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The Implementation of Tangible Interaction in Microcontroller-Based Interactive Animal Introduction Game "MARGA" for Intellectual Disability Children

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ABSTRACT

According to the interview results with the headmaster of Autism Pelita Hafidzh Bandung Special School, children with intellectual disabilities have learning limitations, including difficulty remembering, quickly forgetting, being distracted, having little interest, and IQ below the average of normal children. Therefore, the innovation of the MARGA game, an acronym for Multimedia Embedded Rig for Guided Assistant, was created using tangible interaction to assist these children in learning about animals. Technical testing was conducted twice, namely testing the suitability of tags and the speed of tag reading time, resulting in an average speed of reading RFID tags of 2,653 seconds. In addition to conducting beta testing on two children with intellectual disabilities at Autism Pelita Hafidzh Bandung Special School. Research shows that children with intellectual disabilities who have tried playing MARGA reach the learning target set by Autism Pelita Hafidzh Bandung Special School more quickly.

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1. Introduction

Education is a process of learning that all human beings, including children with special needs, can easily understand. Children with special needs have abnormalities or limitations that can sometimes be seen physically. However, sometimes the abnormalities come from mental conditions, which can cause further growth and development compared to normal children [1]. There are several types of children with special needs, including children with intellectual disabilities. In this case, the child has a mental limitation called an intellectual disability or "tunagrahita" in Indonesian [2]. Children with intellectual disabilities require guidance in all aspects, including education [3]. Children with intellectual disabilities have limited intellectual abilities, making adapting to their surroundings and comprehending learning materials challenging. Law and government regulations state that special education is intended for students with various disorders, including those with below-average IQs. Education is a right for all individuals, regardless of whether they are normal or have special needs [4].

Every child has a unique ability or potential. Child rights declare that every child has an equal right to live and develop according to their potential. However, children with special needs face obstacles in their behavioural development, such as children with intellectual disabilities, also known as tunagrahita, who experience mental and intellectual delays [2]. Children with intellectual disabilities usually have an IQ below 70 and struggle to adapt to their surroundings [5]. Other developmental delays that affect children with intellectual disabilities include communication, academic, and cognitive speed. Treating children with intellectual disabilities requires adequate facilities, including a suitable learning space that caters to their developmental needs [4].

Interviews conducted at the Autism Pelita Hafidzh Bandung Special School revealed that children with intellectual disabilities have varying levels of learning motivation that depend significantly on their mood. Despite requiring extra effort to understand new material, children with intellectual disabilities can receive an education. However, they are more prone to forgetting the material. Research indicates that children with intellectual disabilities can acquire and retain material more effectively when given an exciting and enjoyable learning method, such as learning through play. Using photography as a medium to show the shape and characteristics of animals is an effective and enjoyable alternative to teaching concepts that are difficult to understand for children with intellectual disabilities.

The cognitive learning process comprises five interrelated aspects: knowledge, understanding, application, analysis, synthesis, and evaluation. Gaining understanding requires acquiring knowledge, followed by its application. Multiple experiences are combined with knowledge and understanding for practical application and evaluation [6]. Using a tangible interface allows for trial-and-error exploration as it provides a continuous display of the object of interest and enables quick and reversible actions that immediately affect the object. Another benefit is that it is not limited to a single user, as children can work together and collaborate naturally, providing a social experience that has been shown to enhance productivity. Studies by various researchers have already demonstrated the advantages of tangible interfaces in learning. From a psychological and educational standpoint, tangible interfaces are advantageous for learning because they promote physical activity, utilize concrete objects, allow for mental imagery, enable learners to derive symbolic relations from a range of concrete examples, and are more easily comprehensible to children than abstract representations [7]. Tangible interaction, aligned with the Montessori method, focuses on stimulating motor, sensory, and

language abilities to help children develop cognitive abilities [8]. This method emphasizes sensorial education and practical life activities to help children learn about the world. Various media can stimulate children's cognitive abilities in different learning activities, including those with disabilities [9].

