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Playful Learning: Teaching the Properties of Geometric Shapes through Pop-up Mechanisms for Kindergarten

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Abstract

Teaching the properties of geometric shapes in traditional ways does not help children to understand them, nor does it enable them to visualize them. It may need methods that correspond to the characteristics and tendencies of children and more interesting methods based on fun learning. Designing 3D geometric shapes with children through pop-up mechanisms can offer a solution to their difficulties. Therefore, the current research aims to verify the current geometric thinking skills of children and the development of their geometric thinking skills in terms of distinguishing between the names of 2D and 3D geometric shapes and the properties of 3D geometric shapes after presenting a program based on the pop-up design mechanisms. The researchers developed a program to teach children to distinguish between the names and properties of 3D geometric shapes based on the design mechanisms that emerge. It has been called 3D through pop-ups in kindergarten children (3D POP-UP in KC). The research sample consisted of 12 children of (5:6) age groups. The study adopted the qualitative approach; data were collected through semi-structured interviews, observation, video recordings of children's handiwork, and photos during application. The results indicated that the participating children have a limited understanding of geometric thinking skills regarding the nomenclature and properties of 2D and 3D geometric shapes according to the results of the pre-test. It was also found that it is possible to teach them some geometric thinking skills such as distinguishing 3D and 2D geometric shapes and knowing their properties through the proposed program (3D POP-UP in KC). This result was shown in the difference between the children's scores on the pre-and post-test.

Introduction

The advanced math skills children learn in school are built on a strong foundation of early childhood math understanding. Children begin to form a basic understanding of mathematics even before their first birthday. They begin to learn about numbers, numerical relations, measurement, algebraic relations, and geometry. Mathematics is important in all its fields. Therefore, it should be introduced to children early, and not limited to a specific area.

Learning mathematics goes not only toward mastering numbers but also to other equally important aspects such as geometric concepts and relationships. For early childhood, geometry and spatial reasoning serve as the basis for learning mathematics and other subjects. Furthermore, knowledge of geometry concepts is essential in many real-life contexts (Sarama et al., 2006). Geometry is an important area of mathematics that supports the development of students' spatial sense and geometric thinking (Clements, 2004). It also supports their abilities to engage in geometric and spatial thinking and general mathematical and cognitive development. However, geometry is not always covered in early childhood curricula and is even included, and it is not explored in appropriate ways for children (Jatisunda, 2021). Given the importance of geometry in early education, the developmental early learning standards document mentioned five areas of mathematics that children should learn early, including geometry and spatial sense (Ministry of Education, 2015).

By focusing on teaching geometric shapes to children, we find that they help in acquiring and developing spatial skills that play an important role in learning mathematics and what they need for logical thinking and building relationships between different data (Badawi, 2004). Learning geometric shapes also helps the child to understand concepts such as forming a shape, lines, angles, the number of sides, and how to build on existing shapes, or arrange them in a certain space or a certain pattern. These are all skills that if the child acquires early, he will be able to perform better in mathematics (Badawi and Muhammad, 2021). By analyzing the curriculum (2.0) and the self-curriculum for the kindergarten stage in Egypt and Saudi Arabia, we find a complete absence of mathematics. Based on the observations and interviews that the researchers made with female teachers in Egypt and Saudi Arabia, it was found that the reality of teaching geometry in kindergarten classes focuses only on teaching the names of 2D shapes and the use of traditional educational methods based on paper, pencil, and drawing. This makes learning media lack the attraction and suspense necessary to attract children's attention. Presenting 3D and 2D shapes drawn on paper, the children confused their understanding of their properties, and they could not even distinguish between their names. For example, while interviewing the children: They were shown a shape (square, cube) one by one and asked the following question: What is the name of the shape in front of you? The child named a square on both shapes. Even with a real cube displayed, the child called it (square). He does not distinguish the difference between them although he sees 3D shapes daily and trades them while playing in the construction corner, for example.

Children always want variety and unfamiliarity while learning about things in general. Geometry concepts are a complex subject that needs to look for attractive ways to children so that they can absorb them based on understanding, not memorization. Therefore, the current research seeks to find an unfamiliar way that teaches children geometry in an attractive performance way to consolidate these concepts in their minds. Looking at the characteristics of children at that age, we find that they are attracted to things that have movement, color, sound, anthropomorphism, and other stimuli. Therefore, the pop-up design mechanisms were chosen because they have enough elements that are engaging enough to make kids wonder and research. Pop-up design mechanisms depend on the transformation of 2D shapes into 3D in easy ways that only need paper, scissors, and glue (Carter, Diaz, 1999). These tools are easy to handle with children.

