Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 11, 1423-1432
2025
Publisher: Learning Gate
DOI: 10.55214/2576-8484.v9i11.11222

The development of Flanatomy as a learning media for ADHD students based on a 3D puzzle and augmented reality

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Abstract: ADHD students have low concentration and face significant challenges in engaging in cognitive activities. Therefore, it is necessary to utilize concrete and engaging learning media that meet their needs and characteristics. The goal of this study is to develop Flanatomy, a learning media that integrates 3D puzzles with augmented reality technology. This research is categorized as Research and Development (R&D) using the ADDIE *model (Analyze, Design, Develop, Implement, Evaluate)*. The study employed research instruments such as questionnaires and interviews. The feasibility of the Flanatomy product was assessed through validation by subject matter experts, who gave an average score of 3.37; learning media experts, with an average score of 3.6; and design experts, using the User Experience Questionnaire (UEQ), which indicated an average score above 0.8, classified as highly feasible. Practicality testing showed that the product is highly practical and easy to use, with validation from teachers at SLB Putra Mandiri Surabaya as users, who provided an average score of 3.48. Based on these results, the Flanatomy product is deemed highly feasible and practical for use as a learning medium for ADHD students.

Keywords: *3D Puzzle, Attention deficit hyperactivity disorder, Augmented reality, Learning media.*

1. Introduction

Attention Deficit Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder affecting brain and nervous system development [1, 2] classified by the WHO as a mental disability [3]. ADHD is very often found in children and adolescents [4-6]; however, several studies reveal that it can also occur in adults [7, 8]. Globally, the prevalence of ADHD is reported to be 5.9%–7.1% in children and 1.2%–7.3% in adults [9]. In Indonesia, the number of children with ADHD has increased over time. In 2023, it reached 15%, meaning that 1 in 20 Indonesian children suffers from ADHD [10]. ADHD can cause difficulties in maintaining attention [11, 12] as well as hyperactivity [2] and impulsivity [9, 13], which negatively affect the lives of those with the disorder, disrupting social relationships [14, 15], such as difficulty interacting with others and being unable to make friends [16]. It can even have negative impacts on academic aspects, such as experiencing learning difficulties and poor school performance [17-19]. Therefore, early diagnosis is crucial to help address the issue and determine appropriate treatment [15, 18], particularly in educational activities and learning processes [20]. Education or learning that is not adapted to the needs of students with ADHD can worsen their learning difficulties, decrease academic performance, deteriorate social behavior, and aggravate emotional and cognitive development [21, 22].

Students with ADHD have low concentration levels and face significant challenges in engaging in cognitive activities [23, 24]. Therefore, to optimize the learning success of students with ADHD, instruction must be carefully adapted to their characteristics [25], such as by using strategies or

History: Received: 19 September 2025; Revised: 7 November 2025; Accepted: 11 November 2025; Published: 28 November 2025
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learning media that are enjoyable and stimulate their motor skills [26]. In addition, learning should incorporate concrete and engaging instructional media to help capture the attention of students with ADHD [26, 27]. Concrete learning media also tend to improve their responsiveness and can even stimulate their level of creativity [28]. On the other hand, a conducive learning environment must also be considered to support the effective delivery of the material and improve learning outcomes [29]. Several previous studies have revealed that concrete learning media are easier for students with ADHD to understand [30]. Visual-based instructional media also helps ADHD students comprehend more complex questions or information, such as word problems [31]. In addition, the use of gamification-based learning media has been proven to enhance the attention and concentration of students with ADHD [32]. Combining gamification with augmented reality can also be implemented and has been shown to improve focus [33]. Furthermore, other studies have indicated that the use of augmented reality or virtual reality technology can positively impact the cognitive development of children with ADHD [34]. Nevertheless, this does not mean that all digital media, games, or existing technologies have a positive effect on the development of students with ADHD. Some may even worsen antisocial behavior, emotional regulation, and academic failure [35] and may increase addiction [36]. Therefore, only well-structured instructional media can enhance the attention and learning outcomes of students with ADHD [36].

Based on the facts and conditions described above, it is evident that learning for students with ADHD requires instructional media that are concrete, visual, and incorporate technology suited to their characteristics and limitations. Therefore, this study proposes the development of a learning medium for children with ADHD that combines concrete learning with 3D visual elements made of flannel fabric, which can be physically handled, and augmented reality, called Flanatomy. This research is crucial to enable ADHD students to learn more effectively through engaging and characteristic-appropriate instructional media, with the expectation of increasing their learning interest.

