Teaching Design Science: An Exploration of Geometric Structures

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Abstract

The late Dr. Arthur Loeb, professor in the Department of Visual and Environmental Studies at Harvard University, developed and taught Design Science/Synergetics, an exploration of three-dimensional space, and Visual Mathematics, which explored the parameters of structure in two and three dimensions for more than two decades. The main foci of design science were geometry, mathematics, design and the beauty that resulted from this marriage. Dr. Loeb's widow, Charlotte Loeb, donated the Design Science Teaching Collection to the Edna Lawrence Nature Lab at Rhode Island School of Design in 2003. In its new environment, the Teaching Collection is inspiring both faculty and students. This paper includes examples of models made by RISD students in response to questions arising from the study of geometry and design science. I will also discuss how a heuristic approach to teaching design science meshes synergistically with an art and design curriculum.

1. Introduction

The cultivation of creativity requires fine balance among the teaching of technique, the stimulation of curiosity, guidance, group dynamics and respect for an individualistic sense of the creative act. In the education of the artist these countervailing forces serve a multifaceted role: a.) guiding young minds without squelching creativity and offering paradigms for further investigations, b.) encouraging a sense of participation within a creative community or tradition while respecting the privacy and introspection necessary for the creative act.

Learning geometry requires the acquaintance with and understanding of a necessary body of core concepts and mathematical techniques. How these concepts and techniques are arrived at is crucial to the ability of students to manipulate them creatively and to feel enabled to further explore.

In drawing or sculpting, for example, simply moving a pencil or molding a piece of clay is considered an appropriate and indeed fundamental component of the larger diet of artistic exploration. The recognition that activity on such a primary level is as central to maintaining and developing artistry as planning and executing a more technically ambitious project such as a large scale oil painting or casting a sculpture in bronze shows a deep self-awareness and understanding of the nature of creativity. With this understanding, an artist realizes that there is no set hierarchy of values attached to a given creative activity - only as I mentioned above, "a diet" based on openness to possibilities that arise via various processes.

In mathematics, in this case geometry, a student's notion of creative manipulation often seems to be the privilege of a gifted few. There is a perception that technique and conceptual apprehension must precede any creativity; that the prodigy who solves a problem or ventures a novel theorem is born with an innate ability that is denied to the vast majority of people. This "perception" per se is open to many debates concerning the role of innate abilities. But what stands in undeniably daunting truth is that this perception is at the root of one of the greatest obstacles to the study and enjoyment of mathematics:

the fear of not knowing something specific, a correct answer for example, can feel as terrifying as trying to land a plane on an island at night in dense fog.

And yet we know that one can have levels of understanding of mathematical ideas. An initial glimpse into the spirit of duality or instantaneous rate of change or the possible implications of the Fibonacci series...and so forth is not simply an incorrect understanding because it seems incomplete but an exciting, stimulating revelation that energizes one to look deeper - like the quick gestural sketch that helps an artist to bring life to a larger, more worked piece.

2. The Heuristic Approach and Results

By taking a hands-on approach to studying geometry, the initial glimpse can be literally tangible such as a paper model of a dodecahedron or the construction with compass and straight edge of a pentagon. In this sort of educational environment, that which is "correct" is also fascinatingly beautiful.

Below are some related images of models made by RISD students:

