

A Shape-based Approach to Creativity and Connection Making

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Abstract

Creativity can be driven by cross-pollinating ideas, often from divergent disciplines, and synthesizing them into something ‘original’. This workshop presents a shape-based activity that uses polyhedra as an abstract external stimulus to inspire creative design responses. Concepts generated during a participatory community workshop are presented as example outcomes of this pedagogic approach.

Introduction

Creativity is considered as the capacity to develop original ideas, or to produce a solution that is both novel and appropriate to its goal. Although there are variations in approaches and ways of working, there are notable commonalities to the processes used by the creative disciplines to support creative thinking and ideation (idea generation). Particularly evident is the separation of divergent and convergent thinking styles. Divergent thinking involves deferring judgement in order to generate the greatest quantity and variety of solutions possible. Typically this occurs in a spontaneous, ‘non-linear’ manner, whereby many ideas are generated in a short amount of time, and unexpected connections are drawn. Techniques such as brainstorming are often used to aid divergent thinking. The ideas generated through use of divergent thinking can be refined using convergent thinking. This involves using critical and analytical abilities to structure ideas and make judgments in order to identify the ‘best’ solution. It is important to note that the creative process relies on using both thinking styles in an iterative manner. Competency in the early ideation stages has been shown to have a significant impact on the overall success of the creative process and its outcomes [9].

It is widely accepted that creative people are better-able to recognize associations, make connections, and see things in an original way [1]. External stimuli have become a cornerstone of creative practice as an aid to unlocking imagination and helping to establish connections and associations between seemingly unrelated information [5][16]. However, depending on the type of stimuli and how they are introduced, the inspiration effect can be both positive and negative. These negative effects are known as ‘design fixation’, whereby an individual unconsciously focuses on a limited set of ideas and narrowly explores the problem area. Studies in design research support the use of abstract stimuli rather than concrete sources of inspiration (e.g. existing design solutions) in order to mitigate fixation [16]. This paper outlines an experiential learning activity developed to explore the potential of math-art as an abstract source of inspiration within the creative process.

Originally created as one of a series of classroom creativity challenges for courses in engineering design and innovation, the workshop has been developed to provide students with experience of a structured creative process, to support group collaboration activities, improve idea generation and encourage creative thinking. Working first individually and then in teams, participants will respond to a hands-on creative challenge. Participants will be encouraged to reflect on their own pedagogical approaches and consider how they might introduce math-art as a stimulus to broaden students’ creative thinking and innovation abilities.

Workshop Background and Overview

The workshop utilizes the K-12 educational material ‘pull-up patterned polyhedra’ [7][8] as a stimulus for connection making. Designed to be accessible regardless of background, the pull-up polyhedra (shown in Figure 1) were developed as an educational tool to encourage visual thinking through the exploration of symmetry, pattern and shape. Based on nets of the Platonic solids, the pull-up polyhedra are created using a method that requires only card, scissors and string, and enables the net to be ‘pulled’ from two-dimensional to three-dimensional form. The patterned nets were developed during a visual arts study that explored the different pattern classes capable of repeating across, or wrapping around, the faces of the Platonic solids, while retaining the regularity of the plane pattern [11][14]. Since their original inception, the pull-up patterned nets have been adopted as a visualization tool in the EU project SeeingNano [2] and a series of icosahedral nets have been adapted for teaching the applications of group theory in virology.

Taking the format of a two-part activity, the workshop introduces an abstract stimulus to promote creative thinking and encourages novel connections to be made through an open-ended task—a method that introduces both inspiration and constraint into the creative process. The workshop format has been developed through use of this technique in three different educational contexts:

1. Undergraduate teaching: A creativity exercise within courses in product design, creativity and innovation at the University of Leeds and Tecnológico de Monterrey.
2. Research collaboration: A shape and spatial design workshop involving 40 participants at *CADI: Innovation and Product Design*, Tecnológico de Monterrey in June 2018. The activity was used to encourage groups to think creatively about how to tackle particular research challenges.
3. Community workshop: A design workshop involving 52 undergraduates (from various disciplines) and 22 high school students as part of a social innovation project [4] to co-design FabLab La Campana in Monterrey, Mexico in January 2019. The activity was used to produce design concepts for a community space within the La Campana-Altamira neighborhood (a Priority Attention Area with high rates of poverty and social exclusion).

Adopting a ‘learning by making’ approach, the initial hands-on activity uses the pull-up polyhedra and the cross-disciplinary connections that inspired these shapes as a stimulus for ideation. Participants are then invited to make their own creative connections to the concepts that have been discussed by responding to a design challenge. An overview of the workshop structure is provided in Table 1 and the process is discussed in further detail below.

