Work-In-Progress: Hands-On Engineering Design Activity for First Year Engineering Students Using Lego Pieces

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Abstract – **Engineering students are required to take several mathematics and science courses along with other general university requirements during their first and second year. They have to wait for several semesters after admission before they get to work on engineering design activities. This can have a demoralizing effect on some students and they may start losing interest in, and passion for engineering. Introductory first-year courses present the perfect opportunity to get students to participate in a hands-on engineering design activity. We developed a concept design activity using Lego pieces to engage students by participating in various stages of engineering product design process. Students were divided into groups of 4 per team and were given 10 regular random Lego pieces. The engineering design activity (labeled as the Widget Activity) was conducted in two parts. In Part one, students were asked to design a product and make a model using the Lego pieces. In Part two, student groups were asked to prepare a list of parts and assembly instructions for their product. All groups then randomly exchanged their widgets with other groups and all groups then tried to put together the widget they received only using the parts list and assembly instructions. Student groups submitted a two-page report highlighting key information about their widget along with a digital design sketch. We timed the groups as they assembled the products and it served as an additional motivation to finish quickly and accurately. The overall Engineering Design activity served several learning outcomes including getting students to work as a team, introduction to product design process, applying problem-solving skills among others. We have assessed the effectiveness of this activity using surveys and focus groups and in the future, hope to expand this initiative to all FED101 sections.**

Index Terms – first year students, engineering design process, Lego activity, teamwork.

INTRODUCTION

First-year engineering students typically have to wait several semesters before they will work on engineering design activities. This delay can be discouraging for some students which may lead to diminished interest and motivation in pursuing their major. First year engineering courses, such as Fundamentals of Engineering Design (FED 101), presents the unique opportunity to get students involved in a hands-on engineering design activity. In order to introduce the students to some basic engineering principles, we used a concept design activity to get students to participate in various stages of an engineering design process. The purpose of our concept design activity is for the students to experience a combination of science and technology, and working in groups with other students. The students work together in groups of four (4) and experience team building and group dynamics. They apply their problem-solving skills and learn about a technical/engineering topic, make friends, meet fellow cohorts, work with an engineering professor, and have fun. The activity, defined as a widget activity, consisted of designing, building, and reverse engineering an abstract unit of production – such as a manufactured device.

In Spring 2018, the widget activity was conducted in several sections of FED101 courses. Each engineering major at our university offers their own version (sections) of FED101 course. We used FED101 sections for Engineering Science (ESC) major and Civil Engineering (CE) major. ESC at NJIT is a placeholder for undecided freshman engineering students. Although, Spring 2018 was the first time this activity was expanded to include ESC major students, CE major students have been participating in this activity for the last couple of years.

DESCRIPTION

Widget: A small mechanical device, as a knob or switch, especially one whose name is not known or cannot be recalled; gadget. For example- a row of widgets on the instrument panel. [1].

The engineering design activity was named "Design/Build/ Reverse Engineer a Widget." The students were randomly selected and placed into groups of four (4) and provided with several ideas of manufactured products (sample widgets) to choose from. They were free to come up with their own ideas and submit the idea to the professor for approval. Each group was given a widget container that contained 10 random regular Lego pieces.

Sample Widgets: Some of the design widgets we presented to the class included-

1. Carburetor
2. Lunar Excursion Module (LEM)
3. Hologram Apparatus
4. Atmospheric Water Generator (AWG), aka Cloud Seeding Device
5. Enigma Machine
6. Portable Particle Accelerator

An example of a design activity (see Appendix) was given to the students and was used by them as a reference to prepare a two (2) page written report. The widget report included a definition, the purpose, the uses, the construction and operation, references, a parts list, assembly instruction, and a sketch. The engineering activity consisted of the following three (3) parts,

Part 1: Design

The design activity included a research of the team's selected widget for the purpose of building their product using the 10 Lego pieces. Students were asked to consult any reputable source of their choice to research the widget. Once students identified a product and gathered information about it and created a design sketch, the design phase of the activity was considered complete.

