USING LEGOS TO INTEREST HIGH SCHOOL STUDENTS AND IMPROVE K12 STEM EDUCATION

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Abstract *- Wichita State University is actively using LEGOs to encourage science math engineering and technology (SMET). There are two major thrusts in our efforts. The college of engineering uses LEGO blocks to simulate a factory environment in the building of LEGO airplanes. This participative demonstration has been used at middle school, high school, and college classes. LEGOs are used to present four manufacturing scenarios of traditional, cellular, pull, and single piece flow manufacturing. The demonstration presents to students how the design of a factory has significant impact on the success of the company. It also encourages students to pursue engineering careers. The college of education uses robotics as a vehicle to integrate technology and engineering into math and science preservice and inservice teacher education.. The purpose is to develop technologically astute and competent teachers who are capable of integrating technology into their curriculum to improve the teaching and learning of their students. This paper will discuss each effort, the collaboration between the two, and provide examples of success.*

Index Terms – K-12 initiatives, Legos, Manufacturing

MOTIVATION

"Are we providing students with the intellectual skills and background they will need to appreciate and continue learning about SME&T [Science, Mathematics, Engineering and Technology] throughout their lives?" [1]. Much effort is underway to encourage students to pursue careers in science, technology, engineering, and mathematics. There is a growing base of infusing these necessary skills and attitudes to pursue these avenues as careers. There is also much effort aimed at addressing the diminishing skills in math and many of the sciences. Technology is becoming pervasive in many US classrooms. The skills and knowledge necessary to utilize this technology is being provided to students. However, there is little effort to build a broad base of understanding and appreciation of engineering principles that lies behind much of our technology today.

Much has been made of building business understanding, communication skills, and the ability to work in teams into engineering undergraduates. At a recent conference of industry leaders, one CEO stated that he wanted engineers with business knowledge ("that know how to calculate a rate of return"). But, he also wanted business graduates to have a basic grasp of engineering principles ("to understand and appreciate the engineering design process"). van der Vink [1], stated that we need our politicians and business managers to consider engineering concepts in their decision making process, "…Our long-term future depends on citizens understanding and appreciating the role of science in our society."

The College of Engineering has been presenting engineering concepts to students for five years. The College of Education has been teaching how to use LEGO Mindstorms to Science and Math Teachers for three years. The Colleges of Education and Engineering have co-hosted a LEGO Mindstorms challenge for middle school students for three years. These efforts strengthen and encourage the skills our society needs for the future.

LEGOS AND EDUCATION

LEGOs have long been the favorite of many children. LEGOs provide a mechanism to understand and do for many concepts. Similarly, Seymour Papert introduced the "Mindstorms" concept which revolutionized much of the way computers were used in teaching [2]. This same book was the inspiration for those at LEGO to develop what is now called, 'LEGO Mindstorms.' LEGO has been used in many classes to teach a wide variety of concepts from spatial relationships [3] to embedded computer control of mobile robotics platforms and data acquisition [4]. There is even a national competitive event using LEGO Mindstorms called the First LEGO League [5].

Much of the pedagogical approach of these efforts is to use a constructionist approach to learning [6], which has been used extensively in computer-based education. This approach works well to perform experiments that are time-consuming as the process can be "sped-up" to allow multiple observations. However, learning is greatly improved with "hands-on" activities. LEGO Mindstorms provides an excellent tool to combine both computer-based education and hands-on learning [7].

The popular press has numerous books on using LEGO Mindstorms from basic ideas to construct robots that enable thoughtful and creative modification [8], to books that deal with using programming languages [9] and interfacing [10].

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Turbak and Berg have developed a "Robotic Design Studio," to introduce Engineering to Liberal Arts Students [11]. Nickels and Giolma [12], use LEGO Mindstorms to teach non-engineers about science and technology. Several use LEGO Mindstorms to teach engineering to engineering freshmen and to integrate engineers of different disciplines [13]-[15]. Garcia and Patterson-McNeill [16] use LEGO Mindstorms to teach software development. There is, therefore, a broad base of knowledge using LEGOs to expose students to a wide variety of concepts. The remainder of the paper presents efforts at Wichita State University in using LEGOs to broaden the science, mathematics, engineering, and technology base.

