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Investigating Pre-service Teachers' Origami-based Mathematics Lesson Plans

Öğretmen Adaylarının Origami Temelli Matematik Ders Planlarının İncelenmesi

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ABSTRACT: Origami became an increasingly used instructional tool in mathematics education and its successful use depends on developing adequate origami-based mathematics lesson plans. Therefore, this study investigated origami-based mathematics lesson plans developed by pre-service teachers who were trained for the effective use of origami in mathematics education in two courses in their teacher education program. In this quantitative study, survey research was combined with causal-comparative research, and there were 88 pre-service teachers who have been enrolling in the Elementary Mathematics Education program as participants. Pre-service teachers in one of these courses received origami-based mathematics education training for four weeks, whereas pre-service teachers in the other course received training for twelve weeks. Descriptive analyses revealed that pre-service teachers were able to develop adequate origami-based lesson plans after receiving training in these courses. Furthermore, it was revealed that they preferred to develop lesson plans mostly in the geometry and measurement content area. To test whether the adequacy level of lesson plans differs based on the training length of pre-service teachers, one-way ANCOVA was performed. Analysis results indicated that pre-service teachers who received longer training developed significantly are better at origami-based mathematics lesson plans. All the findings were discussed, and some implications based on these findings were explained.

Keywords: Lesson plan, mathematics, origami, pre-service teachers.

ÖZ: Origami matematik eğitiminde giderek artan şekilde kullanılan bir öğretim aracı haline gelmiştir ve origaminin başarılı bir şekilde kullanımında uygun bir ders planı hazırlamanın önemli bir rolü bulunmaktadır. Bu nedenle, bu çalışmada öğretmen adayları tarafından geliştirilen origami temelli matematik ders planları incelenmiştir. Bu nicel çalışmada, betimsel araştırma deseni ilişkisel araştırma deseni ile desteklenmiştir ve çalışmaya İlköğretim Matematik Öğretmenliği programında öğrenim gören 88 öğretmen adayı katılım göstermiştir. Çalışmaya katılan öğretmen adaylarından bir grup dört hafta süresince origami temelli matematik eğitimi hakkında bir eğitim alırken, diğer grup oniki haftalık bir eğitim almışlardır. Betimsel analiz sonuçları her iki gruptaki öğretmen adaylarının uygun origami temelli matematik ders planı geliştirebildiklerini göstermiştir. Ayrıca, ders planlarının içeriği incelendiğinde çoğunlukla geometri ve ölçme öğrenme alanına yönelik ders planlarının geliştirildiği görülmüştür. Eğitim süresi ile ders planının uygunluk seviyesi arasındaki ilişkiyi test etmek üzere tek yönlü ANCOVA analizi gerçekleştirilmiştir. Analiz sonuçları daha uzun süre eğitim alan öğretmen adaylarının istatistiksel olarak daha iyi ders planı geliştirdiklerini göstermiştir. Çalışma kapsamında elde edilen tüm bulgular tartışılmış ve bulgular ışığında çeşitli önerilerde bulunulmuştur.

Anahtar kelimeler: Ders planı, matematik, origami, öğretmen adayları.

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Enabling active participation of students during the paper folding process, providing opportunities for mathematical discussions, and making abstract mathematical concepts concrete made origami a valuable mathematics instruction tool appropriate for contemporary learning theories (Boakes, 2009; Kandil & Işıksal-Bostan, 2019; Sze, 2005; Wares & Elstak, 2017). Therefore, origami is increasingly used as an instructional tool in mathematics education literature.

