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REFLECTIONS OF ORIGAMI TO ARCHITECTURE

Origaminin Mimarlığa Yansımaları

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ABSTRACT

In the research, origami studies were made with the students of architecture in the elective course of the second year of the department of architecture, and the relationship between mathematics and architecture was realized with the paper folding with an interdisciplinary approach. Providing students to see the relationship between architecture and geometry in terms of structure and aesthetics; It is aimed to examine the reflections of origami on architecture. In the research, examples of architecture were collected and categorized according to symmetry types. In addition, its relationship with origami is given in the table prepared by the researchers. Using origami as a method, students of architecture have created different design products, including three-dimensional design and symmetry. Based on a data collection exercise with architecture students, origami has proven to be a rich source of inspiration and has paved the way for a wide range of design applications. Even new forms and methods have been discovered. At the end of the study, origami provides an interface to gain cognitive experience in spatial configurations and finding form; It has been concluded that origami helps provide tips and ideas on how to visualize many possibilities in architecture classes. At the end of the study, it is suggested to increase the number of elective courses that include spatial skills such as origami and visualization.

Key words: Origami, symmetry, architecture, tangible products, paper folding

ÖZET

Araştırmada mimarlık bölümünün 2. sınıfındaki seçmeli dersde, mimarlık öğrencileri ile origami çalışmaları yapılmış, öğrencilerin disiplinlerarası bir yaklaşımla kağıt katlama ile, matematik ve mimari ilişkisi fark ettirilmiştir. Araştırmada, öğrencilerin mimari,-geometri ilişkisinin yapısal ve estetik açıdan görmelerinin sağlanması; origaminin mimariye yansımalarınnı incelemesi amaçlanmıştır. Araştırmada, mimarideki örnekler simetri türlerine göre toplanmış ve kategorize edilmiştir. Ayrıca,origami ile ilişkisi araştırmacılar tarafından hazırlanan tabloda verilmiştir. Origamiyi bir yöntem olarak kullanan mimarlık öğrencileri, üç boyutlu tasarım ve simetri dahil olmak üzere farklı tasarım ürünleri oluşturmuşlardır. Mimarlık öğrencileriyle bir veri toplama alıştırması yapmaya dayanan origami, zengin bir ilham kaynağı olduğunu kanıtlanmış ve geniş bir tasarım uygulamaları yelpazesinde yolunu açmıştır. Hatta yeni formların ve yöntemlerin keşfedilmesi sağlanmıştır. Çalışma sonunda, origaminin uzamsal konfigürasyonlar ve form bulma konusunda bilişsel deneyim kazanmak için bir arayüz sağladığı; origaminin, mimarlık derslerindeki pek çok olasılığın nasıl görselleştirileceğine ait ipuçları ve fikirler sağlamaya yardımcı olduğu sonucuna ulaşılmıştır.Çalışma sonunda, origami gibi uzamsal becerileri ve görselleştirmeyi içeren seçmeli derslerin artması önerilmektedir.

Anahtar Kelimeler: Origami, simetri, mimarlık, somut materyaller, kağıt katlama

1. INTRODUCTION

Origami is a traditional Japanese paper-folding activity passed down for generations. There are many beautiful shapes, figures that could be building through paper folding. Origami has been recommended as a useful educational tool considering its several advantages ranging from cognitive to motivational benefits (Gür, Kobak Demir, 2017). From a cognitive perspective, origami is associated with mathematics. The mathematics of origami is a recent focus of study in mathematics (Hull, 2006) that has implications for teaching school mathematics. Boakes (2006) asserted that origami is also suggested to enhance geometric reasoning and spatial visualization (Arıcı, Aslan-Tutak, 2015).

Extremely, it turns out that origami is much more powerful than straight-edge and compass creations, because many things that cannot be created using straight-edge and compass, such as the doubling of a cube and tri-section of an angle, can be created through paper folding (Lang, 2003). This result turns out to be quite unexpected, because we can only fold straight lines in origami due to the fact that curves are completely arbitrary in folding. Since the study of origami is fairly new, there is no limit yet to the type of constructions that can be created through paper folding.