Table 1: *Workshop outline*

Duration (minutes)	Activity	Content	Materials
05	Introduction	Creativity	Presentation
10	Part 1: Connection making	Symmetry, pattern, textiles, polyhedra, crystallography, architecture, virology	Presentation
20	Pull-up polyhedra	Polyhedra, nets, symmetries, pattern/tessellations	Pull-up nets (Figure 1) on A4 card Thin string (e.g. crochet thread) Scissors and rulers Single hole punches
05	Part 2: Challenge briefing	Design context, stimuli, constraint	Presentation
35	Ideation: Brainstorming Concept refinement Ideation scoring	Group work: Divergent thinking Convergent thinking	Post-it notes Pens, markers and flip chart paper
15	Feedback and Reflection	Sharing ideas Reflection on process	

Part One: Making Shapes and Making Connections

Geometry has long been used as a tool across the disciplines and provides many sources of inspiration for the rich connections between the arts, science and mathematics. The initial workshop activity involves the hands-on making of pull-up polyhedra as a collection of low-fidelity prototype shapes. The activity provides participants with examples of the nexus between crystallographic theory, pattern design and virology, which are visualized within the patterned nets. Participants will use this material as a stimulus for the design task in the second stage of the workshop.

Working in small groups (ideally of 4 or 5), participants will make a series of pull-up polyhedra from the nets shown in Figure 1, ensuring that the group has completed at least one pull-up net of each of the Platonic solids. Participants are guided through the geometric connections between crystal structures and the design of plane patterns, which when folded on to polyhedra create representations of the triangulated protein network of virus shells. The making process enables participants to reflect on the visualization of these principles in the pull-up shapes they have created and to explore the nature of the shapes themselves. For a more detailed review of the cross-fertilization of geometric ideas between crystallography, graphic arts, textiles, architecture and virology see [12][13].

