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RESEARCH ARTICLE

An IoT-Based Approach for Learning Geometric Shapes in Early Childhood

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ABSTRACT In today's world, technology has assumed an indispensable role in everyday life. However, though developments in the Internet of Things (IoT) have laid a foundation for achieving different educational purposes, IoT is not being employed to its full potential. A separate issue is that the topic of geometry has been neglected or received only limited attention in schools, particularly in the early years. Moreover, as geometry is of paramount importance, the idea of teaching geometry in early childhood should be investigated. This paper proposes an IoT-based approach for teaching basic geometric shapes to children aged 5 to 6. Specifically, five nodes were designed to act as the vertices of shapes. In addition, educational videos comprising three sections —identification, recognition, and recollection — were provided. Using a sample of 35 boys the proposed solution was assessed in terms of its effect on learning outcomes and the learning process using pre-test, simultaneous test, and post-tests. The findings revealed a noticeable improvement in learning outcomes. Furthermore, the proposed approach made learning enjoyable, which, compared to the traditional approach toward learning geometric shapes, is considered an improvement.

INDEX TERMS Internet of Things, early childhood education, geometry, geometric shapes.

I. INTRODUCTION

The Internet of Things (IoT), as an emerging technology, has become an indispensable part of everyday life. It consists of billions of physical devices, so-called "things," that are connected to the internet technology and that all collect and share data globally. With the rapid development of other technologies such as cloud computing and big data, the role of IoT will increase. It is employed in a wide range of domains [1], particularly education. The education sector is seen as holding especially promising prospects for implementing IoT applications [2]. The involvement of IoT in education influences different parties namely learners, instructors, and entrepreneurs [3]. A variety of tasks, both learner-oriented or instructor-oriented, will be modified by IoT, those promoting diversity in children's learning processes being one example.

A considerable amount of research has been performed on benefiting from IoT in educational applications. However, the education of children about basic geometry shapes with the help of IoT physical nodes has not featured in any study to date. Additionally, Reference [2] stated that although numerous educational institutions have implemented IoT on their campuses, acceptance of IoT and its potential applications remain limited, particularly in developing nations.

The main contribution of the present study is the integration of educational videos and IoT nodes for teaching geometric shapes to children aged 5 and 6. The IoT nodes, capable of range detection, are designed so that the

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participants can use them as vertices in order to make a geometric shape. Specifically, this paper introduces a proposed approach including hardware design and the creation of educational videos. Then, the approach is assessed through an experiment using pre-test, simultaneous test, and post-tests, to monitor learning processes and outcomes. By the learning process, the change in children's interest in geometry and the approach is meant. Furthermore, by learning outcome, the educational outcome targeting how children performed is meant. The paper's research questions are as follows:

- What will be the impact of the proposed method in terms of learning outcomes?
- How will the proposed solution influence the learning process?

The rest of the paper is as follows: Section II covers the literature review, while Section III explains the methodology. The results of the study are provided in Section IV, and Section V covers the discussion. Finally, Section VI provides conclusions and future research directions.

II. LITERATURE REVIEW

A. TECHNOLOGY AND EARLY CHILDHOOD EDUCATION

Technology is a major component of what children are exposed to on a daily basis [4]. They are constantly developing a sense of creativity and are curious about their surroundings. In this regard, technologies provide them with the opportunity to satisfy their exploratory and creative needs. Each new technology is introduced with the promise to help children's learning [5]. However, despite the enthusiasm around technology, some school administrators and politicians may overlook the fact that technology may have the potential to improve teaching and learning practices in and of itself [6]. Consequently, the practical usage of technology in education sectors, particularly in early childhood education, is still uncommon [7]. Additionally, as an example of this, it is stated that some barriers exist which prevent teachers from successfully employing technology during their work [8].

In today's world, the fact that the settings and connections with which children interact are heavily reliant on technology has been highlighted; as a result, children should learn about technology and have a positive and critical relationship with it [9]. In addition to learning about technology, it can be used to enhance learning quality in other courses as well. Simply put, technology can be beneficial in the learning process and for knowledge acquisition at early ages [10]. Reference [11] reported improvements in reasoning in science when technology was incorporated. The employment of technological instruments leads to qualitative changes in carrying out instructive-educational activities at early ages mainly due to the fact that it provides a saving of time, thereby enabling the appropriate use of teaching aids and teaching-learning techniques [12]. Personalizing learning activities, logically arranging curricular materials, and expediting the communication process during play and learning activities are just a few of the benefits of using modern technology [13].

