AC 2012-5362: OUTREACH ACTIVITIES IN TEACHING ENGINEERING DESIGN

Dr. Arif Sirinterlikci, Robert Morris University

Arif Sirinterlikci is a professor of engineering at Robert Morris University School of Engineering, Mathematics, and Science. He also serves as a Director of Engineering Laboratories as well as Co-head of the Research and Outreach Center. He has been an active member of ASEE and SME, serving as an officer of both societies and engaged in engineering education and K-12 outreach.

Dr. John M. Mativo, University of Georgia

John Mativo is Assistant Professor at the University of Georgia, Workforce Education/Faculty of Engineering.

Outreach Activities in Teaching Engineering Design

Introduction

This paper presents various outreach activities in teaching engineering design to middle, and high school students. Although different methods were utilized, the results indicate a common scenario of active learning experiences. Two universities involved were the University of Georgia and Robert Morris University, located in suburban Pittsburgh, Pennsylvania.

One end of the outreach spectrum was a yearlong program to Hillsman Middle School in Georgia and focused on structural design. This program was similar in technical content and nature to Edmond Saliklis' successful outreach program in building arches for kids[1]. The outcome of the Georgia program enabled the students to realize that light engineering structures can carry large loads. Once a month during the school year, authors visited the middle school to interact with the students and demonstrated structural design capacity concepts. Together with the students, they explored and listed materials needed to construct structures, typical loading conditions, types of structural shapes, and student expectations on how the materials and structures in question will behave under certain loading conditions. In the end, the students were asked to use index cards to build a column structure that would support the largest load. A slow rate loading was applied by placing books on to the columns. Results were compared to the students' expectations. The students and their teachers were involved in the activities as they termed them very interesting and captivating. The students made a breakthrough in relating mathematics with their predictions, analyzed different shape factors and materials while they communicated amongst themselves and with their teachers.

At the other end of the outreach spectrum, middle and high school students participating in Robert Morris University summer camps near Pittsburgh were exposed to engineering design and analysis subjects through a hands-on work-shop. There have been many outreach cases focusing on teaching design and analysis. It still is a popular outreach area and rapidly changing. In a recent work by Carnegie Mellon University, the researchers developed software-agent monitored tutorials in teaching design, analysis, and mathematics to middle school students[2]. However following a unique methodology developed by himself, one of the authors has been employing animatronics as a design education medium over a period of ten years in college curriculum and secondary school outreach efforts[3,4,5,6]. An initial section of the animatronics camps encompass engineering and toy design including computer-aided engineering concepts by employing a wizard driven tutorial, but also is interactive.

At first, students were given a crash course on solid modeling with the SolidWorks software. After designing simple parts in the solid modeler, they were given a crane hook model with multiple boundary surfaces. The students were then asked to analyze the hook's performance based on given boundary conditions including fixtures and loading. By using SolidWorks SimulationXpress, they assigned the appropriate hook material, applied restraints to hold the hook at a point in 3D space as well as loading to represent the maximum loading conditions. The hook model was meshed with different size elements and the structural simulation was run by the students. After obtaining the results, they studied stress, strain, safety factor contours and displacement plots in order to decide if the hook was going to withstand the maximum loading and discussed how to improve the hook's performance.

The paper will conclude with the importance of the hands-on design outreach activities by engineering programs, relating to pipeline development in recruitment. In addition to the case studies covered, competitions will be explored as a means to introduce engineering design for K-12 students.

Details of Outreach for the Georgia Middle School Activities: Try It and See

The yearlong outreach program at Hilsman Middle School, GA is presented first chronologically followed by summer camp experience near Pittsburgh, PA. As part of the Adopt-a-school innovative program to help students in underrepresented communities learn about engineering, authors were assigned 5^{th} and 6^{th} grades to present information, demonstration, or do activities that introduced middle school grades to engineering. A 50 minute class was given to the authors to make their presentations each month for a new class visit. Authors decided that a lasting impact to students would be achieved through presenting engineering aspects that were visible to student daily lives such as columns that students see in buildings or bridges. The structural approach to introducing engineering used basic mathematics that students already knew and materials behavior that they could easily observe. Materials needed included a small weighing machine, index cards, scotch tape, and class textbooks.

After being welcomed to the class by the resident teacher, authors introduced themselves by stating their occupations and why they were visiting the class. They immediately proceeded to raise students' curiosity by asking them what they thought of the following question "did you know that a hollow structure weighing .00625 Ibs can support a load of over 30 lb four inches above a surface?" Authors showed one 4" x 6" index card for the structural column weight, and a dumbbell for the weight. Students responded to the question in different ways though most indicated that the index card could not hold such a load. It was discovery time for the middle school students whether they were ready to prove their answer stood correct.

