Indonesian Journal of Educational Development (IJED)
Volume 6, Issue 4, 2026, pp. 1322-1337
ISSN: 2722-1059 (Online); ISSN: 2722-3671 (Print)
DOI: https://doi.org/10.59672/ijed.v6i4.5696

Development of Android-based interactive applications to stimulate children's cognitive development

Andi Agusniatih[1], Ika Anggraini As Sayyidah[*)2], Shofiyanti Nur Zuama[3], Amrullah[4]
[1]Universitas Tadulako, Palu, Indonesia; andiagusniatih@gmail.com
[2]Universitas Tadulako, Palu, Indonesia; anggraini04.ika@gmail.com
[3]Universitas Tadulako, Palu, Indonesia; shofiyantinzpaud@gmail.com
[4]Universitas Tadulako, Palu, Indonesia; amrullah26bs@gmail.com
[*)]Corresponding author: Ika Anggraini As Sayyidah; E-mail addresses: anggraini04.ika@gmail.com

Article Info

Article history:
Received November 27, 2025
Revised December 23, 2025
Accepted December 25, 2025
Available online February 15, 2026

Keywords: Android application, Cognitive development, Interactive media

Abstract. Early childhood cognitive development requires engaging learning media. However, many PAUD classrooms still rely on monotonous activities that reduce children's motivation and limit cognitive progress. This study aimed to develop an Android-based interactive learning application to stimulate early childhood cognitive development, particularly in recognizing colors, geometric shapes, and sizes. The study used a research and development method based on the ADDIE model, which consists of analysis, design, development, implementation, and evaluation. The population comprised children at RA Al Ikhlas Birobuli. Participants for the classroom trial were selected through purposive sampling, focusing on children who took part in the learning activities during the implementation stage. Data were collected using observation sheets to measure learning engagement and cognitive performance, expert validation questionnaires to assess media and material feasibility, and cognitive tests in the form of a pretest and posttest to measure learning outcomes. Expert validation results indicated that the application was highly feasible, with a media feasibility score of 95% and a material feasibility score of 92%. Classroom implementation showed a significant improvement in children's cognitive abilities, as indicated by higher posttest scores than pretest scores and a p-value of 0.000. The application includes interactive features such as visual animations, sound effects, game-based tasks, and a reward system, which increased engagement and motivation and supported constructivist principles that emphasize active and multisensory learning. In conclusion, the Android-based interactive application is effective, practical, and innovative for supporting early childhood cognitive development. It is recommended that PAUD teachers use this application as complementary learning media. Future studies should involve larger and more diverse samples and evaluate long-term learning retention and usability across different devices.

Introduction

Early childhood education (PAUD) is a crucial foundation for future human resource development because the early years constitute a "cont" when children's physical, cognitive, social, and emotional capacities develop rapidly (Annisak et al., 2023; Nurachadijat & Selvia, 2023; Bintang et al., 2024). During this period, children require appropriate and continuous stimulation to optimize cognitive growth, including the ability to recognize, connect, evaluate, and interpret information (Erviana et al., 2024; Nur et al., 2025). Cognitive development in early childhood is commonly reflected in

basic reasoning and classification skills, such as recognizing colors, geometric shapes, and sizes, which are essential prerequisites for later literacy, numeracy, and problem-solving abilities.

In addition to these developmental needs, the rapid advancement of information and communication technology has increasingly influenced educational practices. Technology-supported learning media, such as interactive multimedia, animations, and game-based applications, can enhance engagement, provide multisensory learning experiences, and support children's active participation (Tobondo & Putra, 2022; Alfiah & Salsyabila, 2025; Zuama & Agusniatih, 2020). Constructivist learning theory emphasizes that children learn more effectively through direct experiences that involve visual, auditory, and kinesthetic interaction, making interactive learning media particularly relevant for early childhood learning (Munawaroh et al., 2022; Vaiopoulou et al., 2023; Ayu & Manuaba, 2021). Furthermore, smartphones and tablets are widely used in daily life, including by children, which creates opportunities for integrating Android-based learning applications into classroom activities (Sartika et al., 2023; Lutfiah, 2022; Desyani et al., 2020; Herman et al., 2025; Adawiah et al., 2024).

However, preliminary observations at RA Al Ikhlas Birobuli (Group B) indicated that children's cognitive learning experiences were still dominated by repetitive and less engaging activities. As a result, several children had difficulty identifying basic colors, geometric shapes, and sizes, and showed low learning motivation and limited participation. This condition indicates a gap between the ideal expectation of meaningful stimulation in PAUD learning and the actual classroom condition, which still lacks attractive and interactive learning media (Rasmani et al., 2022; Zuama, 2024). Therefore, an innovative learning medium is needed to provide structured cognitive stimulation that is engaging and appropriate to children's characteristics (Widana et al., 2024).

To address this gap, technology-based interactive learning media can serve as an alternative solution. Previous studies have reported that Android-based interactive learning applications can improve children's motivation, participation, and cognitive learning outcomes through game elements, interactive tasks, and immediate feedback (Firdaus et al., 2023; Sinvani et al., 2023; Hananto & Rahardian, 2025). Accordingly, the development of an interactive learning application that specifically targets early cognitive indicators, namely colors, geometric shapes, and sizes, becomes important to increase learning effectiveness in the observed context (Wirama, 2023).

This study offers novelty in several aspects. First, the application is developed using the ADDIE framework based on a needs analysis conducted at RA Al Ikhlas Birobuli. Second, the application focuses on specific cognitive indicators relevant to Group B children, namely recognizing colors, geometric shapes, and sizes, and integrates interactive features such as animations, sound effects, game-based tasks, and a reward system. Third, the study evaluates product feasibility through expert validation and examines learning effectiveness through classroom implementation, thereby providing practical evidence for improving learning in PAUD settings.

Based on the above background, this study aims to design and develop an Android-based interactive learning application to stimulate early childhood cognitive development, particularly in recognizing colors, geometric shapes, and sizes. The findings are expected to contribute to the development of innovative learning media and to support teachers in creating more engaging and effective PAUD learning environments.