Pop-up design mechanisms depend on building different angles such as acute and obtuse angles, tapered,

geometric shapes such as cubes and parallelograms, and spherical, curved, and hierarchical shapes (Birmingham, 2010). The researchers believe that designing pop-up mechanisms with children can indirectly contribute to understanding the properties of 3D geometric shapes. The child himself will build the geometric shape with the teacher, and in the presence of dialogue and discussion about shape formation, the properties of 3D geometric shapes can be understood. According to Rahmawati and Rukiyati (2018), Pop-up books are effective media to improve cognitive ability in children aged (4-5 years). Also, Muhammad and Ismail (2022) confirmed that adding the element of color, movement, and anthropomorphism to children's educational media makes them more attractive and adds a great value to them, and the same applies to pop-up books.

Therefore, the researchers seek to use some pop-up mechanisms to teach children 3D geometric shapes in a performative manner. These mechanisms are designed with the child so that they develop their understanding of some geometric thinking skills early and performatively, and not as followed in traditional teaching methods, where the names of geometric shapes and some of their properties are repeated, so deaf memorization is done as a result of repetition. The children's design of the geometric shape manually is an attempt to follow the correct ways to present 3D geometric shapes to avoid the occurrence of false learning. In addition, this is an attempt to establish properly some of the marginalized geometric concepts in the content of the curriculum (2.0) and the subjective curriculum for kindergarten.

Statement of problem

By analyzing the mathematics curriculum for kindergarten in Egypt and Saudi Arabia, which are very similar in content, the following was found:

First: Curriculum 2.0 deals with mathematics in the following units: counting, operations, and algebraic reasoning, numbers, and operations in the decimal system, measurement, geometry. Each unit includes several lessons explained in an explanatory manner in the teacher's guide. The weaknesses are also evident in the child's workbook "Kindergarten Discover Term2", the Egyptian Ministry of Education and Technical Education (EMETE), (2018/2019). They are blank pages on which the child applies what is in the teacher's guide. Therefore, it is not compatible with the content of the guide in terms of the number of activities or the way they are formulated. As for geometry, it is a very weak part that depends on drawing geometric shapes, knowing their names without recognizing their characteristics in a manner appropriate to the child's age, and ignoring the sensory aspect of children to understand of geometric shapes. The shape is drawn from one direction so it is difficult for the child to distinguish the faces and angles of the shape, and thus the child confuses between 2D and 3D.

Table 1. Geometry Content in Curriculum 2.0 (EMETE, 2018/2019)

Unit	Content
Geometry	<ul style="list-style-type: none">• Describe the geometric shapes in the environment using the names of the shapes.• Correct use of the terms of up, down, next to, in front of, behind, next to.• Name 2D shapes (triangle, circle, rectangle, square).• Create larger shapes by merging simple shapes.• Match and categorize 3D shapes.

Second: The subjective approach: Attention is focused on numbers, classification, and arrangement. There is no interest in the field of geometry despite its explicit presence in the developmental learning standards (Ministry of Education, 2015). Also, there is no stand-alone math content but implicit within the educational units. By analyzing five educational units (National U1, Water U2, Sand U3, Food U4, Home Life U5), directed to kindergartens, it was found that mathematics are items within the activities, not stand-alone content. The geometry content is almost hidden.

Table 2. Geometry Content in the Self-curriculum Units (Ministry of Education, Kingdom of Saudi Arabia, 2015)

Unit	Content
U1 N	• No geometry content
U2 W	• The designation of 2D geometric shapes (triangle, circle, rectangle, square).
U3 S	• 2D geometric shapes.
U4 NU	• 2D geometric shapes.
U5 L	• Arranging 2D geometric shapes by model.

Studies show that geometry is one of the subjects with the lowest performance levels in the mathematics curriculum (Novita, 2018; Elia, & Gagatsis, 2007). This was confirmed by the results of analyzing the (0.2) curriculum and the subjective curriculum for the kindergarten stage. Also, the geometry content in both the Egyptian and Saudi curricula is weak.

In addition, how the geometry is presented does not suit the characteristics of children, which may cause them confusion. Eventually, it may lead to deaf education without understanding. Given the importance of learning geometry early on, many studies have presented attractive approaches to teaching children geometry such as the use of techniques and technology, tangrams, pop-up books, and fun learning (Crompton, Grant, & Shraim, 2018; Rahmawati, & Rukiyati, 2018; Blaisdell, et al., 2018). This notion was also confirmed by the interview of Egyptian and Saudi female teachers about teaching geometric shapes.

Excerpts from answers by Egyptian teacher (ET) and Saudi teacher (ST) are given below:

- Do children study geometric shapes?

- *Yes only names of 2D shapes (ST)*
- *Some forms of 2D (ET)*

- What geometric shapes are taught to children, and in what way are they presented to them?