B. CURRENT STATE OF THE RESEARCH FIELD

IoT devices are becoming ubiquitous, and they are starting to have an impact on how young children play, learn, and grow all across the world [14]. Reference [15] highlighted that when IoT is brought into children's learning environment, children conceptualize higher mental functions, such as continuous and ongoing problem-solving dispositions, language acquisition, and social learning. Several fields exist in which researchers have employed IoT for children. Reference [16] explored the involvement of IoT-based 3D books in the learning environment of children acquiring a foreign language. Their overall findings observed a noticeable improvement in oral production leading to a significant enhancement of the learning outcomes. Reference [17] developed an IoT-based learning aid which noticeably improved children's knowledge of air pollution. In addition to studies targeting learning outcomes directly, some focus on the underlying framework or infrastructure. For instance, Reference [18] proposed an online monitoring system for children benefiting from 5G and IoT. In this regard, the goals were related to optimization, including the lowering of energy consumption.

Geometry is a well-known mathematical topic with numerous real-world applications. It is primarily concerned with visual and spatial qualities and is used in a wide array of fields such as art, architecture, and astronomy. Hence, it is of paramount importance to learn geometry at an early age since that is when children start to develop geometric and spatial orientation perceptions. That is to say, education at this juncture plays an important role in children's learning experiences [19]. Another perspective that emphasizes the importance of learning geometry is the claim that geometric concepts underline all mathematical topics. Reference [20] asserts that geometry receives insufficient in the early years. Unfortunately, many elementary school children, as is also the case with many other difficult areas in mathematics, have a negative attitude toward geometry, a result of the textbooks' restricted concept of geometry. This negative attitude will probably also cause difficulties for those teachers following traditional approaches in teaching children geometry. Therefore, adding technology and some physical activity will make the learning of geometry interesting, and assist teachers in offering more interesting pedagogical strategies. Regarding the use of IoT for geometry education, Reference [17] studied the possible learning outcomes for children of integrating IoT and theremins for learning five geometrical shapes. However, while this paper presents valuable findings, the involvement of hand movement without physically interacting with devices might be confusing for children. Furthermore, physical manipulation might provide children with a better connection to technology, which in turn has a positive effect on psychological aspects. Apart from that, physical devices could be personalized in terms of appearance, making them more interesting from a child's viewpoint. To the best of our findings, no similar study targeting IoT-aided children's geometry education in the early years has been carried out.

III. METHODOLOGY

The entire experiment procedure was reviewed by the institute officials. They were provided with the benefits of the study. Additionally, all parents signed a consent form before their children took part in the experiment.

A. PROCEDURE

The overall workflow of the study is shown in Figure 1 (the icons were downloaded from https://www.flaticon.com). The experiment begins with a pre-test which is given to the participants so that their current knowledge of geometric shapes can be assessed. Next, a tutorial is presented in order to make children familiar with how the system works.

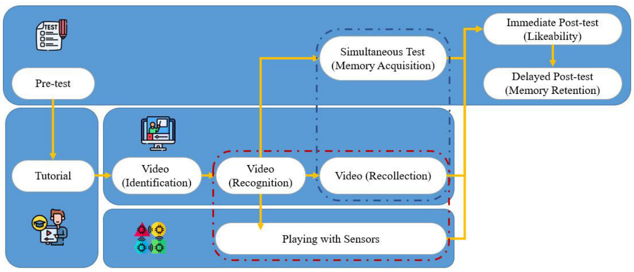
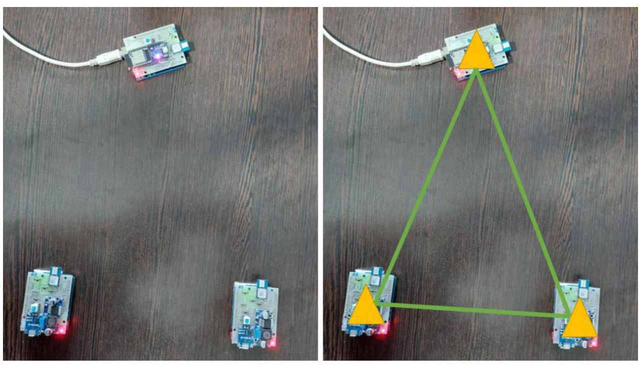


FIGURE 1. Overall framework of the experiment.

