Outreach Potential of Displaying Research Artifacts in Art Museums

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Lynda Palma's career as a museum professional began as a registrar for the Brigham Young University art collection more than twenty-five years ago and continued as collections manager when the BYU Museum of Art was built in 1993. For the last twelve years, Lynda has worked primarily in museum education and public programs. She has presented several papers and workshops in the United States and Canada on museum registration procedures and education methodology, taught in the music and humanities departments at BYU and Utah Valley University, co-directed a six-month Vienna Semester abroad program, acted as assistant editor for the quarterly international bulletin Music Education for the Handicapped and corresponding symposium proceedings, and served for thirteen years as the administrator of the Barlow Endowment for Music Composition. Her broad experiences continue to inform her multidisciplinary approach to museum education.

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Abstract

This paper explores how displaying engineering research artifacts in art museums can facilitate expanded outreach opportunities. A combination of visual art and innovative engineering offers an unusual opportunity to engage a wide spectrum of society. To evaluate the potential, faculty and students collaborated with the Brigham Young University Museum of Art to create a museum exhibition that connected the art of origami to engineering, math, science, and product design. A framework is introduced that includes the creation of a museum exhibition; and once the initial investment is made to create the central exhibition, the results are efficiently used to extend outreach efforts through first-generation products (coincident with the exhibition) and then through second-generation products (after the exhibition). The paper describes a detailed example of this framework and provides evidence to support the concept that displaying research artifacts in an art museum can expand research opportunities. Products from the exhibition that provided expanded outreach opportunities include the following: an exhibit catalog originally created for the gift shop that was expanded for publication with a national publisher; a tablet/smart phone app that includes origami instructions followed by related engineering activities, which has had broad use beyond the museum activity room; a video that was prepared for museum patrons but has since been made available to larger audiences; materials created for hands-on museum activities that were used for outreach activities after the exhibition; and leverage for industry visits that led to additional applications and research projects. This paper describes the museum exhibition, the first- and second-generation products, the impact of each product, and the benefits and pitfalls of using a museum exhibition to extend outreach impact.

Introduction

This paper introduces a framework for displaying engineering research artifacts in an art museum to efficiently facilitate expanded outreach opportunities. Education of the public about new technologies and scientific discoveries is key to the technological growth of a society. A U.S. National Science Foundation Strategic Plan summarizes this verity: “Effective integration of research and education at all levels infuses learning with the excitement of discovery and assures that the findings and methods of research are quickly and effectively communicated in a broader context and to a larger audience.” [1] When a new technology is understood by a variety of individuals and groups, it can be accessed and used in diverse ways to benefit others and improve society as a whole.

It was hypothesized that a combination of visual art and innovative engineering had the potential to engage a wide spectrum of society in science, technology, engineering, and mathematics (STEM), and that the effort of creating an exhibition could be exploited to efficiently expand the research efforts. Research in origami-based engineering offers an outstanding opportunity to test and evaluate this premise. The means for assessing this supposition was a collaborative Brigham

Young University (BYU) Museum of Art exhibition that facilitated faculty and students in relating the art of origami to engineering, math, science, and product design. Substantial effort and resources were required to create museum-quality exhibition materials; and once that investment was made, it became readily apparent that related activities could build on that investment to efficiently extend the outreach efforts. This led to the framework introduced in this paper: a museum exhibition is created as the foundation of the outreach effort, and the investment in time and resources can be built on to efficiently create first-generation outreach products (coincident with the exhibition), which can then facilitate second-generation products (after the exhibition).

By partnering with the museum, the team was able to access the discourse mechanisms normally beyond the means of typical engineering outreach. Engagement with the museum director, art curator, museum educator, and exhibit designers enabled the team's research products to be disseminated among established media channels of art dialogue, including a published exhibition catalogue, exhibition reviews, print and television news coverage, as well as internet and social media coverage. Consequently, the research team's outreach was significantly extended to a broad audience of art consumers and other similarly engaged community members.

