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EXPLANATION OF "ORDER" AND "CHAOS" THROUGH "SEQUENCES": ABSTRACT THINKING IN BASIC DESIGN EDUCATION

Lec. Daniz SHEIBANIAGHDAM*
Assist. Prof. Dr. Gözde ZENGİN**
Lec. Milad HAJİAMİRİ***

ABSTRACT

This study aimed to demonstrate high potential in using mathematics to facilitate the transmission of design principles in basic design education. It provided an example of how students' previous mathematical knowledge could be utilized to assist them in understanding the initial design principles. In this respect, "sequence" as a mathematical concept was used to explain the concepts of "order" and "chaos" to the first-year industrial design students who had basic mathematics knowledge. The case was studied as part of a workshop in which students from a Karabuk University's basic design studio participated. As part of the workshop's theme, waste materials were utilized in the design process. The purpose of this study was to provide a teaching method for improving the dialog between teachers and students in basic design studio without providing existing examples which can interfere the learning process and limit or hinder the students' creativity. A similar methodology can be developed based on other mathematical concepts in order to clarify and teach design principles in the future.

Keywords: Design education, Basic design, Chaos, Mathematics, Abstract thinking.

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*Karabuk University, S. F. T. Faculty of Fine Arts and Design, Department of Industrial Design, danizsheibaniaghdam@karabuk.edu.tr, ORCID: 0000-0002-5684-9914
**Karabuk University, S. F. T. Faculty of Fine Arts and Design, Department of Graphic Design, cakrgozde@gmail.com, ORCID: 0000-0002-6136-6001
***Karabuk University, S. F. T. Faculty of Fine Arts and Design, Department of Industrial Design, miladhajiamiri@karabuk.edu.tr, ORCID: 0000-0001-6771-7143

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TEMEL TASARIM EĞİTİMİNDE SOYUT DÜŞÜNME: "DÜZEN" VE "KAOS"UN "DİZİLER" ARACILIĞIYLA AÇIKLANMASI

Öğr. Gör. Daniz SHEIBANIAGHDAM*
Dr. Öğretim Üyesi Gözde ZENGİN**
Öğr. Gör. Milad HAJİAMİRİ***

ÖZET

Bu çalışma, temel tasarım eğitiminde, tasarım ilkelerinin aktarılmasına yardımcı olmak için matematiğin kullanılmasında yüksek bir potansiyel olduğunu göstermeyi amaçlamaktadır. Çalışma öğrencilerin önceki matematiksel bilgilerinin bir temel tasarım ilkesini anlamalarına nasıl yardımcı olabileceğine dair bir örnek sunmaktadır. Bu bağlamda, temel matematik bilgisine sahip endüstriyel tasarım birinci sınıf öğrencilerine "düzen" ve "kaos" kavramlarını açıklamak için bir matematik konusu olan "dizi" kavramı kullanılmıştır. Vaka, Karabük Üniversitesi'nde temel tasarım stüdyosu öğrencilerinin katıldığı bir çalıştay çerçevesinde incelenmiştir. Çalıştayın temasının ardından tasarım çalışmasını üretmek için atık malzemeler kullanılmıştır. Bu çalışma, öğrencilerin yaratıcılığını engelleyebilecek doğrudan bir örnek vermeden, temel tasarım stüdyosunda öğretmenler ve öğrenciler arasındaki diyaloğu netleştirmeye yardımcı olan öğretilebilir bir yöntem ortaya koymaktadır. Gelecekteki çalışmalarda tasarım ilkelerini açıklığa kavuşturmak ve öğretmek için diğer matematiksel kavramlara dayalı benzer yöntemlerin geliştirilebileceği düşünülmektedir.

Anahtar Kelimeler: Tasarım eğitimi, Temel tasarım, Kaos, Matematik, Soyut düşünme.

