AC 2011-190: EMPLOYING ANIMATRONICS IN TEACHING ENGINEERING DESIGN

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Employing Animatronics in Teaching Engineering Design

Introduction

This paper presents a cross-disciplinary methodology in teaching engineering design, especially product design. The author has utilized this animatronics-based methodology at college and secondary school levels for about a decade. The objective was to engage students in practical and meaningful projects. The result is an active learning environment that is also creative. The methodology was also employed for student recruitment and retention reasons. The effort has spanned two universities and included a senior capstone project[1], an honors course[2], multiple summer work-shops and camps[3,4,5,6,7] as well as an introduction to engineering course.
The curriculum encompasses the basics of engineering and product design, and development as well as team work. Students follow the following content sequence and relevant activities through concept development, computer-aided design (CAD), materials and fabrication, rapid prototyping and manufacturing, mechanical design and mechanisms, controls and programming. Integration of subsystems and costuming are the last two stages of the curriculum.

Brief History and Evolution

The author's original concept was realized when he and his students designed and developed an animatronic polar bear robot shown in Figure 1[1]. The robot successfully competed at the 2003 Society of Manufacturing Engineers/Robotics International (SME/RI) event at Rochester Institute of Technology, earning the 3rd place in the Robot Construction Category. This capstone

Figure 1. Animatronic Polar Bear for the 2003 SME/RI Competition

course project led to the development of a cross-disciplinary honors course, enrolling art, engineering, technology, and pharmacy students[2]. Puppetry and mechanism design projects were the focus of this 4 hours a week course. Also following the capstone project, the author started collaborating with art and technology education faculty members for enhancing the art content and preparing secondary school initiatives [3,5,7]. A pilot study funded by the author's previous institution allowed a small group of high school students to design and develop their own animatronic structure. Concept development through artistic sketching, sculpting, and molding contents were studied and their role within the methodology were determined. In the process, a high school team designed an organ grinder monkey for the 2005 ToyChallenge competition while multiple grant proposals were submitted to National Science Foundation (NSF) ITEST program and the Ohio Department of Education Summer Honors Institute for the Gifted and Talented[7]. The author did not work towards the completion of the high school competition project, but offered one Summer Honors Institute course before moving to his current institution where he teaches Animatronics as a part their high school summer camps as well as the introduction to engineering course.

The author originally employed the idea of using non-kit-based structural, mechanical, electrical and electronics parts while he took advantage of the scrap components and materials in his laboratories. Over the first few years, this proved to be a challenging but a good concept because of the low cost. ZOOB construction toys, shown in Figure 2, were also used due to their flexibility and help in 3D visualization of concepts alongside the sculpting materials. Five years ago the author decided to alter his original concept by employing VEX Robotics Development System. With the new approach, students are able to make use of standard mechanical, electrical/electronics, and pneumatic components the VEX system offers. Students are still able to custom design parts by altering structural VEX components through cutting, bending, and joining or simply designing and making what they need outside the VEX system .

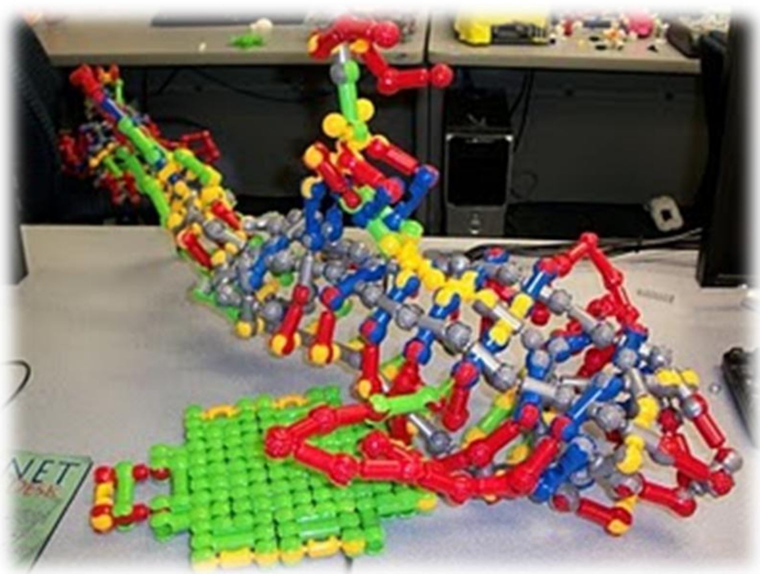


Figure 2. ZOOB construction toys – utilized in 3D concept development

Another advantage of the VEX Robotics Development System is its versatile microcontroller that is both programmable and radio controls (RC) driven.

