Waves of Engineering: Using a mini-wave flume to foster engineering literacy

Ms. Alicia L Lyman-Holt, Oregon State University

Ms. Lyman-Holt has been the Education and Outreach Coordinator at the O.H. Hinsdale Wave Research Laboratory since 2005. She manages and leads the diverse outreach and education programing at the laboratory which serves over 5000 visitors per year, including K-12 students, undergraduate, graduate students, media outlets and the general public. She also takes the mini-flume "on the road" to large public events, such as Smithsonian Folklife Festival and Engineering Week Family day , both in Washington DC, training and working with volunteers to broaden the reach of the programing about coastal engineering outreach, particularly tsunamis. She is dedicated to increasing engineering literacy among the general public, and interest in STEM among K-12 students. She holds a BS in from Whitman College, and MS from Oregon State University.

Ms. Laia Cari Robichaux, Oregon State University

Ms. Robichaux is a doctoral student at Oregon State University in the Environmental Sciences program. Her research focus is how free-choice learning venues such as science centers present socially-controversial science. She holds a B.S. in Marine Biology from Texas A&M University at Galveston, and a M.S. in Science Education from Oregon State University.

Waves of Engineering: Using a mini-wave flume to foster engineering literacy

Abstract

Recent disastrous tsunamis have created an interest in learning about tsunamis which translates to an opportunity to teach the general public about engineering and potentially increase their engineering literacy. A portable tsunami wave tank was developed in conjunction with a hands-on engineering activity for families, to provide a mobile experience with tsunami research. The miniature tank is a 16' long, 18" high, 6" wide clear acrylic tank, with a beach at one end and a wave maker at the other to create a tsunami-like wave. Legos are used by participants to build a structure that will protect a Lego "person" from the wave. The activity takes between 10 and 30 minutes including introductory technical background and build time. A survey was used to measured awareness of: coastal hazards/tsunamis; interest in learning more about costal hazards and engineering; engineering challenges, and advanced engineering concepts. Results show a generally positive response to this activity about awareness and increased interest in coastal engineering.

Introduction

At the Oregon State University O.H. Hinsdale Wave Research Laboratory and NEES Tsunami research facility there are two large tanks used for research. These two tanks which are both unique in their size and capacities combine to provide a rich platform for coastal engineering research, including but not limited to tsunami research. The laboratory serves research groups from around the world. A significant portion of the funding is from the National Science Foundation. As an NSF funded program, broader outreach and impact (BOI) is part of our mandate in accordance with the stated NSF goal to provide the needed science understanding to its citizens[i]. Science, mathematics, engineering and technology (STEM) are important foundational core in our modern, technology driven western society. The needs of the society drive the development of these fields just as much as society is driven by them[ii]. As science continues to grow in our society, so does the need for science literacy among the population. As more science appears in the news, citizens need to be able to understand and participate in public policy discussions and make informed decisions based on their understanding of the information from the discourse[iii]. Therefore, the education and outreach programs at the laboratory are an important part of its mission.

The BOI of the laboratory is generally separate from that of its researchers. The general laboratory goals of the outreach are:

1. To increase awareness of and esteem for the profession of engineering as whole, and specifically civil engineering
2. To enhance and reinforce science and engineering concepts taught in accordance with state science teaching standards at 5th and 8th grade level
3. To increase awareness of the use of models in engineering research

4. To increase awareness of local coastal hazards in the Pacific Northwest specifically tsunamis

Live demonstrations are often available to the over 5000 annual visitors the facility, providing a rich platform for meeting these goals, along with our presentations and guided tours. While 5000 annual visitors is admirable for any research laboratory, live demonstrations at the site do not truly reach a broad audience in a national sense. For several reasons a small, not quite to scale, version of the large wave flume, called the mini-wave flume, was developed for both local and national outreach activities (Figure 1). The tank is a 16' long, 18" high, 6" wide clear acrylic tank, with a beach at one end and a wave maker at the other to create a tsunami-like wave. The tank was built in two sections so that it was easier to transport. Having a small tank dedicated to BOI allows us to demonstrate waves at any time and from a unique perspective of a cross cut of the wave. It also allows us to take the mini-flume "on the road" to reach more people who might be geographically distant, allowing the mini-flume to be used in a variety of informal, or free-choice, learning settings.