Method

This study employed a Research and Development (R&D) approach to develop an Android-based interactive learning application and evaluate its feasibility and practicality for early childhood

learning. The development process adopted the ADDIE framework, which comprises five systematic stages: Analysis, Design, Development, Implementation, and Evaluation. The research procedure in this article follows the ADDIE model for developing interactive Android applications to stimulate cognitive development in early childhood. The following flowchart presents the stages in sequence with descriptions of the main activities in each stage. This diagram facilitates understanding of the research method flow.

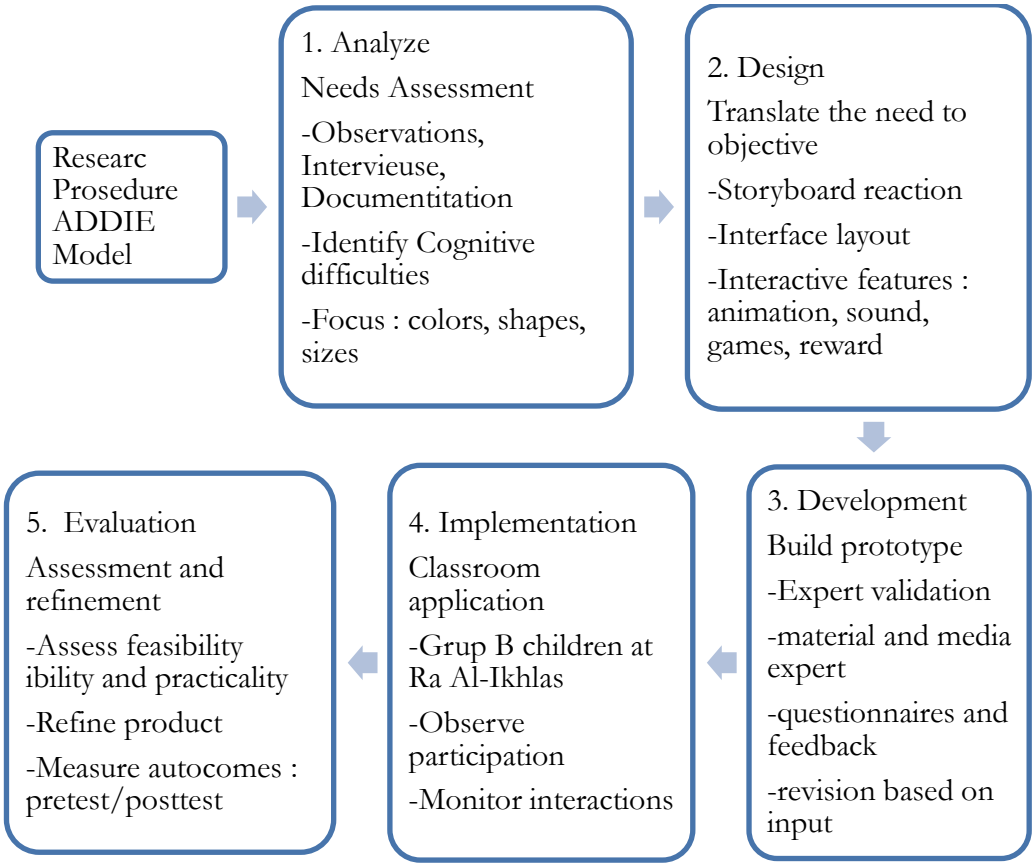

Image 1. Diagram of the research stage

Analyze Stage

This stage involves assessing needs through classroom observation, teacher interviews, and documentation to identify the cognitive difficulties of children in Group B at RA Al Ikhlas in recognizing colors, geometric shapes, and sizes. The results show monotonous learning activities that reduce children's motivation.

Design Stage

The needs are translated into learning objectives, indicators, and content sequence, including storyboards, navigation structures, and interface designs with interactive features such as visual animations, sound effects, game-based tasks, and reward systems.

Development Stage

The application prototype was developed using Adobe Animate, followed by validation by subject-matter and media experts through questionnaires to assess content suitability and functionality, with revisions made based on qualitative and quantitative feedback.

Implementation Stage
The revised application was implemented in Group B classroom activities, with observations of children's participation, responses, and interactions conducted by teachers and researchers, supported by field notes, photographs, and learning recordings.

Evaluation Stage
Formative and summative evaluations were conducted to assess feasibility (95% for media and 92% for content) and practicality, including a pretest–posttest that demonstrated a significant increase in scores ($p=0.000$), and concluded with the refinement of the final product.

The research was conducted at Group B Raudhatul Athfal (RA) Al Ikhlas, Birobuli, South Palu, located at Jalan Kijang, BTN Birobuli Housing Complex, during [month–month, year]. The population comprised all children in Group B at RA Al Ikhlas Birobuli, which amounts to 15 children. Participants in the classroom trial were selected through purposive sampling, namely, children who were present and actively participated during the implementation stage, totaling [n] children aged [age range]. In the Analyze stage, a needs assessment was carried out through initial classroom observations and semi-structured interviews with the class teacher to identify the learning context, children's cognitive difficulties, and the availability of learning media, with a focus on early cognitive indicators related to recognizing colors, geometric shapes, and sizes. In addition, the analysis stage documented the classroom learning pattern, the learning resources commonly used, and barriers that potentially reduce children's engagement, so that the product could be aligned with the actual conditions of the target setting.

In the Design stage, the identified needs were translated into learning objectives, indicators, and content organization, which were then arranged into activity sequences. At this stage, the storyboard, navigation structure, and interface layout were drafted, including the arrangement of menus, learning sections, practice activities, and feedback screens, as well as the design of interactive features such as visual animations, sound effects, game-based tasks, and a reward system to support children's motivation and sustained attention. In the Development stage, the application was built into a functional prototype, and feasibility was validated by a material expert and a media expert using structured questionnaires based on predetermined indicators (Tables 1 and 2).

The material expert validation emphasized the content's suitability and accuracy for children's developmental characteristics, whereas the media expert validation assessed the interface's attractiveness, display clarity, and usability. Both experts also provided qualitative feedback, including comments, criticisms, and revision suggestions, which were used to refine the prototype before field testing. In the Implementation stage, the revised application was used in classroom learning activities with Group B children. The teacher facilitated the learning process, and the researcher observed children's participation, responses, and interaction patterns while documenting the implementation through field notes and supporting evidence, such as photos and learning records. In the Evaluation stage, the study examined the results of expert validation and classroom trials to determine whether the product met feasibility and practicality standards, and refined it based on the evaluation findings to produce the final version for learning use.