In the next sections of this paper, details of each element of the methodology as well as outcomes assessment from the introduction to engineering course are presented. A brief section on the current state of the summer camps is also covered before the conclusions.

ENGR 1010 Introduction to Engineering Course Project

This section presents the most recent attempts on integrating animatronics into ENGR 1010 Introduction to Engineering course with a semester long project. The main objective of this open-ended team project is to design and develop an animated robot or puppet. The teams are composed of three to four students and required to follow a process based on product design and development. Main stages of the process are described below in their actual sequence:

- **Concept Development:** Through a brainstorming activity students develop alternative designs for their project. They need to visualize their design ideas using sketches. A problem statement explaining their design idea must also accompany each alternative design. They choose from at least two alternatives based on certain constraints including costing, marketability, and manufacturability. For extra credit, they can carry their best design into the CAD environment using SolidWorks.
- **Armature and Mechanical Design:** The students are given VEX structural components. They combine VEX parts with the custom parts they choose to design and fabricate. Once they determine the material type(s) to be utilized, fabrication can be done manually using machine tools in the machine shop or they can take advantage of the features of the Rapid Prototyping and Manufacturing (RP & M) Laboratories. They also need to select the power train components like gears, belt and chain drives for their mechanisms.
- **Electrical Design:** This stage is about adding the appropriate sensing and actuation elements to the designs. Electrical motors including servo or continuous DC, and associated sensors and switches are chosen. Wiring system has to be designed at this stage as well.
- **Radio Controls/Programming:** Students need to select between radio controls and autonomous microcontroller based designs. C programming may still be required in RC controls since students may want to modify RC settings by using the C programming language.
- **Integration**: This is where students work the bugs within the mechanical, electrical, and control subsystems as they integrate the subsystems. This stage is concluded with costuming of the animatronic robot or puppet.

Teams have to submit a progress report for each of these 5 stages. These progress reports include design ideas and calculations based on physics' laws and other supporting information, and need to be converted into a final report and presentation. The progress is followed by the instructor throughout the project. Each student's contributions and interactions with fellow team members are counted towards his/her attendance and participation grade for the course. With the conclusion of the project, each team needs to deliver a working product. Members also need to assess their peers' work through peer review.

Each progress reports are 12% of the project grade adding up to 60% of the overall project grade. Final report, presentation, and successful demonstration are worth 30%. Peer review is the remaining 10% of the grade. 10% extra credit is added to the grade if teams choose to use CAD in the design process or utilize additional means not mentioned within the objective section of this assignment sheet.

Student teams conduct relevant fixed-goal laboratories and homework assignments to progress through the stages of the project (They receive a separate grade for these activities in addition to an overall project grade) indicated in Table 1. Each laboratory activity relates to the previous ones. Thus, continuous involvement is required throughout the term.

Table 1. Laboratory schedules along with project stages

Stage	Requirements	Time Frame
1- Concept Development	Brainstorming Activity 1) Problem Statement and Sketch Development 2) Extra Credit CAD Design 3) Reverse Engineering with 3D Scanners – Disassembly Activities	1st 3 Weeks
2- Armature and Mechanical Design	4) Structural Design with VEX Drive Train Design Laboratory with VEX Gears/Drives 5) and Fabrication through RP/Molding	2nd 3 Weeks
3- Electrical Design	6) Actuation Laboratory with VEX Switch and Sensing Laboratory with VEX 7) Wiring Laboratory with VEX/NI Multisim or ACAD Electrical	3rd 3 Weeks
4- Radio Controls and Programming	8) Radio Controls Laboratory VEX 9) C Programming 10) Autonomous Controls Laboratory 11) Hybrid Systems	4th 3 Weeks
5- Integration	12) Integration of Subsystems 13) Costuming and Finalization	5th 3 Weeks

Examples of the laboratories relating to project stages are given below. Figure 3a is a product of student scans of a Halloween Jack Lantern with Creaform's Handy Scan 3D scanner while Figure 3b is taken from a Reverse Engineering report where students dissected animated toys. Both activities relate to Reverse Engineering through its technology and methodology.