Several studies have been conducted to enhance learning for individuals with intellectual disabilities and visual impairments. The first study used the Button Board as an effective digital learning medium that significantly improves the learners' motor, cognitive, and communication abilities [10]. The second study developed an Arduino-based innovative mannequin as a human anatomy teaching aid that can assist visually impaired and children with intellectual disabilities in better understand human anatomy [11]. The third study produced a 3D map-based learning tool using Arduino Uno to help intellectual disability individuals understand geography concepts interactively and enjoyably [12]. In conclusion, technology and innovation can provide practical solutions to enhance learning for individuals with intellectual disabilities and visual impairments. Furthermore, microcontroller technology effectively improves learning for individuals with intellectual disabilities.

One of the applications of technology that can be taught to children with intellectual disabilities who can answer problems at Autism Pelita Hafidzh Bandung Special School is a game. Games are an exciting discovery for children, including children with disabilities. Games can be a part of visual therapy, as they often contain visual images that interest users in playing the game [13]. From that background, researchers aim to create a game called MARGA. MARGA stands for Multimedia Embedded Rig for Guided Assistant, a game that uses RFID and microcontroller technology to introduce children to animals. The game uses animal dolls and a magic box as tangible interactions, motivated by the Montessori method of animal recognition.

MARGA was designed using direct interactions that align with Maria Montessori's observations regarding independence, sensory experience, and error control in children with intellectual disabilities. Yeni Rachmawati, M.Pd., PhD, a lecturer in the Early Childhood Education Teacher Education Program at the Indonesian University of Education, validated MARGA. According to Yeni Rachmawati, MARGA has fulfilled several Montessori principles, including independence, sensory experience, and error control. This game is expected to help children with intellectual disabilities learn about animals and improve their cognitive and motor abilities.

2. Methodology

The research conducted by our team began with a visit to the Autism Pelita Hafidzh Bandung Special School. This visit aimed to conduct in-depth interviews regarding the needs of children with intellectual disabilities in the learning process. Based on the results of these interviews, the team identified the needs that would form the basis for developing an educational game application for children with intellectual disabilities.

The team developed an educational game application called MARGA, created using the Serious Game or SGDM (Serious et al. Model) method [14]. The Serious Game Development Model shown in Figure 1 is a game development framework based on game-based learning principles that adopt an adaptive GDLC iterative approach. It maps the four main pillars of the GBL Foundation (affective, behavioural, cognitive, and social/cultural engagement) as indicators of the suitability of severe game characteristics for each development activity. The model emphasizes the importance of using information and communication technology to

develop serious games and tailor games to the learning objectives and user characteristics. It also highlights the crucial role of clear instructions and appropriate feedback in serious game-based learning [15].