Free-choice learning is often self-initiated and occurs outside of the formal educational institutions in venues such as museums, science centers, libraries, and, increasingly, the Internet[iv]. Learning that occurs in these settings is often intrinsically motivated, context specific, and may even be incidental to the main goal of the activity[v]. Additionally, many free-choice learning events are culturally oriented around family activities[vi]. Individual exhibits, such as the mini-flume activity, special collections, and entire institutions are dedicated to the specific objectives of free-choice science learning[vii]. As such, they are valuable resources in promoting science literacy in general as well as specific literacies. The mini-wave flume has been specially designed to facilitate engineering literacy. Engineering literacy is defined as a "person [who] is able to understand the relationships between parts and the whole, uses models for representing concepts, and applies knowledge to solve problems in our [lives]"[viii]. Knowing about engineers and engineer training, and engineer "habits of mind"[ix] could aid citizens in public policy discourse and decision making by consumers[x]. However, despite efforts in engineering education, the majority of Americans have little to no understanding of what engineers do and why it is important to our society[xi]. The mini-flume activity allows participants to experience how civil engineers involved in coastal engineering work towards building safer communities through planning for natural disasters, helping to fill the gap in public understanding of engineering.

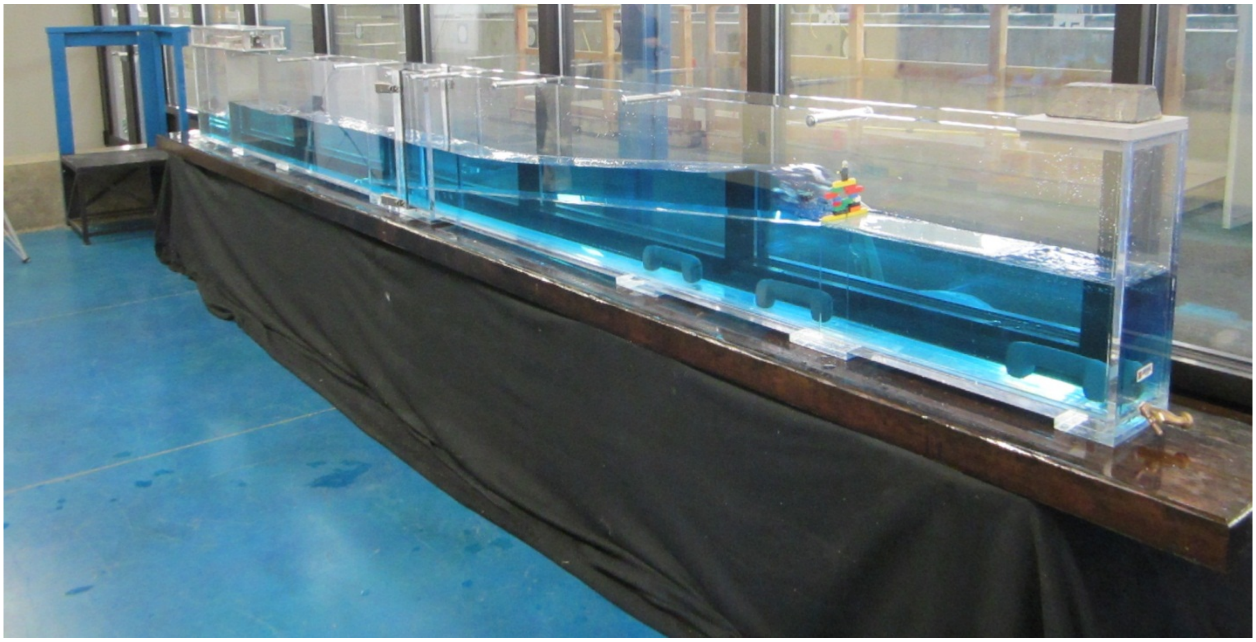

Figure 1: Mini-Wave Flume with Lego wall

Mini-Flume Hands-on Activity

The mini-flume has been presented at in a range of events, from a Museum of Science and Industry to national events in Washington DC such as National Engineers week Family Day and the Smithsonian Folklife Festival. These events all have several common factors that shaped the mini-flume activity:

1. Geared towards family groups
2. Limited time engagements
3. Outdoor or large convention hall environments
4. Many other competing booth/exhibitors

With these factors in mind a hands-on activity for the mini-flume which would take families 15-30 minutes to complete and would highlight some of the main goals of our BOI program, such as awareness of coastal hazards and esteem for engineering, was created.

The participant goal of the activity is to build a structure out of a limited number of Legos to protect a Lego person from a tsunami wave (see figure1). The activity has three stages

1. Introduction – activity leaders provide a brief introduction about tsunami hazards and engineering and explains the Lego building portion of the activity to participants
2. Participants build their structures

3. Participants test their structures in the mini-flume

If time allows, participants can rebuild their structures. This helps reinforce the design-build-test-evaluate process of engineering.