In the existing literature, origami was used for various mathematical purposes and ages of students. At the pre-school level, Yuzawa and Bart (2002) explored that origami activities improved 5 and 6-year-old children’s size comparison strategies. In another study, Mastin (2007) stressed that combining origami with storytelling, which was called storigami, improved her pre-school students’ geometry knowledge and the use of mathematical language. At the elementary school level, Golan and Jackson (2010) exemplified how origami can be used to cover all geometry concepts in the elementary school curriculum and emphasized their positive experiences related to origami-based geometry instruction conducted in more than 70 Israeli schools. Supporting their claim, it was revealed that origami-based mathematics activities improved elementary students’ geometry knowledge (Golan, 2011) and spatial skills (Çakmak et al., 2014). At the middle school level, origami-based mathematics activities were found to improve students’ geometry knowledge (Georgeson, 2011; Kandil & Işıksal-Bostan, 2019), spatial visualization skills (Boakes, 2008), algebraic thinking (Georgeson, 2011; Higginson & Colgan, 2001), and understanding of ratio relationships (Boz, 2015; DeYoung, 2009; Hartzler, 2003). At the high school level, Budinski et al. (2018) exemplified how origami activities can be used by combining with GeoGebra to teach Platonic solids. In another study conducted with high school students, it was revealed that origami activities helped them conceptualize the properties of two- and three-dimensional geometrical shapes (Canadas et al., 2010). At the higher education level, it was revealed that using origami activities improved college students’ spatial visualization skills (Boakes, 2008), Van Hiele’s geometric thinking levels (Çaylan et al., 2017), and provided opportunities to explore some trigonometry and calculus concepts (Wares, 2019; Wares & Valori, 2020). In addition to the above-mentioned cognitive benefits of origami, it is also mentioned that origami activities helped students to gain self-efficacy in mathematics (Kandil & Işıksal-Bostan, 2019), be aware of the connection between arts and mathematics (Boz, 2015; Wares & Elstak, 2017; Wares & Valori, 2020), enjoy mathematics lessons (Boakes, 2009; Georgeson, 2011; Golan & Jackson, 2010; Higginson & Colgan, 2001), and develop knowledge about different cultures (Tuğrul & Kavici, 2002; Wares & Elstak, 2017).

As exemplified above, research studies related to origami-based mathematics education focused on the learner side either by investigating the effects of origami-based mathematics activities or sharing the experiences in such activities. Research studies with in-service or pre-service teachers seem to be less. These limited studies investigated views and beliefs of pre-service regarding the use of origami in mathematics education. The findings revealed that pre-service teachers consider origami as a beneficial instructional tool to be used in mathematics lessons, and they plan to benefit from origami activities in their teaching career (Arslan & Işıksal-Bostan, 2016; Fiol et al., 2011; Masal et al., 2018).

Origami can be an effective instructional tool in mathematics if only the teacher makes the appropriate connections between origami folding steps and mathematical concepts, and making this connection is not an easy task for teachers (Cipoletti & Wilson, 2004; Georgeson, 2011; Golan & Jackson, 2010; Sze, 2005). When the teacher could not make this connection, origami-based mathematics lessons do not differ from traditional teacher-centered mathematics instruction (e.g., Uygun, 2019). Therefore, various training (e.g., courses, workshops, or professional development programs) opportunities were offered to pre-service (Çaylan et al., 2017; Fiol et al., 2011; Masal et al., 2018; Mastin, 2007) and in-service teachers (Cipoletti & Wilson, 2004; Golan & Jackson, 2010; Mastin, 2007) to support the effective use of origami in mathematics lessons. However, no research study in the accessible literature investigated how effective pre-service or in-service teachers plan and apply origami-based mathematics lessons after receiving such training. Therefore, this study focused on the origami-based mathematics lesson plans developed by pre-service middle school mathematics teachers who were trained to effectively use origami in mathematics education through two courses in their teacher education program.

A Prerequisite for Successful Lessons: An Adequate Lesson Plan

A lesson plan is defined as "a teacher's detailed descriptions of the course of instruction for an individual lesson" (Mishra, 2009, p. 2). Lesson plans are described as road maps for teachers guiding their teaching practices (Haynes, 2010; Milkova, 2012), thus, effective lesson plans are considered essential for successful lessons (Li et al., 2009). Supporting this claim, special emphasis is given to lesson planning in countries such as China, Japan, and Finland, which show top performances in PISA and TIMMS studies (e.g., Hemmi et al., 2017; Li et al., 2013; Melville & Corey, 2021; Shimizu, 2008; Yang & Ricks, 2013). Investigating lesson plans reveals a teacher's professional competence (Blömeke et al., 2008). Therefore, various studies in the mathematics education literature focused on the lesson plans developed by pre-service or in-service teachers (e.g., Backfish et al., 2020; Li et al., 2009; Shimizu, 2008).