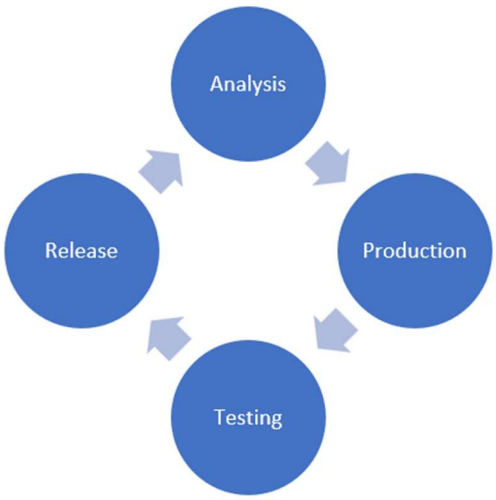


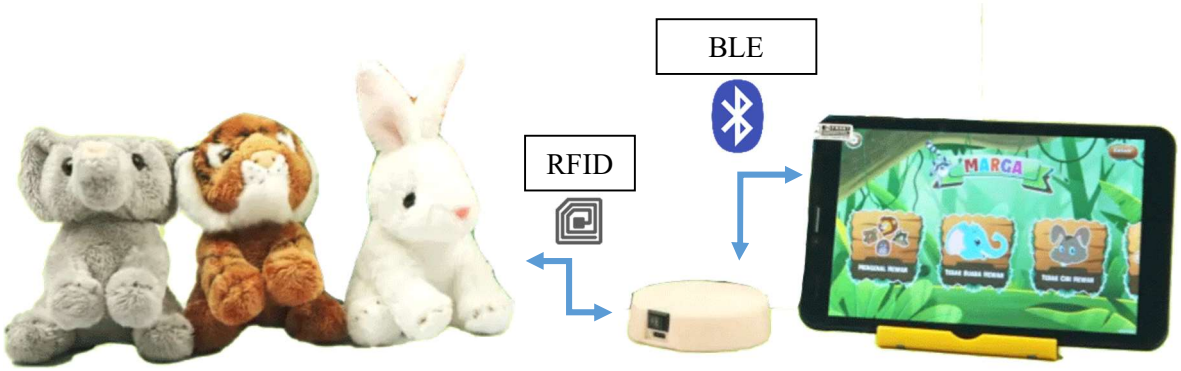
Figure 1 Scheme of Stages in The Serious Game Development Method

This method consists of four stages: Analysis, Production, Testing, and Release [14].

1. The analysis involves analyzing the user's needs and educational aspects that can be incorporated into the game. This process will identify what is needed to create a game suitable for the target audience.
2. Production is where the game development process starts. This includes wireframing, creating necessary assets, game design, game mechanics, programming, and a prototype.
3. Testing involves testing the prototype created earlier. This test is done again at Autism Pelita Hafidzh Bandung Special School to observe the reactions of children with intellectual disabilities when trying the game and collect any shortcomings and errors that emerge during the testing. After that, continuous iteration is done through programming and content processes to make the game better and ready to be played.
4. Release involves releasing the game by giving it to Autism Pelita Hafidzh Bandung Special School. This stage marks the end of the development process, and the game is now available to the target audience. Overall, this method ensures that the game is tailored to the target audience and that its quality is thoroughly tested before release.

3. Discussion

The MARGA game, an acronym for Multimedia Embedded Rig for Guided Assistant, is an animal introduction game with RFID and microcontroller technology, animal dolls, and a magic box as props. The game can only be played using these props. The animal dolls are divided into three categories, namely herbivores, carnivores, and omnivores, and a total of 15 dolls are used, as displayed in Figure 2 (a). Each doll has an embedded tag containing its unique identity. The magic box resembles a tree trunk and is a tool for detecting or reading the selected animal doll. The game is played by placing the chosen doll on the top of the magic box, as seen in Figure 2 (c). The use of RFID technology was selected based on factors such as affordability, accessibility, and ease of installation. The RFID embedded in the dolls is detected by the RFID reader in the magic box, which is then connected to the system via a Bluetooth Low-Energy (BLE) connection.



(a) (b) (c)

Figure 2 Animal Dolls (a), Magic Box (b) as The Game Props, and The Visualization of How to Play MARGA (c)

The MARGA Game consists of four menus: animal introduction, guess animal characteristics, guess animal sound, and animal comparison. In the animal introduction menu, as seen on, players can watch video explanations of selected animals by tapping on the magic box. These videos describe the animals' characteristics, food, and habitat. The game tests the player's understanding by guessing the animal's characteristics, sounds, and size. It is a combination of physical and digital games that use display tools as direct interaction media, applying the tangible interaction approach and motivated by the Montessori method. The game display can be seen in Figure 3 below.