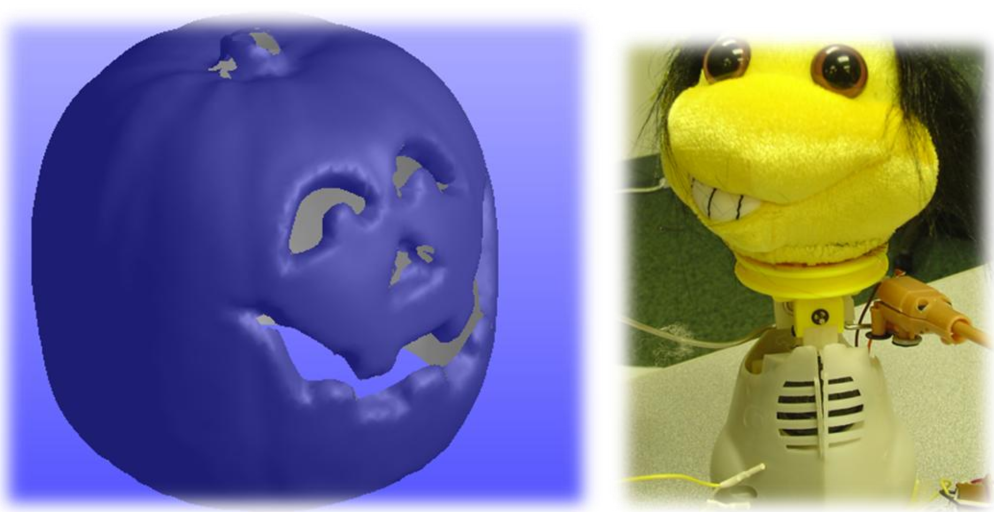


Figure 3. a) 3D Scanning of a Halloween Jack Lantern b) Dissecting an animated toy

Figure 4 is presenting a simple but combined VEX and non-VEX structure. VEX components in the design included structural pieces, continuous DC motors and gears. Figure 5 is illustrating silicone rubber Room Temperature Vulcanization (RTV) mold halves and resulting polyurethane piece molded by the students.

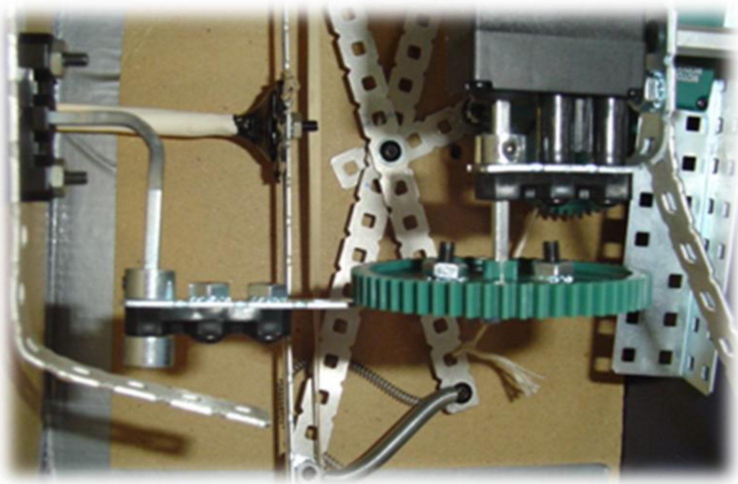


Figure 4. VEX and non-VEX components combined in a design

Figure 5. RTV mold halves and resulting polyurethane part

Figure 6 is about a Square Bot and its radio transmitter. The Square Bot design is an example robot design supplied in the VEX inventor guide with the basic set of parts. Each group has to build this robot and control it using the VEX RC system. The next exercise is to use a C-based programming language as shown in Figure 7. The author used to employ Easy C programming language. It is now replaced by the more comprehensive Robot C. A finalized project example of a costumed one is shown in Figure 8.

