Journal of Education and Practice
ISSN 2222-1735 (Paper) ISSN 2222-288X (Online)
Vol.8, No.15, 2017

Geometry Teaching via Origami: The Views of Secondary Mathematics Teacher Trainees

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Abstract
Considering the performances of the students in the Timss and Pisa examinations, it is seen that they can not solve the problems, do not animate the objects they can not ask geometry questions in three dimensions and can not understand them. For this reason, origami lessons should be put into teacher training programs. Secondary teacher trainees were examined in this study according to their views about using origami activities in maths courses. This qualitative study was carried out with 18 secondary mathematics teacher trainees. Data were gathered by semi-structured interview and 3D tangible materials. Findings revealed that prospective teacher candidates can associate large quantities of mathematical and geometric concepts with some achievements and that they have a constructive view on origami activities. However, it was seen that the teacher candidates did not associate with the geometric levels of Van Hiele. They reached the idea of two dimensions and three dimensions easily and without confusion. They made different 3D objects from a square paper. Visualization is the result of helping meaning. Moreover, it was observed that they had difficulty in some long-step shapes. In addition, all of the participants in the study have reached the point that the origami is entertaining and never thought it could be so enjoyable.
Keywords: origami, mathematics education, geometry teaching, 2D objects, 3D objects.

1. Introduction

Origami is considered as a basic mathematics teaching tool in the literature raising attention is attributed to studies this topic. Origami courses and training programs give theoretical knowledge to the pre-service teachers regarding the use of origami in mathematics education. Importance of the study: There is a lack of research in Turkish venue, which provides voice to prospective teachers about what they believe considering the use of origami in mathematics and related lessons. As known, origami is the Japanese art of paper folding. Origami takes great mathematical potential when used in education (Boakes, 2009) especially in geometry (Cornelius & Tubis, 2009). Also geometry can be used to support the geometry comprehension of students (Arıcı & Aslan-Tutak, 2015). Origami also used to teach some subjects such as algebra, functions, fractions, spital visulisation, trigonometry, … etc. Georgeson (2011) and Wares (2011) asserted that origami is the bridge between the nature and mathematics. Robichaux and Rodrigue (2003) showed that origami is helpful students' mathematical abilities such as mathematical problem solving abilities. Cagle, 2009) asserted that origami is benefit to improve usage of mathematical language. Students and also teachers have fun while doing paper folding activities in math classes (Fiol, Dasquens & Prat, 2011, Boakes, 2009). If the teacher does not make a connection between origami and mathematics, using origami in mathematics education would be nothing more than an enjoyable activity (Georgeson, 2011). To make the connection between origami and mathematics, the teacher needs to be prepared for such kind of an instruction (Cipoletti & Wilson, 2004). Çakmak, Işıksal and Koç (2014) studied how origami-based mathematics instruction affects elementary students' spatial ability, and they showed that origami-based mathematics instruction significantly increased students' spatial ability scores. Arıcı and Aslan-Tutak (2015) found that using origami activities in geometry lessons improved high school students' achievement in geometry. Also geometry uses in mathematics lessons (Erktin, Aydan & Balcı, 2011). Fiol, Dasquens, and Prat (2011) stated how they train pre-service teachers on using origami in mathematics and geometry lessons of Spanish kindergarten and primary schools. Secondary teacher trainees' views about using origami activities in maths courses were examined in this study.

2. Method

Turkish secondary mathematics teacher trainees have to take some major courses mathematics education courses, pedagogy courses, compulsory courses and some elective courses. The mathematics and origami course is elective courses in our secondary science and mathematics department. This study is a qualitative study (Miles & Huberman, 2009). In the study, case evaluation was used from qualitative research methods. The purpose of the situation assessments is to analyze one or more situations in their entirety within the boundaries (Yıldırım & Şimşek, 2011, p.79). In this study, student opinions about origami activities were analyzed. In accordance with the purpose of the study, the following study questions were investigated in the current study: How is origami used in geometry teaching? Do you have any difficulty in mathematics and origami lessons? What concepts do you reach for mathematics and geometry? What grade levels can be associated with which gains? Does it affect your learning? Are you discussing how to paper folds in your group? What does making an origami project mean

to you? Should studies about origami be done in schools? How do you relate the Van Hiele geometry levels? How are origami activities used in chemistry, physics, mathematics and engineering? In this study used purposive sampling (Fraenkel & Wallen, 2006). All participants were in second grade of secondary science and mathematics department. They all were selected elective course of "mathematics and origami 2+0 credit= 6 ECTS". The course is takes places 14 weeks. The pilot study was conducted last years' secondary science and mathematics teacher trainees (Np=20). Main study is conducted 18 of secondary science and mathematics teacher trainees in fall term 2016-2017. Also reliability was considered.