4" x 6" Index Cards

Dumbbell Weight

Figure 1. Materials utilized in the activity

First, students had to establish the weight of one index card. With the demonstration materials placed on the table at the front of the class, students were asked how the weight of one index card could be determined. This determination was made when student response to the question was appropriate, that is, to weigh the index card pack and divide it by the number of index cards.

The process allowed students to express their ideas of estimating index card weights. Authors invited the eager students to weigh of the cards and establish the weight of one card. This exercise allowed students to use their math background for a practical purpose.

Next, the class was invited to help authors in choosing a shape that would give the index card the best design to hold the most weight. A constraint that authors placed on the design was that the load be 4” above the ground. One author presented various column designs in cylindrical, square, or triangular and star cross-sections on the board as alternative designs. The author proceeded to ask whether shape was a factor in structural design. In addition to selecting shapes, students were asked to state reasons why they selected a given shape. Responses ranged from simply put as nice shape, strong, beautiful, to those that suggested association such as many bridge columns are cylindrical.

Cylindrical

Square

Figure 2. Cylindrical and square cross-sections

After two or three responses, students were grouped in teams of threes or fours and allowed to design their columns and test them for strength to support maximum load. Each team received a 4” x 6” index card, and six inches of scotch tape. Following section describes the experimental procedure followed by the students and their analysis:

Experiement#1: The first experiment was allocated a 10 minute limit for design and building of their column. When done with the design and construction of the structure, students in a team would raise their hands to signify completed structural construction and one of the authors would beckon the team to take its structure for testing. Textbooks were used as weights for loading as shown in Figure 3. A textbook would be weighed and its weight established. The structure would be placed on a flat surface like a table top and then the load would be centered on the structure. Equal increments (one textbook at a time) would be placed on the structure until the structure failed. At this point, the total number of books placed on the column would be multiplied by the weight of one book resulting to a calculated total loading weight. This would be recorded as the actual weight prior to failure. Next, a reason for failure would be established. Some of the common reasons for failure included, poor workmanship like a loose scotch tape along the seam that resulted to premature failure; and uneven edges of the structure that caused a weight shift to the lower end of the structure. The best structure supported the most loads before failure. Shape factor role was discussed and in the seven classes that the authors visited in seven months, the cylindrical structure emerged as the shape that supported the most loads. This agrees with the loading distribution of structures.

After testing and analyzing causes of structural failure for one column, students were asked what load they now thought four index cards would support and reasons for their response. Nevertheless, some students estimated load values without giving reasons while some estimated

Figure 3. Conducting experiment #1

with very thoughtful reasons such as if one index card could support a certain load, then four cards would support four times that load. It was time to test if the prediction of four times load would be supported by four columns or equivalent structural strength as some decided to make one column out of the four as the tapped all four together.

Experiment #2: Each team was issued four 4" x 6" index cards and 24" scotch tape. They had 10 minutes to design and develop their structures and test them. When a team was ready for testing they would raise their hands and one of the authors would invite them to step up for testing. The arrangement of the structures was left to students to determine. From the yearlong project that involved seven classes, the most load that was supported by four index cards four inches from the ground was 166 lb. This was more than the group had predicted. Its initial prediction was 80 lb because during the individual loading one card had held 20 lb.

Details of Outreach for the Pennsylvania Summer Camp Activities: Computer-Aided Engineering in a Snapshot

Pennsylvania secondary school students attending Robert Morris University Summer Camps and their teacher chaperons were exposed to the role of Computer-Aided Design (CAD) and Engineering (CAE) in product design and development process. The main goal of the camps were designing and developing animated toys, Figure 4. However, the authors used a simple product such as a crane hook.