Data collection in this study employed observation, interviews, documentation, and questionnaires. Observation was conducted using an observation sheet to record children's engagement, participation, and cognitive performance during learning activities; interviews were conducted using an interview guide to explore teacher perspectives on learning problems, media needs, and expectations for the developed product; documentation was used to strengthen evidence and facilitate verification, including photos of activities, lesson notes, and relevant school records; and

expert validation questionnaires were used to obtain feasibility evaluations from material and media experts, with the indicator grids presented in Table 1 and Table 2.

Instrument validity was ensured through expert judgment by reviewing the relevance and clarity of each indicator and refining the instruments based on expert input; if reliability testing was conducted, include the technique and coefficient here. Data were analyzed using quantitative descriptive procedures, supported by descriptive information from observations and interviews, to provide contextual interpretation. For the feasibility analysis, expert questionnaire scores were converted to percentages and interpreted using the feasibility categories in Table 3; the product was considered feasible if it achieved at least 51 percent, categorized as Suitable or very suitable. For practicality analysis, the product's practicality was assessed through classroom trials by considering ease of use, smooth implementation, and children's responses during learning. The application was categorized as very practical when it was easy to operate and effectively supported learning activities that stimulated children's cognitive abilities. The feasibility percentage was calculated using the formula Feasibility (%) = (Total score obtained / Maximum score) × 100. The final product of this study is an Android-based interactive learning application designed to stimulate early childhood cognitive development, particularly in recognizing colors, geometric shapes, and sizes, and it integrates interactive learning components such as animations, sound effects, game-based tasks, and a reward system to increase engagement, motivation, and learning effectiveness.

Tabel 1. Material Expert Instrument Grid Table

No	Criteria	Indicators
1	Key material aspects	a. Appropriateness of material for recognizing various shapes and capital letters. b. Appropriateness of material for recognizing various colors and lowercase letters. c. Appropriateness of material for recognizing various sizes and numbers. d. Accuracy of material for children's cognitive abilities.
2	Supporting information aspects	a. The suitability of images of various geometric shapes and selected capital letters. b. The suitability of images of various colors and selected lowercase letters. c. The suitability of images of various sizes and selected numbers.
3	Appearance aspects	a. The size of the image media displayed is appropriate. b. The media displayed attracts children's attention. c. The images used clarify the shapes and letters displayed. d. The images used clarify the colors and letters displayed. e. The images used clarify the sizes and letters displayed.
4	Additional material aspects	a. Stimulate children's cognitive development. Introduce various shapes and capital letters. b. Introduce various colors and lowercase letters. c. Introduce various sizes and numbers.

Tabel 2. Media Expert Instrument Grid Table

No	Criteria	Indicators
1	Media cover design aspects	a. Cover Attractive media cover. b. The media cover title represents the product content. c. Accuracy in the placement of the cover title. d. Accuracy in the placement of the cover display size.

No	Criteria	Indicators
2	Media quality aspects	a. The media design is attractive. b. The selection of images of various geometric shapes is appropriate. c. The selection of images of various colors is appropriate. d. The suitability of the selected images of various sizes.
3	Functional aspects of media	a. Anak Children actively play and explore the media. b. The media can develop children's cognitive aspects. c. The media is designed to attract children's interest and enthusiasm. d. The media can help children recognize various geometric shapes and capital letters. e. The media can help children recognize various colors and lowercase letters. f. The media can help children recognize various sizes and numbers.

The steps used to test the feasibility of Android-based interactive applications are aligned with the ADDIE model development procedure. The research instruments used to assess the feasibility of Android-based interactive applications by experts were analyzed and compiled using the rating scale in Table 3.

Table 3. Feasibility Assessment Percentage

No	Average Score	Category
1	0 – 25	Not suitable
2	26 – 50	Less suitable
3	51 – 75	Suitable
4	76 – 100	Very suitable

Table 1 Feasibility Assessment Percentage: No 1 (0–25) Not suitable, No 2 (26–50) Less suitable, No 3 (51–75) Suitable, and No 4 (76–100) Very suitable. Products considered suitable for learning are those with a rating of 51% to 100%, or are categorized as Very Suitable or Very Good for use by users, in this case, the early childhood education children who were studied. To determine the practicality of the Android-based interactive application, the author conducted a trial. The application developed by the author is considered very practical when the media is easy to use as a learning medium that stimulates children's cognitive abilities.

Results and Discussion

The implementation of interactive Android-based applications to enhance early childhood cognitive abilities faces several noteworthy challenges, even though research by Ayuningrum and Afif (2020), Net (2023), and Pratiwi and Tirtayani (2021) has confirmed their effectiveness. One major issue involves the diversity of children's motivation and interests, meaning not every child benefits equally from the application. Furthermore, limited access to Android devices and inadequate network infrastructure pose significant barriers, particularly in regions with scarce resources (Setiawati et al., 2024). Another concern is the lack of sufficient guidance from teachers and parents, which is crucial to ensuring that children use the application appropriately and effectively. From a developmental standpoint, maintaining content relevance and adaptability to curriculum standards and children's developmental stages requires substantial resources and strong

technological support. Equally challenging is that many children still struggle to use digital applications, underscoring the need for an intuitive, child-friendly interface to maximize usability.

In addressing these obstacles, this study highlights that with a structured development process and expert validation, interactive learning applications can successfully boost learning motivation and enhance children's cognitive abilities, particularly in recognizing colors, shapes, and sizes. This aligns with the findings of Ayuningrum & Afif (2020) and Kirana et al. (2024), which demonstrated that well-designed educational applications significantly foster cognitive development during children's golden age of growth. This study produced an interactive Android application tailored to enhance cognitive abilities in young children. Its development was guided by the five-phase ADDIE framework, which structures the process into a sequence of systematic stages.

Analyze

In this initial stage, a needs analysis was conducted through observations, interviews, and documentation involving Group B students. The findings indicated that the existing learning activities were monotonous, with minimal use of stimulating media, resulting in low interest in learning and underdeveloped cognitive skills, particularly in differentiating shapes, colors, and sizes. These results underscore the need to develop interactive, structured learning media tailored to children's needs.