Table 1. Demographics information of the participants

	Male		Female		Total	
	f	%	f	%	f	%
Main study	4	22	14	78	18	100

In the study the data were collected through a semi-structured interview form, observation and concrete materials. In the preparation of the interview form, firstly, questions were asked to establish appropriate data for the purpose of the research. The prepared questions were taken from two teaching members who were experts in the field of mathematics education and two experts in the field of qualitative research. Teacher trainees took the course a year ago. These teacher trainees were taken in pilot study. At the end of these studies, the final form was given to the interview form. Interviews with each teacher trainees lasted approximately 20 minutes. The obtained data were taken in writing by the researcher. During 14 weeks, they were observed. Firstly, the data obtained from the pilot study was analyzed and then some corrections were made. Descriptive analysis was used to analyze written data collected through semi-structured interview form. The main purpose of this analysis is to describe the data obtained systematically and clearly. These representations were interpreted, the results were analyzed and the results were presented to the readers (Yıldırım & Şimşek, 2011: 224). The students were coded Ö1, Ö2 .., and the statements passed on were read and approved. All data were transcribed; teams and sub teams were determined. The opinions of the students who participated in the analysis were coded according to their frequency of use. The concepts used in the creation of the codes are taken into account in the research questions and the concepts in the related field writing. The coding result is presented in tabular form in the findings section. In addition, examples from students' statements are also given as examples. In order to improve the validity and reliability in this study, Researchers carried out elective courses together for a term (Yıldırım & Şimşek, 2011); They have also taken their observations and 3D materials to confirm the data obtained from interviews. Thus, the data triangulation is provided. The data obtained from the observations were read to participants and approved by the participants. The breakdown process is explained in detail. Finding given directly without comment.

3. Findings

This section includes findings from interviews with students. They are grouped under the five headings. 1. **Is origami used in teaching mathematics? How is origami used in geometry teaching?** All secondary mathematics teacher trainees gave an opinion on the use of origami in mathematics teaching.

What are the benefits of using origami in geometry teaching? The benefits of using the origami in geometry teaching are described below Table 2:

Table 2.

BENEFITS	f
Visuality	*3*
Facilitating understanding	*6*
Animation	*3*
Three dimensional thinking	*3*
Embodied	*5*
Understanding the concept of symmetry	*1*
Understanding the properties of geometric shapes	*2*
Understanding the concept of ratio proportion	*1*
Retention	*2*
Increasing the desire for learning	*1*
Modeling skills	*2*
Making the geometry tasteful	*3*
Liking mathematics	*3*
Increase creativity	*3*
Makes them happy	*3*
Entertains	*2*
Develop hand skills	*3*
Increase the meaning	*2*
Allows to use the integral method	*2*
Make a trip in history	*1*
Gain different perspective	*1*
Gain the universal benefits of thinking	*1*
increase self-confidence	*1*
increase curiosity	*1*
Improve thinking ability	*1*
Improve your imagination	*1*
Teaching research	*1*
Allows a product to be introduced	*1*

In addition to having fun, it allows us to use our minds and improve hand coordination." I thought that by thinking of different projects, my creativity was difficult and I had to look more closely at the environment (St3). I could not produce something using the skill of the hand, I sometimes made new things by thinking, working on different projects and thinking universally that they could develop both my self confidence and my ability to think. It was a model of the panel, which would be quite energy-saving if a thought could be passed on (St 6). I just folded square papers. It helped me to make more convenient and practical ideas about a subject (St5).
I created a model with my own work while I did not know about Origami, I was happy with the different models I created, and I wondered as I thought of what I could do (St 7).

Secondary science and mathematics trainees' views on the first question is given below:

Origami helps the students to make their abstract shapes easier to imagine in their mind (St2).
Three-dimensional shapes are often difficult for students to understand. The geometric shapes we make with Origami bring more concrete lessons. It makes it easier for students to understand (St5).
Origami teaches students to do volume calculations (St8).
Origami is the basis of geometry, for example, we use square paper to make swan, we use geometry from beginning to end, we make it easier for students to understand geometry with origami. (ST12)

We ask how to use origami, they given the name of the topics in geometry lessons.