Architectural models are created using different origami papers. The first original origami book (Figure 1a, Figure 1b, Figure 1c and Figure 1d) was described how to fold paper or cut the paper in order to produce architectural models (Fig. 1).

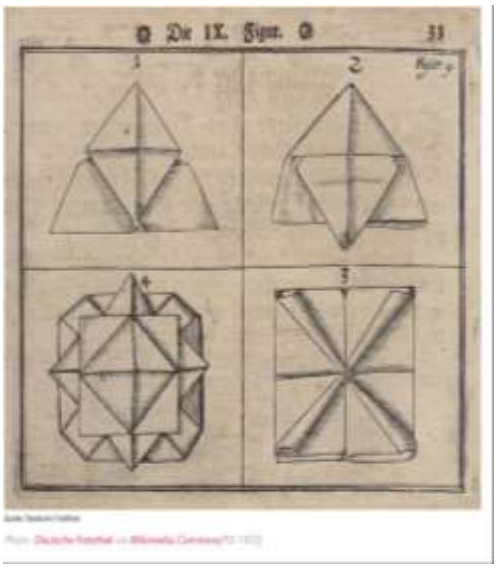
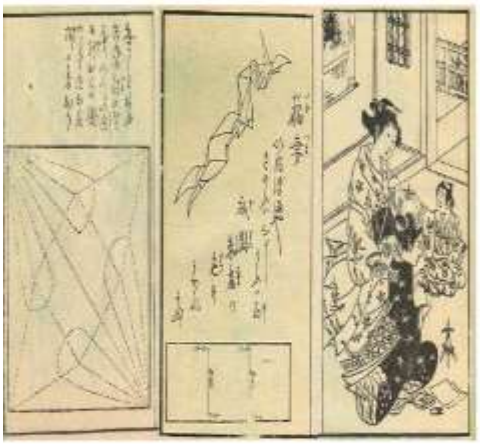


Figure 1a

Figure1b

different type of Noshi. Source: noshi collection by Yamanaka Kyoko (1850-1928).

Figure 1c



"Hiden Senbazuru Orikata", the first known book about origami, first published in 1797.

Figure 1d

Figure1. (a, b, c, and d): Traditional origami manual from The Metropolitan Museum.

An origami-inspired design has the fundamental aim of creating 3D objects from 2D sheets. Origami has proved to be useful in areas such as structural and architectural design. This folding strategy has been explored as a method to generate spatial and structural concepts in architecture by applying complex geometry. Gür (2020)'s studies found that origami helps students to improve, generalizing geometric ideas, investigating invariants, balancing exploration and reflection. Thus, both origami and architecture have become more sophisticated disciplines over the years. In the practice of architecture, it is not surprising to see the impact of origami as a medium to generate different architectural forms (Hemmerling 2010; Sorgu., Hagiwara, and Selçuk 2009). In this

regard, when studying the inspiration behind an architectural design, one can take advantage of the recent developments in origami folding.

The pedagogical issues are related to in origami different ways. Mathematicians are study the geometry of origami and use it to develop some mathematical concepts. Architectures, engineers and physicians researches structural applications of the origami. Architects are research not only the structural potential, but also the aesthetics aspects of the technique of origami. To prove the efficiency of the origami technique, we carried out a workshop with students in the Faculty of Architecture in the Balikesir University (Figure 2).

Figure2. Examples of the works of architecture students with the origami technique.

The aim of this research was to defined reflection of origami to architecture. The first part of this research consisted of a study about several types of symmetry and their applications in architecture. This type of origami includes in particular regular polyhedrons. The study shows in a characterization of bi-dimensional (frieze, wallpaper, cyclic and dihedral) and three-dimensional (crystallographic) symmetry groups. The first section of the research different types of symmetric origami were categorized according to their type of symmetry, giving in Table 1.