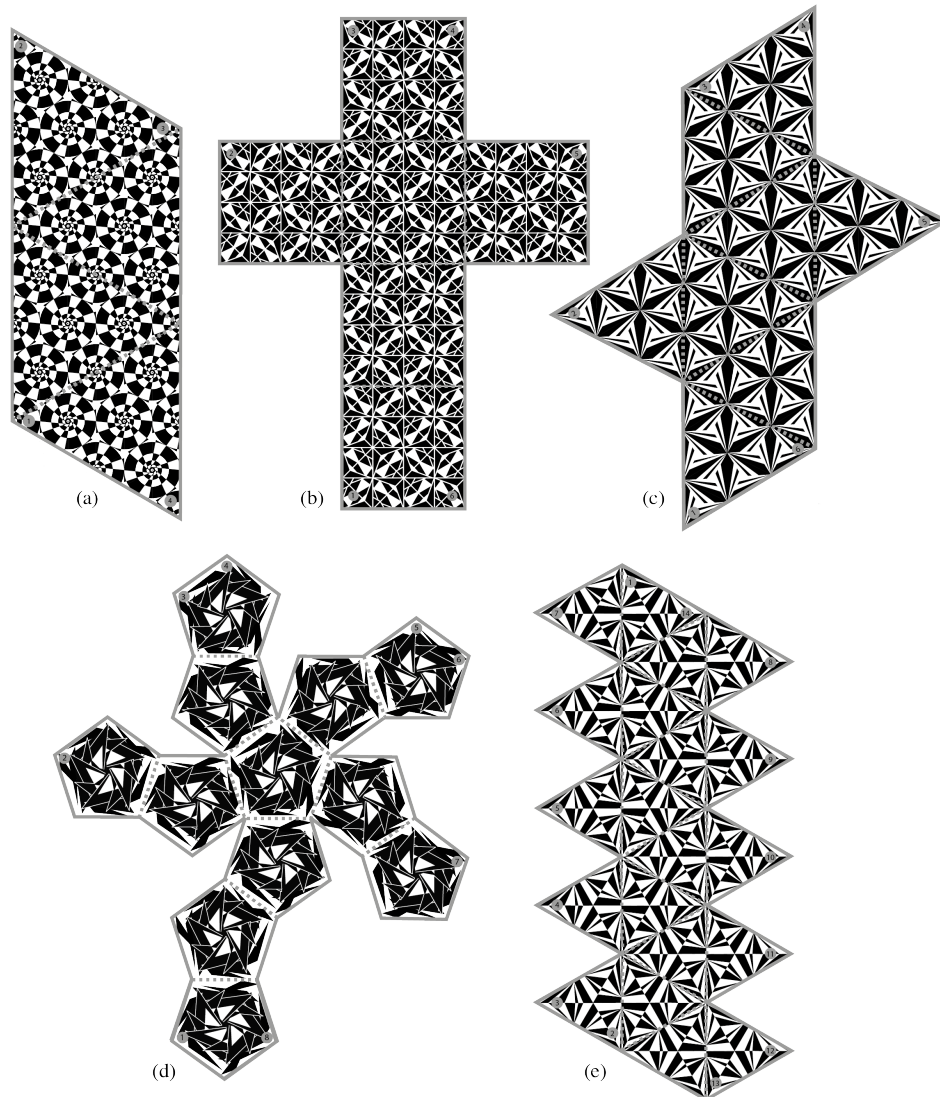


Figure 1: Pull-up patterned nets for (a) the tetrahedron, (b) the cube, (c) the octahedron, (d) the dodecahedron and (e) the icosahedron

Basic instructions:

1. Carefully cut out the net for your pull-up polyhedron.
2. Use a ruler and sharp point to score lightly along the dotted gray lines.
3. Using the single punch, make holes at the corners with gray circles marked 1, 2, 3, 4, etc.
4. Weave thin string/thread through the holes 1, 2, 3, 4, etc. to link the faces together.
5. Tie the ends of the thread together and gently pull up the net to make your polyhedron.

Participants will have the opportunity to construct a number of pull-up nets during the workshop. Full details of the background of the pull-up net activity is provided in [7]. Downloadable teaching resources supporting this activity are also available [15]. A variation of this stage of the activity is possible using Escher tessellations and polyhedral models as a stimulus, allowing exploration of similar cross-disciplinary concepts and creative leaps. Pull-up net designs incorporating Escher's tessellations can be found in [8].

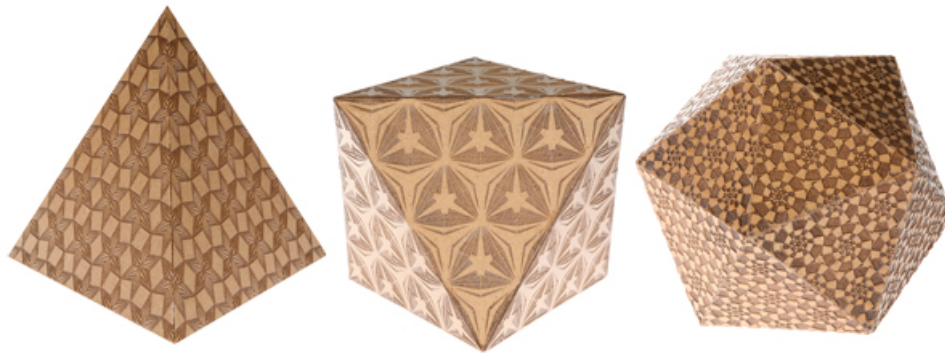


Figure 2: *Patterned polyhedra from the series 'Polyhedra de los Leones' by Briony Thomas [11]. The collaboration and development of pull-up patterned polyhedra was inspired by this exhibition.*

Part Two: The Creative Challenge

Working in groups, participants are invited to respond to a design challenge, using the pull-up polyhedra as an external stimulus for connection making. The design challenge is introduced to participants after the pull-up net activity is complete in order to mitigate fixation, whereby participants unconsciously focus on a solution early within the process, limiting their creative exploration. This problem-based challenge is structured in a design studio teaching format that involves the following steps: briefing, hybrid brainstorming, ideation scoring and feedback. These stages are outlined below.

The design brief is presented with a defined objective, e.g. a design for a product or solution to a particular circumstance/problem for a specified user. The objective of the brief is determined according to the context of the workshop and the experience of the group. Groups are challenged to propose a design solution using the pull-up polyhedra as an inspiration source. The only constraint imposed on the process is that concepts must in some way relate to the pull-up polyhedra (or elements of these shapes) and math-art concepts that have been discussed. Participants are free to choose the shapes or elements of the stimuli that they wish to use, and these can be developed or manipulated in any way. The imposition of only one constraint allows the task to remain open-ended. The briefing avoids the use of examples of potential solutions, products or designs as this has been shown to lead to fixation [16].

Participants are guided through the ideation process where they will first be asked to generate as many varied ideas and connections as possible. A hybrid brainstorming activity is used for an initial divergent thinking stage involving both individual and group ideation for greater quantity and quality of ideas [4]. The four rules underpinning this brainstorming process are: 1) there are no bad ideas; 2) capture everything; 3) combine and build; and 4) quantity over quality. Following this brainstorming activity, ideas are then thematically grouped, and a second stage of convergent thinking is used by each group to structure, combine and refine ideas.