Design

At this phase, the researcher began creating the Android-based interactive application, emphasizing a fun, engaging, and educational experience for young learners. The main design concept aimed to stimulate children's understanding of shapes, colors, and sizes through game-based activities, animated visuals, and captivating sounds. The program structure, interface layout, and user experience were all crafted to ensure accessibility and ease of use for children. The design process involved the following steps: a) Launch Adobe Animate 2021 software. b) Create a new worksheet with dimensions 720x1280 pixels to begin the design of the interactive Android application.

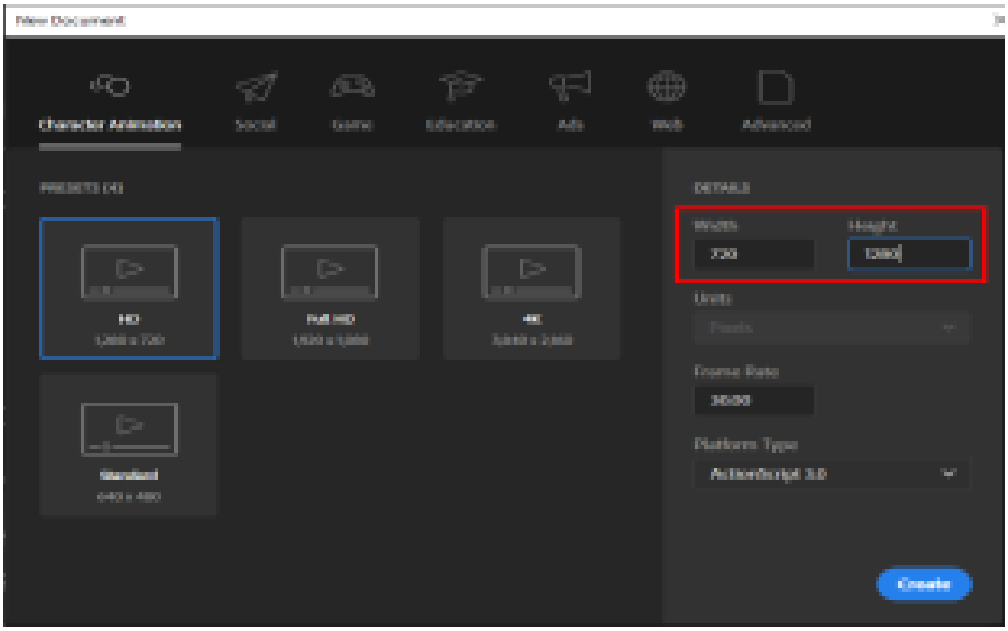

Image 1. The Android-based interactive application

First, save the worksheet by clicking File -> Save. Select the storage folder and name it according to the media. Save it in .fla format.

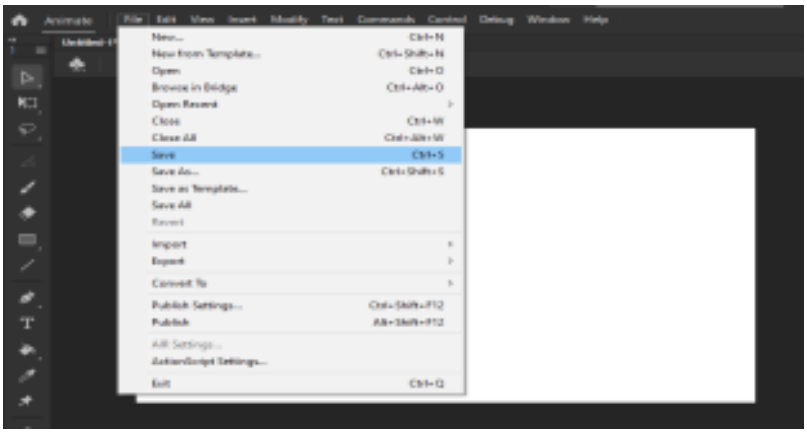

Image 2. Select the storage folder

Next, import the images and sounds by clicking File -> Import -> Import to Library. Select all the necessary images and sounds in the media.

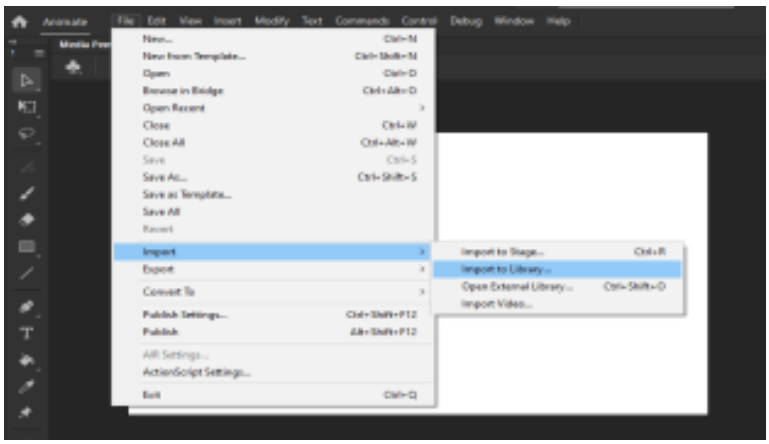

Image 3. Import to Library

The next step is to adjust the image layout according to the concept that has been created previously. Drag the image from the Library and adjust it on the first layer and first frame.

Image 4. Adjust the image layout

After the first frame is arranged, don't forget to rename each frame to match its content so it's easier to edit later. To do this, double-click on the layer.

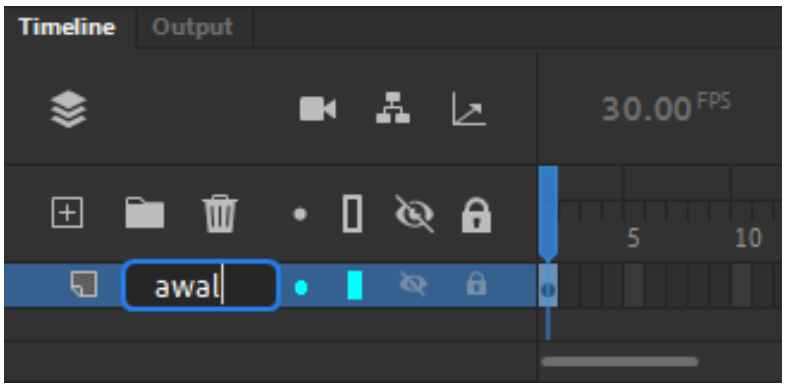

Image 5. Rename frame

Next, create a new layer by clicking the button marked in the image below. After that, adjust the layout of the image in the following frames.