In the next step, the children are requested to watch the first section of the educational videos which is the Identification section. Then, the Recognition section of the educational video is displayed. During this, the participants can play with the sensors, creating different shapes with the help of sensors (Figure 2). When the last section of the educational video starts, a teacher records the children's answers. Specifically, the children are asked to recollect the shapes and create them using different sensors. These answers are used for assessing memory acquisition.



(a) (b)

FIGURE 2. (a) The configuration of nodes, (b) The created geometric shape.

Lastly, two types of post-tests are required. The first one, the immediate post-test, targets the likeability of the proposed solution. Memory retention is evaluated from the second post-test, which is carried out one week after the experiment.

B. PARTICIPANTS

Thirty-five children aged 5-6 participated in the experiment; this age group was chosen mainly due to the fact that these years are seen as vital in terms of children's overall development [21]. Additionally, early childhood has been identified as a suitable age for children to learn geometry and spatial reasoning [20]. That is to say, although children can partially recognize different shapes, it is beneficial that they learn to think about shapes and space in their early years, before school. Regarding the required number of participants, there is no simple solution because the ideal sample size depends on the aim of the research and the characteristics of the population being studied. In general, a larger sample is desirable since it provides more dependability and allows for the application of more complex statistics. As a result, it is commonly agreed that if researchers want to perform any kind of statistical analysis on their data, a sample size of 30 should be used as a minimum [22]. Therefore, in this study, a sample size of 35 was used.

C. HARDWARE DESIGN

In this section, the sensor design is explained. The purpose of having these sensors is to enable the children to play with and move and place them at the vertices of the requested shape. Then, the local coordinates of each node are calculated using measured distances and with the help of mathematical equations, the created shape is predicted.

The DWM1000 module is used in this experiment was an IEEE802.15.4-2011 Ultra-Wideband (UWB) compliant wireless transceiver module based on Decawave's DMW1000 Integrated Circuit (IC). The precision of this module is said to be within ± 10 cm, offering 6.8 Mbps communication capability [23]. The UWB signal offers a wide range of benefits, including causing no disturbance to other wireless technologies and superior multipath performance. However, its most important benefit for this research is its high precision ranging capability. In other words, UWB technology generates short pulses integrated with time-of-flight measurements, providing precise locations with centimeter level accuracy.

The design of the Printed Circuit Board (PCB) is of paramount importance to ensure a board that is both reliable and cost-effective. Several stages were considered in the design process, including concept definition, circuit schematic, component placement, refinement, routing, and testing. For instance, it is recommended that there should be no metal, even batteries, near the antenna of the module for better performance. The PCB is shown in Figure 3(a), and the assembled board is displayed in Figure 3(b).

D. MATHEMATICAL CONSIDERATION

As discussed in the previous section, the final devices are only capable of sending distances. The distance between two radio

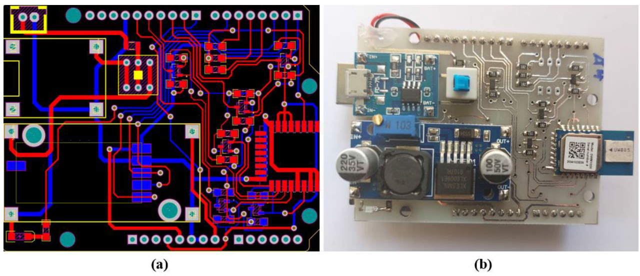


FIGURE 3. **(a) The design PCB, (b) The final PCB.**

units is calculated using two-way ranging/ time of flight, by exchanging messages and monitoring the times of transmission and reception [24]. Therefore, the local coordinates of each node must be calculated using the measured distances. Finally, these local coordinates can be used to deduce the geometric shape constructed by the nodes as the vertices of the shape.