Participants are introduced to metrics that can be used to evaluate the success of their ideation process [10]. Focusing on the criteria of ‘novelty’ and ‘quality’ (or feasibility), groups are asked to select their ‘best’ or highest scoring concept to share with the other participant groups. The workshop concludes with groups reflecting on their experience and the value of using abstract math-art concepts as a stimulus to kickstart creativity.

Example outcomes from the FabLab La Campana workshop

The delivery of this workshop to student groups has shown that a wide range of ideas can develop from the initial geometric forms. Participants often use the pull-up nets as hands-on prototyping material in both two- and three-dimensional form to evolve the initial shapes. Outcomes from undergraduate classes have included abstract responses, such as an algorithm that computes three lines of code inspired by the three edges that meet at each vertex of the tetrahedron. More product and architecture-focused responses have included designs for tables that change shape based on their geometric form and geometrically-based concepts for housing and infrastructure systems (e.g. water and power supply networks). The delivery and outcomes of this workshop during the project FabLab La Campana [3] are discussed below to illustrate the potential application of the workshop method.

The design brief for the FabLab La Campana workshop was based on the outcome of a diagnostic participatory process, which had been undertaken with the local community in order to understand the urban and social context of the area. Through these activities the needs of the community and key areas for improvement were identified, from which a design intervention brief was elaborated. Workshop teams were challenged to produce a design for a product or an installation for a specified site within the community. The product/installation was required to be of value to the community and to be based on their needs and ideas, as identified through the diagnostic process. Each team comprised a mixed group of students from a local high school (CBTis 99) (to provide a community perspective and input); undergraduate students from the project’s Digital Design and Manufacturing group (for knowledge of the design intervention proposal and manufacturing context); and undergraduate students studying creativity and innovation (to support the idea generation process).

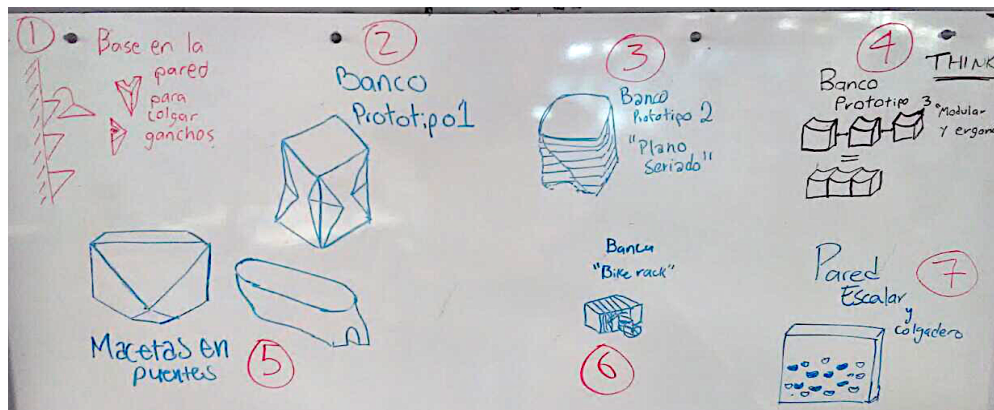


Figure 3: Ideas resulting from the FabLab La Campana workshop 1) wall piece/product hanger, 2) first bench prototype, 3) second bench prototype ‘serial planes’, 4) third bench prototype ‘modular’, 5) hanging planters, 6) bike park bench, and 7) climbing wall hand holds.

Ideation concepts generated during the workshop (Figure 3) were developed by the Digital Design and Manufacturing group, comprising members of the community and students from Tecnológico de Monterrey led by Institute mentors [6], with the aim of showing how digital fabrication tools within a FabLab can achieve larger-scale elements for the community. The student group generated designs for urban furniture and architectural installations using 3D modeling software (SolidWorks and Rhino 3D), ensuring these could be cast in concrete (to reduce the likelihood of theft) and met manufacturing

requirements (e.g. feasibility for mold casting, demolding, modularity, etc.). A total of nine design concepts were digitally prototyped. Of these, five design concepts were fabricated for the community space (see Table 2). A CAD model of the concept design for Banca Bici/skater (Bike/skate Bench) is shown in Figure 4.

