moreover, the application's features can identify trends or nutritional deficiencies that may require improvement, making meal planning more structured and data-informed. A monthly data recap on each child's status generates a comprehensive summary of nutritional progress and health, with growth assessment features allowing the app to evaluate each child's health and development trajectory, and provide recommendations for nutritional enhancement. By integrating these features, the application offers parents deeper insights and more effective support, empowering them to make informed decisions on their child's nutritional and developmental needs.

D. *Implementation*

The application's implementation within the study area demonstrates significant potential to support health facility programs such as community health centers and integrated health posts (posyandu). During this phase, the application was tested in preschool/early childhood education settings, receiving positive feedback, particularly for its utility in enabling healthcare workers to quickly and accurately assess children's nutritional levels using the nutrition calculator feature, ensuring that advice provided to parents is based on reliable data. The educational resources within the application have become a valuable tool during consultation sessions, enhancing parental awareness of balanced nutrition and preventive actions to support optimal child growth.

Fig 8. Implementation of Applications in Kindergarten Environments

As shown in Fig. 8, the *NutriGuard* nutrition monitoring and stunting prevention application also proves valuable for community health posts (posyandu) and kindergartens, supporting stunting prevention and child health monitoring programs by enabling posyandu nurses to efficiently assess children's health and nutrition. With features such as meal planning and nutritional education, the application simplifies nutrition management for parents, allowing them to better oversee their children's dietary intake. This program aims to empower communities to independently monitor child health without requiring frequent visits to health centers, particularly benefiting those in remote areas. The educational resources and AI-based consultation feature within the app provide parents with comprehensive information and clear guidance on best practices for supporting their child's growth and development.

E. *System Usability Scale (SUS) Test*

NutriGuard, as Integrated Nutrition Monitoring Application with Machine Learning and Artificial Intelligence (AI) for Child Growth Monitoring has proven effective in assisting parents with tracking and improving their children's

nutrition. Leveraging advanced technologies such as machine learning and AI, the application offers a range of innovative features, including dietary pattern recognition, an AI-powered nutrition calculator, customized intake menus, virtual consultations with nutrition experts, and a nearby nutritionist locator. This technological integration enables the application to provide accurate, personalized recommendations, empowering parents to make informed decisions about their child's nutrition. The application's effectiveness was validated through a System Usability Scale (SUS) test involving 38 respondents, yielding an excellent usability score of 82.5%, indicating that the application is not only functional but also highly user-friendly and well-received by users.

Fig 9. Grade System Usability Score [23]

As shown in Fig. 9, the application's implementation score is within the "acceptable" category. This score reflects the success of the optimized user interface (UI) and user experience (UX) design, effectively meeting parents' needs for monitoring child growth. With this high level of acceptance, the application has significant potential to positively impact stunting prevention efforts and improve the nutritional status of children.

CONCLUSION

The development of the integrated nutrition monitoring application, *NutriGuard*, represents an innovation in addressing stunting among children in Indonesia, a pressing public health challenge with profound implications for child development. By leveraging machine learning (ML) and artificial intelligence (AI), *NutriGuard* combines innovative features such as dietary pattern recognition, an AI-based nutritional calculator, customized meal recommendations, and virtual consultations with nutrition experts. These capabilities empower parents and healthcare professionals to monitor and enhance children's nutrition effectively. The application demonstrated high user acceptance and ease of use, achieving a System Usability Scale (SUS) score of 82.5%, highlighting its potential for widespread adoption. Its implementation in healthcare facilities and early childhood education institutions in Yogyakarta as a study case place has positively impacted parental education and the efficiency of child nutrition monitoring, particularly in areas with limited healthcare access.

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