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Use of Origami in Mathematics Teaching: An Exemplary Activity

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Abstract

Students' attitudes and motivations toward mathematics decrease as they intensively confront cognitive information along the process of mathematics teaching in general. One of the most important reasons for this is the lack of activities for affective and psychomotor domains in the mathematics teaching process. One way to overcome this problem is to include activities through which students can participate effectively in the teaching process. For example, activities performed using origami can be one of them in teaching the attainments covered by the field of geometry learning in mathematics curriculum. Therefore, this study was carried out to present an exemplary activity about how origami can be used when teaching mathematics in secondary schools and to identify preservice teacher opinions on this activity. The activity presented in this study was performed with 32 preservice elementary mathematics teachers attending the faculty of education at a university and taking the Mathematics Teaching with Origami course, and their opinions were taken afterwards. At the end of the application, the preservice teachers stated that such activities would have very positive contributions to students' mathematics learning. In addition, the preservice teachers communicated and exchanged ideas with each other during the application. It is therefore recommended to use such activities in mathematics teaching.

Keywords: Mathematics teaching, Origami activity, Mathematics teaching with origami, Preservice mathematics teacher, Use of Origami, Opinions about origami.

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Contents

Contribution of this paper to the literature
Given the potential the potential of origami in mathematics education, it is important to development of activities concerning the use of origami in mathematics teaching. This paper will provide important contributions to the literature as it offers an exemplary activity on the use of origami in mathematics teaching.

1. Introduction

Mathematics, which is taught as a basic and weighted course throughout all years of education from elementary to the end of secondary education, is regarded by students as a course that is abstract and hard to be understood. One of the reasons why mathematics is perceived as an abstract and difficult course may be that mathematical concepts and rules are presented to students in a way they can memorize directly them and that efforts are made only to reinforce them. According to most teachers, success in mathematics means being able to use formulas, rules and methods instantly and properly and do the calculation in a right way today (Soylu & Aydın, 2006). In other words, when teaching mathematics in traditional teaching processes, the information is readily presented, and then, solutions with predetermined single correct answers that require to use the learned information are performed. In such an educational environment, it is difficult for students to acquire the skills and attainments foreseen by the mathematics curriculum (Inan, 2006). Thus, many students are not aware of the mathematical concepts underlying the operations they use when solving a mathematical problem or question and what mathematics actually means. Indeed, students think of mathematics learning as doing operations by using meaningless formulas and symbols and try to learn mathematics by rote learning (Oaks, 1990; Soylu & Aydın, 2006). As a result, students find it difficult to perceive the characteristics of the concepts they have learned and associate them with other concepts (Yılmaz & Yenilmez, 2008). Mathematics teaching should be carried out efficiently to overcome such problems. If it is intended that students learn a mathematical concept meaningfully and retentively, they should be allowed to ask questions about the concept, exchange views with others and perform activities. As it is known, students learn best by doing and experiencing. Then, by selecting the appropriate tools and materials, classroom environments should be designed to ensure that students can be active in the learning process (Türksoy & Taşlıdere, 2016). In other words, the teacher needs to prepare appropriate learning environments that will be effective in the students' learning process and to help them guide their own learning processes, discover and structure the information by ensuring their active participation (Akpınar, 2010; Baki, 2008; Köğce, 2017; Köse, Ayas, & Uşak, 2006). Furthermore, teachers are expected to select and use appropriate materials that will help students materialize the concepts when teaching mathematical concepts that are abstract by nature (MEB, 2018). Teyfur (2011) states that effective teaching environments can be prepared by using the proper tools and activities, and consequently, objectives of the curricula can be achieved more easily. Moreover, according to Oztap, Ozay, and Oztap (2003) the hand-made activities which students perform themselves by actively participating in them during the course enable them to learn the concepts better. The standards of NCTM (2000) also emphasize that mathematical models, tools and materials should be used for allowing students to take a more active role in mathematics teaching processes. Learning environments using different teaching materials allow students to study the concepts which have been previously investigated, express their ideas in a clear way, explore some of the new features of the concept, discuss and make their information meaningful (Inan, 2006).

Students can achieve easier and retentive learning by introducing tangible outcomes in the course process (Wittrock, 1992). In the mathematics curriculum which started to be gradually implemented as of 2005 and revised later in Turkey, it is recommended to associate mathematical concepts with real and tangible experience and to attach importance to conceptual learning. Accordingly, it is stated to be important and necessary to use tangible materials as much as possible in the teaching of new concepts and in evaluations to be made when teaching mathematics in primary and secondary schools (MEB, 2018). Furthermore, the necessity and importance of using many tangible models and materials for teaching the mathematical concepts is emphasized in the literature (Bozkurt & Polat, 2011; Bozkurt & Akalın, 2010; Kennedy & Tipps, 1994; Ozdemir, 2008). How learning by doing and experiencing is more meaningful and retentive is also emphasized in American educational technologist Edgar Dale's cone of experience (Celik, 2014). In addition, Huetinck and Munshin (2004) state that teaching tools can be effective in moving students' level of mathematical comprehension from concrete experience to abstract thinking. Moyer (2001) also demonstrates that the teaching materials, which present abstract mathematical concepts by visualizing them in a tangible and clear way, help students perceive the basic characteristics of the concept and improve their imagination.

One of the ways to perform meaningful and retentive mathematics teaching is to carry out activities using the teaching materials through which students can actively participate in the teaching process and which enable them to visualize concepts in a clear and tangible way (Clements & McMillen, 1996). For example, activities performed using origami can be one of them in teaching the attainments covered by the field of geometry learning in mathematics curriculum. Origami is a paper folding art that emerged in Japan (Yoshioka, 1963). Origami has two types, classical origami and modular origami (Tuğrul & Kavici, 2002). A single piece of paper is used in classic origami. Different items, animal figures and two-dimensional geometric shapes can be made with classic origami. Also known as unit origami, modular origami is formed by combining similar pieces (Gür, 2015). Modular origami is rather used to construct three-dimensional geometric figures (Tuğrul & Kavici, 2002).