Description of the Museum Exhibition

Researchers at Brigham Young University (BYU) received a grant from the National Science Foundation (NSF) Emerging Frontiers for Research and Innovation (EFRI) for "Uniting Principles of Folding and Compliant Mechanisms to Create Engineering Systems with Unprecedented Performance." This NSF grant provided for an outreach component that enabled the engineering research team and the BYU Museum of Art (MOA) to collaborate on an exhibition, displayed from January 29, 2015 through June 20, 2015. The concept was to combine stunning visual art and innovative engineering to engage broader segments of society than might occur in more traditional outreach efforts.

The museum exhibition included works by premiere origami artists from around the world and also made the connection between origami and math, science, engineering, and product design. The intent was to employ this combination of exciting artworks and STEM principles in reaching a broader audience than the individual disciplines could accomplish independently. The exhibition was complementary to, and not competing with, other origami-related shows (e.g., "Flip It, Fold It, Figure It Out" [2], the Smithsonian's "Paper Engineering: Fold, Pull, Pop & Turn" [3], and Cooper Union's "Surface to Structure: Folded Forms" [4]).

To fulfill these goals, the MOA exhibition included art from "Folding Paper: The Infinite Possibilities of Origami" [5] and additional artwork by origami artist and research collaborator Robert Lang. In addition to origami art, the traveling exhibition included some displays of origami-inspired technology and products, including fashion design apparel, a heart stent, and an eyeglass telescope. These displays provided a complementary springboard for the exhibition created by the MOA-research team called "Y Origami?", which focused on origami-inspired engineering with artifacts created by the research team. An activity room with hands-on activities

for patrons was also developed by the team. The entire exhibit spanned several galleries and exhibition spaces, covering over 400 m^2 (4,350 square feet).

Benefiting from graduate student support and guidance by faculty and museum staff, project teams consisting mostly of undergraduate students were responsible for the fabrication of engineering and product design displays. Selected models developed by others in using origami to teach math and other concepts [6-10] were used to create hands-on activities targeting K-12 students, their parents, and teachers. The activities built on the familiarity of paper and folding as a bridge to math and design concepts, leading to the application of these principles in engineering problem solving. A museum curator and museum educator were members of the team and administered all aspects directly related to the museum phase of the project.

The "Y Origami?" portion of the exhibition shown in Figure 1 included the following displays:

1) Origami-flasher-based solar array [11]
2) 3D printed titanium two-degree-of-freedom positioner [12]
3) Oriceps device for minimally invasive surgery [13]
4) Nanoinjector [14]
5) Origami-inspired backpack [15]
6) Kaleidocycle- [16] inspired table
7) A kinetic sculpture that deployed from four-foot square to eight-foot square [17]
8) A monitor looping a BYU-produced video [18]
9) A progression of a complex origami model, beginning at the crease pattern and showing the steps leading to the final features (designed and created by Matthew Gong)
10) A hands-on activity room that employed a custom-designed iPad app to guide patrons through folding exercises that concluded with a connection to a STEM topic

The "Art after Dark" opening event (teamed with the opening of a Japanese-art-themed exhibition) saw approximately 2,000 attendees, which is an unusually high number for the series. Figure 2 shows a popular hands-on activity that was part of the opening event, where students guided museum patrons in folding activities. In Figure 3, visitors are viewing the art (top) and engineering (bottom) elements of the exhibit.

The MOA also involved more than 400 family members in the Van Gogh to Play Dough program for toddlers and Open Studio program for families, with accompanying origami gallery activities and hands-on origami projects. The MOA's biannual Night at the Museums brought 1,000 university students to the exhibition, and the annual Summer Family Arts Festival was enjoyed by more than 1,500 community members.

