Engineering 101: Peer Teaching with LEGO NXT Robotics

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Abstract

The vast amount of knowledge and the multitude of disciplines encompassed by engineering can often be intimidating and difficult, creating an educational barrier for beginning students. The goal of an introductory engineering class is to present engineering as an exciting and welcoming field of professionals who work together to solve problems. An introductory engineering class that lacks creativity, teamwork and encouragement often fails to inspire students and may turn some away from engineering. This paper describes a modern approach to team-based learning and peer teaching in the context of an introductory course for freshmen engineering students. More specifically, the use of LEGO NXT© construction kits was tested as tool to enhance the experience of group projects. LEGOs are approachable, intuitive and have application in numerous construction projects. The low cost, reusability, and availability of a variety of sensors for LEGO kits make them ideal teaching materials compared to other expensive, specialized products. Our project involved presenting students with a task of designing a ribbon-climbing robot which must detect a randomly placed marker and report its height through a wireless communication link. The students were provided with basic mechanism design formulas and calculations allowing them to optimize their design. The project culminated in a final competition between the teams in the class. The project emphasized self- and team learning. The teamwork and the final competition encouraged flexibility, interaction and support between the students, behavior necessary of successful engineers.

Introduction

Engineering is often a daunting subject for incoming students. Lack of knowledge about their chosen field can be very intimidating to new engineering students, and may result in difficulty maintaining high retention rates in engineering disciplines among undergraduates [4]. Introductory courses aim to inform students about both their field of interest and what skills and processes are needed to be a successful engineer [1]. However, it is often difficult to construct a course that introduces concepts of the different engineering disciplines while developing team working and project design skills that does not also require prerequisite knowledge, specifically

within math and science. Students frequently enter college without sufficient knowledge in these areas that would allow for more complex projects in their introductory courses [4]. This often results in introductory engineering courses that are remedial and boring, potentially deterring students from pursuing engineering.

Beginning courses often employ projects that are contrived such that a "correct" solution is made apparent at the beginning and does not require an iterative design process. For example, the introductory course ENGR 102 at the University of Arizona uses a catapult project in which students must launch a ball a certain distance by utilizing different configurations of rubber bands on a pre-constructed wooden catapult. One student could easily arrive at the "correct" solution without consulting their team, making it both a pointless and boring exercise that does not meet the intent of an introductory engineering course. In order to create a more exciting and relevant project for undergraduates, a replacement project employing the LEGO NXT© construction kit was implemented in ENGR 102 classes. LEGOs are an ideal educational engineering tool, incorporating a highly versatile construction set that is approachable, intuitive, and not prohibitively expensive allowing iterative designs and implementation of projects with a team [2].

Methods

Students were given the task of building a robot capable of climbing a ribbon. ENGR 102 students were provided with basic information about the LEGO NXTs, specifically graphs on motor information (Fig 1; Fig 2).