During the introduction trained volunteers, usually undergraduate engineering students, discuss coastal engineering, coastal hazards and the laboratory. At the Smithsonian Folklife Festival the participant groups were smaller than at other events, so in that setting usually one presenter would speak with a small group of 2-10 people. In other setting there are usually multiple family groups and presentation is for 20-30 people. The presentation takes the form of a conversation through a set of prompted questions. The questions start out general, for example the first question is almost always “Do you know what engineers do?” The purpose of this question is to introduce the subject and allow the presenter to gauge the level of the participants’ knowledge. The main message of this part of the presentation is: Engineers use STEM to help people by solving/working on problems. After a brief discussion of engineering, that often includes personal anecdotes about the presenter’s connection to engineering, the presenter moves on to coastal hazards. Since the Folklife festival was on the East Coast, hurricanes and tsunamis were both discussed to create a more personal connection to the content. Once coastal hazards have been established as a “problem” for people, the “conversation” makes connections between “the problems” and engineers’ roll in addressing them. Finally the challenge is presented, as the participants practicing to be engineers by “saving” a Lego person from the mini tsunami. The participants are challenged to build a structure that is at least 8 Lego bricks high and no more than 16 wide, then a Lego person will be placed on top and the whole structure will be hit with a “tsunami”. At this point, most participants have seen a wave in the mini-flume. This is also the point in the presentation in which we discussing limitations such as time and money. It is explained that the number of Lego and time to build will be limited for each participant.

After the introduction each participant who wants to build a structure (including all adults) is provided with a small number of Legos, randomly scooped from the master supply. The Legos have a volume equivalent of approximately 75 ml or 1/3 cup. The Legos have also been altered by sanding down the studs (or bumps) on about ½ the Legos. The purpose of the sanding is to weaken the connection between the Legos as the unaltered connection are strong and easily resist the lateral loading of the tsunami wave. Participants usually spend between 5-10 minutes building their structures. During this time the volunteers provide guidance as participants ask and remind participants about the building rules. Guidance is provided on an age/cognitive appropriate manner, older children (age 9+) are firmly reminded of the rules, where younger children are freer to just build as they see fit. Parents and other family members often “assist” children to varying degrees. If an older sibling or parent is domineering the building they will often be offered their own Legos to build with to let the younger child explore. During the building process participants are reminded of the Lego person and the tsunami load as they build.

In the testing phase participants bring their structures to the mini fume and choose a Lego person from the available assortment. Lego people are added right before testing to ensure fewer of our people "walk" away. A volunteer places the structure into the mini-flume and another volunteer makes a wave. After the wave hits the structures, the participants can observe how well the structure performed. At the Folklife festival participants were able to make modifications or changes to their structures and retest them. At other events this is not possible due to time constraints.

The mini-flume hands-on activity is one example of a free-choice learning venue that promotes engineering literacy. The Lego building activity introduces the Engineering Design Process (EDP), the goal of "teach[ing] students that engineering is about organizing thoughts to improve decision making for the purpose of developing high quality solutions and/or products to problems"[xii]. As discussed previously, part of engineering literacy includes understanding that constraints and limitations influence the engineering process, and how engineers work with trade-offs to mitigate their limitations in the design process[xiii]. The Lego activity mimics these engineering principles by limiting the type and number of Legos available, thus encouraging participants to think creatively when designing their structures. In the authors experience one of the most common misconceptions about engineers is that they simply build things. The mini-flume structure challenge provides an opportunity for participants to understand fuller nature of the EDP, including identifying the problem, planning a solution, testing the solution, and then evaluating the results and making changes to the design as necessary[xiv]. Participants are free to engage in the activity at their desired level, allowing each individual to build meaning in a personal context based on their interests and prior knowledge. Finally, the mini-flume structure challenge is presented as part of a relevant societal concern: safety for individuals and communities in the event of a tsunami. The public perception of engineering currently does not include how engineering is important in keeping our society and communities safe, or how engineers work to save lives[xv]. The mini-flume activity helps create the societal and cultural understanding in engineering literacy, and fills an important gap in the public understanding of engineering.

Goals of evaluation

Unlike a structured curriculum in a formal education setting, free-choice learning engagements are usually very brief, and participation can range from a single partial completion of an activity to frequent repeated visits and engagements. Levels of guidance within the activity are also wide ranging, and visitors have differing levels of prior knowledge when they engage in an activity. All of these factors present a unique challenge when determining the desired outcomes of the activity, as well as in assessing the activity to ascertain whether or not these outcomes are being met by participants. Since FCL encounters like the mini-flume structure challenge are so brief, assessment of learning is particularly difficult. Thus the desired outcomes for the mini-flume structure challenge are increasing awareness and understanding of engineering, EDP, and the cultural importance of engineering.