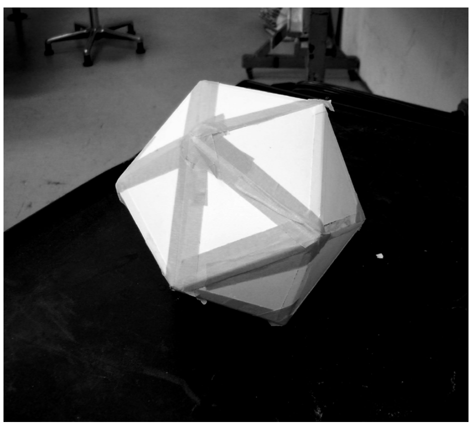

Figure 1: *Icosahedron*

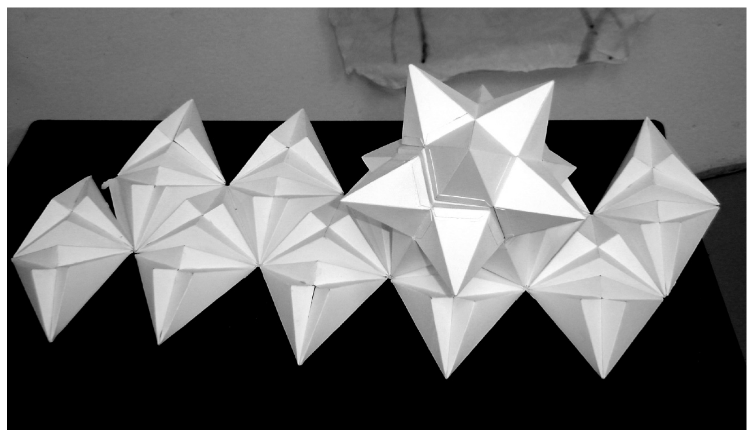

Figure2: *Model shown in figure 1, unfolded to show a stellated pentagonal dodecahedron embedded in it*

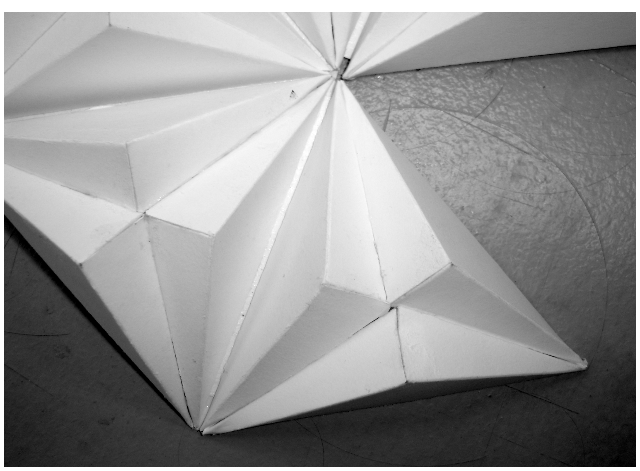

Figure 3: *Detail: interior surface of model Shown in figure 1.*

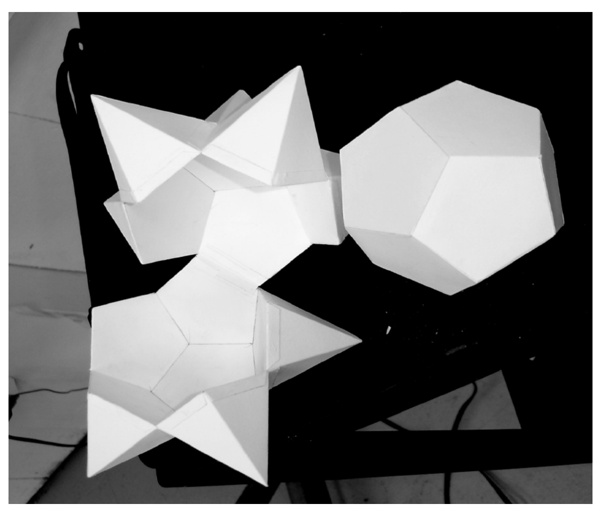

Figure 4: *pentagonal dodecahedron embedded in the stellated dodecahedron shown in figure 2.*

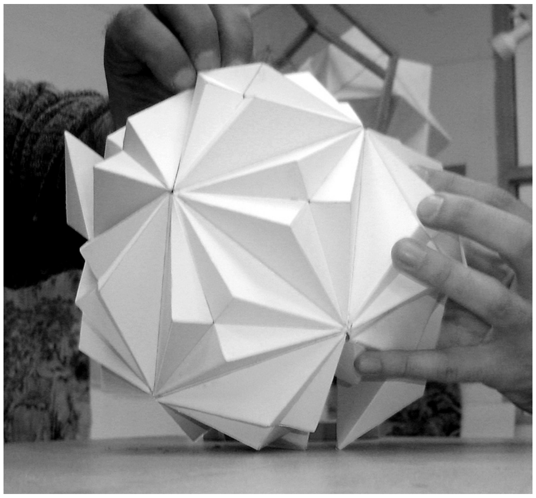

Figure 5: *Polyhedron obtained by turning the model shown in figure 1 inside out.*