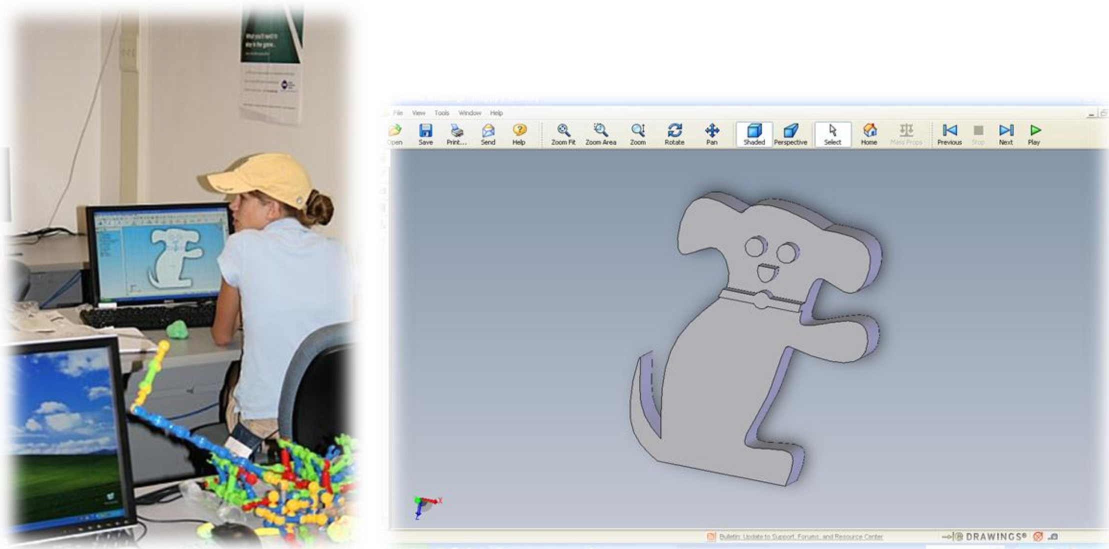

Figure 4. SolidWorks as a toy design environment

After the introduction of 3D solid modeling, the students are exposed to Finite Element Analyses (FEA) with an example. The example is taken from the SolidWorks tutorials for the SimulationXpress. Students are given the solid model of a crane hook shown in Figure 5 and asked to utilize the SimulationXpress Analysis wizard. They learn about the basic steps of design analysis, assess the safety of the design by calculating the safety factor of the design, and can evaluate the accuracy of their results.

The exercise starts with the selection of the hook material, followed by application of a restraint that holds the hook in place, shown in Figure 5. A second boundary condition is also applied in the form of a distributed force representing the weight of an object hanging down the hook as shown in Figure 6.

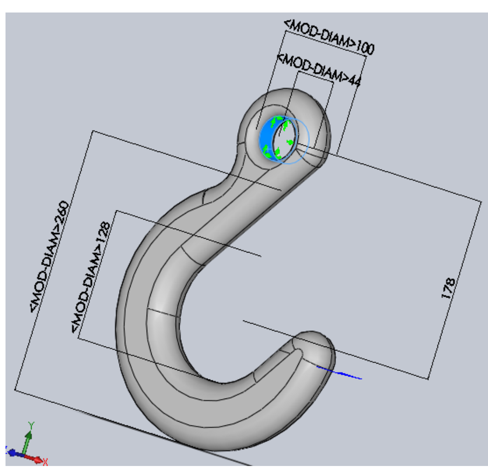

Figure 5. Solid model of the hook and a constraint being applied at the hole

Figure 7 and Figure 8 are presenting the results of the analysis. The lowest factor of safety is given in Figure 7, while Figure 8 is about the stress distribution in Von Mises form. Fundamentals of the numerical simulation is covered simultaneously with this design analysis exercise. Students are exposed to the concepts of finite elements, solid or shell, initial and boundary conditions, as well as simulation parameters including the time step. After the completion of the simulation, there is an in-class discussion where students are engaged in understanding of the results.