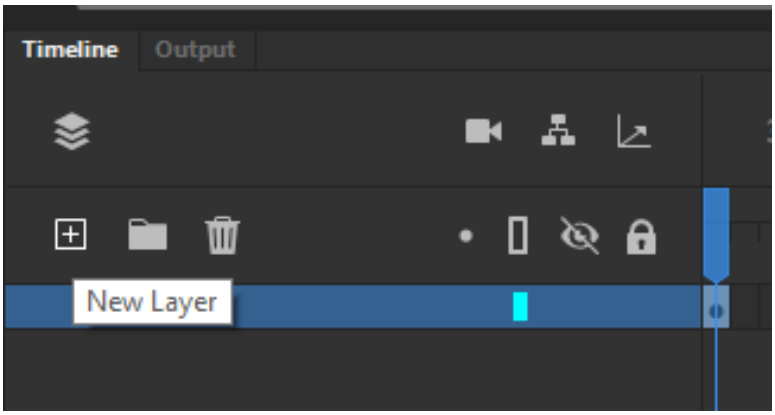

Image 6. Create a new layer

To add text, select the Text Tool and then write as desired. Font type, text type, size, and margin settings can be adjusted in the Properties section.

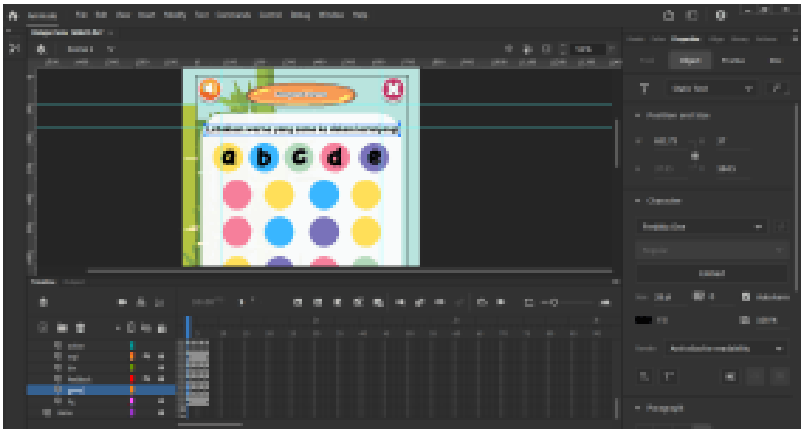

Image 7. Text tool

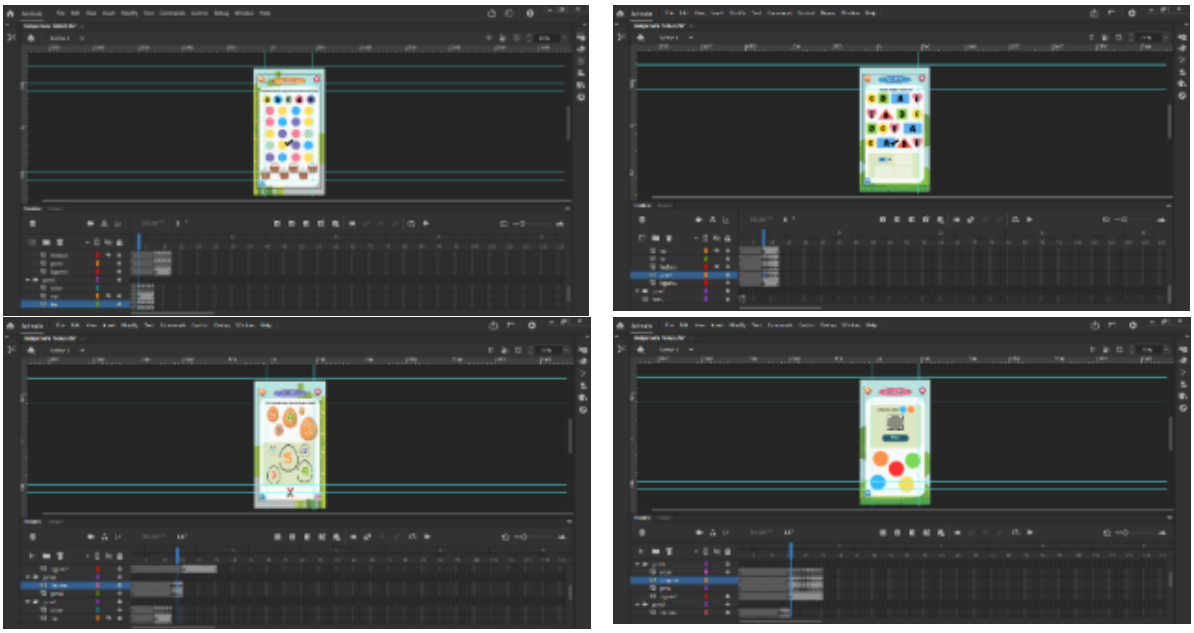

Image 8. Game page display

The next step is to convert the image into a button by selecting the image -> F8 -> change the type to Button.

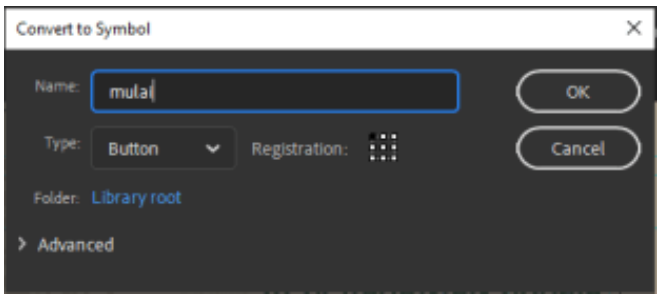

Image 9. Convert the image

Next, to make all the buttons functional, additional coding is required. To do this, create a new layer specifically for action coding. Select the frame and press F9 to write the code. The following is the display on the coding panel.