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*Karabük Üniversitesi, S. F. T. Güzel Sanatlar ve Tasarım Fakültesi, Endüstriyel Tasarım Bölümü, danizsheibaniaghdam@karabuk.edu.tr, ORCID: 0000-0002-5684-9914
**Karabük Üniversitesi, S. F. T. Güzel Sanatlar ve Tasarım Fakültesi, Grafik Tasarımı Bölümü, cakrgozde@gmail.com, ORCID: 0000-0002-6136-6001
***Karabük Üniversitesi, S. F. T. Güzel Sanatlar ve Tasarım Fakültesi, Endüstriyel Tasarım Bölümü, miladhajiamiri@karabuk.edu.tr, ORCID: 0000-0001-6771-7143

1. INTRODUCTION

In the first year of higher education in all departments of architecture and fine arts faculties, a fundamental practice-based course that is mainly referred to as basic design is included in the curriculum. This course is based on Vorkurs of the Bauhaus school that Johannes Itten initially directed. The course includes principles of design that students are encouraged to learn by doing (Lerner, 2005).

In Turkey, there are two methods for selecting the students who want to enroll in any department of architecture or fine arts faculties. One is the student selection examination organized annually by Measuring, Selection and Placement Center, and the other is the aptitude exam applied independently by the higher education institution itself (Akbulut, 2010).

In most industrial design departments in Turkey, including Karabuk University, where this study had conducted, students are accepted according to their rank in an annual national university-entry exam. These science-based students have been educated in the K-12 education system administrated in Turkey by the Ministry of National Education. In this system, mathematics is included in the primary and secondary education curriculum, so the students who continue in higher education have basic knowledge of mathematics.

In departments that offer design-based education, first-year students whose education is drawn from the national education system are expected to think abstractly and apply critical thinking principles. These skills are acquired through studio projects during class time. Since there is no single solution in design, the instructor is more of a guide than a teacher, and the student must actively produce the project within the given time basic design education can cause anxiety in students. Mainly, the topic is explained without detailed information so as not to hinder the development of original design ideas, causing students to be anxious and think that they "don't understand" or "can't do". According to Şenel and Sönmez (2017), the stress of rapid production in the studio environment creates pressure on the students who have the habit of doing homework. In particular, due to the abstract nature of the projects, comprehending the topic and realizing it is a troublesome process for the students. Hence, first-year basic design students need a design process that supports their rapid production processes, develops their abstract thinking skills, and assists them in thinking critically.

According to Taber (2006), human learning is an active process. Hence, new knowledge is constructed based on previous experiences and awareness and cannot be transmitted directly and instantly from educator to learner. However, by accounting the learner's existing knowledge, the educator can teach more effectively. In this respect, interdisciplinary studies encourage critical and creative thinking by connecting disciplines and facilitating research (Jacobs, 1989). In addition, it suggests new design solutions by uncovering new inspiration sources. *Visual Schemas: Pragmatics of Design Learning Foundations Studios (Ozkar, 2011) and Schematizing Basic Design in Ilhan Koman's "Embryonic" Approach* (Gursoy and Ozkar, 2015) are the other examples that have manipulated mathematical concepts in formalizing the pedagogical discussions in basic design studios. These studies are based on developing "shape grammars" which is one of the main themes in the nexus of mathematics and design (Sheibaniaghdam and Selçuk, 2022) in the foundation design studio.

This study adopted a mathematical approach to assist basic design students with developing abstract thinking and support them in overcoming the challenge of starting the design process. It used mathematics to enhance the students' abstract thinking and design process skills and to facilitate them in quickly identifying the starting point of the design process. For the purpose of transferring abstract concepts, lectures containing detailed information or concrete examples were avoided in order to prevent directly influencing student design outcomes. Instead, mathematical concepts were employed to enable students to gain a greater understanding of the subject matter. Another reason for choosing mathematical concepts is to enable basic design students to experience how they can integrate their previous knowledge into the design processes in the early stage of the design process. Accordingly, based on the students' educational background, their mathematical abilities in sequences were used to develop an understanding of the concepts of "chaos" and "order".