2. Methodology

2.1. Research Design

This study is categorized as research and development (R&D) utilizing the ADDIE model, which is practical and suitable for use in the field of instructional design to produce effective designs [37, 38]. The ADDIE model consists of five stages, which form the acronym: Analyze, Design, Develop, Implement, and Evaluate [39-41]. These five stages are interconnected, with the evaluation phase placed among the others, meaning that each stage can be evaluated [42] and must be implemented systematically [43]. The five development stages of the ADDIE model are illustrated in Figure 1.

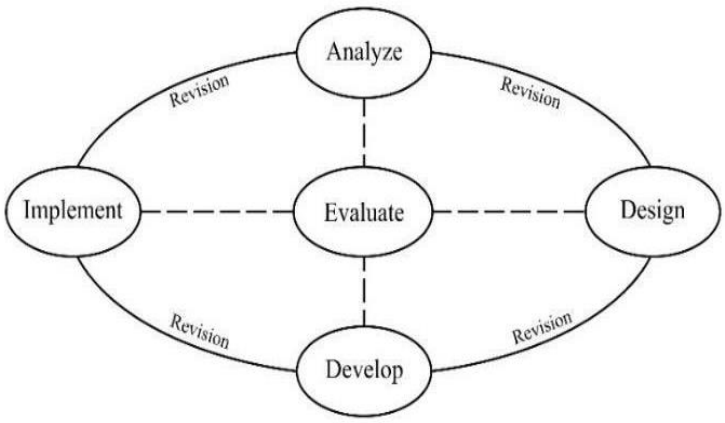

Figure 1.
ADDIE Model Stages.
Source: Branch [39] and Efendi et al. [41].

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 11: 1423-1432, 2025
DOI: 10.55214/2576-8484.v9i11.11222

Analyze. At this stage, a learning needs analysis for students with ADHD was conducted through a literature review based on previous studies. This was complemented by interviews with teachers at SLB Putra Mandiri Surabaya, following established guidelines, and by observing the learning process. These steps were taken to determine the appropriate learning media that meet the needs and characteristics of students with ADHD.

Design. This stage involved designing the Flanatomy learning media, starting from sketches of 3D flannel figures and digital designs (augmented reality), as well as prototyping the 3D flannel and augmented reality components. Additionally, the learning materials were designed to align with the characteristics and abilities of students with ADHD.

Develop. At this stage, all designs created in the previous phase were developed into the Flanatomy product, ready for testing and accompanied by a user manual. Validation tests were also conducted with instructional media experts, content experts, and design experts.

Implement. Once the Flanatomy product was validated, it was tested by teachers and students with ADHD at SLB Putra Mandiri Surabaya. The teacher trial aimed to measure the practicality of the developed Flanatomy product using a predetermined questionnaire. The student trial was conducted qualitatively through observation during the implementation process.

Evaluate. The evaluation stage was carried out at the end of each phase, as the Flanatomy product required improvements and refinements throughout the development process.

2.2. Data Collection and Analysis

The Flanatomy product, developed through the stages of the ADDIE model, was tested for feasibility and practicality.

2.2.1. Feasibility Test of Flanatomy Learning Media Products

The feasibility test of the Flanatomy learning media was conducted through validation by material experts, media experts, and design experts using a questionnaire. The results of the material and media validation were averaged and analyzed, then interpreted and concluded based on the validity or feasibility criteria of the learning media product, as shown in Table 1.

Table 1.
Feasibility Criteria for Learning Media Products.

Score	Criteria	Description
3.30 <P < 4.00	Very Feasible	Can be used as a learning medium without revision
2.30 <P < 3.30	Feasible	Can be used as a learning medium with minor revisions.
1.80 <P < 2.30	Less Feasible	Can be used as a learning medium with major revisions
1.00 <P < 1.80	Not Feasible	Cannot be used as a learning medium without revision, and still requires consultation

Source: Hariadi et al. [44].

Meanwhile, the design validation was conducted using the User Experience Questionnaire (UEQ) to obtain assessments based on direct impressions of the product across six main components of user experience, resulting in the following findings: 1) Attractiveness – The product was perceived as highly enjoyable and well-liked overall by users. 2) Perspicuity – The product was easy to understand and learn, allowing users to interact without significant difficulty. 3) Efficiency – The product effectively supported users in learning quickly and efficiently. 4) Dependability – The product demonstrated good control and consistency, though there remains room for improvement to make it more predictable and reliable. 5) Stimulation – The product provided motivation and a positive experience for users, making them interested in continuing to use it. 6) Novelty – The product was considered innovative and creative, not monotonous, and capable of delivering a fresh experience to users.

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2.2.2. Practicality Test of Flanatomy Learning Media Products

The practicality test was conducted with teachers at SLB Putra Mandiri Surabaya to determine the ease of using the Flanatomy learning media as an instructional tool. The data obtained were then analyzed and interpreted based on the practicality criteria adopted from several studies [44, 45] as shown in Table 2.

Table 2.
Practicality Criteria for Learning Media Products.