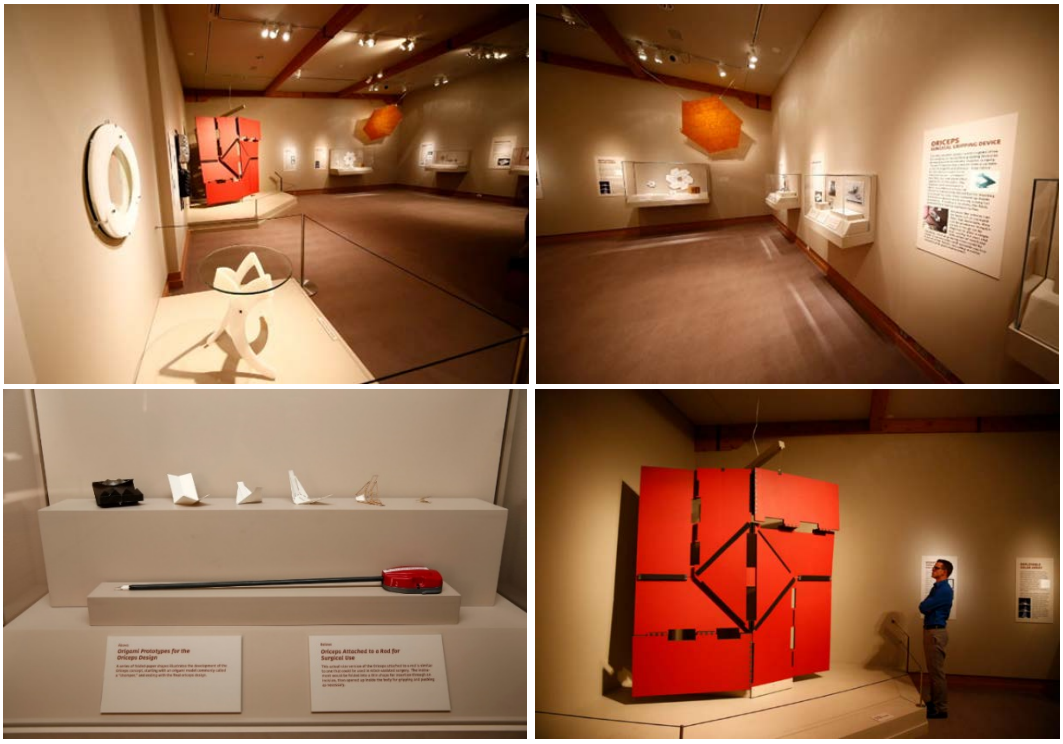

Figure 1. The "Y Origami?" section of the exhibit displayed engineering and product design artifacts (top). The Oriceps display (bottom left) is an example that shows an origami-inspired succession of prototypes leading to an instrument for robotic surgery. The kinetic sculpture (bottom right) illustrated that large deployable systems can be made from thick materials. (A button initiated automatic folding of the sculpture.) Courtesy of BYU Photo.

Figure 2. The opening event included hands-on activities that were popular throughout the evening.

Figure 3. The exhibit was popular during its run, and the opening event had approximately 2,000 attendees.

Although attendance figures for specific exhibitions are not recorded at the MOA, the average monthly museum attendance throughout the duration of the exhibition was over 30,000 visitors. There were a total of 109 tours of the exhibition, with 71 tours (2,099 patrons) participating in traditional guided tours and at least 38 tours (1,300+ participants) that were self-guided (usually K-12 teachers leading tours with museum-provided educational materials), in addition to the hundreds of university students assigned class projects in the exhibition and the tens of thousands of patrons that visited over the course of five months. These results support the idea that displaying engineering research artifacts in an art museum can facilitate expanded outreach opportunities. A summary of these activities is listed in Table 1.

Two major guest lectures were presented in the museum auditorium, including a standing-room-only crowd for Dr. Robert Lang's talk on the math and magic of origami, and a discussion on origami in space by two scientists from the NASA Jet Propulsion Laboratory (Figure 4).

Figure 4. (Left) Banner outside the museum advertising the exhibition, with guest speaker and collaborator Robert Lang in center. (Right) Exhibition guest speakers from NASA Jet Propulsion Laboratory discussing origami in space applications.

Table 1. Estimated number of participants in exhibit-related events and activities.