It is mentioned in many studies that origami can contribute to the comprehension of the concepts of geometry (Cipoletti & Wilson, 2004; DeYoung, 2009; Wares, 2013; Wares., 2016). Origami allows students to perceive abstract mathematical concepts in a concrete manner and improve their mathematical ideas and thoughts (Cornelius & Tubis, 2006; Pearl, 1994). Tuğrul and Kavici (2002) state that using origami in education have significant contributions to the development of children's motor, mental and creativity skills. Moreover, as it is in question in origami activities that students personally participate in and do it, origami can ensure that they achieve learning in the sensory (attention-grabbing and motivating) and psychomotor (requiring hand, eye and muscle coordination) domains in addition to the cognitive domain of learning (MEB., 2011). Duatepe Paksu (2016) stated that the use of origami in mathematics teaching would increase the participation of students from cognitive, affective and psychomotor aspects, and consequently, they could learn mathematics more easily.

It is possible to see clearly that different geometric shapes are formed even if we fold and unfold any piece of paper we handle. Fold traces and intersections formed when making origami represent the different elements (side, angle, corner, edge, surface, etc.) of that shape or object Duatepe Paksu (2016)The use of origami especially in the teaching of geometry subjects, in other words, enables the visual presentation of some concepts, features and relationships without measuring instruments such as miter, ruler and protractor. Origami also provides visual evidence to support meaningful and retentive learning in teaching mathematical attainments (Olson, 1975). It is observed in the literature that few studies have been conducted on the use of origami as a teaching instrument in the classroom setting in Turkey (Boz, 2015; Duatepe Paksu, 2016; Hacısalihoğlu Karadeniz, 2017; Polat, 2013). Moreover, given the abovementioned problems related to learning and teaching mathematics and the potential of origami in mathematics education, it is important to consider the development of activities concerning the use of origami in mathematics teaching.

1.1. The Purpose of the Study and the Problem Case

This study was carried out to present an exemplary activity about how origami can be used when teaching mathematics in secondary schools and to determine preservice mathematics teacher opinions on this activity.

To this end, the following were decided to be the research questions:

1. How can an activity using origami in mathematics teaching be developed?
2. What are the mathematical attainments that can be taught using this activity?
3. What are the preservice mathematics teacher opinions and thoughts on the use of this activity?

2. Method

2.1. Research Design

Aiming to develop an exemplary activity that uses origami in mathematics teaching and identify preservice mathematics teacher opinions on this activity, this research is a descriptive study utilizing the qualitative research design. Qualitative research ensures that data are read over and over to be divided into codes and categories based on their similarities and differences and research results are presented (Cepni, 2012; Karasar, 2016; Merriam, 1988; Yıldırım & Simşek, 2016).

2.2. Study Group

The study was carried out with 32 preservice teachers who were studying in the elementary mathematics teaching program in the faculty of education of a public university and took the Mathematics Teaching with Origami course in the fall semester of 2017-2018 academic year.

2.3. Data Collection Tool

The data of the study were collected in two different ways. The first one is the Spiral Cube and Square Prism Activity which the preservice teachers constructed together during the course, and the second one is the question form asking four open-ended, structured questions that could explore the preservice mathematics teacher opinions on the Spiral Cube and Square Prism Activity.

The open-ended questions allow preservice teachers to express the reasons for their answers and reflect the way they thought of the activity (Gronlund & Linn, 1990). This is why open-ended questions were utilized as data collection instrument. The question form prepared to achieve content validity was submitted to the opinion of two branch education experts and finalized on the basis of their opinions and suggestions. The questions used in the question form include:

1. What are your opinions on the clarity of the instructions of the Spiral Cube and Square Prism Activity that you prepared and its applicability in terms of mathematics teaching?

2. What are the grade levels and mathematical attainments associated with the shapes which were formed in each making stage of the Spiral Cube and the Square Prism Activity? Please explain your opinion in detail.

3. What are the advantages and disadvantages of the Spiral Cube and Square Prism Activity for mathematics teaching in your opinion? Please explain your opinion in detail.

4. What are the contributions of the Spiral Cube and Square Prism Activity to you as a preservice teacher? Please explain your opinion in detail.

2.4. Development of Spiral Cube and Square Prism Activity

The application was carried out in Mathematics Teaching with Origami course in three weeks (9 class hours). In the first week, the instructor showed the preservice teachers how to do the Spiral Cube and the Square Prism step by step and asked them to do it at the same time. They were then asked to repeat the making of the Spiral Cube and Square Prism on their own to gain practice. At the end of the three class hours, all the preservice teachers gained practice about the making of Spiral Cube and Square Prism. In the second week, the preservice teachers were asked to write down folding instructions for each stage of the origami folding for the making of Spiral Cube and Square Prism. They were encouraged to share their thoughts with each other and to discuss in the classroom during the writing stage of the activity instructions. In this way, the origami activity (Spiral Cube and Square Prism Activity) introduced in detail below were structured step by step along with the participant preservice teachers. After the structuring of the activity, the preservice teachers were divided into 8 groups of four. Next, each group was asked to perform their activity with the 6th-grade students at their internship secondary schools within the scope of the Teaching Practice course and to ask students and secondary mathematics teachers about their opinions on the clarity and applicability of the activity instructions. The activity was carried out by the preservice teachers in the class of 8 mathematics teachers in 3 different schools. In the third week, the participants were asked to provide their opinion in the question form in regard to the clarity and applicability of the activity instructions, which mathematical attainments and concepts the shapes formed at each stage were associated with, the advantages and disadvantages of the activity in terms of mathematics teaching, and the activity's contribution to them as preservice teachers.

2.5. Data Collection and Analysis

The data of the study were collected by applying the question form prepared for the fourth-grade preservice mathematics teachers in the Mathematics Teaching with Origami course in the fall semester of 2017-2018 academic year as stated in the application section above. After the question form had been applied, form of each preservice teacher was assigned a number. For example, "PT1" represents the preservice teacher 1.

The origami activity (Spiral Cube and Square Prism Activity) structured by the preservice teachers under the guidance of the instructor and their opinions on the clarity and applicability of the activity instructions were descriptively examined and presented in the findings section.

The preservice teachers' answers to the open-ended questions in the question form were subjected to content analysis, and "data coding" was utilized as the data analysis method (Yıldırım & Simşek, 2016).