Table 2: Fabricated design concepts resulting from the FabLab La Campana workshop

Name	Function	Problem/solution area
Avioncito (Little plane planter)	luminaire, market, gardener	<i>Problem:</i> lack of elements for hanging during the street market. <i>Solution:</i> 3D printing technique to produced mold for casting concrete pieces. Painted in luminescent paint for visibility. Multi-use hanger or planter embedded into the walls of CBTis 99.
Octobanca/ Icosabanca (Octo-/icosa-bench)	parkour, furniture	<i>Problem:</i> lack of seating within the public space. <i>Solution:</i> manipulated polyhedra to produce unusual seating.
Triángulo tile (Triangle tile)	Aesthetic, color, games	<i>Problem:</i> neglect of the public space and lack of community ownership. <i>Solution:</i> extruded/painted triangle shapes proposed by the community as they saw the evolution of the designs.
Banca bici/skater (Bike/skate bench)	skateboard, bicycle parking, furniture	<i>Problem:</i> lack of activity areas and seating within the public space, particularly for school children who mentioned interests in bikes and skating. <i>Solution:</i> Mixed-use proposed by students and the community suggested a larger heavy design to prevent theft.
Banca triángulo (Triangle bench)	furniture	<i>Problem:</i> lack of seating within the public space. <i>Solution:</i> Inspired by the repetition of triangles in the polyhedra. Extruded lines of one triangle with the addition of a curved horizontal plane to create an ergonomic shape for seating.

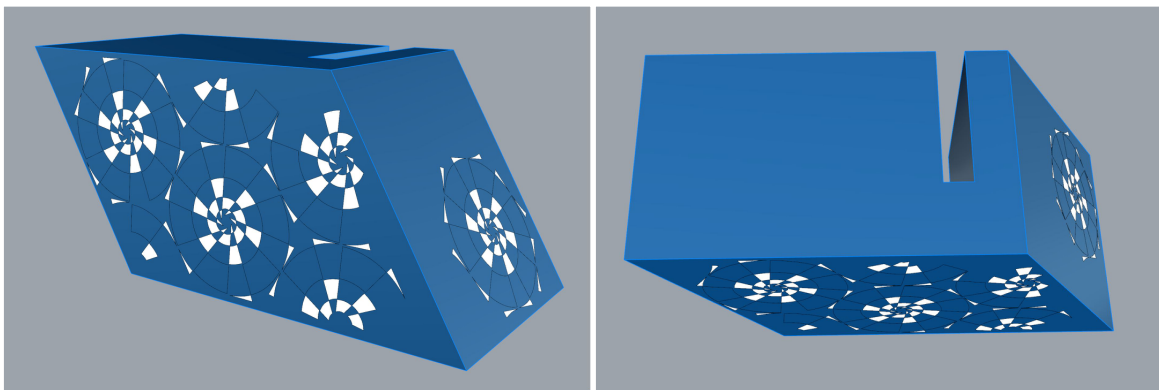


Figure 4: CAD modelling of a concept for Banca Bici/skater, a multipurpose bike park/bench

The five designs selected for fabrication were successfully installed within the public space. Figure 5 shows Banca Bici/skater installed and in use within the public space. The site selected was identified as a place that most of the community transits through and where a community project is underway to rejuvenate the space in collaboration with Tecnológico de Monterrey. The area adjoins the CBTis 99 high school, where the FabLab has been installed, and on the weekends the space is used for an informal pop-up market. The design intervention has been well-received by the community who have since shown a greater sense of ownership of the space and have been working to improve the site through removal of rubbish and the planting of trees and shrubs. Following the installation, the community has also painted several of the concrete pieces (see Figure 6), indicating the sense of value that has emerged through the community's involvement in the co-creation of the space.



Figure 5: Banca Bici/skater in-situ within the community space



Figure 6: Community intervention by colorful painting of the concrete

Summary and Conclusions

The two-part workshop activity presented above is designed to encourage creative thinking through the use of math-art concepts as an abstract source of inspiration. The use of abstract concepts assists in mitigating the negative effects of fixation that can be caused when concrete designs and existing solutions are used as stimuli. Using a ‘learning by making’ approach participants are introduced to math-art concepts within a structured creative process and gain experience of a number of techniques that can be applied to other problem-solving activities. Through the delivery of this workshop in different educational contexts, the use of geometry as an abstract visual stimulus has been shown to engage participants from a wide range of backgrounds and abilities. The structure of the workshop provides a framework within which different activities and stimuli may be used. Alternative examples of cross-disciplinary concepts and/or a substitute geometry-based making activity may be used as a creative stimulus depending on participant’s backgrounds, specialities and the desired outcome.

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