What concepts do you reach for mathematics and geometry?

All secondary mathematics teacher trainees expressed that that origami could be used in geometry lesson. They described the concepts of mathematics they have reached as given Table 3.

Table 3.

Concepts				
*Triangle** *rectangular*, *** *square*, *** *pentagon*** *parallelogram*** *angle***	*corner** *slope*** *equilateral triangle** right angle triangle*** *problem solving* fractions***	*pattern*** *cube*, *** *equilateral quadrangle*** *deltoid*,** Butterfly** *Flower**	*Sphere** *Eiffel tower** *Crane** *DNA chain*, *** *prism*, ***	*Pythagorean theorem** *(Do not show it open at 30º without using an angle meter)** *conic***

*primary school **secondary school

What grade levels can be associated with which gains? Most of the secondary mathematics teacher trainees suggested that all the achievements of geometry can be reached from the middle school to the high school. **Does**

it affect your learning? Are you discussing paper folds in your group? Most of the secondary mathematics teacher trainees asserted that they all discuss their group what they were. They specified origami affects in their learning (Table 4). Their answers were collect under eight headings:

Table 4.

Affect learning
• *Group Work;* *We work in-group collaboration.* *We are doing collaborative group work.* • *Fun/Pleasant/happy:* *Makes mathematics and geometry fun.* *My attitude towards geometry changed.* *I'm forgetting the world when I'm doing origami. I can make something too!* • *Problem Solving:* *My ability to analyze has improved.* • *Related Daily Life:* *I associate it with everyday life.* • *Improve Maths/Geometry Test Marks:* *I believe that my problem-solving ability has improved.* • *Difficulty Afraid/self-reliant:* *Before this lesson, I am afraid of geometry. Now I understand very pleasantly and I know why I should learn. I was having difficulty folding together but now I am able to do it comfortably. I was self-reliant.* • *Attitude:* *My attitude towards geometry changed. I never loved anymore.* • *Interdisciplinary* *I saw interdisciplinary relations*

What does making an origami project mean to you?

The following are the opinions on what the origami project means (Table 5).

Table 5.

Origami project for me
• *To develop creativity ability*
• *To develop three-dimensional thinking ability*
• *To improve learning by doing*
• *To develop hand-arm-brain coordination*
• *To develop communication- face to face*
• *To develop different culture recognition*
• *To develop language skills*
• *To develop mathematical language*
• *To develop active and effective learning*
• *To develop team work, cooperative learning*
• *To motivate me to learning mathematics*
• *To develop symmetry-drawing-measurement information*
• *To increases the permanence*
• *To helps to think in three dimensions*
• *To increase solidarity and help within the class*
• *Embody abstract subjects*
• *To allows to create a pattern*
• *To develop detailed thinking skills*
• *To provide alternative ways of seeing*
• *To improve hand skill*

Teacher trainees have expressed the above opinions. They have often stated that they use the less frequently used arguments in the group in order to follow the steps. **Should studies about origami be done in schools?** Most of the secondary mathematics teacher trainees have emphasized that work on origami should be done at schools. All prospective teachers have stated that they should make studies about origami in their schools.

It helps us to think in three dimensions. The folds are both entertaining and enhancing solidarity and help within the class. Origami improves intelligence development in the positive direction, increases the ability to see the questions (St 3).

I question why I am doing folding about folding, and if I find a rule between folds I do the next steps at a level. It allows students to have different perspectives, both in the development of handicrafts and in more concrete thinking." (St5).
Folding with origami gives me the ability to think in more detail, I look more closely at everything I see and I get more information from them. We are learning how to create proportions in relation to geometric shapes, features of shapes, dimensions that can change as we entertain. (St 6).
Students gain different perspectives (St 8).
With Origami, the creativity of students increases their participation in the classroom and makes learners and forms alike fun (St 1).
Studies on origami should be done especially in primary and secondary schools because it is the best time interval for students to gain hand skills (St2).
Schools should work on origami, because visualization makes it easier to visualize a theme, and Origami provides a way to make sense of the shapes and to animate them in a way that makes it easier to understand and comprehend the lesson (St7).