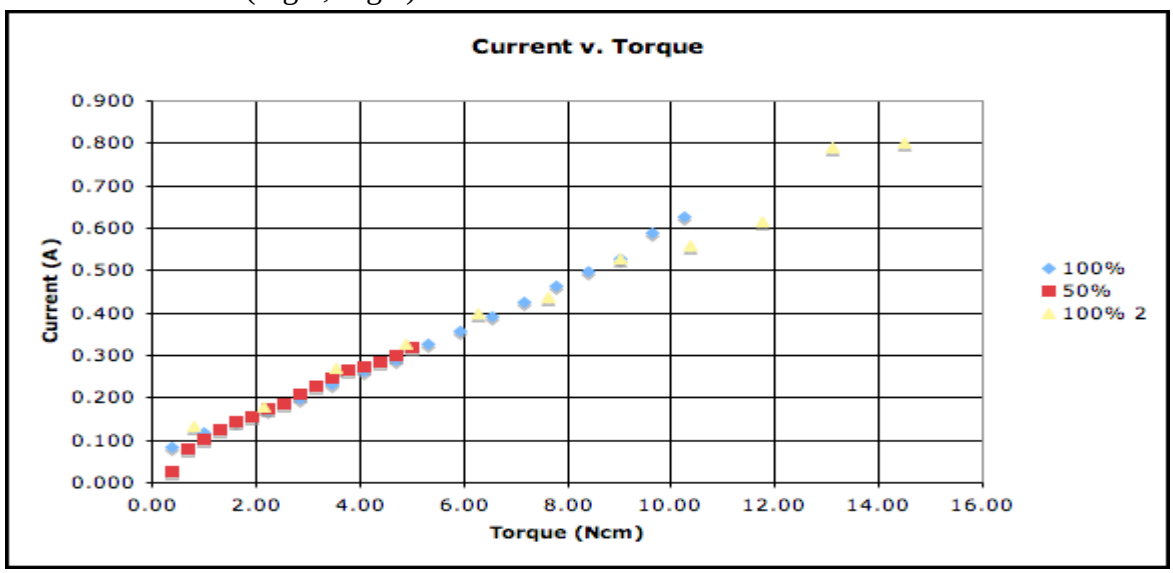

Figure 1: LEGO NXT motors Current vs. Torque Graph. The Blue and Yellow data points are with the motor running at 100% power: blue with a small hub for the pulley, yellow with a large hub. The Red data points are with the motor running at 50% with the small hub[5].

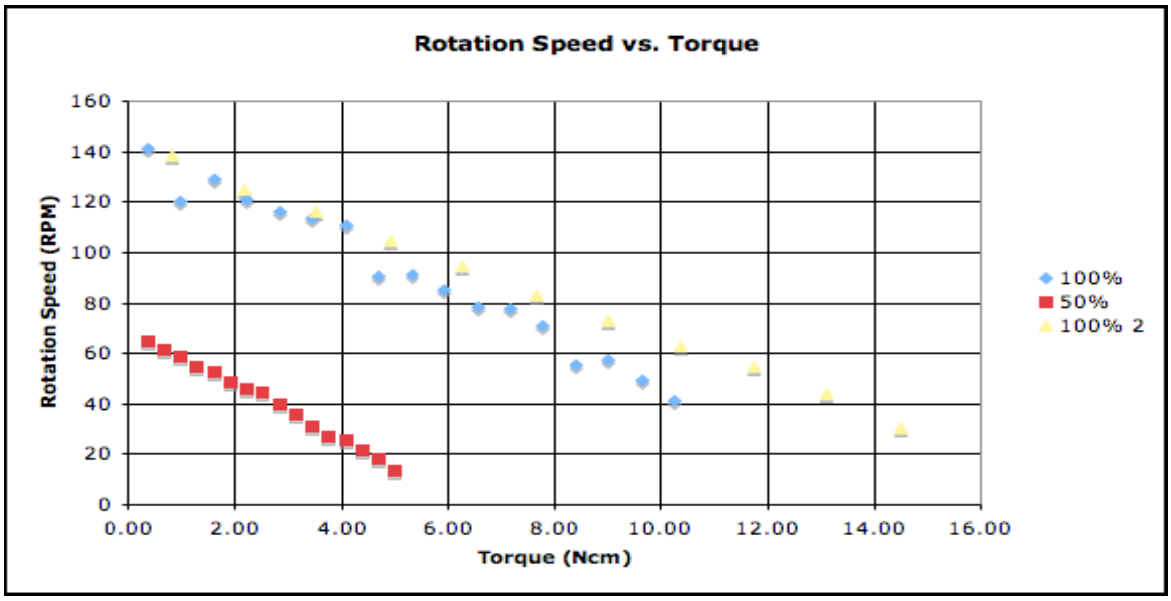

Figure 2: Angular Velocity vs Torque of a LEGO NXT motor. The Blue and Yellow data points are with the motor running at 100% power: Blue with a small hub for the pulley, Yellow with a large hub. The Red data points are with the motor running at 50% with the small hub[5].

Given the graphs and an overview on basic physics, the students were given the details of their assignment: design a robot that could climb a ribbon two stories, stop at markers at unknown distances along the ribbon, send information on height of the markers (from the bottom of the ribbon) wirelessly to a robot on the ground, and return to the ground after making it to the top. The final setup for the competition can be seen in Figure 3.