To analyze the obtained data in a reliable way, the answers given by 10 randomly chosen preservice teachers to the questions were classified and analyzed categorically according to their similarities and differences separately by the researcher and a field expert (Merriam, 1988; Yin, 1994). The degree of agreement of the coding performed by the researcher and the field expert was calculated with the formulation "Reliability=(Number of agreed categories) (Total number of agreed and disagreed categories)" (Miles & Huberman, 1994). The reliability degree regarding the agreement between the analyses performed individually by the researcher and the field expert was calculated to be 0.88. Miles and Huberman (1994) state that agreement between the two coders being 0.70 and above is sufficient for reliability. Accordingly, it was decided that the agreement between the coders was reliable.

Next, these categories formed by the researcher and the expert were reviewed by them together to clarify the similar categories, and different categories were discussed to achieve consensus (Merriam, 1988; Yin, 1994). The answers given by the remaining preservice teachers were categorically analyzed by the researcher alone in terms of their similarities and differences. The codes and themes, which were created once the analysis of all the data was completed, were submitted to the review of the same field expert and finalized in accordance with expert's recommendations; they were next presented in tables with percentage-frequency values and citations from the actual answers given by the preservice teachers. M.a.b.c.d. coding of mathematical achievements related to the prepared activity means the following. The meaning of M.6.3.4.2 coding is given in Table 1.

Table-1. Meaning of M.6.3.4.2. coding.

M.	6.	3.	4.	2.
Course Code	Class Level	Learning Area	Sub-Learning Area	Achievements Number

Source: Mathematics curriculum (Primary and Secondary School 1, 2, 3, 4, 5, 6, 7 and 8th Grades).

2.6. Validity and Reliability

The validity and reliability measures required for the qualitative research method were taken in this study (Yıldırım & Simşek, 2016). Hence, it was ensured that the participant preservice teachers answered each question in consideration of their current status to achieve internal validity during the implementation of the data collection instruments.

For the external validity, the findings were presented in consistency with the research questions in an effort. To achieve the external reliability, the position of the researcher conducting the data analysis within the research process, conceptual framework used for the data analysis as well as the codes and themes were described, and detailed explanations were made on the data collection and analysis methods. For the internal reliability, the researcher and a field expert participated in the analysis steps and the achieved data were presented in a detailed way and in a descriptive approach.

3. Findings

Introduction to the activity and its making stages, which mathematical attainments that can be taught with it, its advantages and disadvantages for the mathematics teaching and how it contributed to them as preservice teachers are addressed in this section.

3.1. Introduction to Spiral Cube and Square Prism and the Making Stages

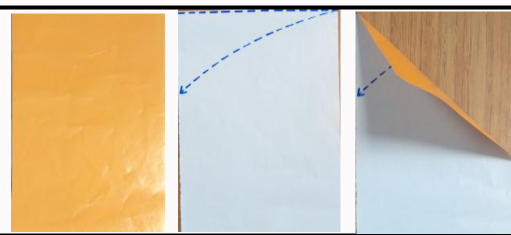
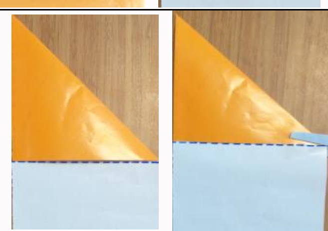
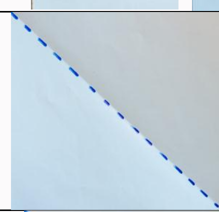
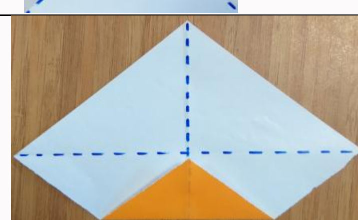
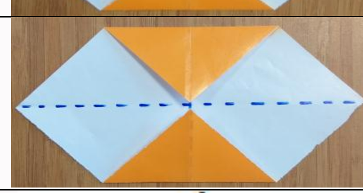
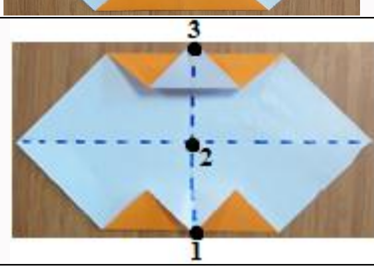
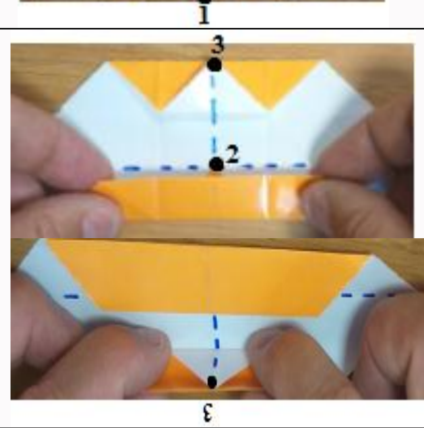
Spiral Cube and Square Prism and the making stages was given in Table 2 below. The Spiral Cube and Square Prism, which was structured by the preservice teachers, is an activity that will be useful for the students to structure the concept of volume. It is a student-centered activity in which students will be able to participate as if they were playing a game using only paper in a classroom environment, and at the end, they will generate a tangible product about rectangular prism. The main purpose of the activity is to present a tangible material that can be directly used in the teaching of the following attainment specified in the mathematics curriculum which is implemented at the public schools under the Ministry of National Education in Turkey.