1.1. Basic Design Studio

The basic design studio is included in the first-year curriculum of the undergraduate architecture program. Following its starting point in Bauhaus, design principles are educated in this course and became a fundamental course in design education. Since it is also a typical course in all design and art education departments, it acts as a bridge between all these fields.

The basic design studio is the first place that students face in their entrance to any field of design or art in university. Students enter universities from high schools with various backgrounds (Akbulut, 2010). They mostly do not have any idea about design and aesthetic principles that are basic knowledge in art and design. Hence, the importance of their education in this stage to achieve good knowledge and proper understanding of these principles is undeniable. This perception deeply influences their educational success in the following years and future careers.

The course aims to improve students' creativity by eliminating their prejudices and enabling them to produce new ideas through their subjective perceptions. The content of the course and the applied method in the course follows the Bauhaus school in many design schools in different countries today (Boucharenc, 2006).

For the first time, a basic design course was included in the curriculum of Bauhaus as Vorkurs. Unlike Beaux Art, which was based on learning from a master, Bauhaus introduced a new kind of education pedagogy. The founder of the course and its first tutor, Jonathan Itten, was influenced by psychologists like Montessori and Frobel that worked on "learning by doing" (Lerner, 2005). After the separation of Itten from Bauhaus, Moholy-Nagy and Albers directed the course, and then methods of the school were transferred to Chicago by Mies van der Rohe and Josef Albers. Considering the history of the course is important because, after a long time, most art and design schools worldwide are deeply affected by school of Bauhaus (Boucharenc, 2006).

Although the content of the course and the applied method in the course have evolved based on the needs, conditions, and sometimes restrictions in different universities in Turkey (e.g., rlevant departments at Middle East Technical University, Istanbul Technical University, Marmara University, and Eskisehir Technical University formerly known as Anadolu University), the influence of the Bauhaus school is visible in the faculties of architecture and design (Sarıoğlu Erdoğdu, 2016; Esen, Elibol and Koca, 2018).

The content of the course is based on transferring the basic concepts of art and design, including design principles. However, there is no unity in the list of these elements. The content covers the basic elements such as shape, color, texture, light, and rhythm that Itten, showed in his book Design and Form (Itten, 1975). In addition, concepts such as balance, hierarchy, pattern, fullness/space, proportion, emphasis, movement, harmony, and contrast are other concepts included in this course.

First-year curriculum in architecture and other art and design departments like painting, sculpturing, product design, and interior design involves basic design studio courses. However, each disciplines studies these concepts within itself (Tseng and Ieee, 2016).

The basic design studio is a typical course in the curriculum of all these departments. Being an intersection between different disciplines makes it possible to be examined from different points of view. It seems that this potential can be helpful in basic design education. Coming together and discussing the subject from different points of view can help students better understand these principles.

In design education, there are difficulties in the communication between the student and the teacher from time to time. Several studies have been conducted with the help of mathematics to solve these difficulties. Goldschmidt, Hochman, and Dafni (2010) investigate one-on-one desk critiques accrued in the design studio in their article, "The design studio crit: teacher-student communication.". Using coded verbalizations, they identify links between concepts in teacher-student communication through a method. Within a pedagogical framework for design education, they describe this method as an effective feedback instrument.

A second example can be found in Oxman's (2004) article "Think-maps: teaching design thinking in design education," in which she uses graph theory to develop design theory. She assumes the design elements as nodes in this approach. Concepts are related by their links between nodes. This leads to the design's idea of creating a map that consists of nodes and links. Oxman (2004) reveals that a "think-map is a teachable method that provides the means to organize the knowledge acquired by the learner and makes it explicit." Therefore, it has a profound impact on architecture and design education. In parallel, this study attempts to clarify the dialogue between the student and the teacher using mathematics.