This form of architecture aims to take generate of planar surfaces by folding them. On folding, the surfaces can assume different forms that create a range of spatial configurations. Based on these potentials, origami thinking is now used in a wide variety of applications. But what does paper folding have to do with these applications? In this context, the following research questions on origami folding need to be discussed:

This study will present examples of architectural structures similar to these origami shapes. This article also describes a possible way to explore folding architecture based on the rules of origami. This form of architecture aims to take advantage of the elastic capacities given to planar surfaces by folding them. On folding, the surfaces can assume different forms that create a range of spatial configurations. Based on these potentials, origami thinking is now used in a wide variety of applications. But what does paper folding have to do with these applications? In this context, the following research questions on origami folding need to be discussed:

- ✓ What is the structure of the Origami formation and geometric characteristics?
- ✓ What are the structure of Symetry/polyedron, origami examples, and architectural examples?
- ✓ What are the strategies that were implemented to develop the origami making experience?
- ✓ What are the tangible products of participants and collaboration skills?
- ✓ What are understanding of architectural experience achieved throughout the phases of the workshop?

In the next section, origami potentials in architectural education are presented based on workshops with architecture students.

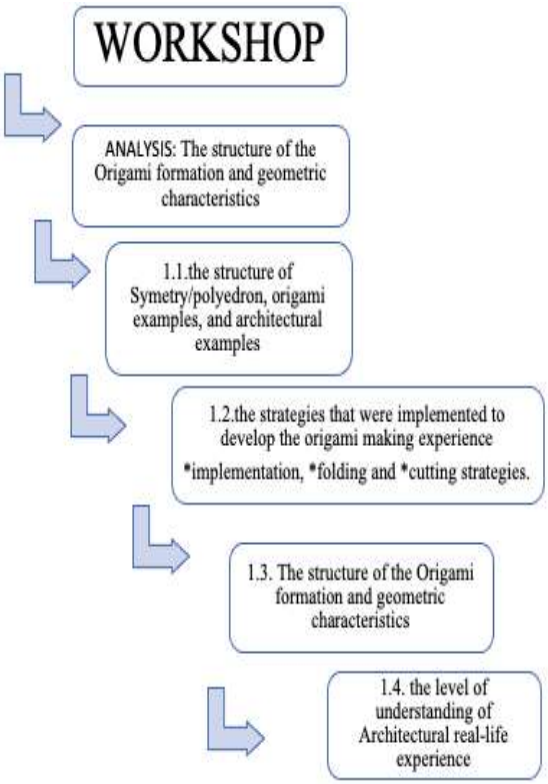
2. WORKSHOP

The reseacher provided an introductory presentation series in a PowerPoint format about origami and usage. The presentation was consisted of a brief introduction to origami and its components,

and different types of origami examples (simple to complex). Then, the students participated in was the origami examples. Different origami pattern were made with the students. The students experienced how to switch from 2D to 3D and how the paper turned into a three-dimensional form. Each student was included in a group of three to four and given supplies to construct a small structure that was intended to built 3D shapes such as plant, animal, tangible object (lamp, boxs, ...). The group's designs were left completely up to their creative imagination. Each group had many different structural variations within their designs. At the end of the workshop, students are expected to associate mathematics, geometry and architecture with origami.

3. METHODOLOGY

The population for this study included about 53 undergraduate architecture students who participated in the workshop in the Faculty of Architecture in the Balikesir University. The objective of this paper is achieved through the analysis of the workshop.

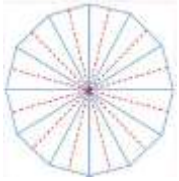
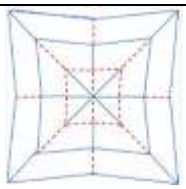


The analysis is done on four main features as follows: At first, the structure of the Origami formation and geometric characteristics were determined. Secondly, the structure of Symetry/polyedron, origami examples, and architectural examples were established. Thirdly, the strategies that were implemented to develop the origami making experience were explained. These included implementation, folding and cutting strategies. Furthermore, the end products of participants and collaboration skills were assessed. Finally, the level of understanding of Architectural real-life experience achieved throughout the phases of the workshop was detected and accessed.