Event or Activity	**Participants**	**Notes**
"Art after Dark" opening event	2,000	Combined with the opening of a Japanese-art-themed exhibition
Museum attendance	30,000 per month	Average monthly museum attendance
Guided tours	2,099	Throughout the duration of the exhibition
Teacher & self-guided tours	1,300+	Throughout the duration of the exhibition
Summer Family Arts Festival	1,500	Included hands-on activities
Van Gogh to Play Dough and Open Studio Family Programs	400	Offered twice weekly for two months, and twice per single month, respectively
Night at the Museum	1,000	Combined with the Japanese Art Deco show
University course-related assignments	Inestimable	Difficult to calculate but assumed to be in the hundreds

First-Generation Outreach Products (Coincident with Exhibition)

The museum exhibition created an unusual opportunity to engage segments of society that researchers would not otherwise reach. The exhibition was the foundation of the framework, but we discovered that the creation of the museum exhibition also drove the development of other major outreach products that could coincide with the exhibition. We call these first-generation outreach products, each of which is detailed below.

1) A **book** titled "Y-Origami" (similar to a museum catalog) is an 81-page full-color book (Figure 5) created to accompany the "Y origami?" exhibition. It begins with a foreword by Dr. Robert Lang and includes photos and descriptions of origami-based designs (including those in the show and others), and mathematics- and engineering-related activities. This first-generation version was self-published and sold in the MOA Store and led to an expanded, second-generation version that has been published by a national publisher for wider distribution, as described later.

Figure 5. The book "Y origami" was available at the MOA Store.

2) The **iPad/iPhone app** called "Folded BY-U," created by the research team, features origami tutorials for all ages and skill levels and provides each tutorial with photos, videos, and engineering activities (see screen shots from the app in Figure 6). The app was made available at the Apple app store (e.g. search "Folded BY-U" on iTunes).

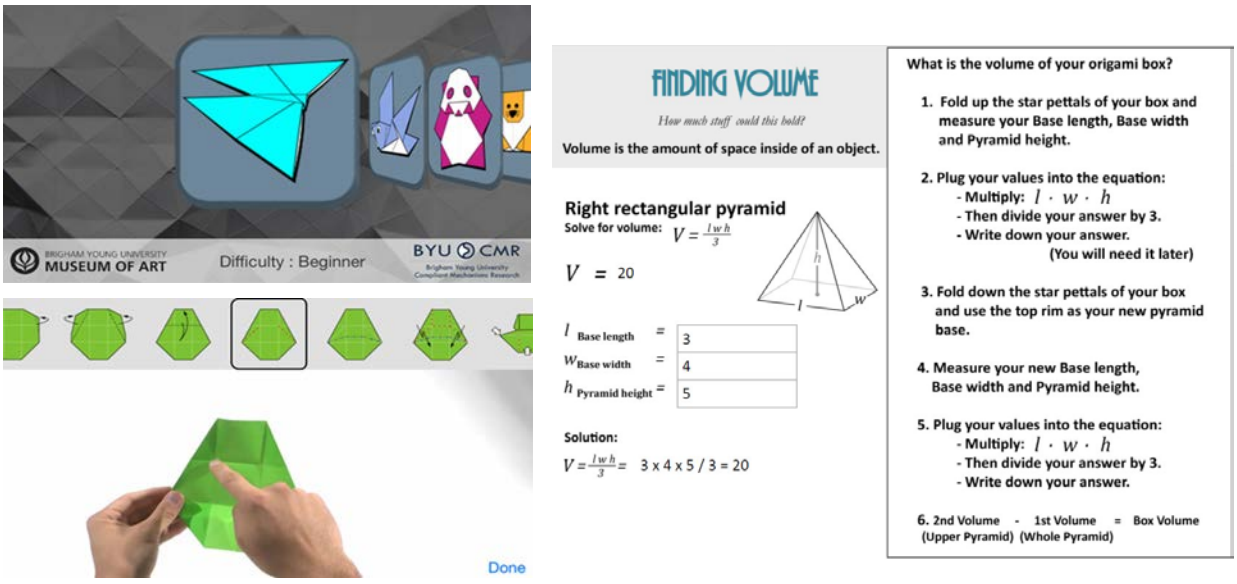

Figure 6. Screen shots from the "Folded BY-U" app, including the menu (top left), an example screen shot of video instruction (bottom left), and an engineering/mathematics activity at the end of the folding instructions (right).