1.2. From Chaos to Order

Scientists in the 16th century believed that the only way to explain natural phenomena is measuring the variables that produced them. According to this view, the rules of universe should be explained in numbers, not verbal statements. This view is regarded as the foundation of modern science, which started to develop after the 17th century. Numerical information with definite assumptions emerges once physical sciences use mathematics as a tool to understand matter and natural phenomena. (Karaçay, 2004).

Determinism is the philosophy on which the classical scientific paradigm is based. Ülken (1972) explains determinism as the cause-effect relationship between A and B events in imperatives related to natural events, resulting in B in every case of A. In short, determinism can be defined as predictability based on scientific causation (Oestreicher, 2007). According to this view, it is possible to determine every movement and event in advance. Newton's three fundamental laws of motion play an essential role in modern science based on determinism. According to these laws, what is happening now originates from what happened before, and what will happen next is due to what is happening now. Knowing the initial conditions in determinism enables its analytical solution to be made (Karaçay, 2004). In other words, it can be precisely determined in advance which reaction may occur in response to each effect. Thus, there is nothing ambiguous in the cause-and-effect relationship (Ertürk, 2012). While determinism advocates such precision, the introduction of probabilities with quantum mechanics revealed the impossibility of analytical solutions for many systems, which created the phenomenon called "chaos" (Bülbül, 2007). Chaos theory revealed that classical science should change the deterministic perspective (Akçin and Zengin, 2020).

The concept of chaos was first mentioned scientifically in 1899. That year, The Second King of Sweden and Norway organized an award-winning math competition commemorating Oscar's 60th birthday. The competition committee focused on generating an unsolved problem through four questions for choosing the best mathematicians from different disciplines to participate (Barrow-Green, 1994). Poincaré, who provided a solution for one of these questions, stated that the objects' motions in the solar system's orbit, also known as the three-body problem, show unstable and nonperiodic behavior. The concept of "chaotic behaviors" is used for this unpredictable situation (Watts, 2004).

Despite the fact that Poincaré introduced this concept to the world of science in 1900, it was only in 1963 that it became a scientific theory. Edward Lorenz discovered the chaos theory by chance while working on long-term weather forecasts, unaware of the concept of chaos that Poincaré had found before him. A tiny cause overlooked can have an effect that can have big consequences. For this reason, this effect is said to originate from coincidence (Oestreicher, 2007). Lorenz observed that small changes in the initial conditions he dealt with in his study had significant effects on the result and showed that it is impossible to make a long-term forecast (Lorenz, 1963). To explain this situation, Lorenz (1972), claimed, "Did a butterfly's wing beat in Brazil trigger a hurricane in Texas?" By using the expression, he states that a small difference in the initial conditions will cause huge changes in the system's behavior According to this situation, called the butterfly effect, small changes in the initial conditions can lead to large errors in the results (Oestreicher, 2007). When these events are described as coincidences and result in negative outcomes, they are described as chaos (Bübül, 2007).

Science and social sciences have been working on complex structures in recent years. Studies in these disciplines focus on chaos and order. Although the studies have gained importance in recent years, the concept of chaos is not considered a new idea. The concept is seen as old because it takes place in mythological discourses describing the creation process of God and the universe (Hayles, 2010; Ural, 2004). This situation is mentioned in Hesiod's Theogonia as the Gods, in the creation process of the universe, it arrived at the cosmos, representing order from chaos itself (Eyuboğlu and Erhat, 1977). After mythological discourses, the concept appears in the Bible, the holy book of Christians (Korkut, 1987). According to Hayles, the new part of the concept is the emergence of a new space between order and disorder. In the meaning used in this field, "chaos" refers to complex processes that continue unpredictably despite acting according to deterministic laws (Hayles, 2010). Even though the concepts of "order" and "disorder" are perceived as the opposite, chaos is thought to contain order. According to Gürsakal, Chaos theory is concerned with investigating the order that exists in disorder (Gürsakal, 2001). The order can be expressed as a set of repeating rules. To understand the rules that make up the order, one must understand how and in what way the parts can come together. Although when we talk about chaos, the complication is the first thing that comes to mind, chaos contains order in itself.