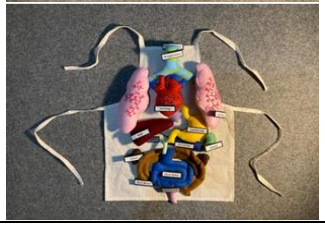
Score	Criteria
3.30 <P < 4.00	Very practical
2.30 <P < 3.30	Practical
1.80 <P < 2.30	Less practical
1.00 <P < 1.80	Not practical

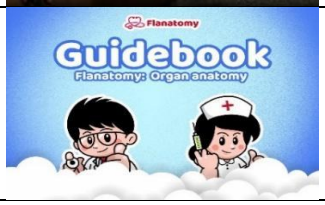
3. Results

3.1. The Development of Flanatomy

The development of the Flanatomy product utilized the ADDIE model, meaning that its development process went through several stages in accordance with this model (Figure 1). Based on the needs analysis conducted, it was found that learning for students with ADHD requires instructional media that are concrete, visual, and technologically suited to their characteristics and/or limitations, especially for anatomical materials that cannot be observed directly. Therefore, the Flanatomy product was developed with these considerations in mind. The results of its development are as follows.

Table 3.
Results of Flanatomy Product Development.

Aspects	Display	Description
Packaging		The packaging consists of two parts: primary and secondary packaging. The primary packaging uses plastic that directly wraps the Flanatomy product, while the secondary packaging uses a hard box.
3D puzzle of human organs	 	The Flanatomy product consists of two main components: a 3D puzzle made up of various stuffed models of human body organs and a flannel cloth that serves as a base for attaching these organ models. All organs are equipped with removable labels to assist the learning process for students with ADHD. The flannel cloth can be worn by the user by placing it on the front of the body, similar to wearing a cooking apron.

Flanatomy Cards		The Flanatomy product also comes with flashcards integrated with augmented reality representations of human body organs. When scanned using a smartphone, they display 3D images.
Augmented Reality (AR)		The AR application is designed to be minimalist yet informative, presenting organs as interactive 3D visuals accompanied by labels, audio narration, organ sounds, and animations that illustrate each organ's physiological functions.
Guidebook		Each Flanatomy product set comes with a manual book.

3.2. The Development of Flanatomy

To determine the feasibility of Flanatomy as a learning medium for human body organs for students with ADHD, a feasibility test was conducted through validation by learning media experts, content experts, and design experts. The results of this feasibility test are shown in Table 4.

Table 4.
Results of The Feasibility Test by Content Experts and Learning Media Experts.

Assessment	Content Experts			Learning Media Expert		
	V1	V2	V3	V1	V2	V3
Validation Score	3.5	3.2	3.4	3.7	3.5	3.6
Average	3.37			3.6		
Categories	Very Feasible			Very Feasible		

Based on the results of the feasibility test above, it can be concluded that the average validation score by the material expert was 3.37 and by the instructional media expert was 3.6, which indicates a "Very Valid" category. Therefore, the Flanatomy product is considered highly feasible to be used as a learning medium for students with ADHD. In addition to validation by content and learning media experts, the Flanatomy product was also validated by three design experts using the User Experience Questionnaire (UEQ). The results of this validation are shown in Figure 2 below.

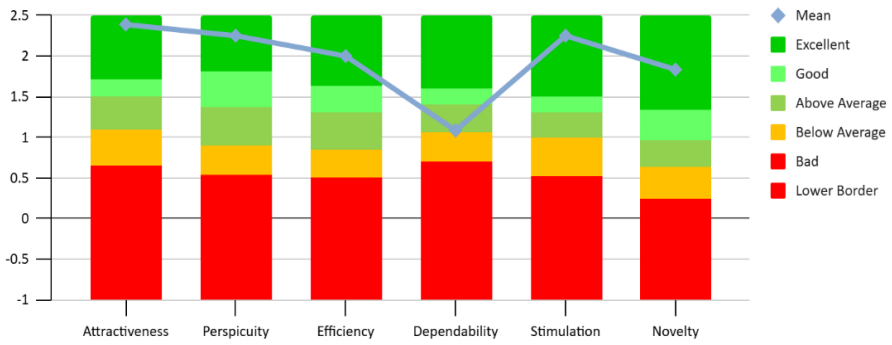


Figure 2.
Validation Results by Design Experts.

3.3. Practicality Test

After the Flanatomy product was declared feasible as a learning medium for teaching human body organs to students with ADHD, its ease of use was also measured through a practicality test involving five teachers from SLB Putra Mandiri Surabaya, who would also be the end users of the developed product. The results of the practicality test are shown in Table 5.

Table 5.
Practicality Test Results.