In order to create a local coordinate system, (0,0) is assigned to the first node as its coordinate (Figure 4(a)). Then, no matter where the second node is placed, that direction is considered the x-axis. Therefore, its coordinate will be (d1,0). The y-axis, then, will be perpendicular to this direction. Finally, if any additional node is used, its coordinate will be calculated using the distances between it and the main two nodes. Figure 4(a) is also used for detecting simple triangles.

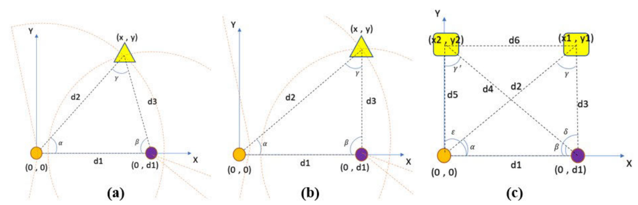


FIGURE 4. **(a) The initial steps and distances for calculating coordinates (b) The initial steps and distances for calculating coordinates of a right triangle (c) The initial steps and distances for calculating the coordinates of a rectangle.**

Equations 1 and 2 for calculating the coordinate are as follows.

$$x^2 + y^2 = d_2^2 \tag{1}$$

$$x^2 + (y - d_1)^2 = d_3^2 \tag{2}$$

where d is the distance between nodes. Using Equation 1 and 2, the final x and y are obtained (Equations 3 and 4).

$$y = 1/(2d_1)(d_2^2 + d_1^2 - d_3^2) \tag{3}$$

$$x = \sqrt{(d_2^2 - y^2)} \tag{4}$$

The angles can be also calculated, using Equations 5 and 6, in order to evaluate the accuracy of the measurements as well as other types of calculations for other shapes.

$$cos^{-1}(((d_3^2 - (d_1^2 + d_2^2))/(2d_1d_2))) = \alpha \tag{5}$$

$$sin\alpha/d_3 = sin\beta/d_2 = sin\gamma/d_1 \tag{6}$$

Figure 4(b) reveals information about the right triangle geometric shape, while Figure 4(c) shows the elements for distinguishing rectangles. Other shapes such as squares and parallelograms are also considered in our work and the equations are similar.

E. MATERIALS

1) EDUCATIONAL MATERIALS

For the learning materials, different videos for different geometric shapes were created. Videos can be significantly educational. If used properly, they can noticeably improve learners' knowledge acquisition, and make the learning process enjoyable [25]. Different elements need to be taken into account in producing educational videos [26]. The considerations for creating educational videos in this study are as follows: 1) videos are brief so that the viewer stays focused on learning objectives; 2) audio and visual features are employed to communicate important portions of a story; 3) signaling is used so as to draw attention to key concepts; and 4) guiding questions are used to make the learning context active. The videos were created to teach children geometric shapes: triangle, square, rectangle, parallelogram, and right triangle. Each video consists of three stages: identification, recognition, and recollection. In the first stage, shown in Figure 5, the user is supposed to identify the geometric shape according to the real-world objects shown.

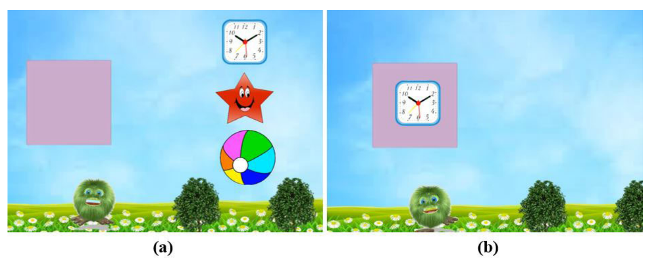
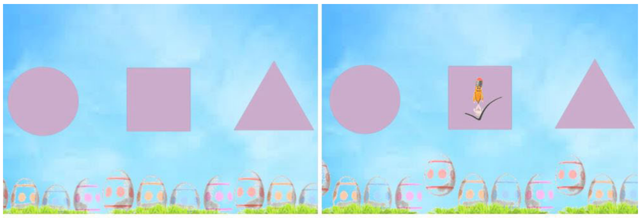


FIGURE 5. **Identification section of the video for teaching the square (a) when a question is asked (b) when the answer is revealed.**

As indicated in Figure 5, the goal is to learn about the square. On the right side of the video, three objects are displayed and only one of them is a real-world example of a square. In this way, the learner is able not only to identify the shape but also to understand the name and shape of this geometric shape. Next, the user should recognize which shape is requested in the recognition stage (Figure 6).