In addition to the free app available for download, it was available on mounted iPads during the show (see Figure 7). The museum made origami paper freely available to guests, and the app and folding activities were extremely popular with museum patrons.

Figure 7. In addition to being available for download, the app was on dedicated iPads at the museum exhibit and was popular with the public.

3) **A video,** entitled "How Origami Is Inspiring Scientific Creativity," was created in collaboration with BYU Communications and looped as part of the museum exhibition. It also received the Overall People's Choice Award in the "Vizzies" international visualization challenge sponsored by the National Science Foundation and *Popular Science* [19]. The video was made available for the general public and has been viewed through links from BYU, *Popular Science*, the National Science Foundation, and YouTube [18]. Figure 8 shows an image from the video (an animation of an origami-inspired deployable solar array).

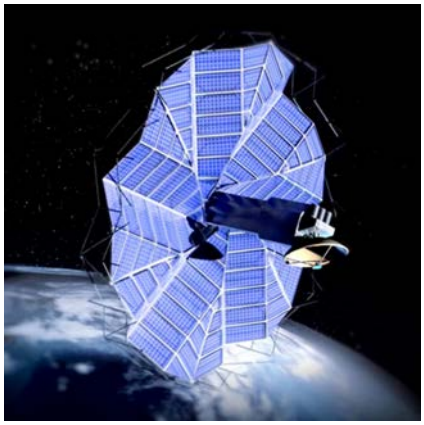

Figure 8. An image from the video "How Origami Is Inspiring Scientific Creativity," which looped in the museum exhibit and received the Vizzies Overall People's Choice Award.

4) **Interactive materials** were designed to engage university students, K-12 classes, and community visitors throughout the duration of the exhibition. Many of the approximately 2,000 attendees at the "Art after Dark" opening event participated in these hands-on activities, and 1,500 community members at the annual Family Arts Festival also joined in similar interactive activities supported by volunteers and staff from our lab and the BYU Museum of Art.

5) **Leverage for industry visits** was beneficial for inviting potential research sponsors and licensees to evaluate the technology. The exhibition provided a unique draw for industry visitors whose companies had potential applications for the research. Hosting industry visits provided the opportunity to transfer knowledge to industry, gain knowledge of current issues faced by industry, encourage the application of new technology in their products, provide valuable interaction opportunities for students, and investigate possible collaborations. Visits included engineers from international, national, and regional organizations.