- *The basic shapes (triangle, square, circle, rectangle). As for the shapes like cube, semi-cube, pyramid, hexagonal, and pentagonal, they do not know them, and we teach them on the whiteboard or repeat the name of the shape to be memorized (ST).*

- 2D shapes such as square, triangle, and circle, and some names of 3D shapes such as ball, by drawing and

sometimes forming with materials and sometimes repeating the names (ET), Is the teaching oral, or does it use models?

- *It depends on the teacher's diligence. Some teachers bring models and ask the children to feel the shape, and some only have a picture and the name of the shape. Because there is no lesson or unit about geometric shapes (ST), (ET).*

- *The teacher reads the teacher's guide and prepares the lesson according to her understanding. The child applies it in another book called Discovery, which is white pages in which only the geometric figure is copied and its name is repeated. (ET)*

- Is the child taught the properties of geometric shapes, how many sides? How many faces? How many angles? How many heads?

- *We can mention the number of sides in 2D geometric shapes. As for the faces, I don't remember because we only teach them the 2D shapes. As for 3D, we don't talk about them, nor about the angles and their types, or how many heads (ST)).*

- *There is no focus on the properties of geometric shapes, whether 2D or 3D, only the child draws the shape and memorizes its name (ET).*

- Are there lessons in the educational units about geometric shapes?

- *There is no current subjective curriculum in which there is no lesson title about geometric shapes. This is the teacher's diligence or its intervention as a linguistic term such as the letter (m), a triangle, or a square. It can be said that the content of geometry in the curriculum is very poor (ST)).*

- *There is no activity book for the child, only a guide for the teacher and in English, this is the curriculum (2.0), and the teacher must understand it and try to convert it into activities for children. As for the Discovery book, it is white pages in which the child draws only. There is no mathematics content in the understandable sense (ET).*

Based on the highlighted research problem, the main research question is formulated:

- Can children be taught the properties of 3D geometric shapes through pop-up design mechanisms?

The following sub-questions emerge from this question:

1. What are the current 2D, 3D geometric thinking skills of children?
2. Does children's knowledge of 3D geometric shapes change if they are presented during activities based on pop-up design mechanisms?

Objectives of the Study

- 1- Verifying the current 2D and 3D geometric thinking skills of the children in the research sample.
- 2- Verifying the development of 3D geometric thinking skills after presenting a program based on the pop-up design mechanisms.

Significance of the Study

The study is significant in directing the attention of officials in the Ministry of Education in Egypt and Saudi Arabia to the importance of including a mathematics curriculum in the kindergarten stage. Also, they need to pay special attention to geometric thinking skills while enhancing the mathematics curriculum with teaching aids for 3D geometric shapes. In addition, teachers' attention is directed to the development of interactive media to teach 3D geometric shapes through pop-up design mechanisms.

Theoretical Framework

Geometric Thinking Skills in Kindergarten

The primary goal of early mathematics education should focus on building mathematical awareness and developing a beginning understanding of mathematical concepts. The quality of early childhood mathematics education is an important issue of global concern for decades. Early childhood experiences have long-term impacts and implications for children's learning in the future. They also have an impact on achievement in mathematics and other subjects as well as in real life (Jordan, et al. 2009; Reyna, et al., 2009).

Geometry as a mathematical content in early childhood curricula is important for understanding the real world. However, geometry and spatial reasoning do not play an important role in the practice of early childhood mathematics education (Rittle-Johnson, Zippert, & Boice, 2018; Sarama and Clements, 2009) although every child has the opportunity to discover geometry in the environment during their daily life (Clements & Sarama, 2011). Every day, the child deals with many things that have geometric shapes. An orange and a watermelon are spherical in shape. The tires are circular. The egg is oval. The TV screen is rectangular as well as the room doors. Thus, most of what the child deals with and sees may have a geometric shape. Knowing this shape helps to find relationships and classification. Therefore, these forms must be explained to him through a tangible means (NCTM, 1989, p. 49). NCTM adds that the child can perceive the things around him. Geometry also develops a sense of space, which is called perception or spatial perception. This helps him to understand the relationship between things and their position in the 3D world (p. 49). According to NCTM (2000), geometric thinking provides an environment for identifying, understanding, and classifying geometric objects, understanding geometric relationships, and visualizing geometric shapes.