An auditory question asks the user to choose the square shape and the user is supposed to recognize and choose the shape presenting a square, within a few seconds. Finally, in the last phase, the user should recollect the name of each shape. This stage monitors children's performance in retrieving information about the previous stages. Figure 7 indicates the recollection stage in which the shape is highlighted and the user is asked to name this geometric shape.



(a) (b)

FIGURE 6. Recognition section of the video for teaching the square (a) when a question is asked (b) when the answer is revealed.

FIGURE 7. Recollection section of the video for teaching the square.

2) EVALUATION MATERIALS

The purpose of this part of the study is to examine whether the program developed has an impact on children's learning skills. Therefore, to achieve this goal, pre-test, simultaneous test, and post-test are performed and analyzed.

3) PRE-TEST

The pre-test is designed to assess a child's skill level prior to applying the geometry IoT device and to evaluate his current knowledge of geometric shapes. The pre-test is designed and monitored by the researchers.

4) SIMULTANEOUS TEST

The simultaneous test is designed to assess the level of the child's understanding of geometric shapes while using the IoT device. In other words, it is used to evaluate memory acquisition. In this phase, each child is observed by the researchers while working with sensors and answering the questions. The responses assist us in monitoring the learning outcome while using the system.

5) POST-TEST

This section consists of two stages: immediate post-test and delayed post-test. These post-tests are beneficial for evaluating the learning process and outcome. In the immediate post-test stage, the assessment is performed with Fun Toolkit v3, a survey tool developed to help researchers obtain technology (web or app) feedback from children. Fun Toolkit has proven to be extremely useful in gathering opinions from children with a noticeably adequate level of dependability [27]. The Smileyometer and Again-Again Table from [28] Fun Toolkit for Children are utilized in this research to assess the children's experiences. The Smileyometer has been widely used and introduced in analyses with children because it is simple to use and does not require any writing on the part of the children, and is used to capture their reactions to both the activities and the IoT device [29]. The Smileyometer as developed for children uses five smileys and is based on a 5-point Likert scale (Figure 8), with responses ranging from 1 (Awful) to 5 (Brilliant). In terms of statistics, descriptive statistics, such as mean and standard deviation are used in this research. As shown in Table 1, the interpretation of the mean score is based on the scale developed by [30].

FIGURE 8. Smileyometer Adopted from [29].

TABLE 1. Mean interpretation [30].

Mean Score	Interpretation
1.00 - 2.00	Awful
2.01 - 3.00	Not very good
3.01 - 4.00	Really good
4.01 - 5.00	Brilliant

Another Fun Toolkit method used in this research is the Again-Again table. Table 2 shows how an Again-Again table is utilized to ask the children if they want to use the App to perform the activity again; this gives insight into their feeling of engagement. Three responses are available: Yes, Maybe, No.

The delay post-test step is to evaluate the durability of children's retention of the geometric shapes taught to them after one week. Simply put, it targets the memory retention of children after using the proposed approach.

TABLE 2. Again-Again table.

Would you like to play again?				
User Name	User Age	Yes	Maybe	No

IV. RESULTS

Thirty-five boys — 10 (29%) aged 5 and 25 (71%) aged 6 — participated in the experiment. Figure 9 shows the number of children and their age distribution.

A. PRE-TEST

Children do not normally have a deep knowledge of all types of geometric shapes at an early age. The purpose of the

TABLE 3. Number of children's correct and incorrect answers in identifying geometric shapes in the pre-test stage.

	Triangle	Square	Rectangle	Parallelogram	Right Triangle
Correct Answers	27	21	20	2	0
Incorrect Answers	8	14	15	33	35

TABLE 4. Number of children's correct and incorrect answers in identifying geometric shapes in the simultaneous test stage.

