

# Using LEGO™ Robotics for K-12 Engineering Outreach

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**Abstract** – The LEGO® NXT robotics system is being used as a tool for engaging middle and high school students in brief, single-session workshops as a means of conveying opportunities in engineering education and as a “conversation starter”. The authors are beginning their second year of using the LEGO system in this context. Anecdotally, students, teachers, and school administrators, alike, are very enthusiastic about the potential for this robotics system to significantly impact learning in their schools. The program objectives have grown beyond the initial focus of using this robotics system as a recruiting tool. A broader objective now focuses on obtaining funding to place these robotics kits in strategic schools throughout Mississippi. Through this effort, the authors seek to establish relationships with teachers, teaming with them to make curricular enhancements—incorporating (or strengthening) project-based learning as a means of preparing students for pursuing STEM majors and ultimately STEM-related careers.

*Keywords:* LEGO, robotics, K-12, outreach, recruiting.

## INTRODUCTION

The importance of using robotics technology to enhance student learning is well documented [Sklar,7; Lund, 5; Lau, 4]. The use of the LEGO™ “Robotics Invention System” serves as a means for increasing student interest in STEM topics. Benefits include several complementary factors including 1) employing a platform familiar to many students (i.e. LEGO building components); 2) “seamless” integration of hardware and software systems; and, 3) minimal startup delays as a result of an easily understood symbolic software package and hardware components that facilitate “rapid prototyping” of devices. These features have allowed us to easily introduce the LEGO robotics system as the focal point in this particular aspect of our K-12 student recruiting system. Here, we report on our program activities to date, some observations of this program’s strengths and weaknesses, and our goals for future activities.

## BACKGROUND



From the origination of Lego computer-controlled products in 1986 and evolving through a collaboration between the LEGO company and the Massachusetts Institute of Technology (MIT) [www.lego.com, 1], the LEGO robotics system has become a global phenomenon transforming the use of technology in classrooms to facilitate learning through a seemingly endless array of robotics devices and processes for vividly illustrating STEM concepts. A bit of interesting trivia—Ole Kirk

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Christiansen (and his son Godfred Kirk), having invented LEGOs in the 1930s when his carpentry shop was nearing bankruptcy, coined the term LEGO from the Danish phrase *leg godt*, which means to “play well” and, coincidentally means “I put together” in Latin [www.lego.com/eng/info, 1].

Robotics projects range broadly from a “compact disc launcher” capable of breaking CDs upon impact with a solid wall [http://www.philohome.com/hammerhead/hammerhead.htm, 2] to an automated “plant waterer” [http://www.vernier.com/nxt/movie.html?id=plant-waterer, 3] to a chemical process controller [Moor, 6]. Through each of these projects, students and teachers can capture highly visual insight into science and engineering principles under study.

### LEGO NXT Technical Specifications

A few of the technical features that are particularly “user friendly” include:

- The LEGO NXT microprocessor “brick” can be programmed using Windows, Mac OS or Linux
- The easy-to-use symbolic software accompanying the LEGO NXT kit is powered by LabVIEW from National Instruments and is therefore “robust” (i.e. highly likely to be supported over time)
- Programming is transmitted via USB rather than an infrared sensor in the previous robotics system model
- The robot can also receive programs or commands from a mobile phone via Bluetooth wireless connectivity
- Digital Wire Interface, allowing for third-party development of external devices
- Firmware for the NXT Intelligent Brick is provided as open source by LEGO along with “developer kits” for customizing software and hardware applications
- In addition to the LEGO sensors provided with the robotics kit (i.e. three servo motors, ultrasonic, sound, touch and light), third party vendors have developed additional sensors and, particularly exciting with regard to chemical engineering applications, an interface that allows a large number of Vernier® sensors (e.g. pH, temperature, and pressure)



Elementary Students from Tupelo, MS area schools visiting Mississippi State Chemical Engineering robotics class

### Author’s experience with robotics and the LEGO system

Emma Seiler has used the LEGO robotics system with two K-12 summer camps (i.e. “Summer Engineering Experience” and “MSU Robotics”) over the past several years. Students, parents and teachers have expressed tremendous enthusiasm for these activities.