LEGO AIRPLANE FACTORY

The LEGO airplane factory simulation presents a mythical aircraft manufacturer. Participants assemble toy size airplanes from LEGOs. The goal of the participants is to build as many airplanes as possible within their six-minute working day. The factory consists of five workstations: four assembly workstations and one inspection workstation. The simulation consists of four different phases. During these phases, the simulation is changed to illustrate new concepts. Participants will experience supplier problems, deadlines, quality control issues, and other real life situations.

The demonstration first begins with an overview of engineering, bringing the students to a working knowledge of what engineers do in general, as well as understanding the different engineering disciplines. Then, the mythical aircraft manufacturer is described as having a high rate of late deliveries, a large number of customer complaints about quality, and a decreasing profit margin. The operational policies of the company are described: participants are told not to communicate with their peers, not to break the chain of command with work related issues, not to work as a team, and other rules that describe a traditional command and control work environment. These instructions are given to emphasize the importance of teamwork and communication later in the simulation.

With these instructions in mind, participants are ready to start the first phase of the simulation. The rules of assembly reflect those commonly found in facilities that have a functional layout, a strict material control department, a traditional batch production flow, a central quality control function, and a workforce that does not work as a team. Participants are separated into five workstations that are spread across the room to simulate the long travel distances commonly found in functional layouts. Airplanes are assembled in batches of five. As participants deplete their raw material supply, they must travel a long distance to the raw material warehouse to emphasize the importance of travel distance in manufacturing. An inspector examines the airplanes after they have been produced. Participants are not allowed to improve quality or correct problems. With these rules in place, participants practice making airplanes for a few minutes to reduce the learning curve effect. After everyone knows how to assemble their portion of the airplane, Phase 1 begins. Participants build airplanes for 6 minutes. At 4 minutes into Phase 1, a material problem is discovered that requires stations 1 and 2 to remove all work-in-process, thus illustrating a problem with poor suppliers. At the conclusion of Phase 1, the results are recorded. See sample results in table 1.

Phase 2 begins with several improvements. First, the separated workstations are brought close together in a logical sequence. Second, raw material is brought to the individual workstations. Third, the quality control inspector can now announce where problems occur to the participants. Another six minutes of assembly follows with similar supplier problems. Results are recorded.

Phase 3 introduces more improvements. Batches are reduced from 5 to 1 and inventory is moved with a pull system. Six minutes of production follows and results are recorded. Finally, Phase 4 introduces the concepts of teamwork and balanced work-load.

At the conclusion of the fourth phase, the participants discuss the results they produced and how the changes in each phase influenced those results. At this point,

TABLE 1
SAMPLE SIMULATION RESULTS

		Simulation Averages				
Phases	Number of Planes Produced	Time to first plane	Rework	Scrap	WIP	Methodology
1	3	5:23	1	16	18	Traditional
2	7	4:15	2	29	30	Cellular
3	14	1:05	2	2	6	One-Piece Batch & Pull System
4	22	:56	1	2	6	Flexible/Balanced Workforce
Percent Change	733%	-83%	No change	-87%	-76%	

participants are amazed at the dramatic increase in production over the four phases. Most participants quickly see the benefit of arranging the workstations into a cellular layout and building airplanes in batches of one rather than five. The value of teamwork and making everyone responsible for quality are also evident from the reduction of rework and scrap.

Addressing a wide variety of learning styles is a benefit of this simulation. Participants engage their hands and their minds in the learning experience. This combination increases retention of the teaching points and motivation to learn more about the topic. This is a fundamental concept underlying all laboratory experiences. Participants generate data themselves. They know how much effort was put into building the airplanes and therefore do not doubt the results. If students just observe the simulation, they may perceive that the participants are not giving their best effort. Involving people in the simulation avoids that problem.

The simulation is extremely flexible in the level of teaching desired. Students in elementary, junior high or high school can learn about an application of Industrial Engineering and gain an understanding of the purpose of the discipline. Undergraduate and graduate Industrial Engineering students can learn concepts in detail with the additional sophistication added to the simulation, such as adding values for cost, process times, on-time delivery, quality, and productivity. Executives, middle managers and operational people can learn about concepts to change their enterprise.