How do you relate the Van Hiele geometry levels? The answers given in the question of how to relate Van Hiele geometric thinking levels are given below. Two teacher trainees Van Hiele expressed that they did not hear geometric thinking levels. Teacher trainees who have heard of these Van Hiele Levels have stated that they only know the simple features of these levels. Teacher trainees indicated that square, rectangle and diagonal acquisition activities for Levels 0 and 1 and pyramid and cubing activities for Levels 2 and 3 were appropriate. Examples of teacher trainees' views on this question are as follows:

Table 6.

Van Hiele geometry levels
I think my Van Hiele's levels has improved (St2).
It contains every level of Van Hiele (St9).
Van Hiele has a chance to practice for every level (St4).
It applies to every level of Van Hiele (ST1).
Origami assignments can vary according to the level of the students. The creativity of the learners enables them to discover different things (ST3).
... allows us to develop analytical thinking, as we relate to Origami (ST5).
Different levels of teaching can be made more productive and easier, such as the steps of understanding the characteristics of an organism and distinguishing it from other forms (St10).

How are origami activities used in chemistry, physics, mathematics and engineering?
The answers to the question of how to use origami activities in chemistry, physics, mathematics and engineering are given below.

Table 7.

Use origami activities
• *Chemistry (atom, atomic structure, ...)*
• *Biology (DNA chain, frog, flower, animals, fish, trees, ...)*
• *Physics (modelling, gravidity, moment, rollercoaster, high solution origami lens, zig-zag tessellation, paper rings & chains, polymer, crashing wave, ...)*
• *Mathematics (calculus, functions, pattern, golden ratio,...,), geometry (triangle, square, typological structures, dragon, ...)*
• *Engineering (modelling, mold, mechanical metamaterials, ...)*
• *Goods (chair, furniture, box, clock, watch, toys, piano, grocery case, airbags in cars, ...)*
• *Space equipment (folding, solar array, solar origami, space telescope, cosmic origami, ...)*
• *Sculpture*
• *Turkish (storytelling and origami, fairy tale, story, ...)*

Most respondents replied that they did not have any difficulty, except for cross folding, when doing DNA modeling. Findings (Table 8) from the opinions of prospective teachers about the origami activities that can be done in fields such as physics, chemistry, biology, architecture are as follows:

Table 8.

Physics	*Chemistry*	*Biology*	*Engineering*	*Architecture*
Space *Celestial bodies* *Work-energy* *Quantum physics* *Electronic devices* *Balance* *Torque* *Alien*	*Periodic table* *Element* *Proton* *Electron* *Modeling of molecules* *Atom-atom diameter* *Allotrop* *Atom models*	*Symmetrical creatures* *DNA model* *Heart* *All creatures* *Human anatomy* *Nucleide* *Protein* *RNA model*	*Design of technological tools* *Robot*	*Designing architectural forms* *Historical buildings*

5. Discussion and Conclusion

In Turkish national mathematics curriculum, origami is interpreted as a beneficial instructional tool to be used in mathematics lessons and teachers are suggested to use origami activities in mathematics lessons. The secondary mathematics teacher trainees stated that they had fun while doing origami. It can be said that revealing something new makes origami activities fun. Also, it is motivating and pleasing to present a concrete model. They also said that origami transformed mathematics into fun. This result is similar to the work of Erktin, Aydan & Balcı (2011). Participants experienced difficulties in folding and unifying. This result is in agreement with that of Çakmak (2009). Similar to the result of this study, Tuğrul & Kavici (2002) also point out that the origami activities of teacher trainees have improved their communication and collaboration skills. Although origami is identified with Japanese culture, when the focus is using origami in mathematics education it is possible to see research studies conducted in various countries. Such studies would enable to see the possible cultural effects on the use of origami in mathematics education and would improve the origami-related mathematics education literature. Origami activities should be included in mathematics teaching. The participants point out that origami is useful in understanding geometry. Origami has been affected by the fact that mathematical topics have been linked to everyday life. In the literature, it has been stated that the relation of mathematics subjects to daily life will be effective in learning mathematics (Doruk & Umay, 2011). This study found that collaborative learning and using cooperative learning facilitated the understanding of mathematics subjects. This result is in agreement with the work of Köroğlu and Yeşildere (2011). Origami activities improve geometry success and geometric reasoning ability (Arıcı, 2012), facilitate the analysis of geometric objects (Cañadas et al., 2010) and improve geometry knowledge (Çakmak, 2009).

Note: A part of this study was presented as an oral presentation at XII. European Conference on Social and Behavioral Science, January 25-28, 2017, Catania, Sicily.

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