4. ANALYSIS OF THE EXPERIMENTAL WORKSHOP

An analysis of the origami workshop is introduced in the coming part of the paper, different aspects of the origami experience are emphasized. For the students of architecture to make their own applications, a table containing the characteristics of origami formation and geometric characteristics (Table 1) and Categorization according to the type of symmetry (Table 2) were presented and examples were made.

Table 1. Origami formation and geometric characteristics.

Origami		A	B	C	D
Formation					
Geometric characteristics	Symmetry	Bi-axial	Rotational around a point	Rotational around the center	Rotational around the center
	Growth	In variable under n-mirroring processes	In variable under n-fold rotations about the center	In variable under n-fold rotations about the center	In variable under n-fold rotations about the center
	Isometry	Equal sizes of tiles of triangular shape	Different sizes of tiles of triangular and trapezoidal shapes	Equal sizes of tiles of triangular shape	Different sizes of tiles of triangular and trapezoidal shapes
	Repetition	Linear repetition of identical tiles	Spiral Development of self-similar rows of tiles	Radial Repetition of identical tiles	Radial development of self-similar rows of tiles

Source: Based on Liapi (2002).

Table 2. Categorization According To The Type Of Symmetry

Symetry/polyedron	**Origami Examples**	**Example in Architecture**
Bilateral (reflection symmetry)		
Bi-dimensional cyclic (rotation symmetry)		
Friese (translation and reflection symmetry)		
Sptial cyclic (3D rotation symmetry)		
Prismatic (3D translation symmetry)		
Polyhedron (Kusudama) (3D symmetry)		
Geodesic domes (Kusudama) (spherical symmetry)		

4.1. Implemented Teaching Methods In Implementation Phase

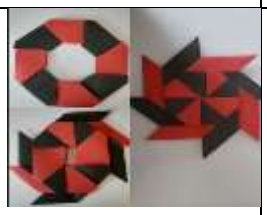
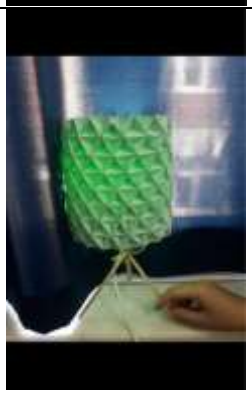
During the implementation phase a Design Problem named "How to design your own lampshade" was given to students. Instead they were given limitation functional, technical or contextual. A number of modelling materials were chosen according to their availability, ease of use and their modelling capabilities. The materials selected included, foam sheets, pre-cut foam units, linear elements (toothpicks and straws), folded paper models and plain square sheets for origami work. Figure2 shows different samples set by the team for different types of materials.

Kusudama and modular origami are defined by a regular structure. The making of this type of origami supports the development of creativity through experiments with colours and textures. It can be seen as a method to explore the use of three-dimensional symmetries in the design of spatial structures. The study of three-dimensional structures has led to a research on the regular polyhedron.

As in any architecture workshop or course the assessment process of tangible products focused on the design process. Researchers evaluated architecture students at various stages of the workshop. These took the form of either informal pin-ups or formal in term and final reviews. However, the most common is for students to pin up their work, display their models and present their work verbally to a panel of reviewers and students. It is important to plan a convincing verbal presentation in order to communicate the project fully in the time allocated. Participants were supposed to perform reflections on actions. The developed products were recognized as the representative of the design process. The steps participants have passed through from the concept generation to the model making were monitored. Students' work was evaluated according to origami formation and geometric characteristics.

Architecture students were asked to find and associate origami classification examples and their building examples according to the symmetry type. Architecture students conducted group research for this and worked collaboratively to achieve a common result (Table 3).

Table 3. Examples Of Categorization According To The Type Of Symmetry Of Architectural Students

Symetry/ polyedron	**Origami**		**Example in Architecture**	
Bilateral (reflection symmetry)				
Bi-dimentional cyclic (rotation symmetry)				
Friese (translation and reflection symmetry)				
Sptial cyclic (3D rotation symmetry)				
Prismatic (3d translation symmetry)				

Polyhedron (Kusudama) (3D symmetry)			
Geodesic domes (Kusudama)(spherical symmetry)			

As seen Table 3, when the students' studies were examined according to Liapi's classification, it was seen that they exemplified those in the A, B, C and D category. However, they have been difficulty-making samples in B and C form. On the other hand, it was observed that while finding building examples suitable for these categories, they often selected and exemplified futuristic buildings. Also as seen Table 3 in the study, examples of building related to origami that architecture students put forward as a group are given.