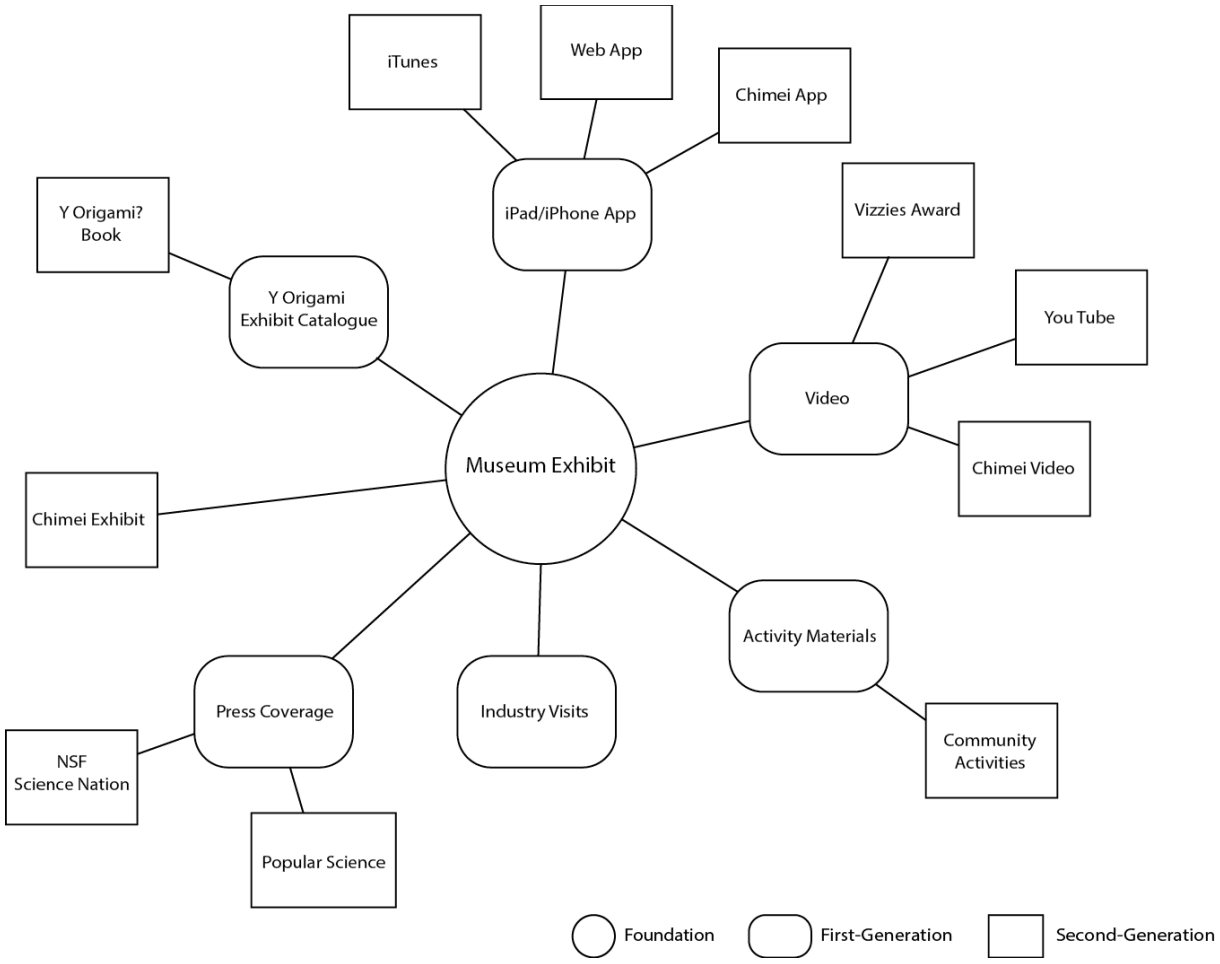

Figure 9. The framework illustrated with the museum exhibit serving as the foundation and showing its influence on the development of first-generation (coincident with exhibit) and second-generation (after the exhibit) outreach activities.

The museum exhibition was the hub of these activities, which would not have occurred without the focus caused by the excitement and pressure of a pending show. The concentrated efforts also drove the quality of the artifacts and other materials, illustrated graphically in Figure 9. In this framework, the museum exhibition is seen as the hub from which the first-generation products are extended to make second-generation activities possible. These activities support the hypothesis that displaying engineering research artifacts in an art museum can provide an efficient way to expand outreach opportunities.

Second-Generation Outreach Products (After the Exhibition)

Although the exhibition and first-generation product elements of the outreach framework were temporary, they drove the development of products that had life beyond the show. These second-generation outreach products are listed in Table 2 and each is described in more detail below.

1) **A book**, *Y Origami?* [20], is an expanded (75% increase in pages) version of the book previously available in the museum gift shop during the exhibition. This expanded version has been published by the American Mathematical Society (AMS) and includes applications beyond what was displayed in the exhibition and instructions for hands-on learning activities for readers and for teachers to employ with their classes. Because it is marketed by a national publisher, the distribution is expected to be significantly higher than the locally distributed version available at the original exhibition. One retailer, Amazon.com, listed the book as the Amazon #1 New Release in Origami.