Bill’s first encounter with LEGO robotics was as a coach of a First LEGO League (FLL) middle school robotics team in 2004, sponsored by the College of Engineering and Science at Louisiana Tech University. Coaching FLL for a second year and in the inaugural year of BEST Robotics hosted by Mississippi State University convinced him of the utility for robotics to convey STEM concepts and principles for *any* branch of engineering and science.



ChE freshman coaches a high school team at a Women in Sci. & Tech. conference

Now using the LEGO robotics in his freshman chemical engineering course, we are developing a strategy for sending our engineering students out to schools as part of our recruiting program. This combination of using LEGO robotics with the help of college student recruiting teams visiting K-12 schools brings a “service learning” component to the program—benefiting not only the K-12 schools we visit, but adding value to the undergraduate engineering experience in line with our chemical engineering program objectives and outcomes.

## OUTREACH PROGRAM

### Program Development

In the fall 2006 semester, using contacts maintained by Emma through her many K-12 outreach activities and from a Bagley College of Engineering Teachers/Counselors reception, we conducted an informal survey among middle and high school teachers. This survey drew immediate interest among teachers regarding the possibility of bringing our LEGO robotics to their schools for conducting a project-based learning exercise accompanied by discussion engineering and science careers and the need for students' participation in the national effort to maintain our global leadership in technology development. Cognizant of the tremendous national need for scientists and engineers, we have maintained a broad-based appeal for students to consider options across the spectrum of STEM careers—focusing not just on a specific set of disciplines, or even solely engineering. Recognizing the diversity of interests and skills sets we are encountering, we have built our discussion around general themes, seeking to appeal to all students interested in STEM fields of study and practice. Particularly among elementary and middle-school student groups, we have emphasized the stream of coursework necessary to enter university study in preparation for these careers.

Site selection for initial visits was made on a “first-come, first-served” basis from teachers responding to a general email solicitation and with regard to scheduling availability between MSU and prospective schools.

We designed our first program iteration with the following features:

- A 50-60 minute time-frame to accommodate typical K-12 class periods (with added activities to accommodate block schedules or laboratory sessions)
- Maximum “hands-on” time with minimal “talk time”
- Limiting group size to approximately 30 (a typical class size) to optimize our personal interaction with the students and students' interaction with the robotics kits we have available.



“Tug-O-War” competition

### Program Activities

Sessions were generally organized along the following schedule:

5-10 minutes—Introduce our personnel, robotics and the basic concept to be studied, break into teams

30 minutes—Experimentation

5-10 minutes—Debrief through sharing observations and conclusions

Remaining class time—distribute recruiting material on engineering at Mississippi State and discuss STEM careers.

During our first iteration of this program, to minimize preparation time by the students, we adapted a LEGO-based module using a pre-assembled, pre-programmed robot. By conducting this work prior to making our recruiting visits, we minimized the confusion of students working through assembly and software orientation.

The LEGO robotic module addressed gear ratios and relationships to speed and power. Students executed the program and recorded data for the robotic movement. After observing and recording data for multiple runs, students interchanged a series of gears to conduct runs at different operating conditions.

After completing the experimental work and data collection, students performed analysis and made some conclusions.

## Site Visits

For this phase of our outreach program, we visited two high schools, a junior college and a high school conference for Women in Science and Technology. Additionally, a group from Tupelo, MS area elementary schools visited our chemical engineering robotics class. At the two high schools and the junior college, students quickly grasped the project objectives and immersed themselves in the work. These students were in upper level math and science classes, many intending to pursue STEM careers.



**Students at Forrest Hill High School**

Approximately 350 female middle and high school students attended at the Women in Science and Technology conference. We conducted three consecutive workshops with approximately 30 students attending each. The nature of this conference is to interest female students in a broad range of STEM careers. The participants come with an equally broad range of interests and similarly varied skill levels. This was observed by some hesitance among some students to “jump in” on the project and an accompanying reluctance to share

observations at the conclusion of the exercise.