(a) (b) (c) (d)

Figure 3 Game MARGA, animal introduction menu (a), Guess Animal Characteristics (b), Guess Animal Sound (c), and Comparing Animal Size (d)

3.1. Technical Testing

The researchers conducted technical testing on the MARGA game that has been successfully created. All the menus in the MARGA game that necessitated RFID scanning were put to the test. This testing is helpful to determine if any flaws in the game need to be fixed and to find solutions to any bugs that may occur in the game. The technical testing was conducted twice. The first is the Validity test,

which aims to determine the compatibility of the tags and the display in the game, and the second is the RFID tag reading speed test, which aims to record the reading time of the RFID tags when attached to the reader. The results of the testing can be seen in the following table.

Table 1 Technical testing 1 (Validity testing of RFID Tag)

Name of Dolls	Animal Introduction Menu		Guess Animal Characteristic		Guess Animal Sound		Guess Animal Size	
	Match	Unmatch	Match	Unmatch	Match	Unmatch	Match	Unmatch
Lion	Yes	-	Yes	-	Yes	-	Yes	-
Tiger	Yes	-	Yes	-	Yes	-	Yes	-
Crocodile	Yes	-	Yes	-	Yes	-	Yes	-
Penguin	Yes	-	Yes	-	Yes	-	Yes	-
wolf	Yes	-	Yes	-	Yes	-	Yes	-
Squirrel	Yes	-	Yes	-	Yes	-	Yes	-
Flamingo	Yes	-	Yes	-	Yes	-	Yes	-
Bear	Yes	-	Yes	-	Yes	-	Yes	-
Orang Utan	Yes	-	Yes	-	Yes	-	Yes	-
Turtle	Yes	-	Yes	-	Yes	-	Yes	-
Zebra	Yes	-	Yes	-	Yes	-	Yes	-
Rabbit	Yes	-	Yes	-	Yes	-	Yes	-
Elephant	Yes	-	Yes	-	Yes	-	Yes	-
Kangaroo	Yes	-	Yes	-	Yes	-	Yes	-
Panda	Yes	-	Yes	-	Yes	-	Yes	-

As can be seen in Table 1, all tags match the display that appears in the game. Then in the second table, we can see the speed of tag reading, specifically in the animal introduction menu.

Table 2 Technical testing 2 (RFID Tag Reading Speed Test)

No	Name of the Dolls	Time of Reading (s)
1	Lion	2.67
2	Tiger	1.88
3	Crocodile	2.49
4	Penguin	2.47
5	wolf	3.04
6	Squirrel	1.81
7	Flamingo	2.11
8	Bear	3.59
9	Orang Utan	2.14
10	Turtle	2.48
11	Zebra	2.94
12	Rabbit	3.00
13	Elephant	4.13
14	Kangaroo	2.91
15	Panda	2.14
	Total	39.8

The purpose of the average calculation that summarized in Table 2 is to determine the speed of the average reading of the RFID tag, which is done by utilizing the following formula to perform the calculation.

$$\bar{X} = \frac{\sum xi}{n} \quad \text{(Equation 1)}$$

Where xi is the total time of reading, and n is total data, in this case, the number of dolls.

Utilizing the formula mentioned above indicates that the overall total reading speed of the RFID tag is 39.8, with 15 data points. Therefore, reading speed can be computed using Equation (1). The reading speed for this technical testing is 2.653 seconds for RFID tags in the animal introduction menu.

3.2.Beta Testing

The author conducted three visits during the Special School visit. During the analysis phase, the first visit consisted of in-depth interviews to identify the target users' needs. The second visit involved testing the game, while the last visit entailed delivering the game to the Autism Pelita Hafidzh Bandung Special School. Based on the results, it was discovered that it took approximately four meetings with the same material for the students to meet the animal learning target.

As part of the trial phase, two intellectual disability students from Autism Pelita Hafidzh Bandung Special School were selected as sample participants. The students were presented with 45 animal-related questions divided into three categories: pictures, sounds, and characteristics (15 each). They were required to guess the correct answers. The scores of the students were determined by the number of animals they could identify correctly, with the maximum possible score being 15 for each question category.