Pierre Van Hiele and his wife introduced the so-called "Van Hiele" theory, which was based on two studies of the difficulties students face in studying geometry. The study indicated that geometric thinking and geometry learning proceeds at successive levels that include growth in the methods and quality of thinking (Obeidat, 2010). Van Hiele (1999) also emphasized that the geometry taught to children must be appropriate to the level of geometric thinking of the children and appropriate to the children's readiness. In addition, Piaget also suggested considering geometry experiences appropriate for children. A study by Türker Sezer and Güven (2019) indicated that age makes a difference in children's geometry skills, and children between the ages of 5 and 7 have no difficulty distinguishing between geometric shapes. Further, Verdine et al. (2016) revealed that 25 to 30-month-olds move from showing little understanding of the names and properties of most geometric shapes to identifying specific

basic shapes. The study found that promoting an early understanding of geometric shapes became a critical aspect of preparing young children for school. This work provides new information about when and how children learn about geometric shapes.

According to Novita et al. (2018), understanding geometry and spatial reasoning is an essential area for learning mathematics. They serve as a basis for learning mathematics, especially for kindergarten children. Unfortunately, early education and professional development for early childhood educators are often overlooked or underestimated. This may be due to the lack of activities that involve geometric thinking in the world around them. Van Hiele believes that one of the difficulties of geometry is partly due to the teacher. The sense that the language used in teaching geometry is a very important factor that he calls the "Language Barrier". Each level of geometric thinking has its language that students understand (Al-Sadiq, 2001). According to Sarama et al. (2006), knowledge of geometry concepts is essential in many real-life contexts not only in its own right but also for the supporting roles it plays in learning algebra, number concepts and skills, and arithmetic. By learning geometry principles, students develop skills in reasoning, justification, interpretation, and description of physical environments (National Mathematics Advisory Panel, 2008). Therefore, it is necessary to introduce geometry at every age, description, and year of education, especially in early childhood (Sarama et al., 2006).

Pop-up Design Mechanisms as a Playful-learning-based Strategy for Teaching Three-dimensional Geometric Shapes

The method of learning and teaching leaves a strong mark on children. Many children take a dark view of the material or education because the teacher fails to use an interesting method that achieves pleasure and benefit at the same time and convinces children of the importance of educational content. Hence, the importance of playful learning is to add joy to the educational process. It provides playful learning spaces for children and researchers so that they can work together to discover fun and interest simultaneously.

Teaching mathematics, especially geometry, at an early age requires an introduction to learning based on fun and enjoyment so that children feel the enjoyment and desire to learn. According to van Hiele (1999), geometry begins with playful activities such as the use of mosaics, paper folding, drawing, and pattern blocks that can enrich children's visual constructions and enhance their knowledge of shapes and their names. According to Blaisdell et al. (2018), children's playfulness can be exploited to support learning. Lucas (2021) also aimed to explore the extent to which gamification affects the learning and teaching of geometry.

Doing research with young children may be a process that does not follow a specific pattern or order. The use of open, fun-based methodologies has helped to engage children energetically. Fun-based learning can lead to a holistic research experience for children, especially since research methods reflect and value children's interests. Fun-based learning also supports a reflective and emotional approach and learning in multiple ways (Brown & Perkins, 2019). One of the playful learning methods is to use children's ideas and perceptions to ask questions about the subject of learning, which can be inspired by their drawings and the Ideas Club. It is an activity that focuses on children's ideas to explore school readiness in ways that violate the principle of measurement and the

principle of dealing with children as research elements. It also includes the use of a wide range of resources such as picture books, toys, clay, and consumables. These ideas are often far from formal and usually provide valuable talking and playtime outside the formal school day (Brown & Perkins, 2019).

The current research adopted the pop-up design mechanisms as a new strategy based on playful learning in which children can use colored paper and carry out folding, cutting, and pasting operations, and notice the transformations that occur for geometric shapes from 2D to 3D. Through dialogue, discussion, and actual practice, they can learn about the properties of 3D geometric shapes. The adoption of pop-up design mechanisms on different geometric shapes and the possibility of employing them in projects such as designing a fish, a boat, an airplane, a house, or a pyramid (Bluemel & Taylor, 2012; Carter and Diaz, 1999). This makes learning fun and exciting for kids and contributes greatly to learning about geometry.

Muthmainnah, Ismah, and Ramadha's (2019) study aimed to develop interactive media for teaching 3D geometric shapes through pop-up books for children. Pop-up books have moving parts and present information in form of an interesting picture because there are parts that can move, change, or shape when the book is opened based on its shape and motion. This is where playful learning comes in. The teacher will suggest to the child to build a design such as a house, a boat, or a train). Each design includes a specific geometric shape. During the design, the child learns the properties of the geometric shape and uses them in building the design. According to Bluemel and Taylor (2012), there are about 18 pop-up mechanisms such as V-folding, parallel folding, zigzag folding, M-folding, plane surfaces, boxes, and parallel, curved, and hierarchical folds. All of them may be symmetrical or asymmetric folds (Bluemel & Taylor, 2012). It is worth noting that all these mechanisms are just geometric shapes that enter into the construction of the various designs. The current research will be limited to teaching children the properties of the following geometric shapes: the cube, the cuboid, the pyramid, and the cone through pop-up mechanisms that employ these mechanisms in simple projects that suit the characteristics of children.