Figure 3: Ribbon set up with two robots attempting to complete their goals. Note one robot is winding the ribbon while the other is rolling along the ribbon[3].

The students' last goal was to accomplish all these tasks in the shortest amount of time possible. The project culminated in a two day competition. The first day gave the students a chance to test their designs outside at the full two story height. The second day was the actual competition in which the students placed their designs head to head with their fellow teams. The goals of the project forced the students to take important factors under consideration, including the final weight of their robot, number of motors to use, and which sensors were most appropriate for the various task. The students were also required to learn the LEGO programming language, based on Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW), a visual based programming language.

Figure 4: A team of students admiring their hard work on competition day[3].

Results

Many students were very receptive the project – they enjoyed being given a specific goal with few constraints, similar to real life engineering situations. The project required introductory programming and basic mechanics principals, thus introducing some basic concepts from Mechanical, Computer and Electrical engineering, while remaining simple enough for entry level engineering students to succeed. The two day competition as well as in-class testing required the students to use an iterative design process if they wanted to be successful. Between the first and second day of the competition, many teams discovered flaws in their initial designs and corrected these flaws before the final day of competition.

Discussion

The goal of the LEGO ENGR 102 project was to design a project for introductory engineering classes that covered a spectrum of engineering disciplines while being simple enough for

incoming freshman to understand. Furthermore, it was important that the project was interesting and necessitated teamwork while requiring the students to go through an iterative design process. In this regard the project successfully met its goals. Students remained interested in the project, working in teams and brainstorming alternate designs to maximize the speed and efficiency of their robots.

The ENGR 102 class use of the LEGO NXT opens many opportunities to expand or change the 102 project entirely to fit the needs of the students. Currently our lab has been able to power an NXT using silicon solar panels. This would allow a solar variant of this project to be incorporated, introducing yet another pertinent and exciting subject, renewable energy, to incoming engineering freshman. While being more complicated than running an NXT off of a battery, the concepts of supplying enough voltage and current through series and parallel panels is a simple subject that can be broached with incoming or first year students while maintaining their interest. Other projects demonstrating the versatility and possible direction for future introductory engineering projects include an autonomous LEGO soccer field with remote controlled soccer playing robots, another system developed in our lab.

LEGOs are extremely versatile and with their many sensors (touch, light, ultrasonic rangefinder, as well as many aftermarket custom sensors) can be made to model many systems that today's upcoming engineers might encounter when moving into the workforce. This system prepares students for the problem solving and designing process required of engineers while being presentable in manner that is both welcoming, relevant, and within the intellectual reach of incoming freshman engineers.

Acknowledgements

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Biographical Information.

Richard Lucio III is currently a Junior in the Electrical Engineering department at the University of Arizona and a Member of the University of Arizona Lego Robotics Club. He has spent three years teaching summer school programs for elementary school children using LEGO Mindstorms. He is also a recipient of the University of Arizona NASA Space Grant (2008). He and a team of three other students won a design competition in a microcontroller design class (2008) with their design of a microcontroller for a toaster.

Thomas Brown, **Stephen Beck**, **Joshua Brent**, and **Agostino Cala** are undergraduates in the College of Engineering at the University of Arizona, and members of the University of Arizona Lego Robotics Club.

Eniko T. Enikov is an Associate Professor of Aerospace and Mechanical Engineering at the University of Arizona. He received his PhD degree from the University of Illinois at Chicago in 1998. Since then he has worked as a post-doctoral associate at the University of Minnesota and subsequently as an Assistant and Associate Professor at the University of Arizona. There, he established the Advanced Micro and Nanosystems Laboratory with sponsorship from multiple federal agencies (AFOSR, NSF, DOE, DE) and the private sector. Prof Enikov has also led numerous educational programs including summer school in micro-systems design held in Udine, Italy, 2004, student exchange programs with ETH, Zurich, Budapest University of Technology and Economics, and Slovak Technical University of Bratislava. Prof Enikov is a recipient of several prestigious awards including NSF Career award (2001), US Dept. of State Fulbright Research Scholarship in Hungary (2007).