It is perceived as a disorder because the rules that make up this order are not yet understood. Considering it as a piece pulled out of the chaos order, it is perceived as chaos because the clues about the order have not been obtained yet. According to Hayles, the curves of the cream in our coffee, which we frequently see in daily life, the rise and fall of the Nile River, global air movements, and epidemics, prove the chaos theory (Hayles, 2010).

Chaos theory, which is considered in different disciplines, is discussed in this article. Furthermore, the relationship between the concepts of chaos and order with design has been investigated, applied, and evaluated from a basic design education perspective.

1.3. Sequences

As a simple definition, "a sequence of numbers is a set of numbers arranged in some particular order" (Hisrt, 1995). In mathematical terminology, members of the sequence are referred to as "the terms of the sequence". As mentioned in the definition, the order of these terms is essential. The sequence is a function (Kudryavtsev, 2011). It works like a machine that gets the turn of the term and gives the term. The general formula of a sequence states the relationship between its terms. Also, the following terms can be guessed if the preceding terms are provided. For example, $a_n=2n$ is the general formula of even numbers. When you give 1 to "n", the function will give you the first even number: 2. If you give 2 to "n", you will achieve the second term of the sequence of even number: 4, so in this manner n^{th} the term will be 2n which is already the general formula of the sequence.

When the sequence's general formula is defined, the sequence's terms can be easily found. However, "for many sequences given recursively, finding an explicit formula for the n^{th} the term can be a challenging task" (Grigorieva, 2016). For example, in the following sequence:

(3,5,7, …)

One may guess that it is a sequence of odd numbers, and its general formula is $a_n= 2n+1$. According to the given terms, it is right, but it can be just a part of a more complex sequence:

(3, 5, 7, 15, …)

In this case, the general formula of the sequence will be $a_n= (n – 1) (n – 2) (n – 3) + 2n +1$. However, in many cases, the general formula of the sequence is too difficult to explore. The sequence of prime numbers is one of the famous examples. As a good example, the Fibonacci sequence is well-known in art and design for its relationship with the golden ratio.

Considering the characteristics of the sequences that can present a simple order and simultaneously be very complex and even complicated, this concept has been chosen to manipulate in transferring concepts of order-disorder and chaos to the students who already have a basic mathematical knowledge about sequences.

2. METHOD

The Basic Design Studio of Karabuk and Atilim Universities Industrial Design Departments were invited to the "Basic Design Workshop for Industrial Design Departments" event hosted by Gazi University Industrial Design Department on April 12, 2018.

In this context, the lecturers of Karabuk University Industrial Design Department Basic Design Studio courses and 20 students who took the Basic Design Studio II course participated in the workshop. Students selected for the workshop were required to have completed the Basic Design Studio I course and to be enrolled in the Basic Design Studio II course. However, the number of students who met the selection criteria and volunteered to participate in the workshop was over 20. For this reason, the first 20 volunteer students who passed the Design Studio I course with high scores was selected to participate in the workshop.

The workshop began with the notification of the material groups and the distribution of the workshop's brochure to the students. According to the brochure provided by the host university, students were divided into five groups: soft drink cans, egg cartons, plastic pet bottles (max. 1.5 lt), cardboard or plastic cups, and tetra Pak boxes (milk or soft drink containers). There were four students in each material group. Before attending the workshop, each university had to work with its students, and each student needed to bring a project that complied with the brochure's criteria. Accordingly, Basic Design Studio's lecturers and 20 students came together to work during extracurricular hours.