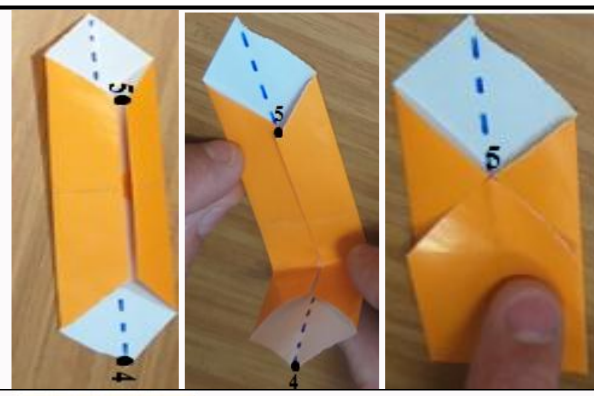
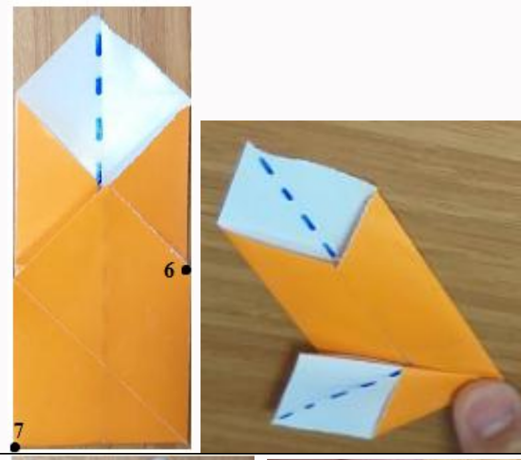
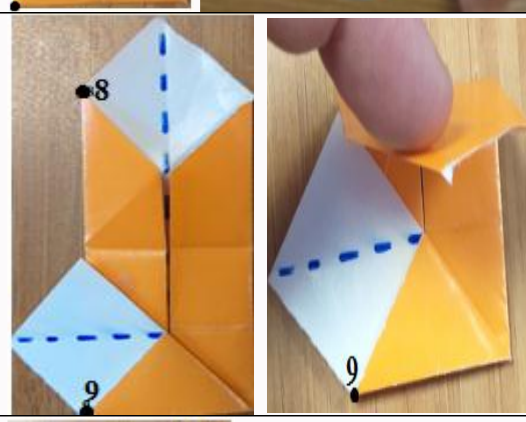
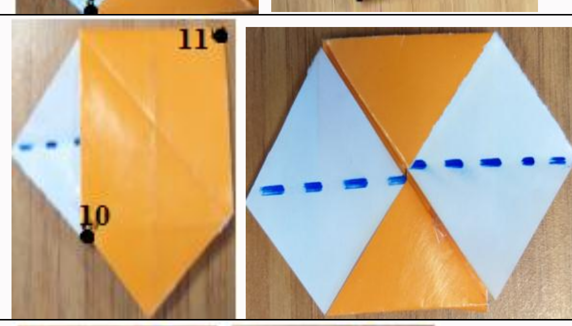
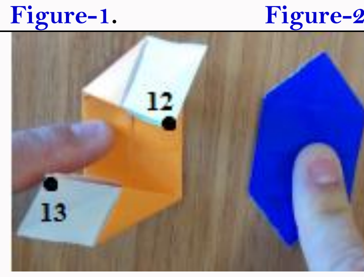
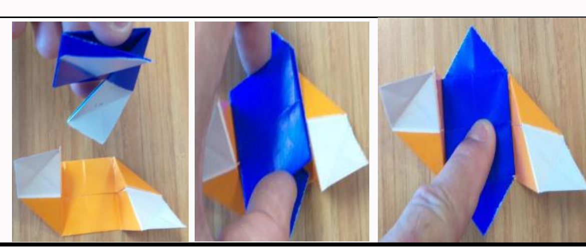
According to 100% of the preservice teachers, this activity is an important teaching material that can be used in the teaching of the "M.6.3.4.2. Attainment: Student creates different rectangular prisms with a given volume from unit cubes and explains it with the justification that volume is the multiplication of base area by height."

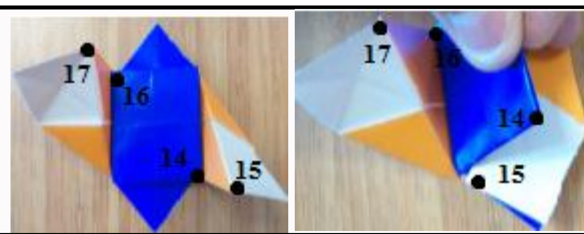
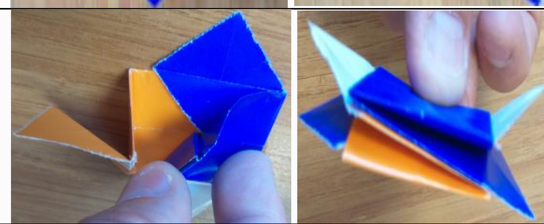
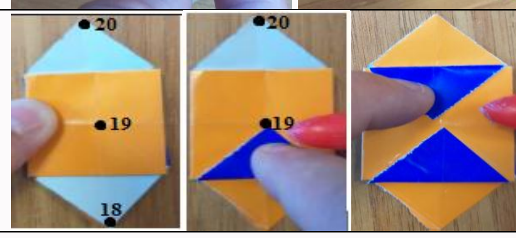
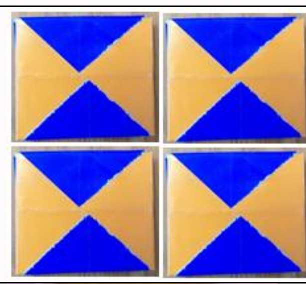
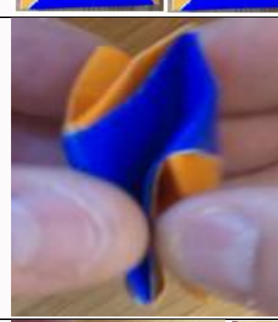
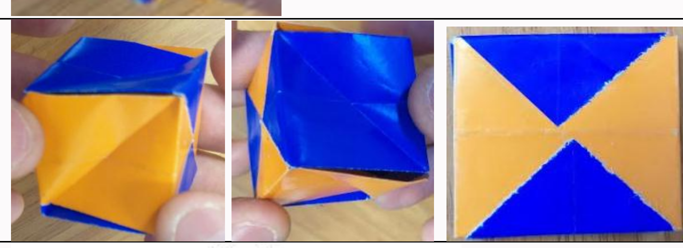
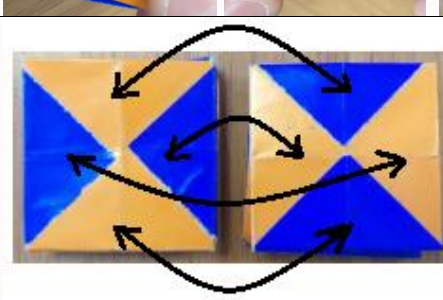
In addition, it is an activity that allows students to comment and explain their opinions to their peers about the geometric shapes that are formed as they fold and their properties at the making stage of the activity.