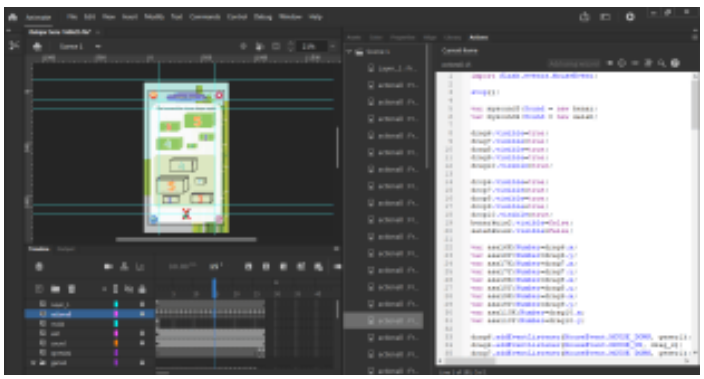

Image 10. Additional coding is required

The media has been created. Next, publish it as an Android or desktop application using the AIR SDK in Adobe Animate. To do this, click File -> Publish Settings. Adjust as desired. Here, we will publish it as a desktop version. Then, select AIR 51.1.3.5 for Android.

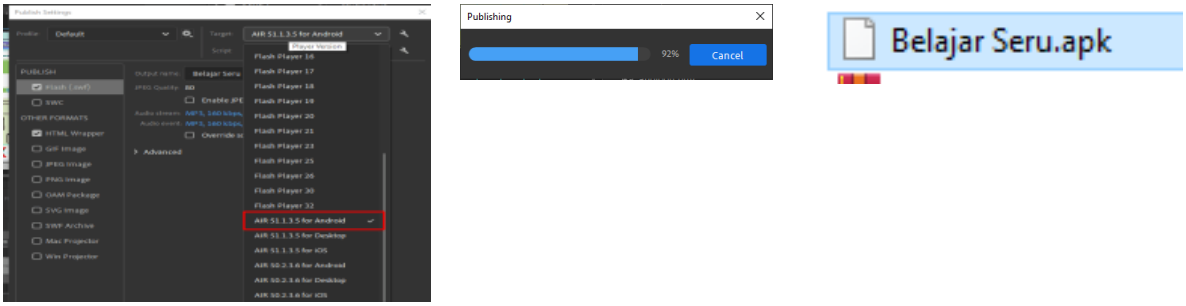

Image 11. Publish settings

Development

At this stage, the previously designed concept is transformed into a functional Android-based interactive learning application. After the product was fully developed, it was validated by material experts and media specialists using a questionnaire. The purpose of this validation process was to collect both qualitative and quantitative information, including comments, suggestions, and scores assessing the product's feasibility. The numerical data were processed using a descriptive-quantitative approach, employing percentages to gauge how suitable and functional the application is for users.

Implementation

Following expert feedback and necessary revisions, the application was implemented and tested on the target users, students in Group B at RA Al Ikhlas. During this phase, the researchers conducted direct observations to monitor children's reactions and engagement with the application. This process aimed to measure how effectively the media could enhance and stimulate children's cognitive development during learning activities.

Evaluation

The evaluation process was conducted in two forms: formative and summative. The formative evaluation took place throughout the development process, primarily based on expert feedback and suggestions. Meanwhile, the summative evaluation was carried out after implementation to assess the product's overall feasibility, practicality, and effectiveness. According to the evaluation criteria, a product scoring between 51% and 100% is considered suitable for use. The final evaluation results indicated that the Android-based interactive application was highly feasible and practical as a learning tool to support and stimulate children's cognitive growth.

Developed Product

The result of this study is an Android-based interactive application designed to introduce children to colors, geometric shapes, and sizes. This application is available on Android devices, allowing children to learn conveniently anytime, anywhere. The interactive application includes the following components: a) Learning materials that focus on introducing colors, shapes, and sizes in an engaging way. b) User guidelines that serve as instructions to help the user operate the application effectively. c) Reward features, where children earn stars as recognition when they successfully complete or master the learning materials. d) Main material menu display, which provides an introductory greeting along with the main learning content focusing on color, shape, and size recognition.

Overall, the development process ensured that the final product was not only educationally sound but also engaging and user-friendly for early childhood learners.

(a) (b) (c)

Image 12. Main Menu (a), Options Material (b), and Children's Reward Display (c)

Based on the findings from the development of the Android-based interactive application aimed at stimulating the cognitive growth of Group B kindergarten students at RA Al Ikhlas, several conclusions can be drawn as follows: a) The evaluation conducted by media experts indicated that the Android-based interactive learning application is highly valid and appropriate for educational use, achieving a questionnaire response rate of 95%. b) Similarly, the assessment from material experts showed that the application is suitable and effective for teaching children, with a questionnaire response rate of 92%. c) Feedback from both teachers and children demonstrated that the application is user-friendly, engaging, and capable of boosting learning motivation.

The average pretest score obtained before using the learning media was 49.07 with a standard deviation of 5.59, reflecting the participants' initial cognitive level. After utilizing the interactive media, the average posttest score rose significantly to 80.07 with a standard deviation of 3.13, indicating a notable improvement in children's cognitive performance following the intervention.

A paired t-test was conducted to examine differences between the pretest and posttest scores. The test produced a Sig. (2-tailed) value of 0.000, indicating a clear and statistically meaningful shift between the two measurements. These findings demonstrate that the application generated a strong, positive impact on the improvement of children's cognitive skills.

The summary of these findings, as presented in Table 4 and Table 5, clearly illustrates a marked improvement in the children's learning outcomes after the implementation of the Android-based interactive learning application.

Table 4. Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest	49.0667	15	5.58655	1.44244
	Postest	80.0667	15	3.12745	.80750

Table 5. Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Pretest Postest	-31.00000	4.10575	1.06010	-33.27369	-28.72631	-29.243	14	.000

Explanation:
If Sig. (2-tailed) < 0.05, reject H0 (significant effect)
If Sig. (2-tailed) ≥ 0.05, fail to reject H0 (no significant effect)
From the T-test results above, Ha is accepted because the P-Value is less than 0.05, indicating that the media has an effect on children's cognitive abilities.

