# (Pattern) $^2$

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## Abstract

In this workshop participants will observe the complexity generated by the interaction of two simple systems; a randomly created two dimensional black and white design and a three dimensional folding pattern. The supplied pre-scored paper guides both the 2D drawing component and the 3D folding component of the activity. Participants decorate and fold the paper to produce a three dimensional form. The activity provides opportunities for the recognition and discussion of numerous mathematical and STEM concepts coupled with the challenge and joy of making.

## Introduction

Questions are emerging in education and industry in relation to the integration of art and design methods into STEM curricula in order to make science and discovery visible and relatable [1]. The Arts can be placed at the centre of STEM learning turning STEM to STEAM, through inter-disciplinary projects that encourage enquiry and critical thinking. In this activity each participant creates something unique and beautiful. See Figure 1. Joy in making is closely linked to the acquisition of knowledge and understanding when the experience of making is imbued with meaning. Making leads to observations, which generate questions, discussion and inevitably, learning. In this activity, the meld of mathematics and *making* provides an inextricable link between form and content. As John Maeda says:

> There is no greater integrity, no greater goal achieved, than an idea articulately expressed through something made with your hands. We call this constant dialogue between eye, mind, and hand "critical thinking – critical making." It's an education in getting your hands dirty, in understanding why you made what you made, and owning the impact of that work in the world. It's what artists and designers do [2].

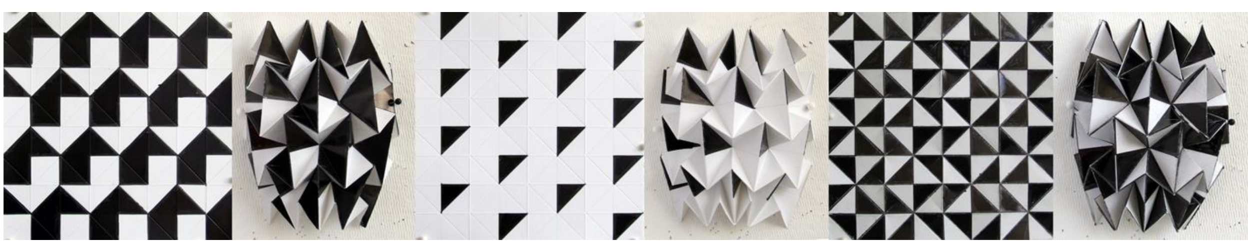

**Figure 1**: *Three pattern and folding combinations.*

Our intention is to encourage the sense of wonderment and awe in a shared experience of learning science, technology, engineering and mathematics where preconceived thoughts about ability and capacity are rendered irrelevant. Our activity promotes amongst other things, ideas related to variability, elementary symmetries and iteration while learning about pattern making via probability theory.

## The Activity

Participants will be provided with paper pre-scored with the folding pattern for a section of the magic ball or dragon's egg origami fold. A section is used rather than the complete pattern because of time constraints for this workshop. The unscored pencil line indicative of a missing line of symmetry is shown in grey in Figure 3.

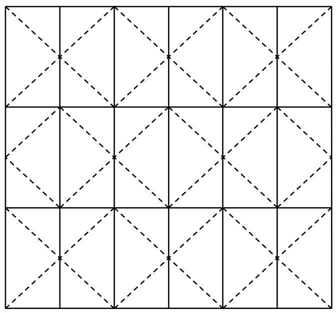

**Figure 2:** *Pre-scored folding pattern*

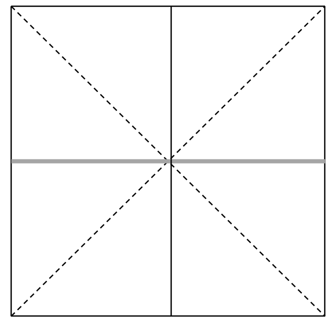

**Figure 3:** *Eight segment design grid*

**Creating the design.** The pattern design is simply generated by flipping a coin 8 times to decide whether the segment will be colored black or left white. In the first instance this design is repeated exactly over the whole grid taking into account that there is glide or translation symmetry in the fold pattern.

**Folding the paper.** Participants use the pre-scored lines to create valley and mountain folds which are then collapsed to form the convex three dimensional forms, somewhat like a hedgehog. The resulting forms can be grouped to create a pleasing display, showing the kinetic effect of the variety of black and white patterns. (See Figure 4.)