Wichita State University is involved in several programs designed to increase community involvement and educate kids about what the university has to offer. We have presented programs to expose grade school students to engineering and science. Our role in these programs is to demonstrate the fun and excitement of Industrial Engineering. We use the simulation as our vehicle for reaching these students. They are familiar with plastic blocks. Most have hundreds of blocks at home. With all this experience working with blocks, they are by far the fastest airplane assemblers we encounter! It is amazing how well these students spot the problems associated with a traditional plant. They are not biased with years of experience in the real world and are not constrained with the realities of budgets and time limitations. As a result, they suggest almost all of the improvements we normally introduce for phase four. We implement most of their suggestions for the next run of the simulation and record the results. Using their ideas validates their participation and holds their attention for discussion afterwards. Most students seem to enjoy their experience with our simulation as evidenced by their comments at the conclusion of the simulation and the requests for future demonstrations by their teachers and sponsors. These students walk out of the room with an awareness of what Industrial Engineers do and the fun we have solving problems. More details can be found at: http://enteng.wichita.edu/legos/

ROBOTICS IN THE CLASSROOM

The Robotics in the Classroom project at Wichita State University started two and a half years ago with an initial seed grant from the Boeing Charitable Co., and instructional support from Project M3, a Department of Education PT3 grant to prepare teachers to use technology. The initial effort, designed to provide teachers with training and equipment to integrate technology into their classrooms, has grown, with continued support from Boeing and the College of Education, into a program that provides teachers technology training and equipment, an annual competition and showcase for students (through a collaboration between the Colleges of Education and Engineering), and an annual summer camp that serves both as a curriculum development and practicum experience for teachers, and a hands-on robotics invention opportunity for students. This project has served over 150 teachers and their students and involved education and engineering faculty, the Engineering Council – a student engineering group at WSU, distance experts from NASA and MIT, and industry professionals from Boeing, Raytheon, Cessna, among other notable corporations. This broad and diverse group has been successful in creating an environment of experimentation that allows for collaboration and development to integrate robotics into STEM curricula. The College of Education's pre-service teacher education also includes robotics units in science and math methods courses.

We recently completed the Third Annual WSU Mindstorms Robotics Challenge (March 2003). This event provided young students with the opportunity for practical application and exhibition of math, science, programming, and engineering skills, as well as promoting teamwork, dedication, and sportsmanship. Teams of fourth through eighth grade students from across the state of Kansas had the opportunity to complete five Mission Challenges designed by Shocker Student Engineers, and demonstrate what they have learned to professional engineers and educators in oral presentations, table displays, and notebooks. Sportsmanship and spirit were judged throughout the day to promote collaboration and teamwork. Figure 1 shows a group of students working on their entry. This event complements the Kansas BEST Robotics Competition also hosted by WSU. The second annual Robotics summer camp planned for July 2003, MER (Mars Exploration Rover) Robotics, is designed to teach students about Mars exploration and robotics. Teachers and students work in teams to construct a Mars-like terrain and build robotic rovers to traverse the landscape taking digital pictures and collecting samples that will be analyzed. Students will use the images and sample analyses to learn more about Mars exploration. Distance experts from NASA and MIT will be utilized as well as engineering and education faculty to deepen the content focus and technology skills. More details can be found at: http://education.wichita.edu/mindstorms.

FIGURE 1. MINDSTORM COMPETITION

A new initiative that the authors are working on together is to add a global perspective to their efforts. A distance learning robotics class is being created to be delivered Fall 2003 over the internet to teachers around the country using Mindstorms in their classrooms. How math, science, technology, and engineering is taught in these different countries and the importance it is given will be explored as well as cultural differences. A similar global perspective is being pursued by developing a Lego factory for web use.