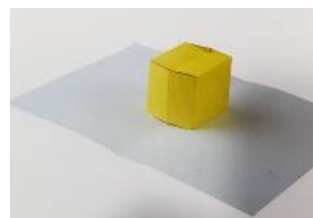
Mechanisms used in Teaching Children Geometric Shapes

The current research was limited to the use of three pop-up mechanisms:

1- Box: A simple cube made of four pieces of paper. This mechanism has been used to teach the properties of cubes and semi-cubes to children. Parameters trained on the mechanism through a tutorial and employed in building a boat:

<https://www.youtube.com/watch?v=iCo2YMMz6X0>

<https://www.youtube.com/watch?v=FzMykSSEVkc>



Box (Bluemel & Taylor, 2012)

2- Pyramids: The current research was limited to the quadrilateral pyramid to teach the properties of the pyramidal shape. The teachers were trained on it through an educational lesson and employed in building a tent:



Pyramids (Bluemel & Taylor, 2012)

<https://www.youtube.com/watch?v=4turSVG8grk>

3- The cone: It is the simplest hierarchical form. It was used to teach the properties of a cone. The teachers were trained on it through a tutorial and employed in constructing sentences.

<https://www.youtube.com/watch?v=WBKCRLn-ni0>

<https://www.youtube.com/watch?v=l5nIJtgMDaI>



Cone (Bluemel & Taylor, 2012)

Methodology

The current research explores the possibility of employing pop-up design mechanisms in teaching kindergarten children the properties of 2D, D3 geometric shapes. Enhancing children's abilities at an early age to learn geometry is linked to the school curriculum and a problem shared by many countries in the Middle East. Therefore, the research analyzed mathematics in the Egyptian and Saudi curricula as a model for curricula in the Middle East to find out more about the dimensions of the problem and try to find a solution based on what was mentioned in previous studies that raised the same problem in other countries. According to the theoretical framework, the research attempted to clarify the importance of teaching geometry early to children.

Research Design

The research adopted a qualitative approach that aims to describe and interpret the practices followed during the implementation of activities based on pop-up mechanisms to develop geometric thinking skills. The instrumental case study was used to help to gain a deeper understanding of the content of the specific kindergarten curriculum.

Population and Sample of the Study

The research was carried out in the third school for early childhood in Hofuf, grades of kindergarten and Saad Zaghloul School in Tanta - Egypt from February to May 2022. Teachers' interviews were also held in the same schools. The research sample consisted of (12) children of the age groups (6:5) years, (6) children of the second level at Saad Zaghloul School in Tanta - Egypt, and (6) children of the second level kindergarten from the third school for early childhood in Hofuf - Kingdom of Saudi Arabia and (14) female teachers.

Instruments of the Study

The focus was primarily on developing children's abilities to distinguish and characterize 2D and 3D shapes:

1- Program (3D POP-UP in KC): 3D geometric shapes to be presented in the activities were identified (cube, Cuboid, pyramid, cone). Each geometric figure was introduced one by one in specific steps. Children were allowed to examine geometric shapes and encouraged to talk about them and similar shapes they had seen or played with. All selected figures were presented with the same cube activity steps as shown in Table 3.

Table 3. An Example of the Activities implemented in the Program (3D POP-UP in KC.)










Geometric shape (subject of the activity)	Time	Steps
Cube	- 40-50 minutes, one session per week, for 4 sessions	<p>Activity 1:</p> <p>1-A cube was shown to the children, and they were asked about its name and properties, then a square was shown, and they were asked about the difference between a cube and a square.</p> <p>2- Providing tools (colored paper, glue, pen, ruler). Is it possible to make a cube from these tools?</p> <p>3- The two researchers cooperated with the children in the steps of paper cutting to prepare the shape of the pop-up cube.</p> <p>4- Helping children in folding the faces of the cube, and then sticking it on the card.</p> <p>5- Coming up with a product and discussing with the children about the properties of the cube again.</p> <p>6- Ask the child:</p> <ul style="list-style-type: none"> -Mark the faces of the cube and count them. -Color the cube heads and state their number. -Touch the sides of the cube and say their number. -Explain the difference between a cube and a square. <p>Activity 2:</p> <p>-Presenting the same tools to the children and reminding them of the steps taken in the previous activity, and discussing with them the properties of a cube and the difference between it and a square. Then, they are asked to perform the steps on their own with the assistance of the researchers. Here, the child is asked to feel the faces, angles, and heads and pronounce their names while working.</p> <p>Activity 3: the same procedures in the second activity with less help from the researchers.</p> <p>Activity 4: Employing the cube resulting from the design is based on the cube shape such as a boat, a house, and discussing with the children about the properties of the cube again.</p>



2D & 3D Geometric Shapes Test

The test was built for the pre and post application as shown in Table 4.