Muti and Wijaya have posed an identical inquiry after participating in the MARGA game. The approach to education for children with intellectual disabilities stresses the significance of material repetition, given their limited ability to remember. As a result, the evaluation was conducted three times to determine whether the educational goal for animals had been met at Autism Pelita Hafidzh Bandung Special School.

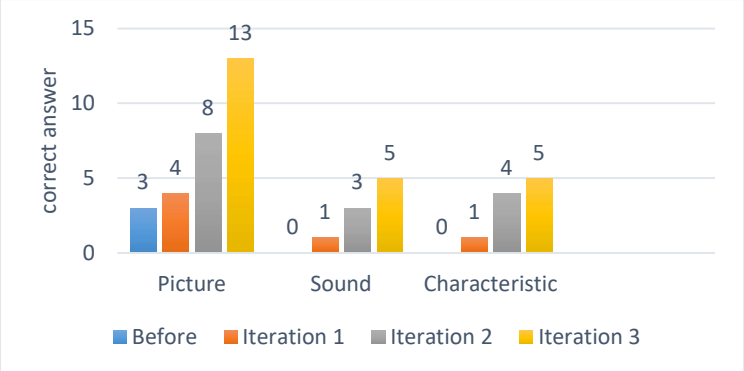


Figure 4 Beta Testing Result: Muti

In Figure 4, we can see the results of the beta testing carried out by Muti. The graph above represents the number of questions answered correctly, with 15 questions, each with three categories of questions: images, sounds and characteristics. In the graph, it can be seen that there has been significant progress after using MARGA.

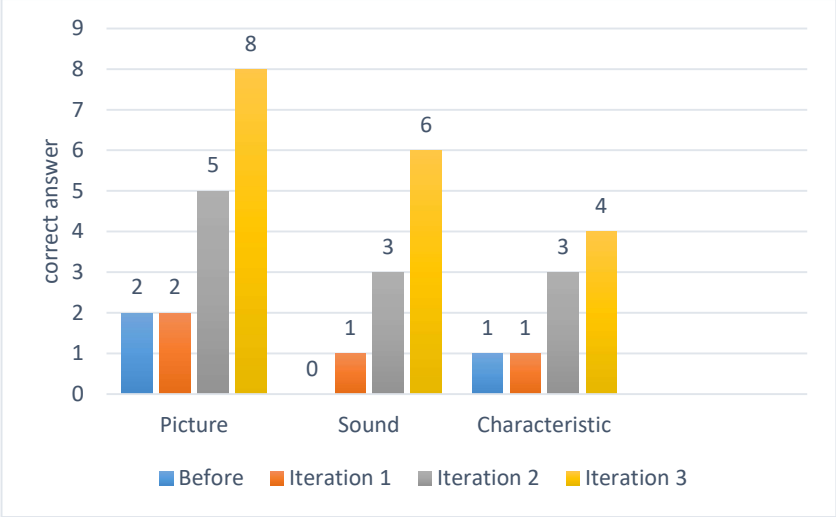


Figure 5 Beta Testing Result : Wijaya

The beta testing conducted by Wijaya is displayed in Figure 5, which shows a noticeable improvement after implementing MARGA. The graph above represents the number of questions answered correctly, with 15 questions, each with three categories of questions: images, sounds and characteristics. From both beta tests of the MARGA game with two intellectual disability children in the Autism Pelita Hafidzh Bandung Special School, after consulting with their principal, it turned out that the learning targets were achieved faster after using the MARGA game to learn about animals. The children were more interested and motivated to learn, thus influencing their understanding of complex abstract concepts to become more accessible.

4. Conclusions

Children with intellectual disabilities have learning limitations, including difficulty remembering, easy forgetfulness, easy distraction, low interest, and an IQ below the average of normal children. MARGA is a microcontroller-based and tangible interaction game developed to help children with intellectual disabilities overcome their learning limitations. Research shows that children with intellectual disabilities who have tried playing MARGA reach the learning target set by Autism Pelita Hafidzh Bandung Special School more quickly.

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