The findings demonstrate that the Android-based interactive learning application contributed to a substantial improvement in children's cognitive performance, particularly in recognizing colors, geometric shapes, and sizes. The descriptive results show that the mean score increased from 49.0667 in the pretest to 80.0667 in the posttest, indicating an average gain of 31.0000 points after the intervention. This improvement suggests that the application did not merely provide entertainment but functioned as an effective learning medium that strengthened children's basic classification and discrimination skills, which are central components of early childhood cognition. Several factors may explain why the application produced meaningful learning gains. First, the application provided multisensory stimulation by combining visual elements (colors, shape images, and animations) and auditory cues (sound effects and feedback). Multisensory learning is especially beneficial for early childhood learners because children at this stage process information more effectively when they can see, hear, and interact with learning content in an integrated manner. Through repeated exposure to visual patterns and immediate auditory reinforcement, children are more likely to form stable mental representations of colors, shapes, and relative sizes, which supports faster recognition and recall.

Second, the learning activities were delivered in a game-based format that encouraged active engagement. Rather than passively receiving information, children interacted directly with tasks, responded to prompts, and received feedback through rewards. From a constructivist perspective, learning becomes more meaningful when children are actively involved in exploring and solving problems within a supportive environment. The application facilitated this by allowing children to learn through trial and error, make selections, and immediately observe the consequences of their actions. This type of interactive practice can enhance attention, persistence, and motivation, which are essential for improving cognitive outcomes in early childhood classrooms (Widana et al., 2021).

Third, the decrease in score variability from pretest (SD = 5.58655) to posttest (SD = 3.12745) indicates that learning outcomes became more consistent across participants after the intervention. This pattern suggests that the application supported not only high-performing children but also helped lower-performing children catch up, reducing achievement disparities. In classroom practice, this is an important indicator because effective learning media should work for children with diverse initial abilities (Surya Abadi et al., 2025). The structured tasks, repeated practice opportunities, and immediate feedback likely provided additional scaffolding for children who initially struggled to recognize colors, shapes, and sizes.

In addition, the findings address a practical challenge commonly observed in PAUD settings, namely monotonous learning activities that reduce children's participation and limit cognitive

stimulation. The application offered varied learning experiences through interactive tasks and reward-based reinforcement, which can reduce boredom and encourage children to stay involved in learning sessions. This aligns with the role of educational media as an instructional tool that helps teachers deliver content more effectively and fosters an environment that supports attention and curiosity.

Conclusion

This study developed an Android-based interactive learning application to stimulate early childhood cognitive development, particularly in recognizing colors, geometric shapes, and sizes. The results indicate that the product meets the research objective. Expert validation confirmed that the application is highly feasible for learning use, and classroom implementation demonstrated improved cognitive outcomes. These findings suggest that interactive features such as animations, sound effects, game-based tasks, and a reward system support engagement and provide meaningful learning experiences aligned with active, constructivist learning. Therefore, it is recommended that PAUD teachers use this application as complementary learning media to enrich classroom activities and reduce monotonous learning practices. Future research should involve larger, more diverse samples, include comparisons with other learning media or control groups, and evaluate long-term retention and usability across different Android devices to strengthen evidence of effectiveness and broader implementation.

Acknowledgements

First and foremost, the researcher expresses sincere gratitude to Almighty God for His blessings, guidance, and strength throughout the completion of this study. The researcher likewise expresses deep gratitude to everyone and every institution whose support helped bring this study to completion. Particular acknowledgment is given to the academic supervisors and lecturers whose insights, guidance, and ongoing encouragement were instrumental throughout the research journey.

Bibliography

Adawiah, R., Ruchliyadi, D. A., & Halidi, W. (2024). A combination of the project-based learning model and value clarification technique in improving students' critical thinking skills. *Indonesian Journal of Educational Development (IJED)*, *5*(1), 68-78. https://doi.org/10.59672/ijed.v5i1.3728

Alfiah, N., & Salsyabila, N. (2025). Design and evaluation of an android-based educational game to support animal recognition learning for early childhood at tk aisyiyah 03. *Blend Sains Jurnal Teknik*, *04*(02), 0–11.

Annisak, A., Adelina, A., Sary, D. P., Fitria, D., & Noviani, D. (2023). Peran lingkungan dan pola asuh orang tua terhadap pembentukan karakter anak usia dini (The role of the environment and parenting patterns in the formation of character in early childhood). *Khirani: Jurnal Pendidikan Anak Usia Dini*, *1*(4), 146–156.

Ayu, N. K., & Manuaba, I. B. S. (2021). Media pembelajaran zoolfabeth menggunakan multimedia interaktif untuk perkembangan kognitif anak usia dini (Zoolfabeth learning media uses interactive multimedia for the cognitive development of early childhood). *Jurnal Pendidikan Anak Usia Dini Undiksha*, *9*(2), 194–201.

Ayuningrum, D., & Afif, N. (2020). Interaksi sosial anak down syndrome di TK Nusa Indah Jakarta (Social interaction of children with Down syndrome at Nusa Indah Kindergarten, Jakarta). *IQ (Ilmu Al-Qur'an): Jurnal Pendidikan Islam*, *3*(01), 141–162.

Bintang, D. W. P., Pertiwi, A. D., & Azainil, A. (2024). Analisis penggunaan teknologi pada proses

pembelajaran di PAUD (Analysis of the use of technology in the learning process in PAUD). *Aulad: Journal on Early Childhood*, *7*(3), 873–884.

Desyani, T., Kasmayanti, Y., Saifudin, A., & Yulianti. (2020). Bagging techniques to reduce misclassification of breast cancer prediction base on gradient boosted trees (gbt) algorithm. *Journal of Physics: Conference Series*, *1477*(2). https://doi.org/10.1088/1742-6596/1477/2/022029

Erviana, Y., Kasanah, U., Sari, N., Munawir, A. N. E. R., Mahendra, Y., Munawaroh, S., Maulidia, L. N., Fajrinur, F., Mulyawan, G., & Mulyani, N. S. R. D. (2024). Perkembangan anak usia dini: Kunci untuk orang tua dan pendidik (Early childhood development: Keys for parents and educators). *Penerbit Mifandi Mandiri Digital*, *1*(01).

Firdaus, Y., Syaipuddin, S., & Suryadi, A. (2023). Aplikasi game interaktif pengenalan huruf berbasis android (Android-based interactive letter recognition game application). *Jurnal Riset Dan Aplikasi Mahasiswa Informatika (JRAMI)*, *4*(02), 280–287.

Hananto, A. R., & Rahardian, M. I. (2025). An android-based multimodal ai application for contextual environmental learning in children. *International Journal of Informatics and Information Systems*, *8*(3), 135–147.

