A Multi-Disciplinary Summer Camp: LEGO Mindstorms for Students and Teachers

Joseph P. Fuehne, Ph.D.
jfuehne@purdue.edu
Purdue University
College Of Technology at Columbus/Southeast Indiana

Kate A. Baird, Ph.D.
kabaird@iupuc.edu
Indiana University – Purdue University Columbus
Division of Education

Abstract

The use of computers in manufacturing and manufacturing environments has been increasing for many years. In fact, Purdue University has changed the name of its Computer Integrated Manufacturing Technology program to simply Manufacturing Engineering Technology, a subtle change that indicates that the use of computers in manufacturing is now routine. Robotics and sophisticated process control are just two areas where computers are utilized in the contemporary manufacturing facility. Fewer prospective college students, however, are choosing careers in science, technology, engineering and mathematics (STEM), leaving manufacturing companies calling for more properly-trained employees. The objective of this project is to increase elementary and middle school students' interest in STEM subjects and careers, including manufacturing, by conducting summer camps utilizing programmable robots made from LEGO™ bricks and programmed with ROBOLAB™, computer software developed by LEGO™. Teams of students are presented with several challenges that require the use of light and touch sensors, as well as well planned and strategically implemented programming to solve. Additionally, teachers are encouraged to engage in a professional development opportunity that emphasizes teaching science and mathematics through inquiry-based instruction. The teachers engage in instruction during the morning session then work with the teams of students during the afternoon to implement strategies learned in the morning, to improve learning.

I. Introduction

Purdue University President Martin Jischke was quoted in an Indianapolis Star article from March 5, 2006, that "*by 2010 more than 90 percent of all scientists and engineers in the world will live in Asia*." Additionally, he said that "*Students in our middle schools and high schools, to an alarming degree, are poorly prepared to study science or engineering in college. Even worse, relatively few are interested. Between 1992 and 2002, the number of college-bound students who planned to study engineering declined by more than 30%. Now, more than half the U.S. work force in these disciplines is near retirement*." Additionally, the National Science Education

Standards (NSES) call for the development of "Science as Inquiry within and across disciplines and grade levels." (National Research Council, 1996, p. 30) This camp brings together students and teachers both from different grade levels in an attempt to increase interest among elementary and middle school students in STEM subjects and careers while also introducing teachers to inquiry-based learning. The objective is to increase interest in STEM learning while at the same time improving that learning by making it more interactive and fun.

Inquiry-based learning uses the Nature of Science as its foundation and has been proven to be more effective than didactic instruction. Students begin by observing something, posing a question and, organizing and performing experiments to discover the results, and considering possible answers to the original question and possible next questions. This is a student-centered learning approach where the teacher functions more as a coach rather than a traditional sage on the stage. (Malicky, Huang, and Lord, 2006)

This paper is a description of two separate one-week summer camps that brought together students from schools throughout this rural county that teamed students of different ages and LEGO™ expertise. The two camps occurred in different years. Although this program was offered during the summer as a camp, it could easily be converted to an after-school or extra-curricular program.

II. Literature Review

Five similar programs have been instituted across the United States. They represent work at Bloomsburg University, University of Texas, New England College, Brigham Young University, and Duke School in North Carolina: Each used Lego bricks to create and program robots. Three focused on Middle School learners while two were directed at Upper elementary learners. The length of the interactions as well as the location of the work varied by site. The actual program focus also varied, however the underlying theme was to support STEM learning and interest. Each program is explored in more detail below.

A. Bloomsburg University

A group of faculty from Bloomsburg University received a grant to create "an innovative problem-solving course that would use a combination of logic, hands-on experience, and a modicum of trial and error to help students identify the processes behind effectively solving problems" (Mauch, 2001, p. 211). This course was to be delivered to middle school students. The description of this work (Mauch, 2001) included developing a plan to "introduce the system (LEGO Mindstorms) to middle school teachers, familiarize them with the system's operation and benefits, and then encourage them to use it in their own classrooms." (Mauch, 2001, p. 211) This plan included a three-week summer course/camp for teachers and students. The first week was for the teachers only and eight middle school teachers enrolled in the course. The second week added forty gifted students in grades 6-8 so that the teachers had an opportunity to implement the skills learned the first week. The forty students were divided into groups which the organizers felt "assisted students in the development of interpersonal, communication and team-building skills." (Mauch, 2001, p. 212)