Adequate lesson plans are also vital for origami-based mathematics lessons. There are several factors to be considered to develop adequate origami-based mathematics lesson plans. The first factor is the decision about the origami model to be folded. The origami model should be appropriate for students' age level and psycho-motor abilities to avoid problems during the folding steps (Boakes, 2008; Golan & Jackson, 2010). Furthermore, the folding steps of the selected origami model should provide opportunities to ask questions in line with the mathematical objective(s) of the lesson (Boakes, 2008; Cipoletti & Wilson, 2004; Golan & Jackson, 2010). After deciding on the origami model, a diagram clearly explaining the folding steps of the origami model should be developed (Boakes, 2008; Sze, 2005). Different than the regular origami diagrams, folding steps should be explained by using mathematical language in the diagrams (Baicker, 2004; Cipoletti & Wilson, 2004; Robichaux & Rodrigue, 2003). For instance, rather than saying "fold in half," it should be said, "fold along the diagonal symmetry line." One of the most critical parts of origami-based mathematics lessons is to ask appropriate mathematical questions in line with the mathematical learning objective(s) of the lesson during the folding steps (Georgeson, 2011; Serra, 1994). Furthermore, there should be additional questions enabling one to remember previously learned mathematical concepts (Baicker, 2004; Serra, 1994). Folding steps of origami models provide opportunities to support learners' higher order-thinking levels (Canadas et al., 2010; Sze, 2005). Therefore, instructors can pose challenging questions in origami-based mathematics activities to improve learners' problem-solving abilities (Georgeson, 2011; Higginson & Colgan, 2001; Wares, 2019). Origami-based mathematics activities also provide opportunities to relate mathematics to art and science (Higginson & Colgan, 2001). By making this relation, instructors can "inspire artistic-minded individuals to think mathematically" (Wares & Valori, 2020, p. 2). Similar to the regular mathematics lessons, origami-based mathematics lessons should be ended with assessment questions to test whether the mathematical learning objectives are achieved (Cipoletti & Wilson, 2004; Serra, 1994).

In brief, an adequate lesson plan could be accepted as a prerequisite for successful lessons and instructors should consider several aspects in the development of origami-based mathematics lesson plans.

Research Purpose and Questions

The successful use of origami in mathematics education depends on developing adequate lesson plans. Therefore, the first research question of this study is to investigate the adequacy of origami-based mathematics lesson plans developed by a group of pre-service teachers who were trained on the use of origami in mathematics education: (1) What is the adequacy level of origami-based mathematics lesson plans developed by pre-service teachers?

As exemplified above, origami can be used for several mathematical purposes in the literature. Investigating lesson plans not only reveals teachers' competence but might also serve as a window to reveal their teaching-related views and intentions (Shimizu, 2008). Therefore, it was aimed to explore which mathematical topics were preferred by pre-service teachers in their origami-based mathematics lesson plans: (2) Which mathematical topics were addressed in pre-service teachers' origami-based mathematics lesson plans?

Although it is acknowledged in the literature that training is essential for pre-service and in-service teachers to support the effective use of origami in mathematics education, there is no research conducted on the content or the length of such training. Therefore, this study aimed to contribute to the existing literature by investigating whether the adequacy of origami-based mathematics lesson plans differs based on the training length (shorter training length–4 weeks; longer training length–12 weeks) of pre-service teachers: (3) Is there a significant difference on the adequacy level of origami-based mathematics lesson plans by considering origami-based mathematics education training length of pre-service teachers?

Method

Research Design

This quantitative research study focused on pre-service teachers' origami-based mathematics lesson plans. It was aimed to answer how adequate the lesson plans were, which mathematical concepts were addressed in those lesson plans, and whether the adequacy level of lesson plans differed based on the pre-service teachers' training length on origami-based mathematics instruction. In line with these research aims, survey research was combined with causal-comparative research, which is a commonly used research design in quantitative research studies (Fraenkel & Wallen, 2006). Specifically, survey research design principles were applied in the first and second research questions, and causal-comparative research design principles were applied in the third research question.