Methods

A survey was developed explicitly for the Mini-Flume activity at the Smithsonian Folklife Festival. The survey was designed specifically to gauge the effectiveness of the activity based on its main goals: increase awareness of and interest in coastal engineering, as well as provide a fun and engaging space to learn about engineering. Additionally, the idea of sustainable practices through planned engineering was added to tie in the goals of the Sustainable Solutions area of the Festival. Fifteen questions were generated and a 5- point Likert scale was employed to measure participant responses. The Likert scale was positioned between dichotomous statements so participants could more easily choose where they felt based on their experience. The evaluation was limited to 15 questions based to accommodate anticipated participant recruitment and time considerations. Also, this number of questions could be easily presented on the front of one sheet of paper, and this was considered to be more appealing to potential participants.

Eight demographic questions were included on the back of each printed survey. These were included for participant tracking, and to explore if responses were different among different demographic groups. Participants were recruited after they had full participated in the Mini-Flume activity, by testing a structure. All survey participants were at least 18 years of age.

Results and Discussion:

We collected 104 surveys out of the approximately 5000 visitors to the exhibit. Visitors were counted on a sport “click” counter, which had a few technical difficulties, resulting in an approximate visitor count. IRB restrictions limited data collection to adults though many of our participants were under age. The demographics of participants are important to understanding the results: 54% were women, 44% were men, 2% preferred not to answer. Figure 2 shows that the age distribution skewed young; over 70% of respondents were 50 or younger, and the largest single category was people in the 41-45 age range. Considering the activity is aimed at elementary aged children it makes sense that many of their parents would be in the respondent group. Figure 3 shows a skewed distribution to participants with higher education, 31% held bachelors, 40% held masters and 14% held doctorate degrees. Reasons for this high concentration of higher education are not clear. However as the rest of the results are discussed, the high level of education should be kept in mind.