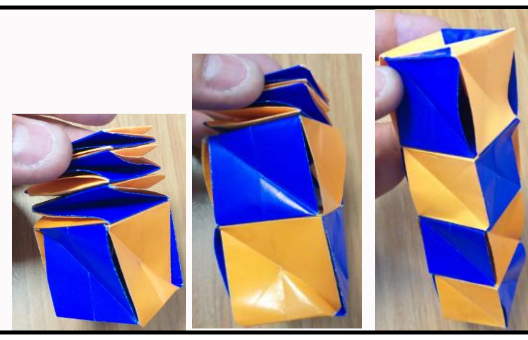
The making stages of this activity are presented in detail below. This activity require colored or colorless 4 pieces of A4 paper, scissors, and glue.

Table-2. Spiral cube and square prism making stages.

Steps	Instructions	Shapes Formed After Folding
Step 1	Fold the rectangular paper so that one of its short sides overlaps with one of its long sides to obtain a square.	
Step 2	Cut the square formed after the folding out with the help of scissors.	
Step 3	Open the square you obtained as a result of the folding. A diagonal line of the square occurred.	
Step 4	Fold the square again to get its other diagonal line.	
Step 5	Fold a corner of the square so that it coincides with the intersection of the diagonals.	
Step 6	Do the same for the opposite corner.	
Step 7	Fold the corners meeting at the intersection of the diagonals back as shown in the figure.	
Step 8	Fold the Shape as shown on the right side so that Point 1 overlaps with Point 2. (Do the same so that Point 3 overlaps with Point 2.)	

Step 9	Fold the Shape obtained in the previous step so that Point 4 and Point 5 overlap.	
Step 10	Fold the Shape obtained in the previous step in the opposite direction so that Point 6 and Point 7 overlap.	
Step 11	Fold the Shape obtained in the previous step so that Point 8 and Point 9 overlap.	
Step 12	Fold the Shape obtained in the previous step in the opposite direction so that Point 10 and Point 11 overlap.	
Step 13	Following the same instructions between Step 1 and Step 12, make another one of the Figure which was obtained in Step 12.	 Figure-1.  Figure-2.
Step 14	Open Figure 1 you obtained at the end of Step 13 by pulling it from Points 12 and 13 backwards. Flip shape 2.	
Step 15	Place the flipped Figure 2 on the quadratic area formed in the middle of Figure 1 at the end of Step 13 as shown on the right side.	

Step 16	Pull the resulting Shape upwards from Point 14 and place Part 15 underneath.	
Step 17	Likewise, pull it upwards from Point 16 and place Part 17 underneath.	
Step 18	Fold the resulting Shape so that Points 18 and 20 overlap with Point 19 and glue it. Flip the Shape and repeat the step.	
Step 19	Finally, you will obtain a closed square envelope divided into four congruent triangles on each of its two surfaces.	
Step 20	Make 3 more of the closed square envelope you obtained in Step 19 by following the same steps. You should now have four shapes in total.	
Step 21	As shown in the figure, slowly open out the resulting closed square envelope by turning your right hand inward and your left hand outward. Observe which geometric object was formed.	
Step 22	Did you get a cube? Press the resulting cube slightly inward to make it into its version in Step 19.	
Step 23	As shown in the figure, Glue the closed square envelopes so that the blue-colored triangles on the surface overlap with the orange-colored triangles. Glue all the square envelopes one by one according to the same rule.	
Step 24	Glue all the square envelopes one by one according to the same rule in Step 23.	

Step 25	Open out each closed square envelope by slowly turning it out as you did in Step 21.	

3.2. Clarity and Applicability of the Activity Instructions

The preservice mathematics student teacher opinions on the clarity and applicability of the activity instructions was given in Table 3.

Table-3. Clarity and applicability of the activity instructions.

Codes	Exemplary preservice teacher answers	f	%
Activity instructions are clear	We performed the activity with the 6th graders. A large number of students could easily do each fold by reading the instructions. ...there were those who had difficulty in folding but I think it is about their own manual skills. During the activity, the teacher did his/her own folds. The teacher said that he/she had never thought about creating a cube in this way. The students were quite willing to participate too. I heard some students say "I wish the course was always taught like this ." In this sense, I can say that the activity instructions were clear and applicable. Students confirmed this as well. (PT20).	32	100
Activity is applicable	We had no difficulties in performing the activity. The students followed the instructions step by step and did their folds. When folding, it was like they competed with each other. The fast ones tried to help those who were slow in folding after they had finished their own folds (PT1).	32	100

After the Spiral Cube and Square Prism Activity structured by them under the guidance of the instructor had been performed with the secondary school 6th-grade students, 100% of the preservice teachers stated that both the students and the teachers of the course found the activity instructions clear and applicable. According to the preservice teachers, the students had no difficulty in following the instructions during the activity. The students also participated in the activity willingly and stated "The mathematics course has not been taught like this before. I wish the course was always taught like this." Furthermore, the students followed the instructions as if they had been competing and the students who did the origami folds earlier tried to help the students who had difficulty in folding.

3.3. Association of the Activity with Attainments

How Spiral Cube and Square Prism activity can be directly or indirectly associated with the attainments in the mathematics curriculum and how it can be used in teaching these attainments is explained below.

3.3.1. Grade Levels and Mathematical Attainments which the Activity is Directly Associated with

According to 100% of the preservice teachers, this activity is primarily an activity that the teacher can use directly in the teaching process of the secondary school mathematics curriculum's attainments in the following grade levels.

3.3.1.1. Second Grade Attainments

M.2.2.1.3. Student recognizes and distinguishes cube, square prism, rectangular prism, triangular prism, cylinder and sphere on models.

PT26's own statement as to how the activity can be directly associated to the second-grade mathematical attainments is as follows:

"PT26: At the second-grade level, this activity can be directly utilized when teaching the concepts of cube, square prism and rectangular prism. When the closed quadratic envelope formed in the twenty-first step of the activity is opened, a three-dimensional cube model appears. On this cube model, the teacher can help students see the basic features of the cube concept in a tangible way. Also, when all envelopes glued to each other as a whole in the twenty-fifth step of the activity are opened, a square prism model is formed. Again, on this tangible model, the teacher can help students recognize the square prism with his/her questions and instructions. Students can sense and apprehend via the model that a prism with its bases being square and side surfaces being rectangles is called a square prism."