Their degree of satisfaction of participants was detected through their own impressions about the workshop. Most of the participants, by the end of the workshop, asked: "When is the next workshop?" This encourages researchers to do these and similar studies.

5. DISCUSSION and CONCLUSION

In the past decade, scientists, engineers and mathematicians showed an increasing interest in the progression of origami. Origami principles require interdisciplinary approaches (Lang 2003, 2004, 2007; Sorguç, Hagiwara and Selçuk 2009). Origami in particular offers new ways for engineers and architects to build, assemble, store and shape structures. It is interesting to explore the potentials of Origami as a tool to design and develop new architectural structural forms (Jiya 2014; Sorguç, Hagiwara and Selcuk 2009). In this context, the inclusions of the idea of origami in some architectures lessons encourage collaborative learning among students. In this context, architecture It is closely related to origami in many ways. Origami is the art and science of taking a square piece of paper and altering it into a 2D or 3D shape. Although origami can be an entertaining arts and crafts activity, the practice of paper folding also provides serious benefits such as being an accessible self-improvement tool, improving spatial abilities.

Çakmak, Işıksal & Koç (2013) state that origami can be a useful instructional tool to improve spatial skills because it utilizes awareness of shapes and has a geometrical connection as one folds the paper into 2D and 3D models. Origami helps to develop a better sense of spatial perception of architectural students. Students build up the idea of how to turn something 2-dimensional into something 3-dimensional. As the same time, Students explore how to the modules fit into each other. Each groups works together and understand the dimensional. They were built it as a whole product. They modified ideas and thoughts with each other and were able to go further for the same type of modules.

Many of the students have gained some type of structural understanding from the origami workshops including lectures and activities. The activities of origami provided the students with added reinforcement in understanding how these components work in design. Overall, the workshop method was a fairly successful introduction into mathematics, geometry and architectural form. Likewise, the results prove integrating workshops and active-student learning techniques

influence students' knowledge and understanding of structures. However, further research is recommended to follow these second year architecture students through their third and fourth years in the program. The research allowed us to obtain more detailed and usable information about origami. The use of symmetry and geometry with a mathematical perspective brought a different perspective.

In the research using origami, examples of symmetry and how to use perspective are included. Origami given an opportunity to understanding of two-dimensional and three-dimensional concepts, symmetry and polyhedrons. The use of origami in design allows students to discover new forms. This study provides students with the opportunity to work together, collaborate, share their thoughts, create a product, and recognize the disruptions in the design and production process. It also helped them understand complex concepts in hands on, visual, and fun way.

Participant's said that using origami in architecture to instruct them in understand to 3D shape, and perspective were beneficial because of its connection to mathematics and geometry. Researchers state that active participation in paper folding increases creativity, makes sense of geometry concepts, improves spatial thinking, and contributes positively to the development of orientation skills. As a results, origami encourages mindfulness, self-acceptance, focus, and connection. Wei (2016) express that it can take time to learn how to re-create a shown model. Therefore, when students start with a simple model, even if they make mistakes, their self-confidence improves. However, the origami is completed with repetitive folds and the correct implementation of the instructions. Sze (2005) states that making origami has enabled students to have patient, disciplined, concentrated, group work, socialize, self-management skills.

It has been found that this origami has inspirational potential for ingenious designs. Architecture students could benefit from origami folding to develop their skills and improve spatial cognition. Architecture students were created the comfortable, practical, and creative designs. As a result of this study, origami should be addressed in some courses of architectural design, to be used as a medium and guide not only for the design of new forms, but also to explore its potential for architectural application. Furthermore, the abstraction of the essence of origami to architectural design can also help in improving the logical sequence of solving architectural issues such as materiality, construction logic, structural stability, environmental performance, and energy efficiency. Apart form these, this study stated that brought exemplified of architectural structures that are similar to those origami shapes. The workshop was able to develop collaboration skills, coordination and learning community throughout all its phases, where the highest level of collaboration achieved. As a last word, it can be said that origami is help provide with hints and ideas of how to visualize the many possibilities in architecture courses.