The Robotic Systems Design Studio (Tonya Witherspoon, Larry Whitman, Cathy Yeotis, Karen Reynolds, Lisa Johns, Sherri Reeves) allows students to solve a series of problems using a systems approach that reflects real world problem solving. Students will work with robotic equipment including a microcontroller, gears, wheels, axles, sensors, motors, lights, cameras, and other building components. Each project has a similar focus of inquiry, problem solving, teamwork and systems thinking necessary to design, build, program, and test robots to complete a specific purpose or job. What specific job or purpose the robot is designed for will determine the curriculum content focus. For instance, if the project purpose is to build a Mars rover that will carry a camera designed to send images back to Earth including an arm to collect samples and sensors to conduct analysis, then the curriculum content will focus on Earth/Space science and mapping while integrating key technology components. The same type of project could be used to study areas of earth where it is difficult for humans to go, such as Antarctica, inside a volcano, deep in a cave, or another planet. If the project is to create a robotic controlled intelligent house that would keep the temperature, lighting, air, etc. at pre-determined levels then the curriculum focus might be on design, invention, and engineering systems. Another project might be to create robotic animals in an ecosystem such as an ocean, a jungle, or a rain forest. Each animal would be programmed to act and respond appropriately so that systems and behaviors may be studied. Another project could consist of building a city transportation system. Robotic trains, subways, traffic lights, and other systems can be created and then studied to observe the functions of these systems on transportation traffic and flow. Students might design an aerial tram to traverse a canyon or a drawbridge that draws up when it senses a boat approaching. Each of these examples infuses appropriate IT through investigation and inquiry into standards-based SMT core curricula while encouraging collaborative teamwork, systems thinking, and career connections. As part of the CALEM module teachers and students will videoconference with distance experts at MIT and NASA for information and advice on their projects. College of Education, Liberal Arts and Sciences, Engineering professors and IT specialists will advise and direct the team as the module is defined. Finally, the team will meet with industry experts to see how robotics is used in real world applications.

These efforts demonstrate the wide variety of ways that LEGOs and LEGOs Mindstorms have been used at Wichita State University to stimulate interest in science, mathematics, engineering, and technology. By presenting these concepts to students directly, as well as to their teachers, a broader exposure to these concepts is achieved.

CONCLUSION

LEGOs have been used in many different classes with many different objectives. Society benefits when younger students understand and appreciate, science, technology, engineering and math. LEGOs have been shown to be a useful tool in achieving this appreciation and understanding. Our primary goal in this effort is to stimulate the awareness and appreciation for science, technology, engineering, and math. Our approach has been to use LEGOs in the classrooms as well as in workshops, competitions, and summer camps. This paper has demonstrated multiple different uses: to teach how some engineers work and to teach some basic science and engineering concepts.

Our approach has been successful in achieving interest in these areas. Students request these demonstrations and the summer camps fill up quickly. Many K-12 faculty are using these methods in the classes themselves. We have built a strong foundation for further efforts and these are underway. The joint effort between the colleges of Engineering and Education makes the team effort greater than the sum of its parts.

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Each year, one high-achieving student from Hoboken High School is awarded a full-tuition scholarship to Stevens Institute of Technology. Since 1992, nearly 50 students have been awarded over $2million in scholarships through this program. Math Circles.Â The day-long event took place at Stevens Institute of Technology where student and faculty volunteers from Stevens guided Hoboken students through activities and encouraged their interest in STEM.Â STEM-a-thon was launched in 2015 with the partnership of Hoboken Family Alliance. Visit the STEM-a-thon webpage for more information. Are you looking for online STEM education opportunities? K12-powered online learning could be the right choice for your student. Learn more!Â STEM is an acronym that stands for four academic disciplines: science, technology, engineering, and mathematics. Rather than teach each area separately, STEM education integrates these disciplines for use in real-life applications. Our 2016 LEGO STEMÂ® contest winner used these disciplines to invent "The Puppet Glove," a mechanized glove meant to assist people with motor function difficulties. STEM in the K12 Curriculum. All K12 courses in science, and math courses in grades 6â€“12, contain activities that include elements of STEM. In addition many courses include exercises, labs, and a The STEM acronym is often used in reference to just one of the disciplines, commonly science. Although the integration of STEM disciplines is increasingly advocated in the literature, studies that address multiple disciplines appear scant with mixed findings and inadequate directions for STEM advancement.Â International concerns for advancing STEM education have escalated in recent years and show no signs of abating.Â An inadequate focus on assisting students (and teachers) to recognize and make mathematics connections to the remaining disciplines further contributes to undermining mathematics learning within STEM.