	Triangle	Square	Rectangle	Parallelogram	Right Triangle
Correct Answers	35	33	34	22	18
Incorrect Answers	0	2	1	13	17

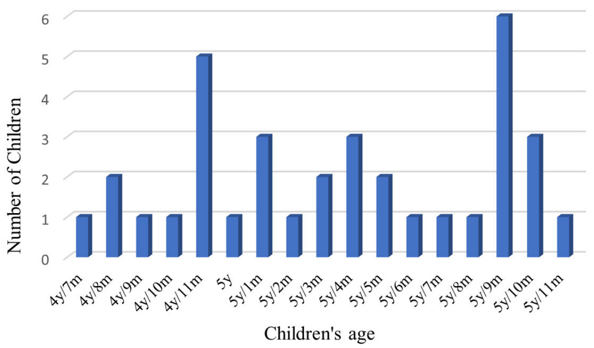


FIGURE 9. Number of children in each age category.

pre-test is to assess their knowledge of a number of geometric shapes appropriate to their ages so that the change can be studied after using the proposed solution. The results of this step showed that a large number of children had prior knowledge about the shape of triangles and squares. Also, as expected, no child had prior knowledge of the geometry of a right triangle, and no child answered the question about a right triangle correctly. Regarding the parallelogram, only two children answered the questions correctly. How children performed in the pre-test stage is shown in Table 3.

B. SIMULTANEOUS TEST

The simultaneous test was performed to assess the children's knowledge of geometric shapes after using the IoT device. At this stage, to assess memory acquisition, children were asked to recall the shapes they had been taught and then construct the shapes using different sensors. Table 4 displays the observational results of the simultaneous test. According to Table 4, all children correctly formed the shape of the triangle. Also, in constructing the shape of the right triangle (in the pre-test phase, all the children answered the questions incorrectly), 18 children correctly formed the shape with the sensor. The number of correct answers to the questions for all types of geometric shapes was higher than in the pre-test stage.

In order to evaluate the status of IoT technology intervention in children's learning, t-tests were performed and analyzed to compare pre-test and simultaneous test data and the significance of any changes in the acquisition of knowledge of geometric shapes. For increased precision, the means and standard deviations of children's outcomes were examined in the context of each intervention situation (Table 5). A comparison of the pre-test and simultaneous test groups revealed a statistically significant difference ($p = 2.82E\text{-}11$, $p < 0.05$). Also, the average number of correct answers in the simultaneous test ($M = 4.057$, $SD = 1.04$) showed that at this stage children performed better than in the pre-test stage ($M=2$, $SD = 1.095$). To further investigate on the differences between the results of the pre-test and simultaneous test, a chi-square test was employed to carefully evaluate children's responses to each question and the results of this are shown in Table 6. It shows in the pre-test, correct answers to the first three questions showed values of 77.14%, 60%, and 57.14%, respectively, while these rose to 100%, 94.29%, and 97.14% in the simultaneous test. Such figures were expected since most children of this age are familiar with simple triangles, squares, and rectangles. In this regard, the chi-square values indicate no significant difference between the correct answers to these questions in the pre-test and simultaneous test. On the other hand, only 5.71% and 0% of children in the pre-test answered questions 4 and 5 correctly, compared to 62.86% and 51.43% in the simultaneous test stage. The difference between the figures is in accordance with the chi-square values for questions 4 and 5, indicating a significant difference in terms of improvement between the two stages. Therefore, it can be said that teaching the geometry of shapes supported by the IoT device increases children's knowledge.

TABLE 5. Pre-test and simultaneous test statistical results.

Test	Mean	SD
Pre-test	2	1.095
Simultaneous test	4.057	1.04

C. IMMEDIATE POST-TEST

After using the IoT device, each child was asked to provide information about IoT devices using the Smileyometer, in response to the question "How enjoyable was it to

TABLE 6. Chi-Square analysis of pre-test and simultaneous test.