Participants and Context

The participants of this study were pre-service teachers who have been enrolling in the Elementary Mathematics Education program in one of the public universities in Turkey. The program lasts for four years, and graduates become eligible to work as middle school (grades 5 to 8) mathematics teachers. The program has some core (such as Teaching Geometry and Measurement, Teaching Numbers, Connections in Mathematics, and Misconceptions in Mathematics) and elective (such as Informal Learning Environments in Mathematics Teaching, Ethnomathematics, and Teaching Mathematics to Gifted Students) courses related to mathematics education. The Approaches in Learning and Teaching Mathematics course is one of the core courses which is offered to sophomore pre-service teachers. As a part of the course, pre-service teachers were trained for four weeks to use origami as a learning and teaching approach in mathematics lessons. During the four weeks of training, pre-service teachers were firstly trained on basic origami skills (basic origami folds, different types of origami, reading an origami diagram, and folding simple origami models), and then on the methods of using origami in mathematics lessons as a teaching approach (developing an origami diagram appropriate for mathematics lessons, origami model selection criteria for origami-based mathematics lessons, exemplary origami-based mathematics activities, and developing origami-based mathematics lesson plans). The content of the other course, Origami, was similar—training on the basic origami skills first, and then on the methods of using origami as an instructional tool in mathematics lessons. However, this training lasted 12 weeks since the course was solely on origami. Therefore, even though both participant groups received similar training in content, the ones in the Origami course received more detailed training.

There was a total of 91 pre-service teachers in these two courses, and 89 of them provided written consent forms for using their origami-based mathematics lesson plans in the current study. Because of some missing data, one lesson plan was excluded from the data set, thus, there were 88 final participants (72 females and 16 males) in this study. Among the participants, 58 of them received shorter training (4 weeks in the Approaches in Learning and Teaching Mathematics course), whereas 30 of them received longer training (12 weeks in the Origami course).

Ethical Procedures

All the ethical permissions to conduct this study were obtained from the researcher's institution (Burdur Mehmet Akif Ersoy University Non-Interventional Clinical Research Ethics Committee, Ethics assessment document number: GO 2021/22). All the participants informed about the study, and they signed informed consent form.

Data Collection and Analysis

As a part of their training in the above-mentioned courses, pre-service teachers were required to develop origami-based mathematics lesson plans, which constituted the data of this study. There were no restrictions about the grade level (as long as it is at the middle school level) and the topic that would be addressed in the lesson plans. The adequacy level of origami-based mathematics lesson plans was assessed by an analytic rubric: Origami-Based Mathematics Lesson Plan Evaluation Rubric. The rubric consists of eleven items with three levels (poor, average, and good). The rubric items were first developed after a detailed literature review and revised based on the views of three experts: one from the measurement and assessment department, and the other two from the mathematics education department who have academic research studies and fieldwork experience related to origami-based mathematics instruction. Sample items of the rubric are given in Table 1.

Table 1

Sample Items of the Rubric

Item Number	Poor (0)	Average (1)	Good (2)
2	The chosen origami model is not appropriate for mathematical objective	The chosen origami model is partially appropriate for mathematical objective	The chosen origami model is appropriate for mathematical objective
5	Most/all of the folding steps given in the diagram are not clear	Some of the folding steps given in the diagram are not clear	All the folding steps given in the diagram are clear
7	Appropriate questions for the mathematical objective were rarely/never asked during the folding steps of the origami model	Appropriate questions for the mathematical objective were sometimes asked during the folding steps of the origami model	Appropriate questions for the mathematical objective were often/always asked during the folding steps of the origami model

To ensure the validity and reliability of the rubric, exploratory factor analysis and some reliability tests (Cronbach's Alpha, Pearson Correlation, and Cohen's Kappa) were performed. Analysis results indicated that the rubric had one dimension, which explained 42.5% of the total variance. All the items in the rubric were appropriate for the rubric: item factor loadings were higher than .30, and item communality values were higher than .10. Furthermore, it was revealed that data obtained through the application of the rubric had high internal consistency: Cronbach's Alpha was calculated as .83. Moreover, the use of rubric provided highly consistent results when two researchers graded the same origami-based mathematics lesson plans independently: Pearson Correlation Coefficients ranged between .75 and 1.00, and Cohen's Kappa Coefficients ranged between .63 and 1.00 for the rubric items.

