

Project Report: Using Mindstorms in a Control Systems Lab to impact next generation engineers

Penn State Erie, The Behrend College

1. Project summary:

The LEGO Mindstorms kits, due to their low-cost, simplicity, and great flexibility, have been widely used in K-12 and colleges for hands on teaching of robotics and controls. The Pennsylvania State University (PSU) Erie incorporate LEGO Mindstorms NXT to develop control lab activities that can be used for K-12 outreach and undergraduate education to foster an interest in Mechanical Engineering, as well as advanced level activities for the purpose of educating undergraduate students in controls and systems, thanks to the IEEE CSS outreach grant 2014.

- 1) An outreach workshop for K-12 programs: an immersive 3 hour Robotics and Control workshop for use in the Minority College Experience/Women in Science and Engineering (MCE/WISE) program was conducted in July, 2014 with over 30 students and in July 2015 with 34 students. The MCE/WISE programs are free programs, offered by PSU Erie, designed for minority or female students from the Erie area in the summer before their senior year in high school. These programs offer students the opportunity to explore their options in higher education and examine possible career paths. This workshop was run by two faculties. In this workshop, those high school students not only have the chance to build an automated wheeled car and a grasping robotic arm, but also observe that changing controller parameters in Matlab/Simulink results in changing performance of their robots.

Details of outreach workshop instruction can be found at: <http://psbehrend.psu.edu/school-of-engineering/faculty-staff-directory/mechanical-engineering/wu>



Figure 1. The MCE/WISE K-12 outreach activity

The outreach activity instruction was developed by two junior ME students supported by the PSU Erie Undergraduate research fund, under the supervision of Dr. Yi Wu. The students reported that the balance of research during the semester allowed them to develop time management skills. They were able to identify the ties between their classes and the outreach activities. By contributing to K-12 activities, they could see their effect on the next generation of engineers. This outreach lab can be incorporated into any immersive engineering outreach activity for middle school or older students.



Figure 2, undergraduate students help to develop outreach activity instruction. (Left: Christina Pendice, Right: Jarett Thompson)

- 2) Three lab activities for junior and senior mechanical engineering students were created by Dr. Wu and updated by Dr. Wu and Dr. de Vries. The Department of Mechanical Engineering at PSU Erie offers a course, System Dynamics, which covers theory of modeling, analysis, and control of dynamic systems. Simulation tools (MATLAB/Simulink) were used extensively throughout the course. The newly designed Lego labs were introduced in Fall 2014, and conducted in Fall 2014, Spring 2015 with 100 students. The labs include (1) a time response of first order system and transfer function identification and verification, (2) a time response of second order system, and (3) a PD controller design for a tracking problem.

Details of the labs can be found here: <http://psbehrend.psu.edu/school-of-engineering/faculty-staff-directory/mechanical-engineering/wu>

2. Survey results:

1) Survey results for outreach activities:

Students were surveyed before the workshop and after the workshop with similar questions. Those questions ask students to rate the importance of feedback, controller, controller parameters, etc in robots. Survey results shows that students have better understanding of these control concepts after the workshop, with increased positive rating on the feedback, controller, controller parameters, from 75%, 56%, 69% before the workshop to all 100% after the workshop.

2) Survey results for System Dynamics courses:

Students were surveyed after the each lab with technical questions. Those questions ask students about the concepts of transfer function, rising time, overshoot, settling time, controller parameters, etc. Survey results show that lab activities help students gain better understanding of those concepts. The results was published in ASEE Annual Conference 2015.

3. Project Personnel

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4. Spending Summary:

2 Undergraduate Students (10 hours/week@ \$10/hr for 6 weeks in spring 2014)	\$1,200
14 Mindstorms LEGO Education kits and Accessories	\$4,934
Subtotal	\$6,134
Overhead (49.5%)	\$2,442
Total Project Costs	\$8,576

Funding resources:

IEEE CSS Outreach Grant	\$4,934
Penn State Behrend undergraduate research grant	\$1,200
University Participation (loss of 49.5% indirect costs)	\$2,442
Total Funds	\$8,576