Table 4. 2D & 3D Geometric Shapes Test

N	The first question: What is the name of the geometric figure?	Mark	N	The second question: About the properties of 3D geometric shapes	Mark
1	 (S)  (C)	2	6	How many faces/square are in the figure (C)? How many sides are in this shape (C)? How many heads are in this shape C?{(What is the difference between square (S) and cube (C)?	4
2	 (R)  (CU)	2	7	How many faces/rectangles are in the shape (CU)? How many sides are in this shape (CU)? How many heads are in this figure (CU)? What is the difference between a rectangle (R) and a semi-cube (CU)?	4
3	 (T)  (QP)	2	8	How many faces/triangles are in the figure (QP)? How many sides are in the shape (QP)? How many heads are in the figure (QP)? What is the difference between a triangle (T) and a pyramid (QP)?	4
4	 (CI)  (B)	2	9	Does the ball (B) have sides? Does the ball have angles? What is the difference between circle (CI) and ball (B)?	3
5	 (CO)	1	1	How many bases in the figure (CO)? 0 How many circles are in the figure (CO)? How many heads are in the figure (CO)? Is there a similarity between the shape (CO) and the shape (T) and (CI)	4
Total					28

Data collection

To achieve the study objectives and answer the research questions, data were collected from different types of instruments:

- Semi-structured interviews: The semi-structured interviews were relied upon to reveal the teachers' methods in implementing geometry activities with the children and their opinion on the curriculum presented to the children, as well as with the children to record their discussions and dialogues before and after the program.
- Observation, audio recordings, videos, and photographs during the application of the test and activities.
- Children's handicrafts while carrying out activities.

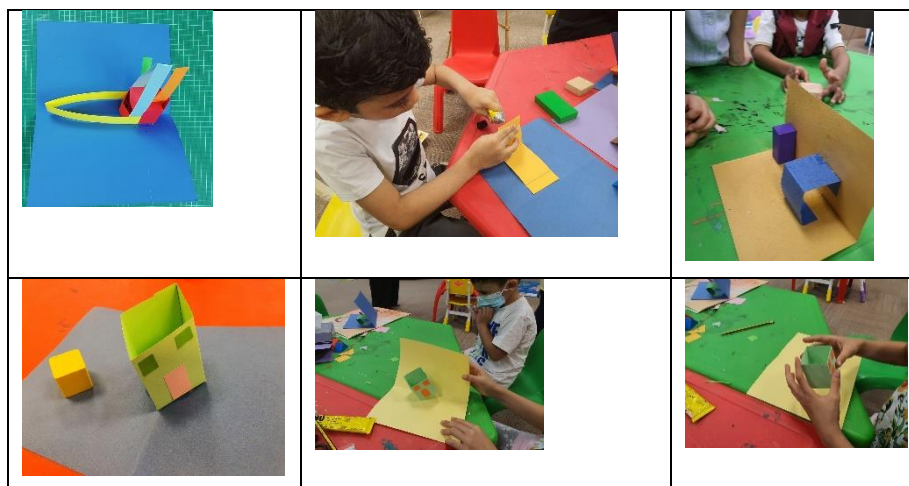


Figure 1. Examples of Designs implemented - Cube and Semi-cube - with Children the Mechanism of the Box

Data Analysis

Upon the completion of the fieldwork, there was a large amount of data obtained from content analysis, teacher interviews, program activities (see Table 3), in-work notes, audio and video recordings, and discussions with children. Verbatim texts, especially those in conversations conducted before, after, and during program implementation were also analyzed. The video recordings of the children were transcribed, and their answers to each task were coded, and then the relevant codes were collected for the reliability of the encoding operations. Then, the answers were analyzed separately and discussed by both researchers. The results of the pre and post-test (see Table 4) were also collected and analyzed to determine the changes in children's knowledge and awareness of the differences in the characteristics of 3D and 2D shapes. The analysis was based first on evaluating the children's changing knowledge about the properties of geometric shapes and their understanding of the properties of 2D and 3D shapes based on the pre and post-tests and activities carried out to answer the research questions.

Results

The first question: What are the current two- and three-dimensional geometrical thinking skills of children?