In brief, the detailed item development process and satisfactory exploratory factor analysis results indicated that the rubric is a valid instrument for evaluating origami-based mathematics lesson plans (Moskal & Leydens, 2001; Pallant, 2007). Moreover, data obtained through the application of rubric had high internal consistency and assured interrater reliability criteria (Cohen, 1960, 1988; Moskal & Leydens, 2001). The details of the rubric development process, validity, and reliability evidence were given in Arslan (2022).

In the data analysis process, descriptive statistics were used to answer the first two research questions, and one-way between groups Analysis of Covariance (ANCOVA) was used to answer the third research question of the study. Before performing ANCOVA, all the assumptions (such as normality, linearity, homogeneity of variances, and homogeneity of regression slopes) were checked and all but one assumption were assured. Data set failed to assure normality assumption, however, ANCOVA was still performed since this analysis was found to be robust for the violation of normality assumption (Olejnik & Algina, 1984). In the analysis, pre-service teachers' Cumulative Grade Point Average (CPGA) was used as the covariate since their overall success in the Elementary Mathematics Education program might affect the adequacy level of their origami-based mathematics lesson plans. The analysis supported this claim and showed that there was a significant relationship between pre-service teachers' CPGA and their score obtained for the adequacy level of origami-based mathematics lesson plan ($F(1, 85)=27.187$, $p=.000$), thus, CPGA remained as the covariate in the analysis for the third research question.

Results

In this part of the study, descriptive and inferential statistics were presented to answer the study questions.

Pre-service Teachers' Origami-based Mathematics Lesson Plans

Descriptive analyses revealed that the mean score of pre-service teachers' origami-based mathematics lesson plans was 18.24. The minimum score that could be obtained from the Origami-Based Mathematics Lesson Plan Evaluation Rubric was 0, whereas the maximum score was 22. Therefore, pre-service teachers' origami-based mathematics lesson plans were above the average and could be interpreted as adequate lesson plans in general. Details about the calculated mean score are given in Table 2.

Table 2

Descriptive Statistics for Origami-based Mathematics Lesson Plans

	N	Minimum	Maximum	Mean	Std. Deviation
Total Score	88	4	22	18.24	3.45

When the lesson plans were interpreted in more detail, it was revealed that pre-service teachers' lesson plans received the highest mean score in choosing the appropriate origami model in accordance with the mathematical purpose of the lesson (M=1.93 out of 2) and the lowest mean score in making the connections between origami and non-mathematical fields such as science, art, and engineering (M=.99 out of 2). Descriptive findings for all rubric items were presented in Table 3.

Table 3

Detailed Descriptive Statistics of Origami-based Mathematics Lesson Plans

Rubric item is about…	Minimum	Maximum	Mean	Std. Deviation
Choosing the appropriate origami model in accordance with students' age and psycho-motor abilities	0	2	1.88	.36
Choosing the appropriate origami model in accordance with the mathematical objective of the lesson	0	2	1.93	.29
Setting the length of the lesson appropriately by considering the chosen origami model	0	2	1.80	.48
Motivating the students to the origami-based mathematics lesson	0	2	1.73	.47
Clarity of the origami folding diagram	1	2	1.75	.43
Using the appropriate mathematical vocabulary in folding steps	1	2	1.92	.27
Asking appropriate mathematical questions during the folding steps in accordance with the primary mathematical purpose of the lesson	0	2	1.82	.42
Asking mathematical questions in addition to the primary mathematical learning objective	0	2	1.71	.48
Asking appropriate questions to support students' higher-order thinking	0	2	1.13	.71
Making the connections between origami and non-mathematical fields	0	2	.99	.85
Choosing the appropriate assessment methods in accordance with the mathematical purpose of the lesson	0	2	1.57	.54

As can be seen in more detail in Table 3, pre-service teachers' lesson plans were quite successful in choosing the appropriate origami model and relating it to the mathematical content through the questions during the folding steps. There were only two rubric items in which the mean score was close (slightly above or below) to the average score: making connections to the non-mathematical fields and asking questions that support students' higher-order thinking.