3.3.1.2. Third Grade Attainments

M.3.2.1.1. Student identifies faces, corners and edges of cube, square prism, rectangular prism, triangular prism, cylinder, cone and sphere models.

M.3.2.1.2. Student explains similar and different aspects of cube, square prism and rectangular prism.

The following is PT32's own statement as to how the activity can be directly associated to the third-grade mathematical attainments:

"PT32: At the third-grade level, the teacher can enable students to identify and show faces, corners and edges of cube, square prism and rectangular prism models made in the activity. They can touch and see on the tangible model that a rectangular prism in general and a square prism in particular has 8 corners, 12 edges, 6 faces and 2 bases top and bottom. It is also possible to ensure they realize that their opposing faces and edges are equal."

3.3.1.3. Fifth Grade Attainments

M.5.2.5.1. Student recognizes the rectangular prism and identifies its basic elements.

M.5.2.5.2. Student draws the net of rectangular prism and decide whether the given different nets belong to the rectangular prism.

PT15's own statement as to how the activity can be directly associated to the fifth-grade mathematical attainments is as follows:

"PT15: At the fifth-grade level, it can be ensured that they see it with the help of the resulting tangible models by associating the fact that square prism and cube are a special version of rectangular prism with the concepts of rectangle and square. By drawing each face of the rectangular prism model on a surface, it can be also ensured that they apprehend its net."

3.3.1.4. Sixth Grade Attainments

M.6.3.4.1. Student understands that the number of unit cubes placed in a rectangular prism without leaving any space is the volume of that object, calculates volume of the given object by counting the unit cubes.

M.6.3.4.2. Student creates different rectangular prisms with a given volume from unit cubes and explains it with the justification that volume is the multiplication of base area by height.

M.6.3.4.4. Student forms the volume relation of prism, solves related problems.

The following is PT15's own statement as to how the activity can be directly associated to the fifth-grade mathematical attainments:

"PT27: At the sixth-grade level, it is possible to make students apprehend how to calculate volume of the rectangular prism by using the unit cubes through the model formed in the 2nd step of the activity. Before opening the tangible model obtained at the end of the activity, it can be asked whether a volume is in question, and then, they may be asked to discuss how the volume has changed when each closed envelope is opened and depending on which elements of the rectangular prism the volume has changed. In this way, it can be ensured with the tangible model that they comprehend volume of the rectangular prism equals the multiplication of base area and height."

3.3.2. Grade Levels and Mathematical Attainments which the Activity is Indirectly Associated with

According to 100% of the preservice teachers, this activity is primarily an activity that the teacher can use indirectly in the teaching process of the secondary school mathematics curriculum's attainments in the following grade levels.

3.3.2.1. First Grade Attainments

M.1.2.1.1. Student names geometric shapes by the number of corners and sides.

M.1.2.2.2. Student gives examples of congruent objects.

PT5's own statement as to how the activity can be indirectly associated to the fifth-grade mathematical attainments is as follows:

"PT5: In the fifth grade, students are asked to examine the shapes obtained in the first, second and third steps by the number of sides and corners. By this means, they can construct their own knowledge by distinguishing geometric shapes easily. In addition, it can be shown that triangles with the same side lengths are congruent by having them measure the triangles formed in the second and fourth steps."

3.3.2.2. Second Grade Attainments

M.2.1.6.1. Student shows what is whole, half and quarter with appropriate models and explains the relationship among whole, half and quarter.

M.2.2.1.1. Student classifies geometric shapes by the number of sides and corners.

M.2.2.1.2. Student creates structures using shape models and draws those structures.

M.2.2.2.2. Student realizes the symmetrical shapes around.

M.2.2.1.4. When the direction, position or size of geometric objects and shapes change, student realizes that their formal properties do not change.

The following is PT1's own statement as to how the activity can be indirectly associated to the second-grade mathematical attainments:

"PT1: At the second-grade level, it can be ensured that students learn the concepts of whole, half and quarter by materializing them on the shapes obtained in the second and third steps of the activity In addition, they may be asked to create different structures by cutting the shapes formed in the second, third or ninth steps. They can be also asked to name the shapes formed in the second, third, sixth, seventh and twelfth steps, and teacher can have them examine their symmetry to notice the concepts of symmetry and reflection."

3.3.2.3. Third Grade Attainments

M.3.2.2.1. Student determines whether the shapes have more than one symmetry line by folding them.

M.3.2.2.2. Student completes the given symmetrical shape of which a part has been given by its vertical or horizontal symmetry line.

M.3.2.3.1. Student makes cover using shape models, draws the covering pattern on dotted or checkered paper.

M.3.3.2.3. Student calculates the perimeter of the shapes.

M.3.3.3.1. Student covers and measures the area of the shapes with non-standard, appropriate materials.

PT19's own statement as to how the activity can be indirectly associated to the third-grade mathematical attainments is as follows:

"PT19: At the third-grade level, it is ensured that they see the symmetry lines on the shapes formed in the second, third and sixth steps. It is ensured by having students fold the shape that they see the line segment left between in the thirteenth step is not a symmetry line although it divides shape into two congruent parts. While the fifth and sixth stages are carried out, it can be ensured that students easily learn the concepts related to the resulting geometric shape. Using the geometric shapes formed in the eleventh and nineteenth steps and in the previous steps, they can be asked to cover a given surface by creating a pattern. Teacher can have them predict the circumference of the shapes formed in each step and check the predictions. Hence, their predictive skills improve. It is ensured that they examine with how many congruent triangles the surface of the square formed in the second or third steps is covered."

3.3.2.4. Fourth Grade Attainments

M.4.2.1.1. Student names the sides and corners of the triangle, square and rectangle.

M.4.2.1.2. Student identifies the side properties of square and rectangle. He/she shows that the square is a special rectangle.

M.4.2.2.1. Student explains the mirror symmetry on geometric shapes and models and draws the symmetry line.

PT28's own statement as to how the activity can be indirectly associated to the fourth-grade mathematical attainments is as follows:

"PT28: At the fourth-grade level, students can be asked where the sides and corners of the shapes formed in the first, second and third steps are and to name them. By placing a mirror on the symmetry axis in the shape formed in the ninth step, it can be ensured that they see whether the mirror symmetry is achieved.

