Paying Homage to Folk Art Using Platonic Solids

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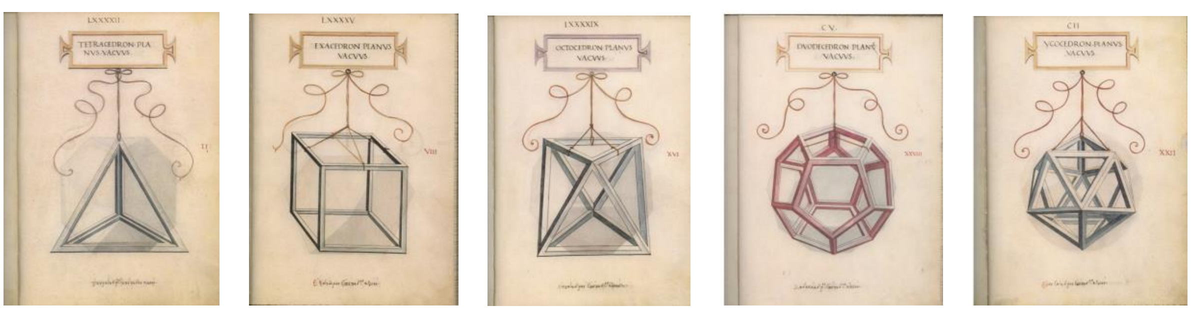
Abstract

Introducing mathematics to students early on in a manner that is not separated from its practical uses or its aesthetic aspects can make the subject seem appealing to wider range of students than can be reached by simply solving problems that the students do not consider relevant to their own life experience. This article demonstrates how an educational tool aiming to add creative, hands-on elements into science education can be used to simultaneously introduce the mathematical concept of Platonic solids while creating art influenced by himmelis, a traditional form of Finnish folk art.

About STEAM-approach

Multidisciplinary approach to education and enrichment of science subjects with elements of arts in different forms has in recent years been met with enthusiasm both in academia and in school environments. Different countries have applied different approaches to STEAM-education, referring commonly to the addition of Art, which is used as an umbrella term to include fine arts, crafts, literature, theatre or even humanities, to the traditional STEM-subjects; Science, Technology, Engineering and Mathematics [2], [5]. For example, South Korea has executed a successful curricular reform using STEAM-approach in order to help the students develop their thinking- and problem solving skills and to improve their scientific literacy along with their motivation and confidence in their own abilities [5]. It is therefore unsurprising that numerous valuable educational tools designed specifically for introducing artistic and crafty elements into science education are also Korean products.



(a) (b) (c) (d) (e)

Figure 1: *Leonardo da Vinci's illustrations of all five Platonic solids from Luca Pacioli's book De Divina Proportione, first printed in 1509: (a) Tetrahedron, (b) Cube, (c) Octahedron, (d) Dodecahedron, (e) Icosahedron.*

In this paper, out of any number of similar tools that could have been used to same effect, an educational tool called 4D Frame [1] is utilized in demonstrating how the mathematical concept of Platonic solids can be studied in a method that is artistic, hands-on, and emerges the students in a rich tradition of cultural heritage, as it is inspired by a form of traditional Finnish and more widely European folk art. The tool has shown merit in previous STEAM-modules (e.g. [7]), and has been presented in the previous Bridges-conferences even by the inventor of the tool himself, Ho-Gul Park (e.g. [6]). 4D Frame is simple to use even for young students: It consists of different lengths of colourful plastic straws, and different kinds of connector units (for details, see [1]). The user is not, however, limited to the lengths of straw or even the connector pieces that are offered in the kit, as using scissors, it is easy to make various kinds of modifications to the existing pieces. While only imagination sets limits to the possibilities of different constructions that can be executed using this tool, it is particularly well suited for building polyhedrons in a way that focuses on vertices and edges instead of faces. This method of building polyhedrons is particularly well suited for taking pictures or making 2D-illustrations of the objects, as the lack of faces makes most, if not all, of the edges and vertices visible simultaneously. In such pictures it is still possible for the viewer is still able to tell which vertices are in the "front side" of the object and which are on the other side. This manner of illustrating polyhedrons such as Platonic solids simultaneously from "front and back" was most likely introduced by Leonardo da Vinci [4]. These illustrations, of which the Platonic solids are shown in Figure 1, were published in the early 16th century. Despite certain flaws, which were no doubt caused by the lack of plastic straws at da Vinci's disposal, they remain an important milestone in the history of mathematical art.

Platonic Solids and Himmelis

The five polyhedrons that can be built to fulfill two simple requirements; the first that each face is the same regular polygon, and the second that the same number of polygons meet at each of the vertices, are called the Platonic solids (pictures in Figure 1). The five different platonic solids are tetrahedron, which has four triangular sides, cube, which has six square sides, octahedron, which has eight triangular sides, dodecahedron, which has twelve pentagonal sides, and icosahedron, which has twenty sides. The number of sides-or in straw models, edges meeting at each vertex for the aforementioned polyhedrons- is three for tetrahedron, three for cube, four for octahedron, three for dodecahedron and five for icosahedron. A tool such as 4D Frame is valuable in teaching the concept of regular polygons and polyhedrons in a relatively simple manner, enabling a more student-driven approach. Using straws that are the same length and connector units of the same type, the short time frame of a single class is sufficient for even young students to be able to build these shapes with minimal scaffolding from the teacher.