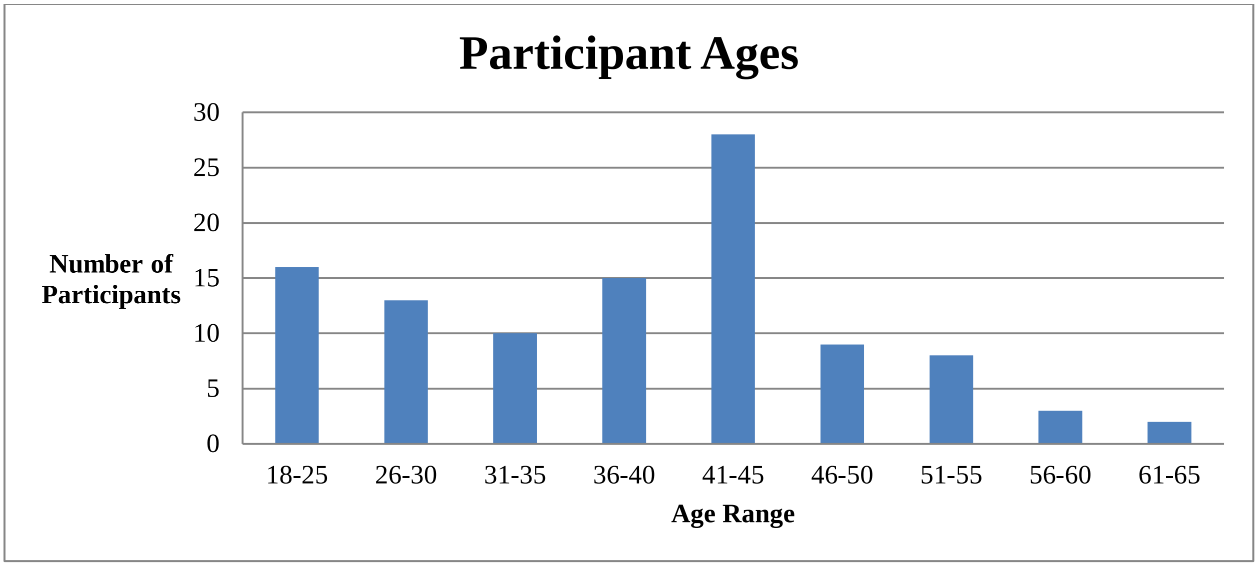

Figure 2: Participant age distribution

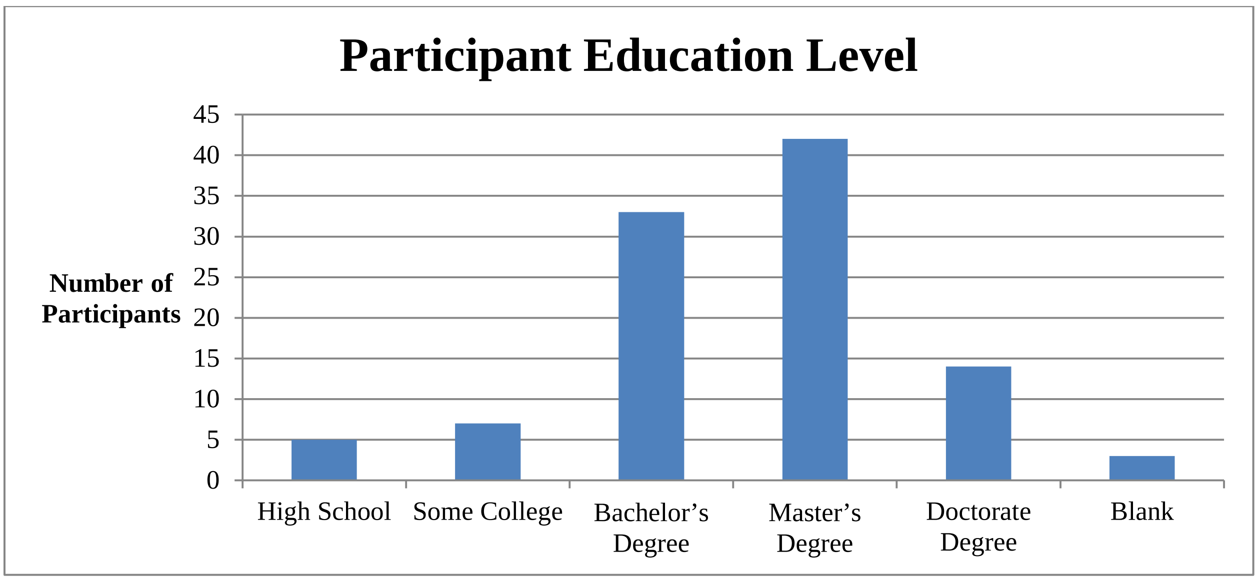

Figure 3: Participant Education

Figure 4 summarizes the reasons that participants choose to engage in the mini-flume activity. They were allowed mark as many responses as was pertinent. While having fun and playing with Legos received the largest number of responses, interest in engineering and tsunamis also received high levels of responses. Figure 5 shows the response of participants to questions about their increase in interest in learning more about coastal hazards and engineering. Due to a formatting error, some of the paper surveys did not have the bubbles in the Likert scale for the question on interest in learning more about hurricanes. As a result, participants were more likely to leave this question blank, resulting in an n of 95 respondents. Overall the results are positive. The average scores indicate that participants left with an increased interest in continuing their learning in these subjects. The high standard deviations, again all greater than 1, indicate significant variations in responses that this may be due to varying levels of prior knowledge in these areas.