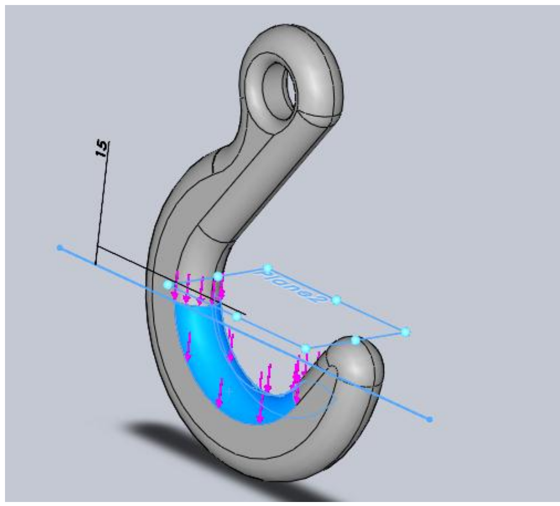

Figure 6. Weight of an object applied as a distributed load

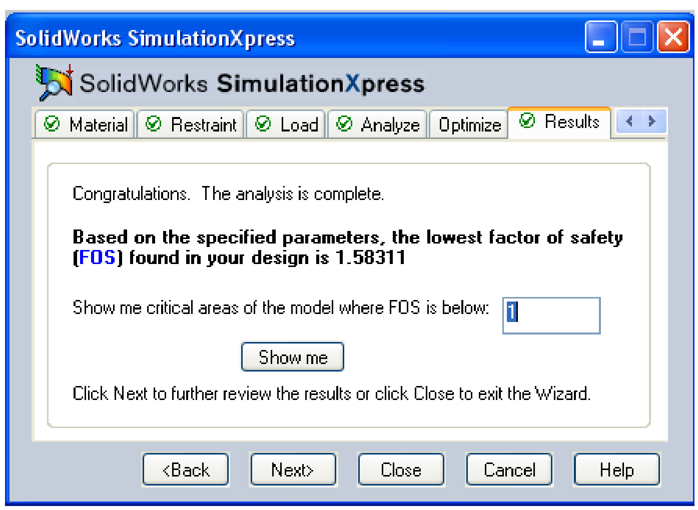

Figure 7. SimulationXpress wizard indicating the calculated safety factor based on the design

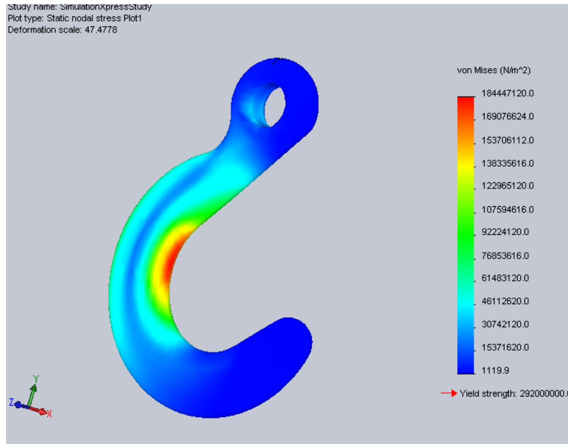

Figure 8. Stress distribution in Von Mises (N/m^2) indicating the critical areas of the design

Conclusions and Assessment

The authors in the Georgia activity reviewed with the students and were able to indicate that prediction can be made on how much load a structure can support. Also, shape was a factor that played a key role to the loading of structures. Two additional aspects that were achieved were teamwork and communication as students presented their results. Students and their classroom teachers were involved in the activities as they called them very interesting and captivating. The authors made a breakthrough in relating math (prediction), shape factor and materials (science) and communication. The authors are in the process of developing a simple instrument for this activity. In future implementations, this instrument will be employed for outcomes assessment.

In the Pennsylvania activity – the students were able to follow through the CAE exercise. In the process, they understood the concepts of finite elements, boundary conditions, simulation time step, and material selections. The results of the discussion also allow them to comprehend the analysis of the results as they look at displacement, stress, and strain plots in color contours. They were able predict the critical parts of the hook prone to failure with ease. They also learned about stress-strain curves and safety factors in a short span of few hours. Since the activity was a section of an animatronics camp, a separate instrument was not given to the students. However, pre- and post-tests are employed in determining effectiveness of student learning as well as student interest before and after the experience. The results overwhelmingly confirm that the expectations are reached and over 90% of the students are impacted positively by the program. In future implementations, the authors will utilize a specific instrument to gain feedback for this activity as well.

The authors strongly believe that competitions like JETS can play a great role in attracting students into engineering. However, engaging students in actual engineering activities such as in the case of FIRST Tech Challenge (FTC) where student teams design and built autonomous and remote controlled robots may be more effective in gaining these students. FTC Engineering notebooks, design presentations, and winning robots teach and influence future engineers.

References

[1] Saliklis, E., Arch Building for Kid. What did they learn? What did we learn?, 2008 ASEE Conference, Pittsburgh, PA.

[2] Beuth, J., L., Kumar, R., Rose, C., P., Use of Software Agent-Monitored Tutorials to Guide Student Learning in Computer-Aided Design, Analysis, and Mathematics Projects, 2011 ASEE Conference, Vancouver, BC, Canada.

[3] Sirinterlikci, A., Open Ended Robotic Design for Enhanced Capstone Experience, 2004 ASEE Conference, Salt Lake City, UT.

[4] Sirinterlikci, A., Mativo, J., A Cross-Disciplinary Study via Animatronics, 2005 ASEE Conference, Portland, OR.

[5] Sirinterlikci, A., Mativo, J., Summer Honors Institute for the Gifted, 2006 ASEE Conference, Chicago, IL.

[6] Sirinterlikci, A., Employing Animatronics in Teaching Engineering Design, 2011 ASEE Conference, Vancouver, BC, Canada.