Scoring	Validator				
	V1	V2	V3	V4	V5
Score	3.6	3.3	3.7	3.2	3.6
Average	3.48				
Categories	Very Practical				

Based on the results of the practicality test above, it can be concluded that the average validation score by users was 3.48, which falls into the Very Practical category. Therefore, the Flanatomy product is considered highly user-friendly and easy to use as a learning medium for students with ADHD.

4. Discussion and Conclusions

To achieve optimal learning, the feasibility of instructional media must be carefully ensured before being used in the learning process. The feasibility of instructional media is determined by its alignment with the predefined learning objectives [46]. Therefore, the Flanatomy product developed in this study underwent a feasibility test through validation by subject matter experts, instructional media experts, and design experts. The validation results by the subject matter expert (Table 4) showed an average score of 3.37, indicating that the Flanatomy learning media is "Very Valid," or in other words, highly feasible. This means that the material or information contained in the developed Flanatomy product is accurate and does not deviate from the core subject matter. This is highly important because the information presented in any instructional media must be accurate and reliable to prevent learners from misunderstanding or misinterpreting the content [41]. Accurate information within instructional media serves as a benchmark for the media's quality. The higher the quality of the media, the greater its impact on students' learning outcomes. Therefore, high-quality instructional media becomes a critical factor in improving the quality of education [47].

The validation results from instructional media experts (Table 4) showed an average score of 3.6, which indicates that the Flanatomy learning media is very valid. This means that the developed Flanatomy product successfully meets the principles and standards of instructional media since media expert validation serves as an evaluation process to determine a product's eligibility as a learning tool [41]. The integration of 3D puzzles with augmented reality (AR) technology makes Flanatomy an

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 11: 1423-1432, 2025
DOI: 10.55214/2576-8484.v9i11.11222

engaging learning medium that addresses the needs of ADHD students for concrete and interactive learning resources [26, 27]. Previous studies have also revealed that leveraging technologies such as augmented reality can significantly enhance the learning experience of students with ADHD [48]. Based on the design expert validation using the UEQ (User Experience Questionnaire) interpretation scale (Figure 2), the results show that the average score was above 0.8, which indicates that the validators had a positive impression of the Flanatomy product. The validation results also suggest that aspects such as attractiveness, clarity, efficiency, accuracy, stimulation, and novelty were above average [49]. Therefore, Flanatomy is declared highly feasible and appealing as a learning medium for students with ADHD.

Since the feasibility tests from subject matter experts, instructional media experts, and design experts all yielded highly feasible results, Flanatomy is officially considered very suitable for use as an instructional medium for teaching human organs to ADHD students. If an instructional media product is deemed feasible by experts, it can then proceed to user testing [41, 50]. However, before implementing the user trial, Flanatomy underwent revisions based on suggestions and comments from the experts to ensure improved accuracy, reliability, and quality. After being validated as feasible, Flanatomy proceeded to a practicality test with five teachers from SLB Putra Mandiri Surabaya to determine its ease of use during teaching. Based on the practicality test results (Table 5), the average user validation score was 3.48, which indicates Very Practical. This suggests that Flanatomy is highly easy to use as a learning medium for teaching human organs to students with ADHD. The practicality of an instructional medium refers to how easy it is for both teachers and students to use, ensuring that the learning process becomes meaningful, engaging, enjoyable, and stimulating for creativity [51]. From a physical or technical perspective, an effective instructional medium should enable teachers to deliver lessons more efficiently to achieve the intended learning objectives [38]. Furthermore, the practicality of instructional media should consider several aspects: (1) format, time allocation, and cost for using the media during lessons; (2) compatibility with students' characteristics, learning styles, developmental stages, and experiences; (3) alignment with the teaching process and the ability to facilitate learners' understanding of the material provided through the media [41, 51].

The study resulted in Flanatomy, an instructional medium for ADHD students that integrates 3D puzzles with augmented reality (AR) technology, aiming to provide a concrete and interactive learning experience tailored to the characteristics and needs of ADHD learners. Based on the feasibility tests conducted by subject matter experts, instructional media experts, and design experts, the Flanatomy product was classified as highly feasible. Additionally, the practicality test involving teachers as end-users indicated that the product is highly practical and easy to use. Therefore, the developed Flanatomy product is deemed highly feasible and user-friendly as an instructional medium for ADHD students.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

Acknowledgment:

We would like to express our gratitude to the Directorate of Research and Community Service, Directorate General of Research and Development, Ministry of Higher Education, Science, and Technology for providing funding for the applied research under the prototype output scheme in accordance with the main contract number: 128/C3/DT.05.00/PL/2025 and the derivative contract number: 075/LL7/DT.05.00/PL/2025. We would also like to thank Dinamika University for supporting this research in accordance with the contract letter number: 009/UDK-P3kM/KPJ/V/2025.

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