Following learning the project theme and criteria, students were given one week to collect waste materials for their project. We conducted concept studies with the students during the one-week material procurement process questioning the concept of “chaos” and “order”. First, students were asked to describe what “chaos” and “order” meant before explaining these concepts. While they defined chaos with concepts such as complexity, disorder, and random, “order” was identified as the set of rules, legible rules, and reproducible.

Next, students were given academic readings on the subject to gain a deeper understanding of how these concepts are addressed in the literature so they could be expected to demonstrate their understanding of chaos and order in their designs. The students were asked to create a form that embodied the concept of “From Chaos to Order: Entropy” using the abovementioned materials. According to workshop coordinators, the form should be 50 cm high and capable of standing independently. Additionally, the students were informed that gluing, string, wire, and fishing line were selected joining materials that they could use two of them to construct the structure.

The students were instructed to create three elements that would comprise the form.
The elements should be made following the abovementioned criteria and designed as if they were members of the same product family. Students were told that they could deform the waste materials while producing the elements. It is possible to crush pet bottles, straighten Tetra Pak boxes, unfold folded edges, bend egg boxes and change their volumes. Despite this, the deformation of the materials and the way they joined together were not allowed to go to the extent that the integrity of the waste material was compromised. It has been stressed that the theme of their projects, “from chaos to order,” implies a transformation, so creating a design that conveys this concept is essential. There is no restriction on the type of tools students may use to process the waste material they will be working with. Following the specified criteria, each student designed three elements (Figure 1).

Produced elements were abstracted as alphabets. Students were asked to create a simple sequence using these alphabets. Then they asked to make it more and more complex in several steps and consequently make it complicated in the end. As a result, the sequence that was easy to read in the first stage became more and more challenging to read in the process. In these stages, the designer was able to clarify the rule of the sequence, but at the end of the process, it was impossible to read the rule of the sequence.

3. RESULT

The design process was composed of three main stages. In the first stage, the elements were produced. In the second stage, they have bought together to create an order, and in the last stage, their combination rule is complicated to show the transition from order to chaos.

First stage: production of the elements

In this stage, initial elements have been produced considering design principles. Every intervention on the material should be done based on the clarified references to be able to produce the element over again. Materials presented to students had different characteristics that required different operations. For example, bending was proper for metal, while folding was suitable for working with paper (Figure 1). Students take the egg cartons apart to create different elements (Figure 2).

In order to create a product family, the references used for making the first element were transferred to the other two elements (Figure 3, Figure 4). The material and the way the elements will bring elements together also were determined in this stage.

Figure 1. *Elements were produced by students with the paper cups (M. Hajiamiri, 2018).*

Figure 2. *Elements were produced by students with tetra Pak, cans, plastic bottles, and egg parcel (M. Hajiamiri, 2018).*

Figure 3. *Product families were produced by students with metal cans (M. Hajiamiri, 2018).*

Second stage: Creating an order

In the second stage, students were asked to combine the elements to create an order. Students had experienced creating an order in the framework of two-dimensional practices of the previous semester. So, they had enough knowledge to combine the elements to achieve the order. However, the transition from order to the chaos was the main challenge of this design work. Students had to determine the rules of the created order to be able to control the process and convert it into chaos. In this respect, students were encouraged to create a sequence that showed the element's coming order. The students had basic mathematical knowledge to create such a sequence.

Figure 4. *The elements have been bright together to create an order (M. Hajiamiri, 2018).*

Third stage: From order to chaos

Like the previous one, this stage occurred in two realms: One as a sequence in an abstract realm of mathematics and the other as concrete design work. In this stage, students were asked to develop the sequence and make it more complex and complicated.

So, students juxtaposed three elements to create an order. Repeating the relationship between these elements was enough to read the order. It means that after some repetition, one could be able to guess the element that probably would come next. The process can be simply explained as follows:

This relationship can be expressed in the form of a sequence.