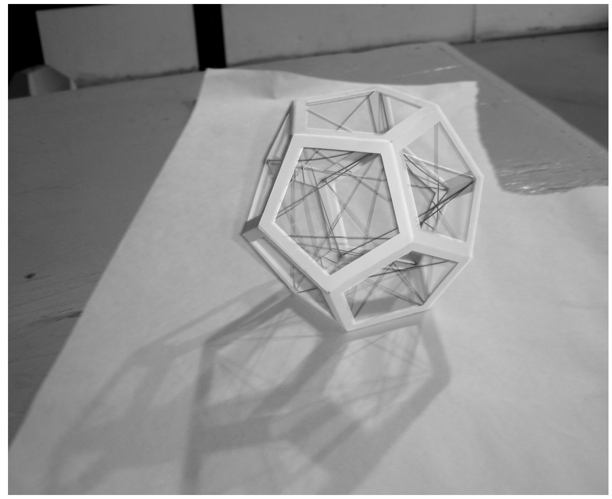

Figure 6*: pentagonal dodecahedron with five wire tetrahedra embedded in it. Models shown above by Andrew Goett, freshman.*

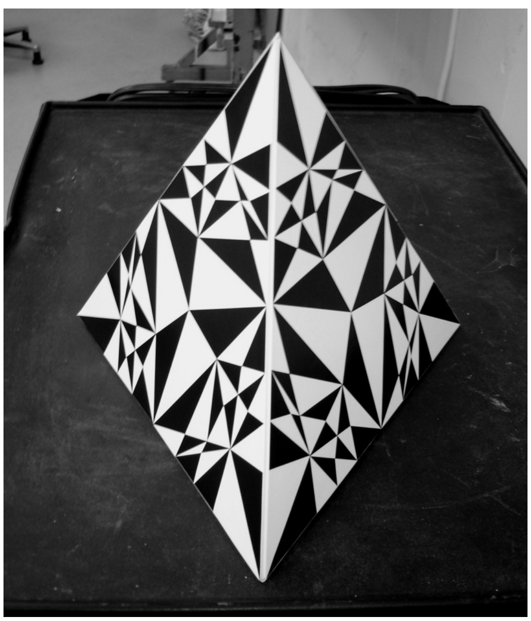

Figure 7

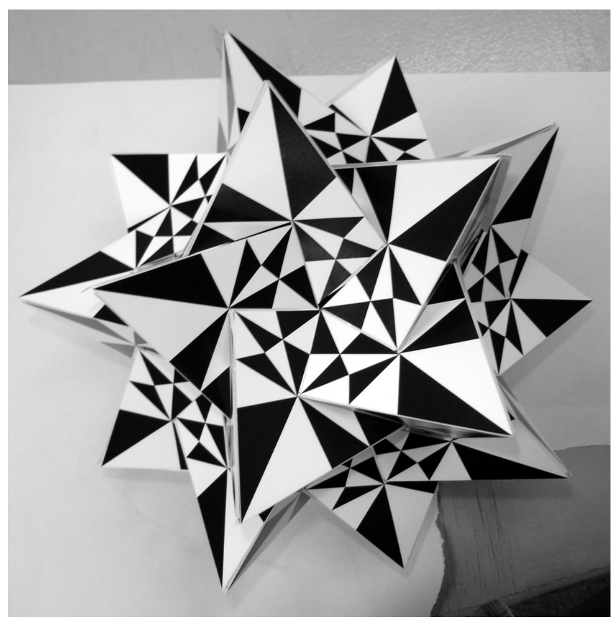

Figure 8

Figures 7 and 8: *Compound of five tetrahedra with pattern that demonstrates a uniform organization of five and three-fold symmetries. Models by photography student Tom Prado, '07*

Some other course topics and activities are: Platonic solids, duality, Euler-Schlafli equation, stellation, truncation, Archimedean solids, rigorous perspective drafting, Schlegel diagrams, space filling: rhombic dodecahedron, octahedron/tetrahedron ratios, introduction to group theory space filling form exercise using either projection drawing or model-making, 5-fold forms: icosahedron, pentagonal dodecahedron, triacontahedron etc, degrees of freedom, stability, jitterbugs, basic tensegrity structures and dome systems, building tensegrity forms, preferably with an eye toward eventual applications to sculpture, furniture, architecture/shelter, etc.