To verify the current geometric thinking skills of children, the geometric shapes test, Table (4), was built based on what is already present in the Egyptian and Saudi curricula. It was found that the two curricula provide the names of 2D geometric shapes (square, triangle, rectangle, circle) and 3D (cube, sphere). By meeting the teachers from both groups, they agreed that the geometric shapes are presented in traditional ways such as colored pictures in the activity book, or drawings on the board with the repetition of the names. As for presenting 3D geometric shapes through stereoscopic models or real models of the environment, this varies from one teacher to another. Geometric shapes were presented in the children's pretest in the same traditional ways. The children's responses were on several domains: the names of 2D and 3D geometric shapes, the distinction between them, and the specification of the characteristics of specific 3D geometric shapes. The results of the pretest were according to Table 5.

Table 5. Results of the Pretest for Children (N12)

The first question: What is the name of the figure in front of you?			
N	Geometric shapes	Qualitative analysis of children's answers	% Researchers' analysis
1.	(S) -(C)	12 children named the two shapes square.	0
2.	(R)- (CU)	10 children named the two shapes a square. 2 of the children identified the R shape but did not all identify the CU name.	0
3.	(T)- (QP)	12 children named the two shapes a triangle.	0
4.	(CI)- (P)	9 children gave a correct answer. 3 children called the two shapes a circle.	75
5.	(CO)	The children never knew the name of the shape. 4 Call out words like stationary, kono, traffic light cones.	0
The second question: the characteristics of the 3D geometric shapes mentioned in Table 5			
N	Geometric shapes	Qualitative analysis of children's answers	% Researchers' analysis
6.	(C)	12 children did not distinguish any of the properties of the cube.	0
7.	(CU)	12 children did not distinguish any of the properties of a semi-cube.	0
8.	(QP)	12 children did not distinguish any of the characteristics of the pyramid.	0
9.	(B)	12 children did not distinguish any of the properties of a spherical cube.	0
10.	(CO)	Twelve children did not distinguish any of the properties of a cone.	0

Children's perceptions and thinking about the names and properties of 3D and 2D geometric shapes are very complex. This calls for the need to research teaching geometry in kindergarten, especially since it is present within the curriculum provided to them as well as the mathematics standards directed to the same stage. According to Jone (2002), the development of spatial awareness, geometry intuition, perception, knowledge, and understanding of properties of 3D geometric shapes can be achieved through geometry education. Therefore, the current research verified the reality of 3D and 2D geometry education at this stage. According to Table 5, children's experiences with 2D and 3D geometric shapes are very weak. There is confusion in the names of the geometric shapes; the word square refers to a rectangle, a cube, and a semi-cube. Also, the pyramid is the same triangle. However, the children were able to distinguish the name of the spherical and circular shapes (75%). This may be due to the abundance of this shape form in their environment and games. The same thing happened with the shape of the cone. Four children gave names from the environment, but not the geometric name of the shape. As for the properties of geometric shapes, they do not exist at all, and this may be due to teaching methods and methods of displaying topics in the curriculum.

The second question: Does children's knowledge of 3D geometric shapes change if introduced through pop-up design mechanisms?

To answer this question, a program (3D POP in KC) in Table 3, and test geometry in Table 4 were designed. The focus, here, is on distinguishing between the nomenclature of specific geometric shapes and defining the properties of 3D geometric shapes (number of faces, sides, heads). The results indicated that the children's ability to distinguish between 2D and 3D geometric shapes and identify the characteristics of 3D shapes increased between the pre and post-test according to Table 5 and 6.

Table 6. Children's Posttest Results (12 N)

The first question: What is the name of the figure in front of you?				
N	Geometric shapes	Qualitative analysis of children's answers	%	
			Researchers' analysis	Change before and after the test
1.	(S)-(C)	12 children answered correctly	100	100
2.	(R)-(CU)	10 answered correctly.	90	90
3.	(T)-(QP)	12 answered correctly.	100	100
4.	(CI) -(B)	12 answered correctly.	100	25
5.	(CO)	9 answered correctly.	75	75
The second question: The characteristics of the 3D geometric shapes mentioned in Table 4				
N	Geometric shapes	Qualitative analysis of children's answers	%	
			Researchers' analysis	Change before and after the test
6.	(C)	10 identified the number of faces, heads, and sides and stated the differences between a cube and a square.	83	83
7.	(CU)	10 identified the number of faces, heads, and sides and stated the differences between a rectangle and a semi-cube.	83	83
8.	(QP)	11 identified the number of faces, heads, and sides and mentioned the differences between a triangle and a pyramid.	92	92
9.	(B)	2 mentioned that the ball has no sides or corners and has one face.	17	17
10.	(CO)	6 identified the number of faces and heads, and added details such as it has a base and a vertex as well as representations from the environment.	50	50