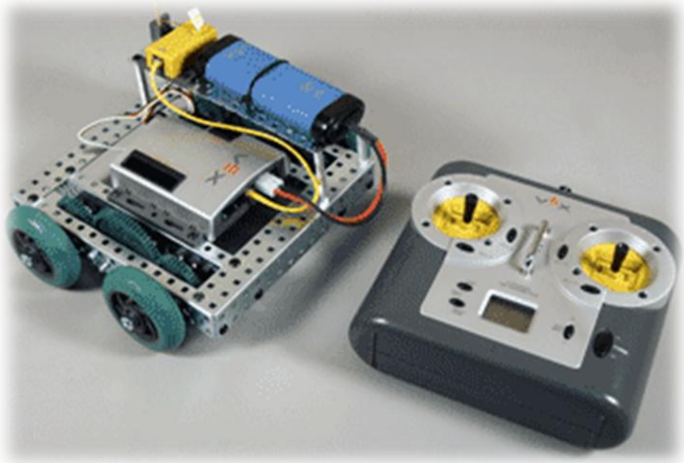
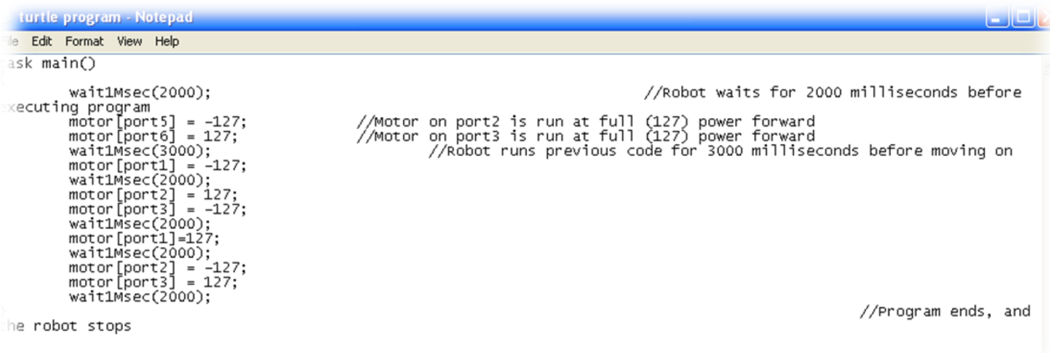


Figure 6. VEX Square Bot used in RC controls exercise



turtle program - Notepad

```
ask main()

        wait1Msec(2000);                                      //Robot waits for 2000 milliseconds before
xecuting program
        motor[port5] = -127;            //Motor on port2 is run at full (127) power forward
        motor[port6] = 127;             //Motor on port3 is run at full (127) power forward
        wait1Msec(3000);                        //Robot runs previous code for 3000 milliseconds before moving on
        motor[port1] = -127;
        wait1Msec(2000);
        motor[port2] = 127;
        motor[port3] = -127;
        wait1Msec(2000);
        motor[port1]=127;
        wait1Msec(2000);
        motor[port2] = -127;
        motor[port3] = 127;
        wait1Msec(2000);
                                                                              //Program ends, and
he robot stops
```

Figure 7. A simple Robot C program for an animated turtle

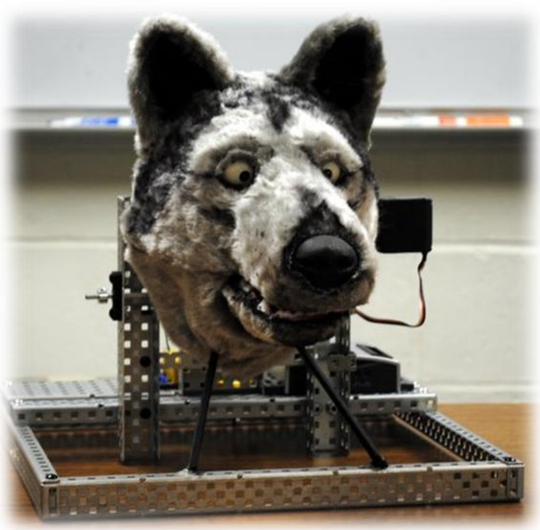


Figure 8. Animatronic wolf head

Assessment

Very positive and constructive feedback has been obtained through the capstone, honors, and finally the introduction to engineering course over a period of eight years. Student performances in ENGR 1010 Introduction to Engineering course resulted in higher student morale and retention due to the inclusion of a multi-faceted project in a fun environment.

The outcomes assessment of ENGR 1010 is based on analysis of the examinations, the laboratory exercises and project assignments. The performance criteria employed for all related outcomes is based on the percentage of students who score at or above an 80% (or B-) grade. If 80% of students score at or above 80% (or B-) grade for certain outcome, performance is considered as acceptable. If between 60 – 79% of students score at or above 80% (or B-) grade, performance is considered as a concern. If less than 60% of students score below 80% (B-), it is considered as a weakness.