3. The RISD Context: Open and Conducive to Sharing

At the end of the first term, Caryn Johnson (Dr. Loeb's Teaching assistant of ten years who was my tutor for design science) and I were discussing the course with a few students. One remarked, "it will be interesting to see how this course affects the (study of sic.) design at RISD". At first I thought that this was a lovely way to make a compliment. On further reflection, I realized that the student was addressing a unique characteristic of the RISD environment (in fact, art and design schools in general). Students make work in clear sight of classmates, and often leave their work in studios that are used by many students. There is an emphasis at RISD on sharing; it is understood from the beginning that ideas must not be considered as proprietary products. When Picasso said, "I do not borrow ideas from other artists, I steal them" (paraphrase), he was not expressing a sociopathic tendency, he was simply being honest. When an artist "steals" an idea, it is to develop it, to incorporate it into his/her own vision. And so the ideas, expressed in models and drawings as a result of the design science course have been "stolen", passed around, expanded upon, integrated into other design studies and influenced students' work in many areas of study.

The ability to visualize, draw, build, to think with one's hands is a huge benefit in terms of being prepared to study design science. During the foundation year (first year of study) and during the course of subsequent years spent in their respective majors, students are primed with strong intuitive and practical understandings of the laws of space and form. Most aspects of this knowledge are defined in a clear, sophisticated and structured manner.

On the other hand, there are large gaps left in design terminology from the standpoint of a lexicon that is common across disciplines. There is also a dearth of understanding about the nature of polyhedra and polygons - their extent, categorization and structural properties. From the point of view of studio practice, this is clearly not an impediment; the RISD student often goes on to create wonderful things and to be successful in his/her field. Students who have taken a term of design science have recognized that it has opened their eyes and minds to another world of possibilities.

4. The Power of Geometric Models for Artists

The discomfort with looking more deeply at art, via geometry, or design science in this case, may ultimately result in an unhealthy emphasis being placed on the product of creative activity. This discomfort may have a paralyzing effect on the ability to see new solutions. Often during the creative process things are discovered which are not sought. One is reminded of the Zen homily which cautions," If you only focus on the goal, you will not see the dangers and pleasures of the path, whereas if you attend to the path, you realize that the path is the goal and the goal the path. If we know what we are seeking, discovery is redundant. So emphasis is placed on enjoying exploration in this design science class.

Artists are inclined by training to be cognizant of the fact that there are ideas attendant to an artwork. These ideas, primarily of an historical/cultural context, become implicit components of artistic intention. By contrast, pieces are not usually undertaken that are meant to demonstrate and elucidate concepts while at the same time embodying those concepts. To put it another way, the geometric models are not denotive or connotative as an allegorical painting or a work that contains religious symbols might be. The models are the physical equivalent of a verbal or written description of the geometric ideas under scrutiny. At the same time, the variations made possible by introducing a physical, materially rich study that utilizes model-making often indicates the breadth of nuances potentially left to be discovered. This is all the more heartening when we reflect on the fact that these are nuances of mathematically precise ideas. So we learn to see that mathematical objects may be as multi-dimensional as a person that we know or a character in a play. We can replace the fearful monolith of "that which is correct and only this" with a sense of playful negotiation; an invitation to muse.

The arts give us joy to the extent that they reveal new ways of thinking and perceiving. This generates optimism that the world might have infinite facets -a most beautifully cut diamond. In that same sense, mathematics is like poetry. Or more precisely, mathematics and poetry are both forms of expression that seek to discover using the tools of form. In both, content is pretext for structural investigations. In each, the structural investigation reveals and abstracts universal principles purely for the sake of this activity. They are both processes of making metaphorical statements and therefore involve a reorganization of information. Each structure that is revealed suggests new paths specific to it and paths towards new structures.

By way of illustration, Sara Kudra, a sophomore in architectural studies writes: "Design Science has allowed me to understand shapes in a new context that I had never considered before. The class has opened my thoughts about simple things; the way solids are formed, their relationship to each other and the mathematics that fundamentally drives them all.

On the first day of class my preconceptions were contradicted, and I was astonished to be seeing new relationships in everyday things. We were asked to slice a cube along a plane in such a manner that we would get a regular hexagon. The solution, it turns out is a rather simple one that proves the old adage, ‘think outside of the box’; but although the answer was not mind bending like some of the conversations about the fourth dimension have been, it still was as astonishing. The reason it such an amazing experience was because it had been in front of my eyes the whole time; I only needed something to open them to it.