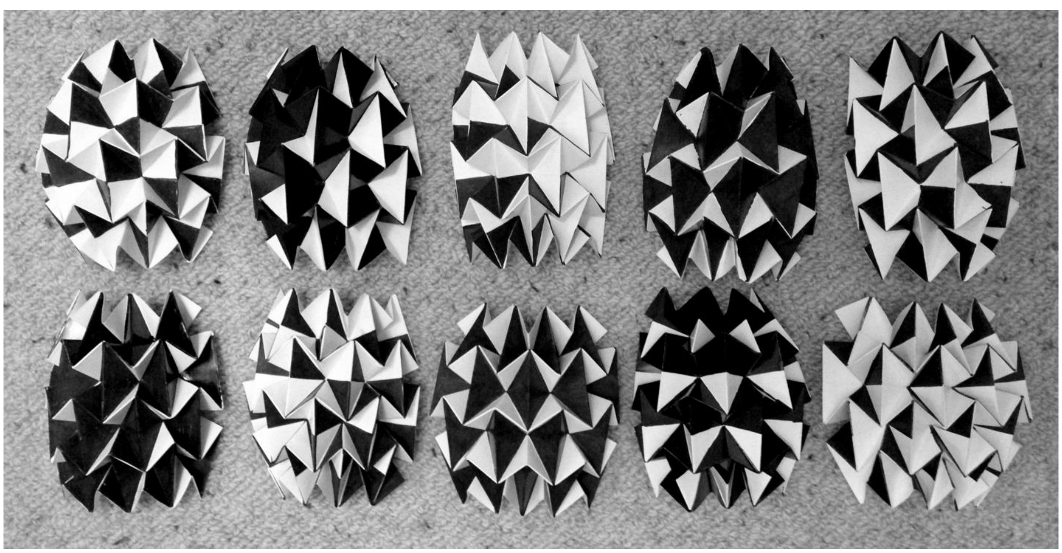

**Figure 4**: *Possible combinations of pattern design and folding*

## Learning Opportunities

The activity is quite simple and anyone with a modicum of manual dexterity should be able to complete the task at least once in 90 minutes. The folding is however, difficult enough for participants to gain a satisfying sense of achievement and an understanding of the physical attributes of flexible paper architecture. Although the activity itself is unpretentious there are many STEM ideas that will be raised during the process. The following is a limited discussion of the possibilities.

**Probability theory and random v choice.** The coin tossing introduces an element of play as well as a chance to discuss random events and bias. It is inevitable that participants will be surprised or even frustrated by the results of the coin toss. Firstly, because they might possibly expect an equal number of heads and tails and secondly because the design that results in the eight segment square may not show the properties of pattern that humans generally find attractive. However, it is important to stick to the rules at this stage because the pattern will be repeated and modified by the second folding system.

The first part of the activity provides the opportunity to challenge common mathematical misconceptions, to discuss probability theory, to calculate the number of possible design combinations, to introduce ideas on wallpaper tilings and pattern theory. It can also lead to discussions of the role of pattern and ornamentation across cultures, pattern recognition and its role in perception, and the aesthetic appeal of pattern where as Gombrich says "delight lies somewhere between boredom and confusion". [3]

As an extension, participants could modify their first random design by introducing elements of pattern design such as reflection, rotation and translation symmetry. They may also desire the freedom to choose a pattern design of their own. It is interesting to note that there is much less variety in the finished pattern if this path is taken and that certain parameters often result in a more aesthetic outcome.

**The folding pattern.** The fold is created with glide symmetry that enables the structure to collapse into a convex shape with the patterned surface facing up. The paper dimensions are 4x4 squares, creating a grid of sixteen single square units. Figure 5 shows workshop participants folding the patterned scored paper.

The glide symmetry that forms the foundation for the folding pattern provides a tactile representation of a mathematical translation. Figure 6 shows a mathematical diagram illustrating the glide reflection process. In the first activity the black and white design will show glide but without reflection. Participants introduce reflection in folding construction phase of the activity.

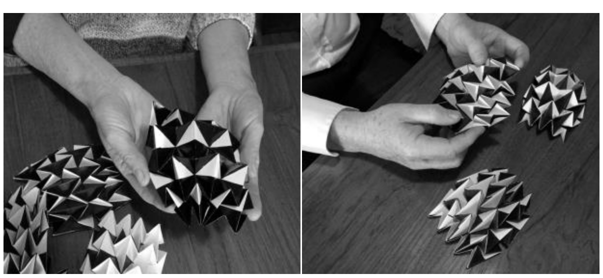

**Figure 5:** *Folding the patterned paper*

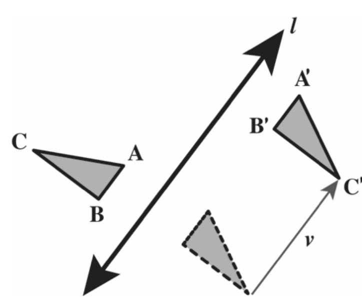


**Figure 6**: *A glide reflection*

Handling the structure and recognizing the geometry of the folds could lead to discussions about the use of origami in architecture, engineering and medicine and the self-folding properties of naturally occurring and man-made structures. The fold used in this activity for example has been used by a British-Japanese team from Oxford University; Zhang You and Kaori Kuribayashi-Shigetomi, to make a collapsible heart stent. [4]

**The finished display.** A final display of collective works presents an opportunity to discuss such ideas as intra-species variability, genetics, adaptation and evolution. In addition, it provides a chance to appreciate the aesthetics visible in the variety of the created forms. See Figure 7.

**Figure 7**: *Dark Fold. 2016 Liz Shreeve*

## Pedagogical Implications

The experience of creativity and community in a motivating math maker setting is a situation aligned with the benefits of engagement and enterprise. [5] These are the skills that begin in childhood and continue throughout life's education journey. The new work order acknowledged globally as attitudinal, places enterprise skills at the heart of learning and must possess the ability to critically assess and analyze information, be creative and innovate. [6] We consider that the arts in STEM education is not just a tool to promote learning in science, technology, engineering and mathematics but carries as much weight as other disciplines in education and in society. Investigating STEM content through creating and making can express the "critical thinking – critical making" relationship that Maeda encourages and where the joy in *learning by doing* may contribute to the acquisition of knowledge.

## References

[1] Marland, J. (2013). Rhode Island School of Design Announces "STEM to STEAM: Full Circle from Education to Economy" Expert Panel at SXSWedu. *Business Wire*.

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