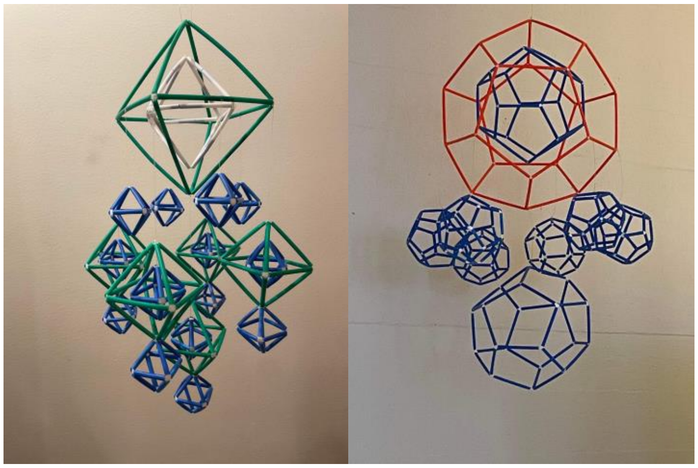
While the artistic or creative value of building one out of five predetermined geometrical shapes using standard lengths of straw and connector pieces may be limited, these shapes can be connected with each other in ways that have indisputable aesthetical merit. Himmelis are a form of traditional Finnish and more widely Northern-, Eastern- and even Central European folk art, where the same geometric constructs are created using pieces of natural rye straw instead plastic straw, connected by threading string through the straws instead of using separate connector pieces. Having historically been used year-round in various different contexts such as weddings [3], himmelis still have an important role in Finnish Christmas decoration. The more traditional himmeli designs are often formed of octahedrons, forming either three-dimensional lattice-like structures or hanging below one another. Designs can, however, vary significantly: any hanging, three-dimensional structure made of straws could be considered a himmeli. A traditional Finnish himmeli is shown in Figure 2.

Figure 2: *Traditional Finnish himmeli, picture from https://pixabay.com/fi/users/mehe-337599/.*

Traditional himmelis are a wonderful, ecological and aesthetically pleasing form of mathematically motivated art. However, as a topic of STEAM-approach math/art-class, studying Platonic solids by methods of traditional himmeli-making would be counter intuitive. Since traditional himmelis are made by threading string through the straws, the approach to the building process is far more methodical and the straws must be placed on the string in a specific order, meaning the Platonic solids that form the building blocks of said himmeli cannot be viewed as separate objects. Further, building a traditional himmeli requires the kind of skill and patience that cannot be expected from the age group that would most likely be studying a topic such as Platonic solids; late elementary school to middle school students, depending slightly on the focus of the class. Time would also certainly become an issue in a regular school environment.

While the plastic straws and connector units are durable, reusable, and enable learning through trial and error, the rye straws are fragile and a break easily, in worst cases forcing the builder to re-start the entire building process. I myself built a simple, individual octahedron in this traditional way and got frustrated by the constant splitting of the straws at the slightest use of excess force in threading. Traditional method of building himmelis would also be against the nature of STEAM pedagogy, as it would require following instructions exactly, thus leaving little room for student creativity and trial and error, both of which are key elements of STEAM- approach. Collaborative work is also much more easily managed using a tool such as 4D Frame, which allows the building of separate Platonic solids that can hold their three-dimensional shape even sitting on a flat surface on their own.

The suggested structure of a STEAM-intervention combining theory about Platonic solids to the creative process of building himmelis would depend largely on the available time. One lesson could for example be spent studying the Platonic solids, letting students build them in the colours and sizes of their choosing. During the next lesson, the whole class or class divided into several smaller groups could build a large himmeli by attaching them together using string. The plastic straws and connector units of 4D Frame are so light that as long as the individual Platonic solids used as building blocks are not too large, they maintain their form well even in larger, hanging structures. Pulling apart and reattaching the straws using the connector units is also so effortless that smaller shapes can be easily placed inside of larger ones, even if they were not originally built that way. Two examples of himmeli-inspired art sculptures, each of which only consists of one type of Platonic solid, can be seen in Figure 3. It is worth noting that the "himmeli" made out of dodecahedrons is not something that could ever be achieved using traditional methods of himmeli-making, as the only reason that a dodecahedron can hold its shape is the semi-rigid nature of the connector units.



(a) (b)

Figure 3: *Himmeli-inspired art made using 4D Frame plastic straws and connector units, separate Platonic solids attached together using string: (a) Octahedron "himmeli", (b) Dodecahedron "himmeli".*

Summary and Conclusions

Himmelis and Platonic solids combined can form a base for a lesson that can serve different purposes and suit different age groups. Focus of the lesson can be either on the artistic and creative aspects, on collaborative efforts, or especially for older students on making mathematical observations about Platonic solids with the help of the hands-on-tool. If the students are aware of the sizes of interior angles in regular polygons, being able to build aforementioned shapes should offer support in tasks such as discovering the number of different Platonic solids. Understanding that the sum of the angles meeting at each vertex has to be less than 360° for the polygons to form a polyhedron should allow the students to also understand that as the size on each angle on a regular triangle is 60°, there can be at most three ways for regular triangles to form a polyhedron: Either with three, four or five triangles meeting at each vertex. They might also observe that since six regular triangles meeting at one point form a 360° angle, this results in a flat rather than a curving surface. Similar observations can be made about the other polygons involved in building platonic solids as well. These hands-on experiments and the resulting observations could serve as a solid basis for understanding some fundamental concepts of three-dimensional geometry.

Whether an educator wants to focus on the mathematical or artistic aspects of himmelis and Platonic solids is entirely their choice. Using colorful plastic straws instead of natural rye straw opens up possibilities to talk about color theory in addition to the perceived aesthetic value of symmetry, which is inevitably present in himmelis. Understanding of how the movement of himmeli affects the way it appears to the viewer requires spatial understanding and awareness from the artist. The more advanced and creative the students are, the more complex and fascinating himmelis they will be able to create.

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