	Pre-test Correct Answers (%)	Simultaneous test Correct Answer (%)	Chi Square
Question 1 (Simple Triangle)	27 (77.14%)	35 (100%)	1.03
Question 2 (Square)	21 (60%)	33 (94.29%)	2.67
Question 3 (Rectangle)	20 (57.14%)	34 (97.14%)	3.63
Question 4 (Parallelogram)	2 (5.71%)	22 (62.86%)	16.67
Question 5 (Right Triangle)	0 (0%)	18 (51.43%)	18.00

TABLE 7. Children's responses to Smileyometer.

	How enjoyable was it to use the IoT device?				
	Brilliant	Really Good	Good	Not Very Good	Awful
Number of Children	10 (28.57%)	10 (28.57%)	9 (25.71%)	4 (11.43%)	2 (5.71%)

use the IoT device?''. Table 7 shows responses. Of the 35 boys, 10 (28.6%) said it was "Brilliant'', while a total of 29 (82.9%) chose one of the three positive responses ("Brilliant,'' "Really Good,'' "Good''). Only 6 boys (17.1%) thought it was either "Not good'' or "Awful.'' The mean score for the responses was 3.63, meaning it was considered "Really good'' when assessed using the Nunnally and Bernstein scale [30].

The children were also asked to report on the device using the Again-Again table: "Would you like to play again?'' Table 8 depicts the children's responses. The reported response of 62.86 percent of children was "Yes'', 20 percent was "Maybe'', and 17.14 percent was "No''. The Again-Again table output is also shown in Table 8. The mean score (descriptive statistics) for the responses to the Again-Again table was 2.46. Based on the results of the Again-Again table, the majority of the children desired to use the IoT device repeatedly.

TABLE 8. Frequency of children's responses to the Again-Again table.

	Would you like to play again?		
	Yes	Maybe	No
Number of Children	22 (62.86%)	7 (20%)	6 (17.14%)

D. DELAYED POST-TEST

The delayed post-test is performed to assess memory retention and it was carried out on the same children one week after the initial post-test. The results are presented in Table 9. The number of correct and incorrect answers for each type of geometric shape, at each stage of evaluation, is shown in Figure 10. The results indicate similar performance in the simultaneous test and delayed post-test which is a testimony to the positive effect of the proposed approach. Moreover, the difference between the results of the delayed post-test and pre-test indicates the durability of children's memory after one week. That said, in general, there was a slight fall in the results of the delayed post-test compared to the simultaneous-test which was expected.

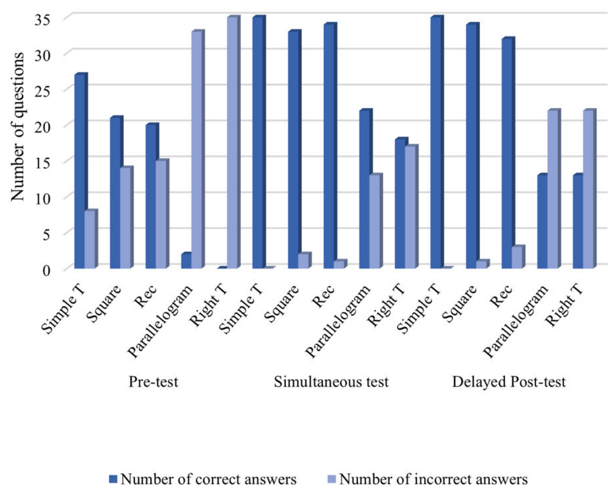


FIGURE 10. Answers to each test.

The analysis of the memory retention test based on mean and standard deviation in Table 10 shows the change in children's knowledge of geometric shapes before and after using the program. The results show that the average number of correct questions (out of 5 questions) has increased by 1.63. To determine whether the program used to teach geometric shapes to children has a lasting effect on children's memory, t-tests were used to compare pre-test and delayed post-test. The results also show that there is a statistically significant difference between the number of correctly answered questions after one week (delayed post-test) and the basic knowledge of children in the pre-test stage ($p = 3.84E\text{-}09$, $p < 0.05$). Therefore, it can be concluded that the implemented program is useful for teaching geometric shapes to preschool children.

TABLE 9. Number of children's correct and incorrect answers in identifying geometric shapes in the delayed post-test stage.

	Triangle	Square	Rectangle	Parallelogram	Right Triangle
Correct Answers	35	34	32	13	13
Incorrect Answers	0	1	3	22	22

TABLE 10. Pre-test and delayed post-test statistical results.