Part 2: Build

The build activity included identifying all 10 components from the design sketch and developing a parts list. The parts list includes the part number, part color, description of the part, number of pieces and array notes. After the parts list was completed the team prepared assembly instructions.

Each team assembled their design using the Lego pieces and sketched the final product. After the build activity was completed each team disassembled their widget and put the 10 pieces into their Lego container. The build portion of the activity was completed at this time.

Part 3: Reverse Engineer

Reverse engineering or the rebuild process begins when the Lego container, with the disassembled pieces, is exchanged with another randomly selected team. The team assembled the widget using only the parts list and the assembly instructions. Sketches are not provided to the other team. After the team has assembled the widget the reverse engineering portion of the activity is complete and the widget is ready to use!

The reverse engineer phase of the activity was timed and discussed with the students at the end of the activity. The timing served as additional motivation for each team to finish quickly and assemble the widget accurately. Some of the items we discussed include.

1. Which team completed the assembly the quickest?
2. What helped assembling the widget the fastest, i.e., was it the written instructions or accurate parts list or both?
3. What did you learn about an engineering design process?
4. If a team finished first, who should get credit for it – the team that followed instructions or the one that wrote the instructions?

Please Note: Building the widget with Lego pieces is key to the speed and accuracy parts of reverse engineering. Students immediately try to make their widget look like their design of choice. This is the most common misinterpretation of the activity. Since the widget is hypothetical, it can look anyway the team wants it to look, and they identify it as their widget.

SAMPLE STUDENT PROJECTS

A couple of examples of widgets designed and reverse engineered by student groups are presented below.

Example 1:

FIGURE 1
SNOW TERMINATOR

Definition: This product is a reinvented model of snowplow vehicle.

Purpose: It will be capable of more efficiently removing snow off the road. It will be equipped with a wider adjustable shovel to fit the size of any street and a powerful engine to propel it to remove more snow. It is also capable of melting snow. It makes the road safer in the winter.

Example 2:

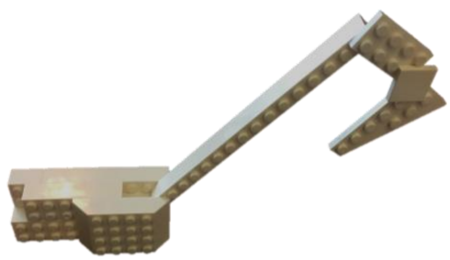

FIGURE 2
THE EXCAVATOR

Definition: Excavator claw is a power-driven machine for digging, moving, or transporting loose gravel, sand, or soil.

Purpose: This machine has many uses rather than just lifting dirt. The purpose of this machine is to innovate the process of construction. The machine is able to carry large supplements of materials to different areas. It can carry materials from rocks to water. This machine helps with leveling areas as well.

STUDENT PARTICIPATION AND FEEDBACK

When the activity was introduced in class, students were initially apprehensive about what can be designed, due to their limited knowledge and exposure. When ideas were discussed, students began sketching rough diagrams and ideas on a paper. As a part of the assignment, they started building models using the parts given to them. Further, the documentation for rebuilding the same model was made by each team and it was circulated. In this way, students benefitted by having an opportunity to gain knowledge about others' documentation styles and rebuilt other group's widget reading their part and assembly instructions. According to the survey taken after the activity from the students, 97% students mentioned that the activity helped improve themselves in some important aspects such as communication, research, teamwork, problem solving and more.

Survey Results: After the activity was concluded, an online survey was conducted post the activity in both FED101-ESC and FED101-CE sections to help better understand the effectiveness of the widget activity and possible ways to improve it for the next semester. 32 students from ESC sections and 24 students from CE section responded to the survey. Table I presents the results.