Table 2. ABET Outcomes and student performances (*: Based on laboratory scores)

ABET Outcome	Explanation	Average Measure (%)
Outcome 1	RMU graduates have an ability to apply knowledge of mathematics, science, and engineering.	87.32
Outcome 2	RMU graduates have an ability to design and conduct experiments, as well as to analyze and interpret data.	95.83*
Outcome 3	RMU graduates have an ability to design a system, component, or process to meet desired needs.	95.83*
Outcome 4	RMU graduates have an ability to function on multi-disciplinary teams.	95.83*
Outcome 5	RMU graduates have an ability to identify, formulate, and solve engineering problems.	95.83*
Outcome 6	RMU graduates have an understanding of professional and ethical responsibilities.	95.83*
Outcome 7	RMU graduates have an ability to communicate effectively.	83.07
Outcome 8	RMU graduates have the broad education necessary to understand the impact of engineering solutions in a global and societal context.	95.83
Outcome 9	RMU graduates have recognition of the need for, and ability to engage in life-long learning.	95.83
Outcome 10	RMU graduates have knowledge of contemporary issues.	95.83
Outcome 11	RMU graduates have an ability to use techniques, skills, and modern engineering tools necessary for engineering practices.	95.83

The author summarized his assessment (based on data from Table 2) by deducing the following reflections and proposed action items for the next offering of the course:

- Final grades show that 95.83% of the students achieved a grade of 80% (B-) or better. This is acceptable. There was only one non-engineering student who withdrew from the course due to not having interest in the laboratory section of the course.
- All outcomes were assessed as acceptable. Outcomes 1, 2, 3, 4, 5, 7, 8, and 11 relate to the Animatronics content of the course. They all indicate acceptable assessment ratings with Outcome 7 being the lowest score at % 83.07 followed by Outcome 1 at % 87.32.
- 95.83% of the students achieved a grade of 80% (B-) or better in the laboratory/project section. Quality of student works in both the labs and project were beyond satisfactory.
- %70.3 of the students received acceptable grades 80% or (B-) better due to not turning in some of their home-works. This can be explained with students' interest in doing. Their learning style was kinesthetic and showed less interest in written assignments.
- 95.83% of the students earned a grade of 80% (B-) or better from their examinations including a take home examination and open-note/books final examination.
- Students were eager to engage in hands-on practical activities.
- Increasing the content on student writing and presentation skills is proposed. This can be done by asking students to write additional papers and more comprehensive project documentation.
- Making laboratory sizes small by opening multiple laboratory sections for the same lecture class is another action item for improving the learning experiences.

Summer Camps

The author spent 2006 and 2007 working with middle school ToyChallenge teams who made to the nationals as well as preparing additional grant applications. A major outreach grant funding was obtained from Claude Benedum Foundation and still in effect. With the help from the grant, three summer camps in Animatronics have been offered in 2008, 2009, and 2010. The camps were used in refinement of the curriculum. Multiple samples of student works are included below in Figures 9 - 13. The main difference between the secondary and post-secondary programs is the CAD and sculpting contents. While college curriculum relies more on CAD, the other use more sculpting and ZOOB elements.

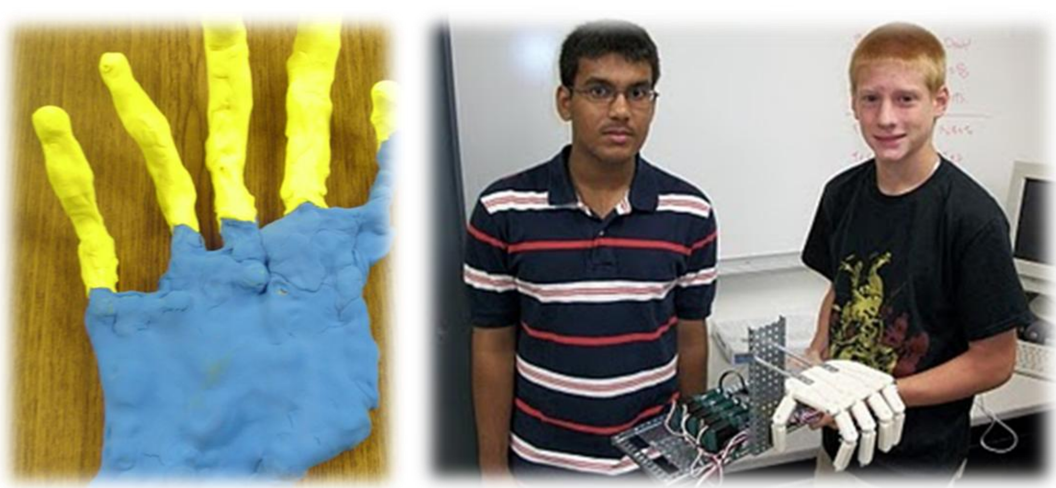


Figure 9. a) 3D concept model with ZOOB pieces covered in Model Magic b) Completed animatronic hand model with parts printed in a Fused Deposition Modeler (FDM)