For later studies, it is considered to use origami techniques and different materials. As can be seen from the findings, since the appropriate building examples for the use of origami in real life are seen in fituristic structures of buildings, origami lessons should be included for architecture students, which can be done both at an advanced level and even with technology.

REFERENCES

Arıcı, S.& Aslan-Tutak, F. (2015). The effect of origami-based instruction on spatial visualization, geometry achievement, and geometric reasoning, *International Journal of Science and Mathematics Education, 13*, 179-200

Boakes, N. J. (2006). *The effects of origami lessons on students' spatial visualization skills and achievement levels in a seventh-grade mathematics classroom*. Ph.D. thesis, Temple University.

Çakmak, S., Işıksal, M.& Koç, Y. (2013). Investigating effect of origami-based instruction on elementray students' skills and perceptions.The Journal of Educational Research, 107(1), 59-68.

Gallian, J. A. (1986). Contemporary abstract algebra/ Joseph A. Gallian. English: Lexington, Mass.:D. C. Heath.

Gür, H. (2020). Determination Of Geometric Habits Of High School Students By Origami Activity (Origami Etkinlikleri İle Öğrencilerin Geometrik Zihin Alışkanlıklarının Belirlenmesi), 6(33), Internationality Social, Mentality and Researcher Thinkers Journal, 1176-1194.

Gür, H. & Kobak-Demir, M. (2017). Geometry teaching via origami: The views of secondary mathematics teacher trainees. *Journal of education and Practice*, *8*(15), 65-71.

Hemmerling, M. 2010. "Origamics: Digital Folding Strategies in Architecture." *Proceedings of the 5th ASCAAD-Conference, National School of Architecture Fès*, Morocco, 89–95.

Hull T. (2006). Project Origami- Activities for Exploring Mathematics A K Peters, Ltd.

Lang, R. J. (2003). Origami and geometric constructions. Self Published.

Lang, R. J. (2004). Origami: Complexity in Creases. *Engineering and Science* 1, 9–19.

Lang, R. J. (2007). The Science of Origami, *Physics World*, 20: 30–31.

Liapi, K. (2002). Transformable Architecture Inspired by the Origami Art: Computer Visualization as a Tool for Form Exploration, *Proceedings of the 2002 Annual Conference of the Association for Computer Aided Design in Architecture,* Pomona, California, October 24-27, 381–388.

Jiya, D. 2014. *Extensions of Origami Principles in Designing Pavilions for Relaxation in Tertiary Institutions in Minna, Niger State*. Master thesis, Federal University of Technology, Nigeria.

March L., Steadman P. (1974). The Geometry of Environment: I.. London: RIBA.

Matsubara, J., Celani, G. (2007). Origami: Symmetry and applications in architecture. *Proceedings of the 5th Mathematics and Design International Conference*.

Retrieved from http://www.fec.unicamp.br/~lapac/papers/matsubara-celani-2007.pdf

Matsubara, J., & Celani, G. (2007). Origami's symmetry and applications in architecture. Retrieved from http://www.fec.unicamp.br/~lapac/papers/matsubara-celani-2007.pdf

Megahed, N. A. (2017). Origami Folding and its Potential for Architecture Students. *The Design Journal*, 20(2), 279–297.

Sorguç, A., I. Hagiwara, and S. Selçuk. 2009. "Origamics in Architecture: A Medium of Inquiry or Design in Architecture." *Metu Journal of the Faculty of Architecture* 26 (2): 235–247.

Sze, S. (2005). Math and mind mapping: Origami construction. ERIC Digest ED490352. Retrieved from https://files.eric.ed.gov/fulltext/ED490352.pdf

Wei (2016). Retrieved from https://www.psychologytoday.com/us/blog/urban-survival/201609/5-ways-origami-boosts-mindfulness