Herman, Sukri, R., & Arismunandar. (2025). Pengaruh penerapan aplikasi puzzle berbasis android terhadap peningkatan kemampuan kognitif anak usia dini (The effect of implementing Android-based puzzle applications on improving the cognitive abilities of early childhood). *Variable Research Journal*, *02*(01), 349–357.

Kirana, S., Pristianto, A., Dewangga, M. W., & Khairuddin, G. W. (2024). Smartphone-based early child dection to monitor children's growth and development. *Gaster*, *22*(2), 224–230. https://doi.org/10.30787/gaster.v22i2.1635

Lutfiah, L. (2022). Aplikasi kamus simplisia dan resep obat tradisional (Sidota) berbasis Android. *Jurnal Sains Dan Informatika*, *8*(1), 61–69.

Munawaroh, H., Fauziddin, M., Haryanto, S., Widiyani, A. E. Y., Nuri, S., El-Syam, R. S., & Hidayati, S. W. (2022). Pembelajaran bahasa daerah melalui multimedia interaktif pada anak usia dini (Learning regional languages through interactive multimedia for early childhood). *Jurnal Obsesi: Jurnal Pendidikan Anak Usia Dini*, *6*(5), 4057–4066.

Net, P. (2023). Developing android-based learning media to enhance early reading competence of elementary school students. *Pegem Journal of Education and Instruction*, *13*(4), 43–55. https://doi.org/10.47750/pegegog.13.04.06

Nur, A., Fatamasho, A., Siblat, J., & Semarang, A. (2025). Media pembelajaran interaktif dalam menstimulasi kemampuan kognitif untuk anak usia dini (Interactive learning media to stimulate cognitive abilities for early childhood). *Bersatu: Jurnal Pendidikan Bhinneka Tunggal Ika*, *3*(4), 39–52.

Nurachadijat, K., & Selvia, M. (2023). Peran lembaga pendidikan anak usia dini dalam implementasi kurikulum dan metode belajar pada anak usia dini (The role of early childhood education institutions in implementing the curriculum and learning methods for early childhood). *Jurnal Inovasi, Evaluasi Dan Pengembangan Pembelajaran (JIEPP)*, *3*(2), 57–66.

Pratiwi, N. K. A., & Tirtayani, L. A. (2021). Multimedia interaktif sub tema profesi untuk pembelajaran anak usia dini (Interactive multimedia on the sub-theme of professions for early childhood learning). *Jurnal Pendidikan Anak Usia Dini Undiksha*, *9*(2), 186–193.

Rasmani, U. E. E., Nurjanah, N. E., Jumiatmoko, J., Widiastuti, Y. K. W., Agustina, P., & Nazidah, M. D. P. (2022). Multimedia interaktif paud dalam perspektif merdeka belajar. *Jurnal Obsesi: Jurnal Pendidikan Anak Usia Dini*, *6*(5), 5397–5405.

Sartika, Z., Ginting, E., Puspitasari, C., & Anggraini, F. (2023). Pengaruh dampak perkembangan teknologi terhadap penggunaan gadget pada anak usia dini (The impact of technological developments on gadget use in early childhood). *UNES Journal of Scientech Research*, *8*(1), 22–31.

Setiawati, S., Sulastri, T., Ningsih, R., Skriptini, A. Y., & Dermawan, A. C. (2024). Application of

android-based sdidtk development stimulation media on the developmental abilities of preschool. *Jurnal Ilmu Dan Teknologi Kesehatan*, *12*(1), 9–26. https://doi.org/10.32668/jitek.v12i1.1489

Sinvani, R.-T., Darel, D., Ektilat, F., Segal, L., & Gilboa, Y. (2023). The relationship between executive functions and naturalistic use of screen-based activities in children. *Child Neuropsychology*, *29*(5), 787–794.

Surya Abadi, I.B.G., Widiana, I. W., Septiari, N. K., Putu Listyana, I.G.A.A., Ari Rahayu, N. K. (2025). The impact of metacognitive-based learning strategies on enhancing students' decision-making and cognitive dissonance. (2025). *Indonesian Journal of Educational Development (IJED)*, *6*(1), 241–253. https://doi.org/10.59672/ijed.v6i1.4805

Tobondo, Y. A., & Putra, S. R. (2022). Analisis pengaruh game edukasi berbasis ai terhadap perkembangan kognitif anak usia dini di indonesia: Sebuah studi pustaka (Analysis of the influence of AI-based educational games on the cognitive development of early childhood in Indonesia: a literature study). *Jurnal Pandelo'e Fakultas Keguruan Dan Ilmu Pendidikan Universitas Kristen Tentena*, *2*(2), 37–49.

Vaiopoulou, J., Papadakis, S., Sifaki, E., Kalogiannakis, M., & Stamovlasis, D. (2023). Classification and evaluation of educational apps for early childhood: Security matters. *Education and Information Technologies*, *28*(3), 2547–2578.

Widana, I. W., Sopandi, A. T., Suwardika, I. G. (2021). Development of an authentic assessment model in mathematics learning: A science, technology, engineering, and mathematics (STEM) approach. *Indonesian Research Journal in Education, 5*(1), 192-209. https://doi.org/10.22437/irje.v5i1.12992

Widana, I. W., Wulandari, V. A., & Sudiarta, I. M. (2024). Improving mathematics learning outcomes of the Pythagorean theorem through the Jigsaw type cooperative method. *Indonesian Journal of Educational Development (IJED)*, *4*(4), 451-458. https://doi.org/10.59672/ijed.v4i4.3464

Wirama, T. G. P., Suja, I. W., & Tika, I. N. (2023). Ethnoscience-based science teaching and learning to improve students' cognitive learning outcomes: A systematic literature review. *Indonesian Journal of Educational Development (IJED)*, *4*(2), 194-208. https://doi.org/10.59672/ijed.v4i2.2897

Zuama, S. N. (2024). Disaster mitigation education: Challenges and opportunities in six areas of paud development. *International Journal on Advanced Science, Education, and Religion*, *7*(1 SE-Articles). https://doi.org/10.33648/ijoaser.v7i1.646

Zuama, S. N., & Agusniatih, A. (2020). Disaster mitigation game model used for circuit game of liquefaction as a children's learning resource in west palu district. *International Conference on Early Childhood Education and Parenting 2019 (ECEP 2019)*, 228–233.