3.3.2.5. Fifth Grade Attainments

M.5.2.2.1. Student names, creates polygons and recognizes their basic elements.

M.5.2.2.3. Student determines and draws the basic elements of rectangular, parallelogram, rhombus and trapezoid.

M.5.2.2.3. Student determines and draws the basic elements of rectangular, parallelogram, rhombus and trapezoid.

The following is PT28's own statement as to how the activity can be indirectly associated to the fifth-grade mathematical attainments:

"PT23: At the fifth-grade level, students can be asked which geometric has formed at the end of the fourth step to ensure that they discuss the properties of this shape. In this way, it can be shown that the square can be formed with four congruent triangles. It can be ensured that they notice the properties of rhombus and parallel edge in the the sixth step and of trapezoid in the seventh step."

3.3.2.6. Sixth Grade Attainments

M.6.3.2.1. Student forms the area relation of triangle, solves related problems.

PT7 explained how the activity can be indirectly associated with the sixth-grade mathematical attainments as follows: "PT7: It can be ensured that students learn and materialize the area relation of triangle formed using the area of square in the ninth step."

3.3.2.7. Seventh Grade Attainments

M.7.3.1.1. Student identifies an angle bisector by separating an angle into two congruent angles.

M.7.3.1.2. Student identifies the corresponding, opposite, alternate interior, alternate exterior angles formed by a cutting line and two parallel lines, examine their properties and identifies the congruent or complementary ones of the resulting angles, solves related problems.

M.7.3.2.1. Student explains the side and angle properties of regular polygons.

M.7.3.2.3. Student recognizes rectangular, parallelogram, trapezoid and rhombus and identifies the angle properties.

The following is PT14's own statement as to how the activity can be indirectly associated to the seventh-grade mathematical attainments:

"PT14: It is addressed what kind of triangles the large triangles formed in the fourth step are. It is ensured that the perpendicular drawn from a corner down to the opposite edge of this triangle divides this side into two equal parts. Moreover, it is ensured that they see the height line divides the angle into two congruent parts when this triangle is folded with respect to the height line. It can be ensured that teachers see the alternate interior and alternate exterior angles are equal on the shape formed in the fourth step. In regard to angles, it is also possible to prevent students from memorizing by making them materialize and learn where the properties, which are named Z rule or M rule by teachers, come from. They are asked to examine the properties of the square formed in the third step. Emphasizing the properties of the shapes formed in the ninth step, the related concepts are concretized. This activity can be used to reinforce this attainment."

3.3.2.8. Eighth Grade Attainments

M.8.3.1.1. Student constructs median, angle bisector and height in triangle.

M.8.3.2.2. Student forms the image of point, line segment and other shapes resulting from the reflection.

M.8.3.3.1. Student associates congruence and similarity and identifies edge and angle relationships of congruent and similar shapes.

M.8.3.3.2. Student determines the similarity ratio of similar polygons and forms polygons congruent and similar to a polygon.

PT3's own statement as to how the activity can be indirectly associated to the eighth-grade mathematical attainments is as follows.

"PT3: In the fifth step, teacher can have students construct median, angle bisector and height of the isosceles triangle in a tangible way. At almost every stage of the activity, students can achieve tangible learning about these concepts. Asking questions about what are the congruent and similar ones among the shapes formed in the third, seventh and eighth steps, it can be ensured that students materialize and learn the concepts of congruence and similarity. It can be also ensured that they find the similarity ratios of the shapes determined to be similar or congruent by measuring their sides."

3.3.3. Opinions on the Advantages and Disadvantages of the Activity

Preservice elementary mathematics teachers explained the advantages and disadvantages of this activity in terms of cognitive, affective and psychomotor skills as follows:

Table-4. Advantages and disadvantages of spiral cube and square prism activity.

Themes	Codes		Exemplary preservice teacher answers	f	%
Advantages	1	Ensures meaningful learning	As the students will be active at all stages of the activity, they can easily create their own information and achieve meaningful learning (PT5).	24	75
	2	Improves the Thinking and Problem-solving skills	All stages of the activity enable the students to improve their thinking and problem-solving skills (PT12).	26	81.3
	3	Enables to learn to be patient	Since new geometric shapes will appear as the paper is folded during the activity, students notice the aesthetics and learn to be patient (PT15).	20	62.5
	4	Enables to notice aesthetics	Since new geometric shapes will appear as the paper is folded during the activity, students notice the aesthetics and learn to be patient (PT15).		
	5	Ensures self-expression	Because students are given the opportunity to talk about the resulting shape at all stages of the activity, it enables them to improve their ability to tell and express their emotions, thoughts and knowledge (PT8).	28	87.5
	6	Ensures sharing and helping	Because students have the chance to help each other about the instructions not understood at all stages of the activity, it enables them to improve their ability to share and help (PT30).	12	37.5
	7	Enables two- or three-dimensional thinking	As a new shape or object will appear in all stages of the activity, it enables the development of their two- or three-dimensional thinking skills (PT13).	32	100
	8	Ensures the materialization of shapes or objects	As new shapes will be formed at all stages of the activity, it enables students to materialize the shapes in their imagination (PT1).	28	87.5
	9	Enables to understand the properties of concepts	It provides a better understanding of the properties of abstract mathematical concepts by means of tangible shapes or objects that are formed at all stages of the activity (PT18).	24	75
	10	Ensures the development of visual-spatial intelligence	Since new shapes or objects will be formed at all stages of the activity, it enables students to develop visual-spatial intelligence (PT20).	22	68.5
	11	Ensures willing participation in the course	As students will see paper folding as a game during the activity, they will be willing to participate in the course (PT9).	20	62.5
	12	Ensures the development of a positive attitude towards the course	As new shapes or objects will be formed and students will form them by themselves at all stages of the activity, it enables them to develop a positive attitude towards the course (PT14).	28	87.5
	13	Ensures the improvement of the attention skill	All the stages of the activity require great attention and rigor, thus improving their attention skills (PT32).	22	68.5
	14	Ensures the improvement of hand-eye and muscle coordination	In all stages of the activity, students will improve hand-eye and muscle coordination as they will use their hands and eyes more actively (PT2).	32	100
Disadvantages	1	Takes time to perform	This activity can be time-consuming due to the difficulty in performance (PT3).	28	87.5
	2	Difficult to perform in small classrooms	Because the making stages of this activity are complex, it can be difficult to perform in small classrooms (PT2).	18	56.3
	3	Causes fallacy due to folding	Since this activity requires the paper to be folded precisely, unless it is a proper folding, the student may have misconceptions about the intended concept as the desired result will not be achieved (PT7).	20	62.5
	4	Causes decreased confidence	Since this activity requires the paper to be folded precisely, it may decrease the participation of students with weak manual skills in the course as they will have decreased confidence.	22	68.5
	5	Causes fallacy due to teacher	If the teacher does not provide appropriate explanations and feedback about the shape or object formed at the making stages of this activity, it may lead to misconceptions and misunderstandings among students (PT12).	26	87.5