Figure 10. a) 3D concept with Model Magic b) Completed animatronic penguin

Figure 11. a) 3D concept with ZOOB b) RC controlled purse – costumed VEX

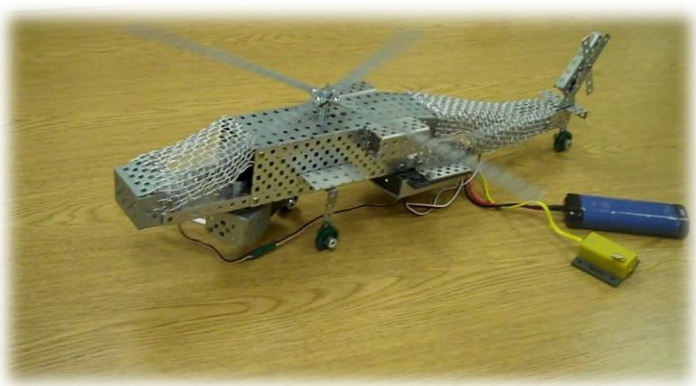


Figure 12. Not yet costumed project – Helicopter gunship

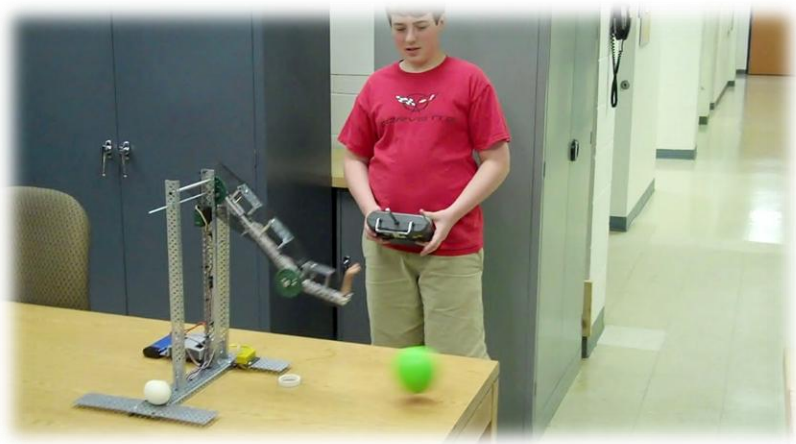


Figure 12. Not yet costumed project – Mini soccer-ball kicker

Figure 13. Almost complete models of a) Harry Potter b) Animatronic eye ball

Conclusions and Future Work

Employing animatronics as a tool for teaching engineering or product design and development has proven to generate an active learning environment indicated by student feedback. After almost a decade the curriculum has evolved to be more effective and fun. In terms of the secondary school level, high enrollments and numbers of repeat students are observed over the years. Some of these students are now studying engineering at the author's current institution. At the college level, student course evaluations are also very strong ranging between 4 -5 out of 5 scale. Another indication is the higher demand for the author's ENGR 2160 Engineering Graphics course, causing formation of long wait lists.

Students going through the set of physical and computer laboratories were able carry what they learned in the laboratories into their projects. Project included a turtle, a cannon for ping-pong balls, a robot that elevates to avoid obstacles, a tank that shoots foam rings, a playing card robot for automatic card dispensing, and a wolf's head shown in Figure 8. ENGR 1010 laboratories and project work were conducted at the actual laboratory times keeping students engaged unlike other sections of ENGR 1010 where students do most of their project work outside the class. However, some students chose to spend additional time outside the classes for better results.

Minor concerns were documented including complaints about a crowded schedule by a couple of students over a group of 25. These concerns were addressed by scaling the semester project down this past Fall. On the contrary, creative student works and resulting pride were other indicators of the successful results. Some students also approached the author to continue their work in the field. Some of these students from the ENGR 1010 class will be working in the future work-shops and summer camps. An attempt gain projects in the field is being done as well as building of the animatronic mascot of the institution by the local SME student chapter.

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