TABLE I
AVERAGE SCORES (1-5) OBTAINED FROM STUDENTS

Q #	QUESTION	AVERAGE RATING (1 – 5)
1.	The widget activity has increased my interest in engineering.	3.4
2.	I found the widget activity to be interesting and fun	3.85
3.	The widget activity is a good way to introduce engineering design to first year students	3.8
4.	The widget activity helped increase my understanding of engineering design process	3.55
5.	The widget activity helped me work better in groups	3.6
6.	I think it's important that students be introduced to the design process early in their first semester in college	4.15
7.	I recommend this activity for first year engineering students	3.9

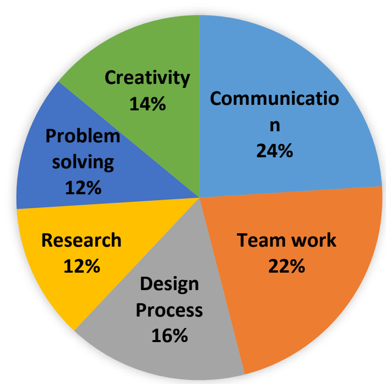

FIGURE 3
CONTRIBUTION OF THIS ACTIVITY FOR IMPROVEMENT ON EACH ASPECT BASED ON SURVEY RESULTS

Students were also asked to indicate if the widget activity helped them improve/learn/explore their understanding and skills. Figure 3 presents their responses in a pie chart. Students were also asked to provide any comments that had about the activity.

General Comments:

- Great idea, one of my favorite activities in the class.
- It was a good early introduction on how to be clear and precise in instruction, while keeping the overall design simple.

- Should be able to build more people's designs and really made it into a competition. Maybe have one person read the instructions and someone else build it.
- The idea and intentions behind the activity were great. I believe it encouraged all students to use real-life problem solving and critical thinking to tackle a project that relates to something that is not theoretical.
- The assignment was very fun from the design process to the presentation and even helps as a way to get people into communicating with each other and getting them more accustomed to the environment. If introduced earlier, it could be a fun ice breaker.

SUMMARY

This widget activity successfully served key several learning outcomes including having students work together as a team, being introduced to a product design process, and applying their problem-solving skills. We assessed the effectiveness of this activity using an online survey and a discussion at the end of the activity. We look forward to expanding this activity in all FED 101 sections.

APPENDIX

To further illustrate the design activity, an example titled "Portable Linear Particle Accelerator (Linac)" parts list and assembly instructions are attached below-

PARTS LIST

Part #	Part Color	Description	# of pieces	Array Note
1	Dark blue	Ion source	1	2 x 2
2	Orange	RF source	1	2 x 2
3	Light blue	Combiner ring	1	2 x 2
4	Yellow	Drift tubes	4	2 – 2 x 3, 1 – 2 x 4, 1 – 2 x 6
5	Grey	Beam Delivery System	1	2 x 3
6	Green	Interaction point	1	2 x 2
7	Red	Beam	1	2 x 4

Step	Assembly Instructions	Note
1	Place Part 1 and Part 6 next to each other.	Parts are not connected.
2	Place Part 3 over Parts 1 and 6. Connect over right array of Part 1 and left array of Part 6.	
3	Place Part 2 directly over Part 3 and connect.	
4	Place Part 4 (2x4) over right array of Part 6 and connect.	
5	Place Part 4 (2x3) under Part 4 (2x4) and connect at last right array of Part 4 (2x4).	
6	Place Part 4 (2x3) over Part 4 (2x3) from Step 5 and connect below at last right array.	
7	Place Part 4 (2x6) under Part 4 connected in Step 6 and connect at the last right array above.	
8	Place Part 7 at the end of Part 4 (2x6) in Step 7.	Parts are not connected.
9	Place Part 5 over Part 4 and Part 7 from Step 8 and connect Part 5 at the last right array of Part 4 and the last left array of Part 7.	
ASSEMBLY IS COMPLETE. THE WIDGET IS READY TO USE		

REFERENCES

[1] Dictionary.com. (2018). *the definition of widget*. [Online]. Available at: http://www.dictionary.com/browse/widget?s=t [Accessed 12 Apr. 2018].

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