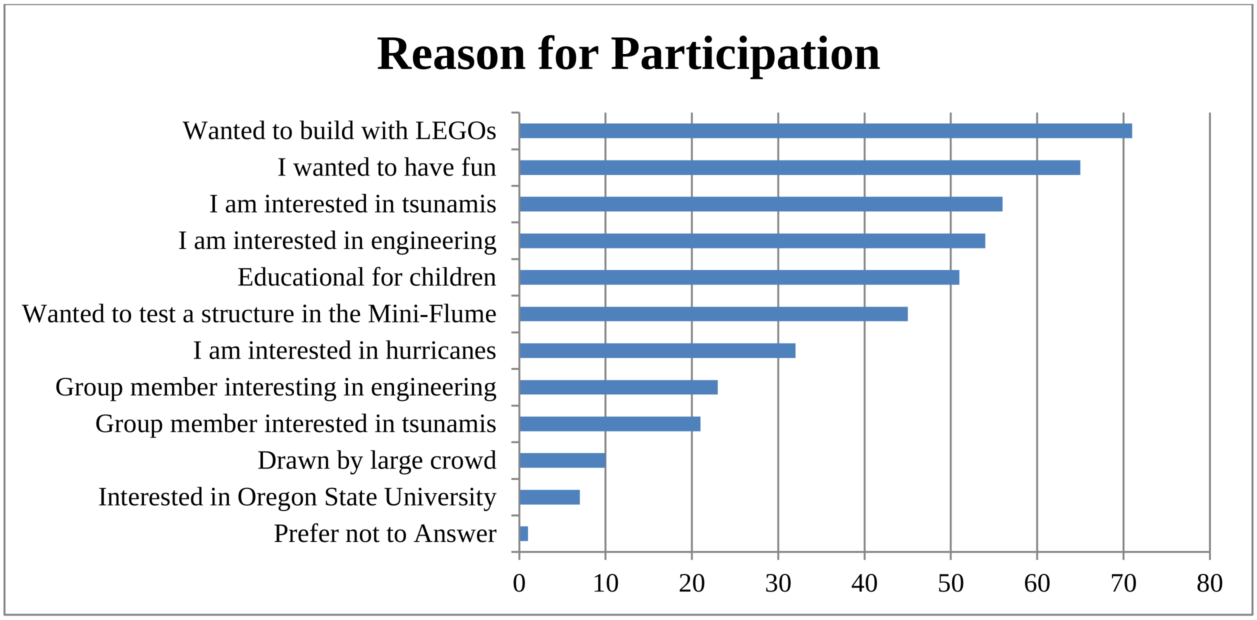

Figure 4: Participant reasons for particpating

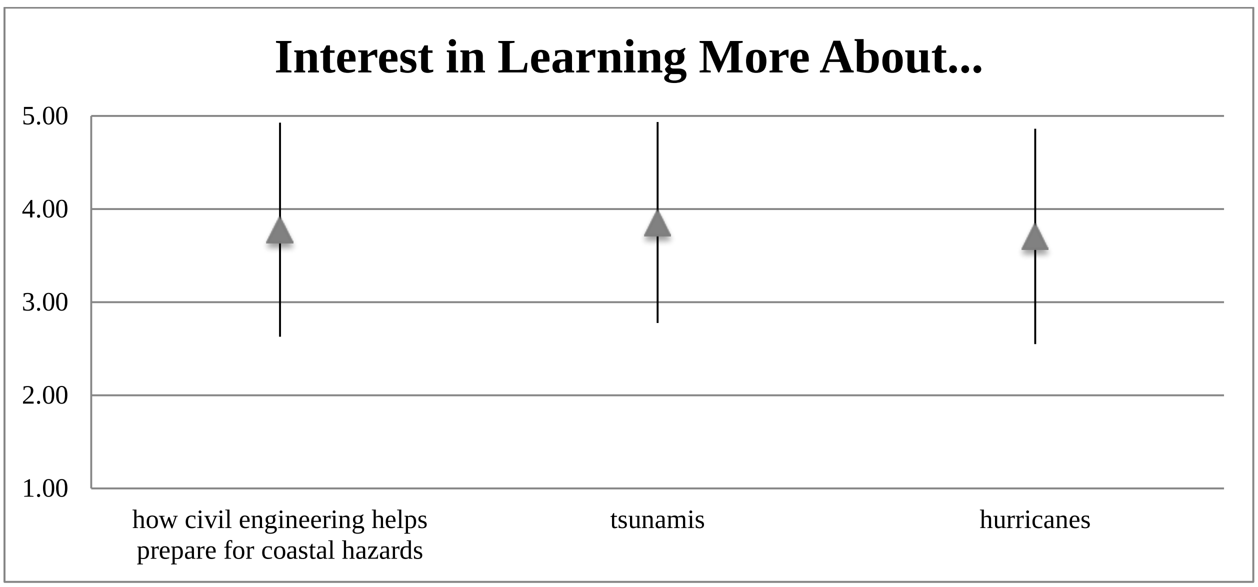

Figure 5: Post activity interest in learning more about . . .

Figure 6 shows the participants response to questions about their increase in awareness of engineering issues. These results would have more meaning if participants had been able to report their level of previous knowledge, and this lack of information may help explain the high standard deviations (all greater than 1), but the results are encouraging. The activity is designed to communicate some basic engineering concepts, and based on these results most of the participants show gains in these areas. There appears to be some room for improvement on increasing awareness of engineering limitations, but without more information it is impossible to tell whether this is due to a deficiency in the activity, a result of prior knowledge, or a result of some other factor.

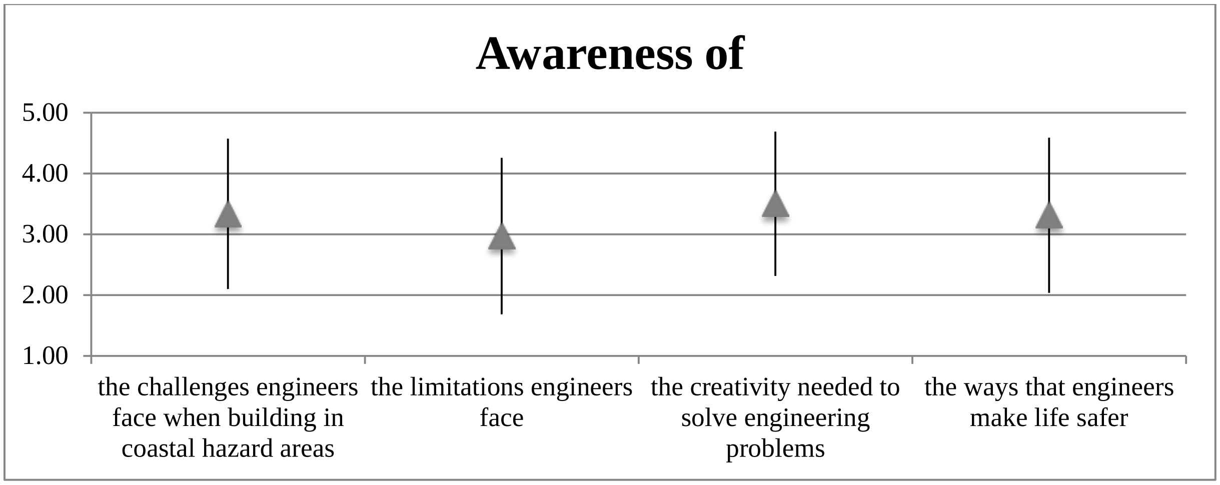

Figure 6: Participants increase in awareness of engineering issues after the activity