Pre-service mathematics teachers' origami-based lesson plans were also analyzed based on the mathematical content and the grade level to be used. It was seen that origami-based mathematics lesson plans were varied by the grade level and mathematical content area (see Table 4).

Table 4

Origami-based Mathematics Lesson Plans Based on the Grade Level and Mathematical Content Area

Grade Level	Content Area			
	Numbers & Operations	Algebra	Geometry & Measurement	Total
5	4	0	25	29
6	9	0	4	13
7	0	0	9	9
8	1	2	34	37
Total	14	2	72	88

As can be seen in Table 4, pre-service teachers preferred to develop lesson plans in 5th (*n*=29) and 8th (*n*=37) grade levels, and in the geometry and measurement content area (*n*=72). The primary purposes of geometry and measurement topics in the origami-based mathematics lesson plans were: distinguishing acute, right and obtuse angles, constructing triangle segments (altitude, median, and angle bisector), determining the sum of the measures of the interior angles of triangles and quadrilaterals, calculating the perimeters of triangles and quadrilaterals, determining the basic elements of rectangle, parallelogram, rhombus and trapezoid, classifying triangles by sides or angles; calculating areas of polygons and solving related problems, determining the properties of complementary and supplementary angles, understanding the side and angle properties of regular polygons, determining side and angle relations of congruent and similar triangles, determining the similarity ratio of similar polygons, drawing two dimensional representation of three dimensional geometrical objects from different directions, examining their properties by determining congruent, reverse, interior reverse and exterior reverse angles, drawing translation and reflection images of points, line segments, and other shapes, recognizing the rectangular prism and determining its basic elements, recognizing the right cone and the right pyramid and determining its basic elements.

The origami-based mathematics lesson plans in the numbers and operations content area were about: establishing the rule of a number or shape pattern, adding and subtracting fractions, modeling the division of fractions, determining equivalent fractions by using simplification and expansion, ordering fractions with the same numerator or denominator, calculating and modeling percentages, determining the ratio of two values, understanding the basic rules of exponentials. There were only two origami-based mathematics lesson plans in the algebra content area. Both lesson plans were about multiplying algebraic expressions.

Influence of the Length of Origami-based Mathematics Education Training on the Effectiveness of Lesson Plans

One group of pre-service teachers was trained for 12 weeks on the effective use of origami in mathematics education, whereas the other group was trained for four weeks. Mean scores obtained from origami-based mathematics lesson plans indicated that pre-service teachers who had trained for a longer period had higher mean scores, and higher adjusted mean scores when pre-service teachers' CGPA scores were used as the covariate for their origami-based mathematics lesson plans (see Table 5).

Table 5

Results of Descriptive Statistics for Pre-service Teachers' Origami-based Mathematics Lesson Plans by Considering the Length of Their Training

	N	Mean	Std. Deviation	Adjusted Mean	Std. Error
12 weeks training	30	19.17	3.64	19.43	.53
4 weeks training	58	17.79	3.31	17.66	.38

ANCOVA results indicated that there was a statistically significant mean difference in pre-service teachers' origami-based mathematics lesson plans when their CGPA scores were controlled ($F(1, 85)=7.43$, $p=.008$). The eta squared was calculated as .08, which indicated a medium effect size (Pallant, 2007). The details of the analysis results are given in Table 6.