According to Table 4, the contribution and advantages of this activity to the students in terms of teaching are gathered under 14 different codes and its disadvantages are gathered under 5 different codes. It is seen that each code related to its advantages and disadvantages was expressed at a high rate by the preservice teachers. All of the preservice teachers think that students' two- or three-dimensional thinking skills will improve as a new shape or object will be formed at all stages of the activity and it will enable them to improve their hand-eye and muscle coordination as they will use their hands and eyes more actively if this activity is used as a teaching tool at the schools.

3.3.4. Opinions on Contributions of the Activity to the Preservice Teachers

Opinions on the contributions of the Spiral Cube and the Square Prism Activity to the preservice teachers are presented in Table 5.

Table-5. Contributions of spiral cube and square prism activity to the preservice teachers

Codes		Exemplary preservice teacher answers	f	%
1	Using origami	The contribution it made to me is how I can use origami in my classes when I become a teacher in the future (PT11).	26	81.3
2	Using in the teaching of attainments	It made contributions about how an activity can be used for the teaching of multiple attainments (PT31).	18	56.3
3	Detailed thinking	The fact that a shape about mathematics was formed at every stage of the activity excited me and made me think in detail (PT7).	10	31.3
4	Improving manual skills	At the end of the activity, I realized my own manual skills (PT12).	26	81.3
5	Using paper	I learned how to make a cube from two pieces of paper (PT16).	8	25
6	Learning by fun	As a preservice teacher, I learned from the beginning of the activity by having fun (PT2).	16	50
7	Being patient and careful	During the activity, I realized that I had to be patient and careful when folding paper (PT15).	18	56.3
8	Using paper to embody concepts	I realized how I could benefit from the paper for embodying the mathematical concepts (PT12).	26	81.3
9	A new method of forming cubes	I learned how to create cubes in a new method (PT1).	20	62.5
10	Communication and exchange of ideas	From the beginning to the end of the activity, as a preservice teacher, I could communicate and exchange ideas with other preservice teachers (PT30).	32	100

The Spiral Cube and Square Prism Activity performed in the Mathematics Teaching with Origami course contributed positively as a teaching tool according to all of the preservice teachers. It is seen that the preservice teacher's opinions on activity's contribution are gathered under 9 different codes. The most important contribution of this activity to all of the preservice teachers was that they communicated and exchanged ideas with each other from the beginning of the activity. Furthermore, another important contribution of this activity to 81.3% of the preservice teachers was how they could use origami in the future when they become teachers, how they could benefit from the paper for embodying the mathematical concepts and that they realized their own manual skills at the end of the activity.

4. Discussion and Conclusion

The preservice teachers reported that both students and mathematics teachers found the activity instructions clear and applicable in terms of mathematics teaching. According to all of the preservice teachers, the Spiral Cube and Square Prism Activity they constructed is an important teaching material that can be used for teaching of the attainment "Student creates different rectangular prisms with a given volume from unit cubes and explains it with the justification that volume is the multiplication of base area by height." in the mathematics curriculum. The teacher can structure the course through this activity to teach a given attainment, and in the meantime, he/she can perform this activity to question students' knowledge on concepts they should have learned previously and to eliminate their deficiencies. Shapes that are formed at each step of the activity and not within the scope of the attainment which is being taught at the moment but that are about other attainments of the mathematics course at different grade levels can be also used. In this case, questions to be asked by the teacher about the shapes that are formed at the making stages of the activity are important. For example, the teacher may ask the question "What is a diagonal?" in Step 4 of the activity. Students who do not know the concept of the diagonal can learn from their friends and learn with the guidance of the teacher and with the appropriate questions. It can be ensured with appropriate questions that students question and associate the concepts they have learned previously with each other, and moreover, it can be effective in reinforcing the previously learned concepts and their properties. In other words, the teacher may want students to express their opinions and discuss with questions such as "Which geometric shape does this shape resemble?" What properties does it have?" in regard to the shape that is formed at the end of each activity step. In this way, students are enabled to demonstrate both their cognitive and psychomotor skills throughout the activity. In addition, the fact that new geometric shapes, and finally, a new geometric object are formed at the end of each step during the activity will enable them to develop a positive attitude towards mathematics as it will stimulate students' curiosity in the course. According to preservice teachers, the Spiral Cube and Square Prism Activity have many advantages and disadvantages in terms of teaching. This activity can provide students with many advantages in terms of cognitive, affective and psychomotor while learning mathematical concepts. According to all of the preservice teachers, this activity can contribute to the improvement of hand-eye and muscle coordination. Besides, it was found that the activity make contributions from several aspects to students such as improving their two- or three-dimensional thinking skills and problem-solving skills, materializing the abstract concepts to achieve meaningful learning, improving their ability to tell and express their own emotions, thoughts and knowledge and developing a positive attitude towards the course (as they will be active all the time and it will enable them to generate their own products in the activity). This result coincides with the results of the study conducted by Gür and Kobak-Demir (2016). Gür and Kobak-Demir (2016) observed that the preservice teachers thought using origami in mathematic teaching would improve students' psychomotor skills and enable them to learn by materializing the mathematics.

Concerning the contributions of the activity, it was found that the activity made the preservice teachers realize how they could use origami in their courses in the future and how potential their manual skills and origami are in regard to embodying mathematical concepts. In the light of these results obtained in relation to many aspects such as ensuring student participation, increasing motivation, stimulating curiosity, offering a playful environment and ensuring hand-eye coordination, more focus should be laid on activities using origami.

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