The two questions summarized in Figure 7 of the evaluation were designed to provide a brief look at how the activity influenced visitors with respect to more complex engineering and social ideas. The final question was included to tie the activity in with the Sustainable Solutions theme within Folklife. For the question on the left in the figure, the Likert scale for the blank ranged from Did Not Learn (1) to Learned a Great Deal (5). The question on the right had a Likert scale from …. to ….. The fact that both of these ideas have positive average scores is highly promising. Model testing has always been a component of the activity, but the idea of thoughtful engineering as a form of sustainable engineering was added specifically for the Festival

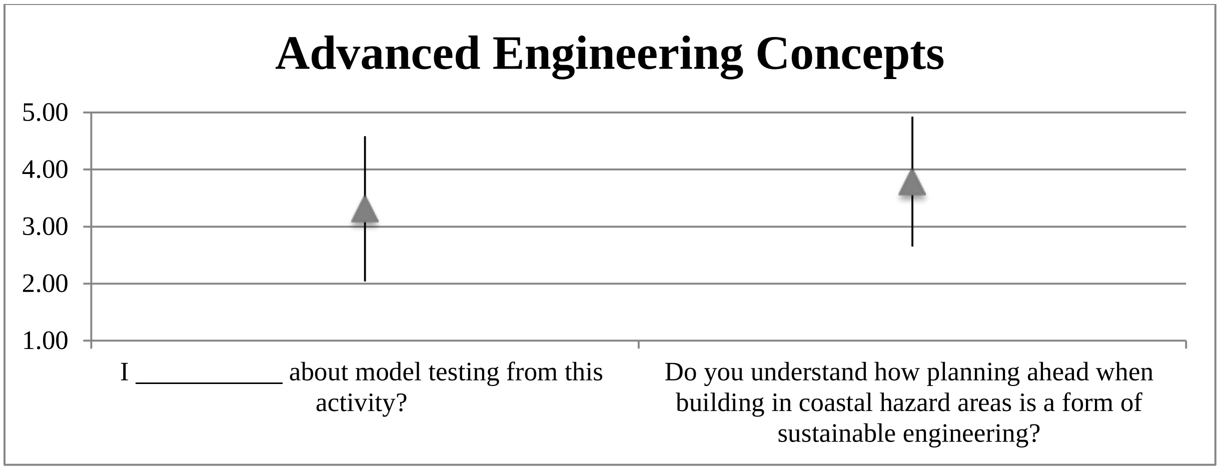

Figure 7: Participants increase in awareness of advanced engineering concepts

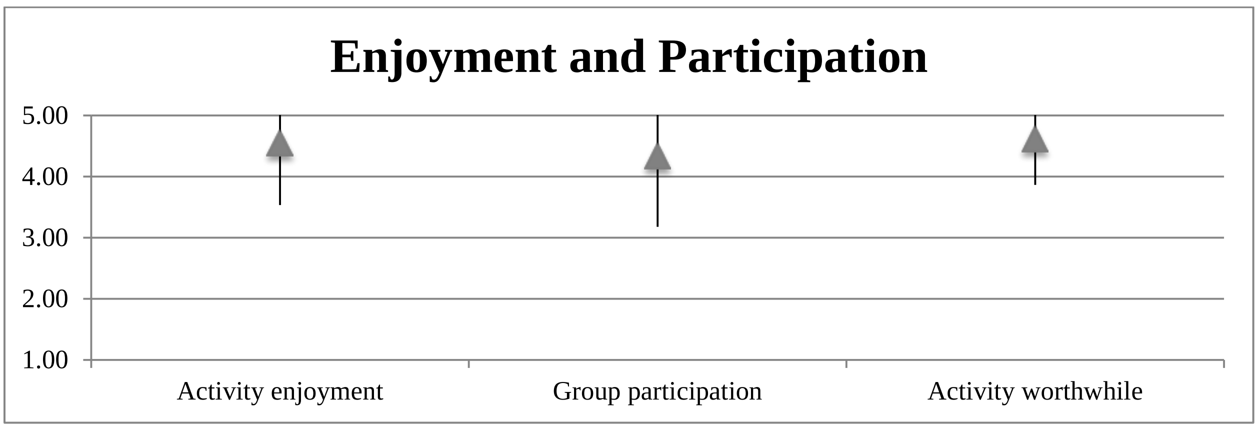

Figure 8: Participants enjoyment and satisfaction with the mini-flume activity

Figure 8 shows the very positive results that most people enjoyed this activity and felt it was worthwhile. Every day of the festival it was above 90^{o}F and humid, most days by noon it was over 100^{o}F (the festival was open from 11 am to 5:30 pm). Most participants indicated they spent between 0-20 minutes at mini-flume activity. The time spent in the unpleasant weather conditions combined with the high level enjoyment and worthwhile indicates that the activity was generally a positive experience for participants. Positive experiences are an important part of free choice learning due to the highly intrinsic nature of this type of learning[xvi] and may impact choices concerning future engineering education, whether free-choice or formal.

Over-all the results suggest the goals of increasing awareness about coastal hazards, coastal engineering and esteem for engineers were met. Figure 4 indicates that participants choose our activity because they were interested in tsunamis and engineering so it is a positive result that they came away with in increased interest in these topics. While we do not show large self-reported increases, we do not know initial level of participant knowledge, and since we know that we had a high level of education in our participant population it seems reasonable to assume that some of them did have high level of initial knowledge. Figure 6 suggests we generally were able communicate about engineering challenges and positive societal impacts. However it also suggests that perhaps we could have done a better job with explaining engineering challenges.