Table 6

ANCOVA Results

	Sum of squares	*df*	Mean square	*F*	Sig.	Partial eta squared
Corrected model	342.35	2	171.17	20.71	.000	.328
Intercept	5.36	1	5.36	.65	.423	.008
CPGA	305.04	1	305.04	36.90	.000	.303
Training Length	61.42	1	61.42	7.43	.008	.080
Error	702.64	85	8.27			
Total	30391.00	88				
Corrected Total	1044.99	87				

Discussion and Conclusion

Research studies regarding the use of origami in mathematics education have hitherto mainly focused on the benefits of using origami in mathematics education. However, it is unlikely to benefit from origami in mathematics education without an adequate lesson plan. Therefore, central to this study was origami-based mathematics lesson plans developed by pre-service teachers. Analysis results revealed that pre-service teachers, who had training, were able to develop adequate, above the average and quite close to the maximum level, origami-based mathematics lesson plans. Pre-service teachers were specifically successful in selecting appropriate origami models, developing clear diagrams by using mathematical language, asking questions in relating the origami model to the mathematical learning objective(s), and preparing appropriate assessment questions. However, they were less successful in making the connection between origami and non-mathematical fields and asking questions supporting higher order thinking levels of students. It is emphasized that connecting origami to fields such as art and science helps to attract students' attention more (Higginson & Colgan, 2001). Therefore, pre-service or in-service teachers should be encouraged to make such connections more in their origami-based mathematics lessons. Even though origami provides a context to ask questions supporting higher order thinking levels of students, participant pre-service teachers were not very successful in doing so. This result might be expected since developing such questions is not an easy task, specifically for pre-service teachers. To support the use of such challenging questions, there should be origami-based mathematics resources in which the use of such questions was exemplified. Such resources are restricted to a few articles (e.g., Georgeson, 2011; Wares, 2019; Wares & Valori, 2020) and books (e.g., Serra, 1994). Enriching these resources might help pre-service and in-service teachers to develop more challenging questions in their origami-based mathematics lessons.

In the origami-based mathematics lesson plans, geometry concepts were addressed most. These lesson plans included all the geometry concepts at the middle school level (such as angles, area, volume, properties of geometrical shapes and objects, symmetry, and reflection). This result supports the claim that origami might be a powerful source to teach various geometry concepts in different grade levels (Boakes, 2009; Golan & Jackson, 2010). Apart from geometry topics, pre-service teachers mostly used origami to teach fractions and ratio concepts. Even though origami-based mathematics activities for all content areas at the middle school level (geometry and measurement, numbers and operations, algebra, and data analysis) were exemplified in pre-service teachers' courses, they mostly preferred to develop lesson plans in the geometry and measurement content area. The findings of this study were limited to shedding light on the underlying reasons for pre-service teachers' origami-based mathematics lesson plan preferences. However, it might be interpreted as pre-service teachers feeling more competent to use origami to teach geometry concepts compared with other content areas, or they might interpret that origami in mathematics education is more appropriate for geometry topics. To support the use of origami in different content areas in mathematics, instructors might emphasize the examples out of geometry topics in training.

Pre-service teachers in this study were able to develop adequate lesson plans regardless of their origami-based mathematics education training length. This might be interpreted as the content of the courses being appropriate to gain knowledge and efficiency in origami-based mathematics education. However, pre-service teachers who received longer training developed significantly more adequate lesson plans when compared with the ones who received shorter training. This result might be expected since developing adequate lesson plans requires training (Li et al., 2009); thus, longer training period might lead to better lesson plans. Yet, this result showed that longer training (e.g., individual course) should be preferred in developing competence for origami-based mathematics lessons when applicable. This study investigated the adequacy of origami-based mathematics lesson plans by considering pre-service teachers' training length. However, there might be further studies that compare pre-service and in-service teachers' origami-based mathematics lesson plans, and there might also be cross-cultural studies that might explore the potential influence of culture in origami-based mathematics lesson plans.

The findings of the current study might contribute to the existing limited origami-related mathematics education by focusing on the lesson plans developed by pre-service teachers. However, there is a need for further studies conducted with pre-service and in-service teachers to develop knowledge in supporting the use of origami in mathematics education to a maximum extent.

Conflicts of Interest

There is no conflict of interest in this study.

Author Bio

Okan Arslan completed his master's and doctoral studies in the field of Mathematics Education at Middle East Technical University. Currently, he is working as a research assistant at Burdur Mehmet Akif Ersoy University. His research concentrates on using origami in mathematics education, mathematics teacher identity development, and affective factors in the teaching and learning of mathematics.

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