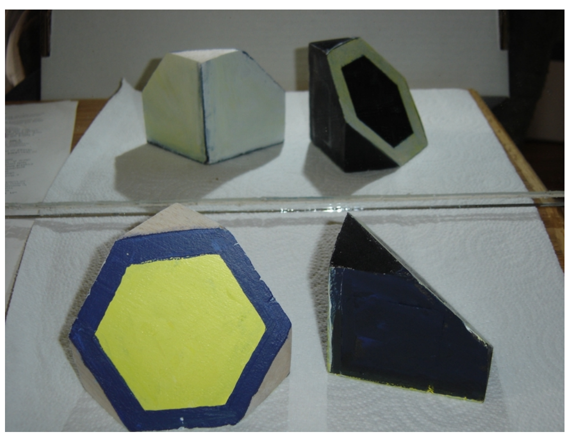

Figure 9: Cube sliced perpendicular to its three-fold axis of symmetry, at the midpoint of that axis.

This awakening is a great benefit of Design Science. There are relationships between all geometry that we use, and to be able to enlist that knowledge to manipulate and inform your work is a wonderful understanding to have. Students do not just pass through this kind of class; although it never feels like work, there is a much greater depth of understanding when you use your hands to make these relationships for yourself.

The advantage of having this kind of class in a studio art and design environment is that the pupils that are engaged in the work are able to find things out on their own by building models and through observation. If it looks like there may be a relationship between forms, or it appears as though one shape is derived form another, then students are encouraged to find that out on their own by constructing the form. I can honestly say that there is no better way, as a student, to understand what I am working with than by being challenged to make it on my own, and draw my own conclusions without being handed the answers for the sake of information. When students are told a solution in order to memorize it and accept it then they do not actually understand it or know why it is so; but when a student is told to make it (specifically in an art setting) he/she comes away from it not only with a greater depth of understanding, but can also show you all sorts of relationships that were previously unseen and they will tell you all about them.

Having gone through this class has changed my view of simple things; I no longer can assume relationships in design without thinking how they have come to be. As I continue into my next semester of school I will take with me a greater appreciation about the world of shapes and forms, and as an architecture student I will use those thoughts to my advantage as I design in the future. The extent of design Science is not limited to polyhedra, but is something that reaches much further than just that. It is a way of understanding- relationships, orders, structures, and reasoning that can be applied to any work; and has an especially strong relation and contribution to the art world. For the select few students at RISD who are not timid about embracing their interest for geometry this class will change them for the better, and they will be able to encourage the next generation to engage and be educated about the ways of Design Science. " -Sara Kudra, architecture student ‘08.

An artistic masterpiece might safely be described as something composed of only necessary parts - and beyond that the composition transports us to its own world - a world of order. It might suggest disorder but the vehicle of the message must itself be orderly - it is from this that expression derives power. In speaking of mathematics Bertrand Russell might well be speaking of the fine arts, "Remote from human passions, remote even from the pitiful facts of nature, the generations have gradually created an ordered cosmos, where pure thought can dwell as in its natural home and where one, at least, of our nobler impulses can escape from the dreary exile of the actual world." [1]

5. Conclusion

We sense an ordered fabric to physical reality but we have only occasional, tantalizing glimpses of it. With the study of design science, students learn that the boundaries between internal and external realms of discovery are fluid. The difference between art and mathematics is that for art this beauty and clarity seems to gestate internally and brings about the birth of living expression. In mathematics this wonder appears all around us. We see patterns again and again in a surprising range of places, objectively distant from our selves.

The great resonant ideas have been voiced repeatedly, not simply for the sake of reiteration or bombastic pride, but in the desire to clarify or even purify them. In the visual arts this is fairly easy to accept; a portrait from ancient Rome and a portrait by Alberto Giacometti may seem equally necessary to the tradition of painting. But a model of a dodecahedron helps students to see that what they know about the power of material exploration to bring new ideas to life applies to geometry as well... and then, what else?

This course in geometry enables students to see that it is the form of these ideas that changes. This is far from meaning that there is a paucity of wisdom. Form is not necessarily the superficial aspect; in fact, the idea resides within the form much as the spirit resides within the body. Without a form to animate, an idea is without voice.

References

[1] **Bertrand Russell**, *from The Study of Mathematics: Philosophical Essays*