(a, b, c, a, b, c, a, b, c, …)

According to this data, there is a group composed of "a", "b" and "c" that are juxtaposing seriatim, and this relation is repeating. So, there is a rule in this sequence, and based on it, the next coming element will be "a". If, for example, "b" be the next coming element, it means that the guess about the rule of the sequence was incorrect. If the sequence continues in this way:

(a, b, c, a, b, c, a, b, c, b, a, b, c, a, b, c, a, b, c, b, a, b, c, a, b, c, a, b, c, b, …)

A new rule will appear in this sequence that is not as simple as before. However, the rule is readable yet. The sequence can make more complex by adding more elements and defining more relations. After a while, it will be complicated. It means that the achieved sequence will be a part of another sequence with a more extensive and complicated order.

The design task continued based on the achieved sequence. The sequence was used as a script that contributed to the emergence of the chaos. Since this method did not determine the quality of the relationship between elements, it did not intervene directly in the design process.

Therefore, making chaos starting from the order is not an arbitrary juxtaposing of the elements. Even if the rule of this relation is so complex that it cannot be read, and even if the design product is beyond the designer's control, there is a defined

Figure 5. *Transition from order to chaos (M. Hajiamiri, 2018).*

relationship between the elements.

A design decision was not made based on the series after the elements were produced. After the third stage, the students who had the rules of "order" and "chaos" with their elements started designing in three dimensions (Figure 5). In this process, they began investigating how each element would come together in the third dimension based on their relationship on paper and in accordance with the design principles. The students were informed that elements are expected to have strong planar relations rather than single-point weak relationships. The established relationship should also be well-defined and repeatable, and each element should be readable throughout the design without being lost. Additionally, the binding elements should not be more dominant than the design elements. As a result of these criteria, the students designed the third dimension of "order" and "chaos" and the design process was concluded.

CONCLUSION

It is challenging to practice abstract concepts in design education. Hence, in order to explain this topic to the design students and facilitate the dialogue between students and tutors, a concept in mathematics was used as the medium of communication. In this study, sequences as a mathematical concept were used to transfer the concepts of order and chaos to basic design students who were expected to design a structure from waste material in the order to chaos theme. Using sequences assists in transferring the topics to the students without the need to provide examples that could influence the design students' solutions. First, the students were asked to build three-dimensional elements based on basic design principles. Second, the concepts of order and chaos were practiced using the sequences as mathematical concepts. Later, the students were asked to make their own sequences, and then they turned their sequences into more complex ones in order to achieve chaos. Lastly, they created the relationships between their designed elements based on their sequences and built a structure demonstrating the concept of order to chaos.

This method offers the advantage of avoiding the use of existing examples, which may interfere with the learning process and restrain the students' creativity. Furthermore, through this method students experienced the utilization of another discipline in conjunction with their design projects. This study attempted to put forward an example for a teachable method that can explain the creative process of design thinking and idea generation as a logical procedure rather than describing it as an inspiration. This attitude is helpful in finding a clue to creating an initial idea for the design work, which is generally a difficult phase of the design process. Mathematics helps clarify dialogues in literature, as shown by the examples given. In this study mathematics provided transfer of the subject without giving concrete examples.

On the other hand, this method might not be suitable to be implemented by the students or tutors who are not familiar with or have difficulties recalling basic mathematical concepts like sequences.

Consequently, determining the level of students' mathematical knowledge was impossible. Due to this limitation, the selection of the students for participation in the workshop was made based on their success in the design tasks, not their mathematical knowledge.

Furthermore, the materials that were used for creating the elements were limited and similar limitations exist in joining techniques and materials. Since this limitation might affect the outcome of the design solutions, future studies can apply a similar method with different materials and production techniques.

To sum up, this study presented an example using a mathematical concept in transmitting a design principle to emphasize the high potential of mathematics in design education. To develop a full picture of the effectiveness of mathematical concepts in design education, additional studies will be needed.

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