2) **An exhibition loan** provided an opportunity for many of the research artifacts (solar array, oriceps, nanoinjector, and backpack) to be displayed at the Chimei Museum in Tainan, Taiwan for their show entitled "Origami Universe" from October 5, 2016 to May 30, 2017 (see Figure 10). In addition to the artifacts, the video and app were also used. This show was the first comprehensive exhibition of origami art and applications in the Republic of China and attracted over 150,000 paid clients, including 3,000 patrons the last day of the exhibition.

Table 2. Summary of outreach products. First-generation products occurred coincident with the museum exhibition and led to second-generation products after the exhibition.

Outreach Product	First Generation	Second Generation
Exhibit	"Y Origami?" exhibition coincident with exhibition of origami art	Many elements of "Y Origami?" loaned to Chimei Museum, Taiwan
Book	*Y origami* (self-published and available in museum gift shop)	*Y Origami?* (expanded version under contract with national publisher)
App	*Folded BY-U* app available in activity room of museum exhibition and for download	App available for download, made as a web app, and used in Chimei exhibition
Video	Video looping in museum exhibition, wins "Vizzies" People's Choice Award	Video available on YouTube and other sites; looping in Chimei exhibition
Materials for interactive activities	Used to facilitate activities at the museum and during exhibition run	Continued use and expansion with school and community groups
Industry visits	Leverage for encouraging industry visits	
Press		The attention from the show generating interest in the popular press

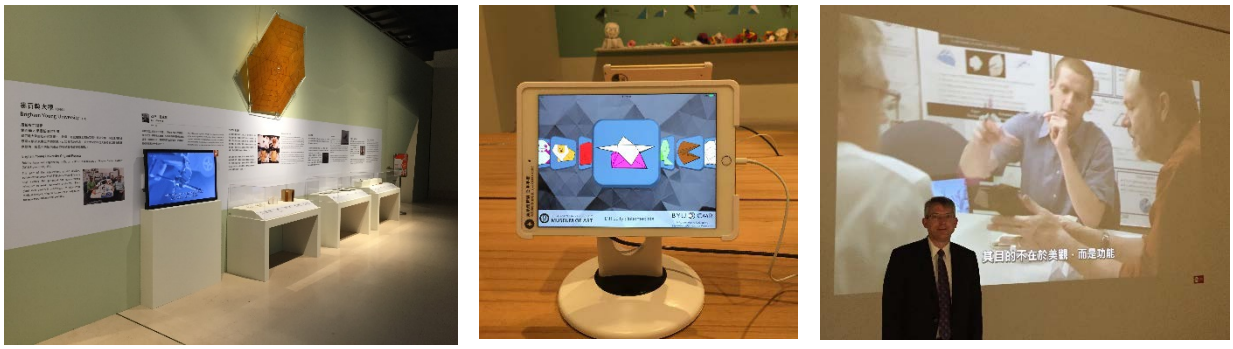

Figure 10: A portion of the BYU-provided artifacts displayed at the Chimei Museum's "Origami Universe" exhibition (left), the app on a mounted tablet in the Chimei hands-on area (center), and the video with a person shown for scale (right).

3) **The app** "Folded BY-U" continued to be available for download after the exhibition ended. It was also converted into a web app that is available for public use through a browser at http://compliantmechanisms.byu.edu/origami (the best performance occurs when using Google Chrome).

   The app was also used by the Chimei Museum in their hands-on activity room similar to the activity room described earlier.

4) **The video** "How Origami Is Inspiring Scientific Creativity" was entered into the NSF/Popular Science "Vizzies" Visualization Challenge, resulting in it being posted on National Science Foundation and *Popular Science* websites [21]. Later, BYU Communications also made the video accessible to the public through its posting on YouTube [18]. The Chimei exhibition added Chinese subtitles, projected the video on a large wall, and looped it alternating with another video.