Pre-Test		Delayed Post-Test	
Mean	SD	Mean	SD
2	1.095	3.63	0.864

V. DISCUSSION

In this section, the main implications of the results are examined. It should be taken into account that this experiment is a gender-specific one which means findings are only applicable to boys. As mentioned earlier, analysis of the results in terms of both learning outcome and learning process provides us with important insights into the final impact of the proposed approach.

Examining the results of the simultaneous test and delayed post-test, positive impacts in terms of learning outcomes can be seen. To begin with, the t-test highlighted a significant difference between the results of these two tests compared with the pre-test. The change between the means of the simultaneous test and delayed post-test is additional testimony to the positive educational effect of the approach proposed in this paper. Specifically, a gap of 2.05 exists between the mean values of the simultaneous and pre-tests. This figure decreases to 1.63 when the delayed post-test and pre-test are compared. This drop could be predicted since there was a one-week delay between the teaching experience and the delayed post-test. However, the gap remained noticeable, which supports the contention that the approach has a positive impact. It is also worth mentioning that the positive feedback obtained relates to all aspects of the system. That is to say, apart from the ability to play with physical sensors, educational videos, divided into three stages (identification, recognition, and recollection) have been proven to be beneficial.

For the learning process, a total of 62.86% of the children showed a desire to use the system again, and a total of 82.86% of the children considered the proposed solution to be "good," "very good," or "brilliant." This, in turn, indicates that the overall process of learning seemed attractive and enjoyable from the children's viewpoints. However, while acknowledging that this indicates a positive attitude and that the children enjoyed interacting with the IoT approach, the figure for the number of children who chose only the middle value, "good," (25.71%), should be taken into account. The design of future approaches needs to take into account that a quarter of the children did not consider the proposed solution particularly enjoyable or attractive. The findings of the Again-Again question reveal that 17% of the children did not want to use the system again. The same number of children also chose "Not very good" and "Awful" as their Smileyometer responses. This could stem from different reasons. First, educational videos and physical devices might seem less attractive to them. Moreover, the results of the pre-test indicated that some of these children had background knowledge of basic geometric shapes, which may have led to their not finding the solution attractive enough to want to use it again. Having said that, 17% of the children are not large enough to consider major downwards to the proposed solution.

As mentioned in the literature review section, children's general attitudes toward geometry are negative. With the help of the approach suggested in this paper, this attitude can be targeted. To phrase it simply, if the learning process becomes more enjoyable for children, that negative attitude might gradually vanish. Apart from improving user satisfaction and enjoyment, this, in turn, will probably have more educational effects in the future when these children become students and attend geometry classes. Therefore, the approach can be beneficial in terms of both learning outcomes and the learning process.

VI. CONCLUSION AND FUTURE WORK

In today's world, although geometry education is of paramount importance and can lead to improvements in mathematical competence, teaching and learning geometry is at best limited or is even ignored in early education. Additionally, there seems to be a negative attitude among children toward learning such topics. This paper targeted this issue and proposed an IoT-based approach for learning basic geometric shapes in early childhood. In addition to sensors for creating geometric shapes on the table, the use of educational videos was added to the system. The proposed solution was assessed in terms of learning outcomes and the learning process and it proved to make the learning process enjoyable. Moreover, the approach showed a noticeable educational outcome. Finally, the proposed approach could make children pay attention to not only the entertainment part but also the educational part.

For future work, some considerations can be named.

- The future studies can target both genders and mixed-gender groups and investigate the suitability of the proposed method in each case.
- A bigger sample size would yield more reliable results.
- After learning the shapes, researchers can work on another aspect of these geometric shapes which is the topological relations between them with the help of IoT.
- Arising from the findings of previous research, as mentioned in the literature review, teachers' attitudes toward IoT-based approaches could be investigated.

- Long-term monitoring of children's performance in geometry when they become elementary students would shed additional light on the long-term success of such an approach.
- The DMW100 module used in this study seemed to lack sufficient precision when sensors were located very close to each other. Therefore, other approaches such as using ultrasonic sensors could be tested to see if they provide more accurate results.

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