The satisfaction and enjoyment of the activity was a very positive result. A major intended outcome of this short-duration activity was a positive association with engineering. The importance of these results is that simple short-term activity can engender interest and potentially long-term engineering literacy in the general public. The charismatic nature of our activity using Legos draws in the audience, and the focused nature of the activity allows a successful completion in a short period of time. In a festival setting most people will want to see many things during their limited time, so activities can only expect to hold an attention of participants for a short time. The current configuration of our activity requires a higher level of staffing than most museums; universities can employ undergraduates to staff these at short term public outreach activities. Other groups can employ volunteers and include a few expert staff to answer more complex questions. While this activity may not be able to reach millions of people a year, it can reach to reach 1000s. To reach many different audiences we need activities of different scale and scope. This activity has proven meaningful in a medium-scale festival event.

References

---

[i] "NSF's Goals...Setting a True Course", n.d., http://www.nsf.gov/nsf/nsfpubs/straplan/goals.htm.
[ii] Y. Chae, S. Purzer, and M. Cardella, "Core Concepts for Engineering Literacy: The Interrelationships Among STEM Disciplines," in *American Society for Engineering Education Annual Conference and Exposition. Louisville, KY*, 2010.
[iii] J.H. Falk, M. Storksdieck, and L.D. Dierking, "Investigating Public Science Interest and Understanding: Evidence for the Importance of Free-choice Learning," *Public Understanding of Science* 16, no. 4 (2007): 455.
[iv] J.H. Falk, "Free-choice Science Learning: Framing the Discussion," in *Free-choice Science Education: How We Learn Science Outside of School*, ed. J. H. Falk (New York, New York: Teachers College Press, 2001), 3–20.
[v] Falk, Storksdieck, and Dierking, "Investigating Public Science Interest and Understanding."
[vi] L. D. Dierking and J. H. Falk, "Optimizing Out-of-school Time: The Role of Free-choice Learning," *New Directions for Youth Development* 2003, no. 97 (2003): 75–88.
[vii] R. W. Bybee, "Achieving Scientific Literacy: Strategies for Insuring That Free-choice Science Education Complements National Formal Science Education Efforts," in *Free-choice Science Education: How We Learn Science Outside of School*, ed. J. H. Falk (New York, New York: Teachers College Press, 2001), 44–63.
[viii] Chae, Purzer, and Cardella, "Core Concepts for Engineering Literacy."
[ix] Ibid.
[x] Committee on Public Understanding of Engineering Messages National Academy of Engineering, *Changing the Conversation: Messages for Improving Public Understanding of Engineering* (National Academy Press, 2008).
[xi] National Academy of Engineering, *Changing the Conversation*.
[xii] M. Hynes et al., *Infusing Engineering Design into High School STEM Courses*, 2011, http://ncete.org/flash/pdfs/Infusing_Engineering_Hynes.pdf.
[xiii] Chae, Purzer, and Cardella, "Core Concepts for Engineering Literacy."
[xiv] Hynes et al., *Infusing Engineering Design into High School STEM Courses*.
[xv] National Academy of Engineering, *Changing the Conversation*.
[xvi] J.H. Falk and L.D. Dierking, *Lessons Without Limit: How Free-choice Learning Is Transforming Education* (Altamira Pr, 2002).