DESIGN LEARNING THROUGH ITERATIVE FOLDING OF NON-PAPER MATERIALS

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ABSTRACT
Iterative folding is a robust and productive way to explore product form and motion behaviour requiring few tools. Paper folding has been recognized and studied as a design method conducive to form generation for architecture and other products of design. Shifting to non-paper folding extends this design methodology by including in its scope not only form exploration, but also material properties study, promising compliant mechanism solutions and possible production approaches. Folding non-paper materials allows modelling of form and also can generate a prototype iteration that seeks to understand material behaviour, mechanical properties and other product design considerations.
This paper discusses sheet material folding as part of a design methodology in the context of two workshops given by design faculty and students with non-designer participants. The outcomes of these workshops vary depending on the degree to which folding principles are discussed and folding activity is implemented.

Keywords: Folding, design methodology, form generation, material properties, design pedagogy

1 ITERATIVE PAPER FOLDING

Perhaps the first well-known example of paper folding as a design learning activity was assigned by Joseph Albers in his Volkurs course at the Bauhaus. [Figure 1] He asked his students, through tacit exploration, to discover paper material properties and potential as they created folded objects for study and reflection. Students' results revealed underlying properties of paper that demonstrated potential exploitation as a design medium. [1]

Figure 1. Albers with his Volkurs course students Photo-Erich Consemüller

Over the decades, relatively few design educators have espoused the usefulness of paper folding as an iterative design strategy. The practice has been sustained largely by origami artists such as Akira Yoshizawa, Mokoto Yamaguchi, Robert Lang and many others who have created sophisticated pieces that reinvented the traditional practice. Recently however, folding as a method of exploration and production has increased significantly throughout the design world. Folded products are becoming

increasingly available in the marketplace and have become a significant area of interest among the many low-volume makers and designer-to-consumer proprietorships.
Publications such as Paul Jackson's *Folding Techniques for Designers* [2] and Sophia Vyzoviti's *Folding Architecture* and *Supersurfaces* [3,4] have infiltrated classrooms and studios and enjoyed influence in the recent renaissance of folding. In addition, each of these authors (and others) has conducted courses and workshops internationally that have resulted in furthering the practice of paper folding. Gilles Deleuze's conception of "the fold" [5] has become a point of departure in design and architectural discourse, supporting a theoretical basis for folded form generation and meaning creation.

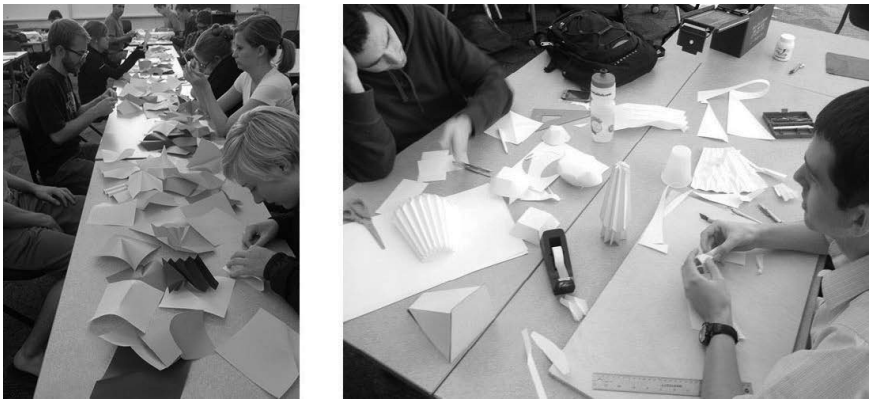

Figure 2. Design students engaged in folding paper studies

Recently folding has surged as a design method and production practice. Paper folding is particularly suited to the iterative design process. [Figure 2] The material is readily available, cheap, relatively simple to manipulate, requires few tools, and eminently familiar to most. Student designers can very quickly transform two-dimensional sheets into three-dimensional studies. Folding is a tacit, freethinking, bottom up, make-it mode, very sympathetic to an iterative approach, which requires one to visualize, validate then iterate, until eventually a desired result is reached.

2 PROGRESS TO NON-PAPER FOLDING

The shift from paper to non-paper materials is a non-trivial problem. Paper has unique properties that make it such an advantageous folding material. Its hinge-like folds are very forgiving to small inaccuracies that result in workable models without the need for undue precision. Other materials, especially semi-rigid materials, lack these folding friendly qualities. Although paper may be optimal for iterative folding, other materials do have some advantages over paper. They allow for greater degree of application over a wider range of required properties. Of course, many product material requirements include durability, liquid and heat resistance, transparency, reproducibility, etc. that extend beyond what paper can supply. If designers can explore form, mechanical, and aesthetic solutions in the same material as the end product, the design process can move with fewer restraints from initiation through completion in a more cohesive manner.
Folding non-paper materials, such as sheet plastics and sheet metals, allow the iterations to swim along in the stream of prototypes and material studies. This means the student designer can transition freely from morphogenetic activity to prototype fabrication and even into production, growing and deploying the acquired tacit knowledge throughout the entire project, without the need to shift to new materials at each step in the process.
Folding materials other than paper may well impact the design process or affect a students' methodology in the following ways:

- Form exploration- Similar to paper, folding other materials, such as sheet polycarbonate, can be conducted as a form exploration. There are thousands of other sheet materials, hand or machine made, more or less flexible, with a range of fold ability.
- Material properties- Creating informal material studies based not in technical information, but on tacit explorations conducted through hands-on manipulation and experimentation.