5) **Community activities** exploited the exposure and the materials developed for hands-on activities. Examples of the outreach activities included a workshop for elementary school teachers, hosting school groups for in-lab activities (including 6th to 10th grades from underprivileged groups and school groups associated with Engineering Week, among others), activities at Utah STEM Fest (a large event for 5th through 10th-grade students), a presentation at the "Research Revolution" series at a local library, an "Astrofest" activity sponsored by the BYU Department of Physics and Astronomy, and several others.

6) **Press** related to the exhibition and the work displayed there also led to an increased audience. For example, NSF Science Nation brought a film crew to the research lab and created a video story on the research, which played on the NSF Science Nation website and was also distributed to other venues, such as PBS, Voice of America, and local news stations around the country [22]. NHK (Japanese Broadcasting Corporation) brought a film crew to BYU, and the resulting news story was aired in Japan, translated into English, and broadcast on their international channel, NHK World. *Popular Science* announced the Vizzies award in its print magazine [19], and also displayed the video on its website [21]. This led to many other opportunities for outreach in the popular press.

Discussion and Conclusion

This paper has shown how displaying engineering research artifacts in an art museum can facilitate expanded outreach opportunities. An outreach framework was introduced that includes an exhibition in an art museum as the foundation, with first- and second-generation outreach products that build on the foundation. For the particular exhibition described here, there are an abundance of possibilities and outcomes. The effort required to create museum-quality exhibitions can be exploited to have impact beyond the temporary show in variety of ways. Via the exhibition, this work reached a larger audience, and a different segment of society, than it would have otherwise. These results support the concept that displaying engineering research artifacts in an art museum can facilitate expanded outreach opportunities. Although the breadth and quantity of outreach is demonstrated, one limitation of the work is the lack of direct means for measuring the effect of the outreach on individual participants.

In addition to developing the framework and experiencing positive outcomes for the research outreach, there are a number of other lessons learned from this museum exhibition experience that might be helpful to others who wish to pursue a similar approach in the future. Some of the key items are summarized below:

- Create a team early that includes researchers and museum curators, educators, and designers. Take time to understand what each group values and choose to pursue those directions that will benefit everyone involved.
- Ensure that the financial resources are available (e.g., make this a budget item in the broader-impacts element of a proposal).
- Develop a consistent theme that connects the elements of the exhibition (e.g., in the exhibition described here, origami was the common thread, and the engineering and product design artifacts showed connections to that theme).
- From the inception of the project, consider how the show's first-generation products might be used beyond the temporary show, with the potential to efficiently lead to second-generation products and continued outreach.

There are also potential challenges that should be taken into consideration:

- There can be significant cultural differences between museums and research labs, and it is important that each group understand and value the other groups' views and needs.
- The serenity of finished exhibitions masks the intensity of the behind-the-scenes activity to prepare it (i.e., it can be a lot of work with firm deadlines).
- Researchers are advised to recognize that aesthetic requirements for the appearance of museum pieces are high, and their artifacts will be evaluated on this basis for potential inclusion in an exhibition. It may take considerable effort and resources to comply with museum standards.

- Moving devices (e.g. the kinetic sculpture in the exhibit described here) require high reliability and need to be robust to withstand continuous interaction with the public over the life of the exhibition, which is often a challenge for one-off prototypes.

Displaying research artifacts in an art museum can potentiate expanded outreach opportunities for diverse audiences. With planning, the efforts expended in this challenging but rewarding experience can result in impacts during the exhibit and beyond. The myriad outcomes resulting from a museum-research partnership can enhance outreach and facilitate exciting and unexpected possibilities that arise with this type of interdisciplinary collaboration.

Acknowledgments

This paper is based on the work supported by the National Science Foundation and the Air Force Office of Scientific Research through NSF Grant No. EFRI-ODISSEI-1240417. The work and support of many students and museum staff is gratefully acknowledged. The tireless efforts of Bernie Peyton in organizing the Origami Universe exhibit at the Chimei Museum and inviting our participation are also recognized. Thanks to Madison Fujimoto for her work helping to prepare the paper for publication. This work is dedicated to the memory of our friend Paul Anderson, whose curatorial efforts made the exhibit possible.

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