Children's responses before and after the program were. According to Table 6, children can distinguish between the names of the specified geometric shapes after the program. However, their abilities in determining the properties of 3D geometric shapes varied. The program (3D POP-UP in KC) provided children with opportunities to practice building geometric shapes. This enabled them to understand the properties of 3D shapes and gave them experiences with using geometric tools and measuring and helping each other out. At the beginning of the program, there was training to distinguish between the names of 3D and 2D shapes and then compare them with models of blocks, then training on the process of building 3D shapes using pop-up mechanisms. The results concluded that children could distinguish 3D and 2D shapes, and build 3D, 2D shapes. This is consistent with the results of Öcal and Halmatov (2021), which confirmed the possibility of enhancing geometric thinking skills such as identifying 3D geometric shapes and determining their properties through a program designed for this purpose.

According to NCTM (2000), children from preschool through second grade can distinguish names and structures, compare 3D objects, explain properties of 3D geometric shapes, and guess and investigate what will happen if parts come together or separate. This result is consistent with the findings of the current research; the participating children were able to name and distinguish 3D and 2D geometric shapes and know the properties of 3D shapes after they were presented to them during the program. This result is in line with the results of Öcal and Halmatov (2021), which confirmed the possibility of enhancing geometric thinking skills such as distinguishing 3D geometric shapes and determining their properties through the 3D in EC program. Children also mastered other skills such as measuring, symmetry, and determining direction with words such as beside, up, and down. In addition, they have improved spatial sense compared (see Figure 2).



Figure 2. Examples of Activities carried out with Children

The results of this research also revealed that children focus on determining the number of faces and heads in the specific 3D geometric shapes, and use the words vertex, face, and side more than using the words angle and edge. The pop-up mechanisms gave them opportunities to measure face length, determine the number of heads, and correlate and compare face measurements in 3D and 2D geometry. These skills did not exist before the application. Table 6 shows an improvement in children's responses to the properties of 3D geometric shapes. They could answer questions that refer to the properties of 3D geometric shapes due to the application of the program. It was an exciting and interesting experience for them as if they were making a game. They also dealt with geometric tools with remarkable skill such as the ruler, the pen, and the eraser, making measurements, cooperating, and

transferring experiences among themselves. Children could easily identify 3D shapes. They can now count heads, faces, and angles. Even with weak responses such as the properties of the ball and cone, there is a marked improvement. It just needs more time and training.

Discussion

The current research identified activities based on pop-up mechanisms to teach children the names of 3D and 2D geometric shapes and the properties of 3D shapes. The above pretest showed limited understanding regarding the nomenclature of 3D and 2D geometric shapes as well as 3D properties. The researchers attributed this result to the weakness of the content provided in the curricula and the methods of teachers in presenting them. By analyzing what the teachers mentioned during the interviews, there is no clear approach to geometry, and teaching is personal diligence that falls on the teacher. Therefore, there is no clear plan for teaching geometry, and this was confirmed by the content analysis. The current research highlights an innovative way to improve the geometric thinking skills of children based on practice and work with them.

The presented activities showed several important conditions for children to understand the differences between 3D and 2D shapes and know the properties of 3D shapes. The most important is that the child himself creates the 3D geometric shape, holds the paper, and cuts, folds and pastes. The 3D shape is made of a flat sheet of paper. He touches with his hand the angles, sides, and heads, counts and checks them. The pop-up mechanisms provide the child with a golden opportunity to learn about the properties of geometric shapes impressively and attractively so that the child can never get bored. He is excited all the time to see the figure pop.

The results also showed the need to continue training in the proposed program to continue improving children's skills. Over time, the children showed the ability to cooperate and transfer experiences among themselves and use the names of 3D and 2D geometric shapes correctly in the discussion sessions. In addition, they were able to express in words their understanding of what they were doing. This result did not exist before the program. This result is in agreement with Öcal and Halmatov (2021). The results showed that the children could not name the 3D shapes before the training, and they preferred to use the names of the specific 2D shapes instead of the actual names. They explained that their teacher taught them this. The children were also much better and could clearly express their understanding of the properties of 3D shapes after the training.

Finally, it can be concluded that more research is needed to determine the generalizability of these results. However, it can be argued that good learning opportunities may be more important than the developmental level when it comes to children's knowledge of geometric shapes (van Hiele, 1999). Many studies also seem to agree that geometry teaching begins early because concepts for young children remain stable after six years of age without necessarily being accurate (Clements & Saramas, 2000). Moreover, the findings of this study are consistent with van Hiele's (1999) study in the idea that to develop accurate concepts, teachers must provide appropriate education to the level of geometric reasoning for children. To achieve this, teachers need to extract, reveal and use elementary knowledge of the forms that children entering primary school already possess. They should also build on the children's ideas.

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