- Compliant mechanisms- These are jointless structures or flexible mechanisms that may be realized in a simple form through folding various sheet materials. Many times it is necessary to locally modify the material to facilitate folding at a particular place or along a certain line, or to create a fold with a particular behaviour.
- Low-volume production- Folding is also a fabrication process that can be used as a manufacture method for many low-volume productions. The advantage here is that folding is a strategy that can be used along the entire design methodology, from initial visualization through production of the final product.

3 WORKSHOP ONE

Two design making workshops were conducted one year apart by industrial design students and their professor. They were held as part of an annual design week at a regional art and science museum. Participants were drawn from the general public and reported a variety of professional backgrounds and reasons for registering for the workshop. Student volunteers were in their 2nd year of an industrial design course, concurrently working on an ongoing project similar to the project presented in the workshop. The format of each workshop was quite similar, which included: an introduction to the problem, some instruction regarding working with sheet polycarbonate as the primary material, discussion of simple examples, then the majority of the workshop was spent working through the problem, followed by an informal end-of-workshop exhibit and brief evaluation discussion. The entire workshop lasted just three hours.

Student volunteers acted as coaches, assisting participants with technique and how-to type questions, and helping participants reflect [6] on the process of designing/making as it was occurring. The professor and students were able to provide individual attention to participants as the venture progressed. This interaction allowed the students to be the "instructor" for a time, which many reported, "opened their eyes" to the learning dynamic as it related to their university studio experience. [Figure 3]

Figure 3. Participants and student volunteer at 1st lamp making workshop

Most participants commented that this individual attention was crucial to achieving their eventual product outcome. All participants were able to produce some satisfactory artifact. Some participants reported surprise at what they accomplished in such a short time. Others had not yet completed their project at the end of the scheduled time and left intent on completing the project on their own. Most expressed excitement at being able to conceive, design and produce a product, a feat that before they had not thought possible.

4 WORKSHOP TWO – FOLDING EMPHASIS

The second workshop, conducted a year after the first under the same auspices, was similar in most ways to the first. Except in one significant way, the emphasis on folding. The instruction section of this workshop provided more detailed and thorough instruction of folding techniques. Each student volunteer was chosen to discuss some aspect of folding, material manipulation, method of attachment,

or demonstrate an approach that the student determined would be helpful. Folding instruction included: scoring, mountain and valley folds, regularly dividing surface space, types of pleating, crumpling, twisting, and the basics of cone, bowl, and box construction. We also briefly demonstrated, as in the first workshop, attachment possibilities including: tabs, weaving, rivets, snaps, sewing, eyelets, grommets, and clips. Again using polycarbonate sheet as the primary sheet material.

Emphasizing folding as a design and making activity enabled participants to progress further than in the non-folding workshop. It appears their production benefitted from a more focused direction and greater skills toolbox to draw from. Although it's unlikely the participants were completely lacking folding experience, we believe the folding instruction could have provided the participants with some new information that developed into skill acquisition during the workshop. [Figure 4] Folding activity also produced an enhanced atmosphere of energy and excitement, as well as open sharing with a general attitude of play.

Figure 4. Student volunteers instructing; participants at 2nd lamp making workshop with folding emphasis

We observed participants demonstrating less self-consciousness and self-doubt. Folding activity seemed to balance differing participant experience levels. In other words, folding served in a way to level the playing field. Everyone can accomplish basic folds, and those who came to the workshop feeling a bit tentative were relieved and encouraged by beginning with familiar non-threatening terrain. In fact, for some there was a bit of a role reversal. Those who considered themselves less skilled found that they were helping others perceived as more skilled.

Some of the written review comments we received from the participants expressed their perceptions this way: "It was fun, pushed my creativity, great materials and tools. Tactile/hands-on learning experience." "I am a bit impressed with my ability to go from an idea to a tangible working product." "Exploring ideas through quick physical prototypes is more informative than ideation sketching in terms of how elements come together." "My project changed three times over the course of an hour- this was a great opportunity to explore the materials with minimal risk."

Figure 5. Participants show results from 1st (left) and 2nd (right) workshops

5 CONCLUSION

We found folding non-paper material in this workshop context to be an informal, tacit, intuitive way of working. [7] It is a low-waste manipulation of a continuous sheet that can simplify and focus design and making activity. In turn, this focus can enable students to penetrate further into the prototype iteration process creating more refined, sophisticated and whole solutions.

When we compare outcomes from both workshops, we found the folding emphasis produced one disadvantage and some advantages:

- Degree of homogeneity- Especially in the early stages of a folding exercise, many results look similar to one another. It takes time to develop folded forms along divergent paths. Perhaps, this disadvantage could be overcome through a longer workshop.
- Faster start- Folding seemed to lower barriers at the beginning the project, making for some the first tentative steps easier.
- Less intimidating- The majority of people have sustained folding experience, maybe more so in their youth. So folding may be linked to pleasant, familiar experiences that could cause participants to feel more confident about themselves and their possible success.
- Skills development- Rudimentary folding instruction provided enough information for some participants to further develop basic skills, giving them greater tools to reach their desired outcome.
- Focused attention-. Limiting a design problem is generally an advantage. We found the limitation of folding to provide a particularly strong focus by maintaining breadth of scope and depth of possible solutions, while also constraining participant attention to the task at hand.

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