With our elementary school visit to the Swalm School of Chemical Engineering robotics class, we learned about the incredible energy and “randomness” of students in those grade levels. Enthusiasm abounded, as did bouncing LEGO parts and frenetic activity. Nonetheless, the visit and activities were a raging success—to such a degree that the Tupelo teachers have received a grant for purchasing LEGO NXT robotic systems and we anticipate partnering with them in the 2008 calendar year to develop curriculum components.

## OBSERVATIONS AND CONCLUSIONS

After this initial phase of the LEGO robotics program, we remain convinced that this method of K-12 visits is a valuable component of our overall outreach activity. However, there are several lessons learned that would improve our future work, including:

- Requesting, where possible, more time for a given group of students to facilitate more discussion and stronger interaction with the robotics
- Establish an evaluation and assessment program to quantify achievement of desired outcomes
- Improve the site selection process to ensure participants from more underrepresented groups and from schools in need of technology are represented
- Most importantly, continue our aggressive search for funding to support the placement of LEGO robotics kits in classrooms around the state of Mississippi. We firmly believe this technology, coupled with an MSU Bagley College of Engineering partnership, can bring real and sustainable strengthening of school curricula and an increase in students pursuing preparation for STEM careers at MSU and elsewhere.

## REFERENCES

- [1] <http://www.lego.com/eng/info/default.asp?page=timeline7>
- [2] <http://www.philohome.com/hammerhead/hammerhead.htm>
- [3] <http://www.vernier.com/nxt/movie.html?id=plant-waterer>

- [4] Lau, K. W., H. K. Tan, B. T. Erwin, P Petrovic, *Creative Learning in School with LEGO® Programmable Robotics Products*, 29<sup>th</sup> ASEE/IEEE Frontiers in Education Conference, Nov. 10-13, 1999, San Juan, Puerto Rico, pp. 12d4-26 through 12d4-31.
- [5] Lund, H., O. Miglino, L. Pagliarini, A. Billard, and A. Ijspeert, *Evolutionary Robotics—A Children’s Game*, Proceedings of IEEE 5<sup>th</sup> International Conference on Evolutionary Computation, IEEE Press, NJ, 1998, pp. 154-158.
- [6] Moor, S. Scott and Polly R. Piergiovanni, *Using LEGO®-based Classroom Laboratory Kits for Learning Process Control*, presented at the 2003 AIChE Annual Meeting, San Francisco, CA, 2003.
- [7] Sklar, Elizabeth and Amy Eguchi, *Learning While Teaching Robotics*, American Association for Artificial Intelligence <http://www.sci.brooklyn.cuny.edu/~sklar/papers/aaaiss04-mentor.pdf> , 2004.

**Bill B. Elmore, Ph.D., P.E.**

Bill received his Ph.D. in chemical engineering at the University of Arkansas in 1990. During his 15 year tenure at Louisiana Tech University, Bill served on a variety of educational initiatives for recruiting and retaining engineering undergraduates. Now in his third year at Mississippi State, as the Hunter Henry Chair (an endowed chair focused, in part, on educational research and activities), Bill has teamed with Emma Seiler, K-12 Engineering Outreach Coordinator, to develop a sustainable program for recruiting students to engineering from Mississippi schools. Whether pursuing research in biochemical engineering with an emphasis on renewable fuels and chemicals production or developing new course materials (e.g. LEGO robotics with chemical engineering applications), Bill has consistently included undergraduates as key participants in his work.

**Emma Seiler**

Ms.Emma Seiler is the K-12 Educational Outreach Coordinator for the Bagley College of Engineering at Mississippi State University. She holds a B.S. in Biological Engineering and a M.S. in Civil Engineering from Mississippi State University. As Educational Outreach Coordinator, she is also responsible for coordinating summer programs such as WISE Women, University Familiarization Program for Minorities in Engineering, Women in Action, Mississippi Summer Transportation Institute, and Summer Engineering Experience. She also hosts teacher workshops for Mississippi Science and Engineering Fairs and BEST Robotics. In addition, she has developed an engineering design project for girls called “The Cinderella Project.” This project uses the engineering design process to design a sturdy, comfortable, yet fashionable shoe.