B. University of Texas

At the University of Texas, the ROBOLAB Summer Institute uses LEGO™ robots to “keep the engineering-student pipeline in Texas full.” ” (Gardner, 2007, p. 1) This initiative is part of the DTEACH (Design, Technology, and Engineering for America’s Children) project and provides an opportunity for elementary school teachers to participate in an “eight-day workshop introducing engineering design concepts through robotics.” No technical background is required of the teachers and overcoming their aversion to introducing technical subjects to their students was a challenge. One of the co-creators of the institute, Richard Crawford, notes that “the key to our success is the pairing of a teacher with a National Instruments engineer volunteer.” (Gardner, 2007, p. 1) The pairing of industry volunteer and teacher lasts for a minimum of three years with the volunteer initially leading the class while the teacher provides support. By the end of the three years, the teacher is the leader while the industry volunteer acts as a consultant. Another reason for success was the use of ROBOLAB. According to Terry Duepner, a manufacturing test development engineer and institute volunteer, “ROBOLAB is visually based and the teachers and students find it easy to master.” (Gardner, 2007, p. 1)

C. Western New England College

To increase interest in the engineering and technology careers, Western New England College School of Engineering, the Western Massachusetts and Pioneer Valley Girl Scout organizations came together as part of a summer camp. The program (Vollaro, 2006) hopes to enable girl scouts in the 4^{th}, 5^{th} and 6^{th} grades to determine if they have the qualities to be an engineer while supporting the girls’ knowledge of the engineering profession and looking for change in attitude following the camp’s activities.

The design process is heavily emphasized and then put into practice using LEGO robotics. The specific design problem was to “develop a vehicle so unique and exciting, that 4^{th}, 5^{th} and 6^{th} grade kids will spend their allowance to buy it!” (Vollaro, 2006, p. 7) The vehicle must “1) travel in a straight line for 10 feet, 2) move forward and backward, 3) use power from the motor/RCX brick, 4) mount the RCX brick on the vehicle, 5) use a touch sensor on front of the vehicle and 6) name the vehicle something descriptive yet catchy” (Vollaro, 2006, p. 7) Post-program surveys answer questions like “Now what do you think an engineer does?”, and “Do you see yourself as an engineer? (Vollaro, 2006 p. 10)

D. Brigham Young University

In Utah, a technology and engineering curriculum is mandated by the Utah State Board of Education at the 7^{th}-9^{th} grade levels and Barrett (2006) and his colleagues at Brigham Young seek to develop this by partnering with schools. Specifically, they have “three years of experience with 6^{th} grade students at Canyon Crest Elementary School, where pre-service technology teachers partnered with, developed and taught integrated technology and engineering units of instruction.(page)” One of the elements of their instruction was Rover Engineering, where students built a “Mars Rover” using the LEGO robotics kits. After four days of instruction and experimentation, the student teams were presented with a challenge to navigate a course with obstacles. A quote of one of the 6^{th} graders involved was “I enjoyed everything, but I especially like making the rover, because you could make it turn right or left, and a lot of other cool things” (Berrett, 2006, p. 4). A final statement by Barrett demonstrates the importance of these projects:

"Teaching technological literacy to our children is a national imperative and one that needs to begin in the elementary schools" (Berrett, 2006, p. 8).

E. Duke School, North Carolina

A more recent work discussed using LEGO Mindstorms in second-grade classroom at the Duke School in North Carolina that was facilitated by a grant from Tufts University (Murray and Bartelmay, 2005). The second-grade teachers prepared a project for their students by posing this question: "Can you build and program the Legos to simulate an invention that would solve a common problem?" (Murray and Bartelmay, 2005, p. 41)These teachers identified appropriate science and technology standards satisfied by this project and hoped to encourage students' scientific inquiry skills and teamwork skills. An interesting practice employed by these teachers was to have all the students gather together at the end of the day and share their difficulties and successes. During these sessions, students brainstormed different solutions to the problems encountered. Teams of students then often modified their original designs due to the discussion. This reinforced the idea that "while we often have a roadmap of ideas in our minds, discoveries along the way necessitate flexibility and adaptation." (Murray and Bartelmay, 2005, p. 42)

III. The Project

A. Description of the camp

In two one-week camps 31 children ages 6-14 spent 4 days learning how to build, program and accomplish missions using LEGO™ Mindstorm™ robots. Two end-of-the-week competitions were held and parents, grandparents, the media, siblings, and community members attended to support and encourage the campers. The competitions began by playing the national anthem, reciting the pledge of allegiance and announcing "Ladies and Gentlemen start your robots." Each camp completed three challenges that ranged from speed events to fine motor control challenges.

B. Materials

Materials for the camps consisted of the LEGO™ Mindstorm™ Team Challenge set which includes the RCX programmable brick, two touch sensors, two light sensors, two motors and an infrared transmitter with a USB cable. Also utilized in the camps were the ROBOLAB 2.5.4 software with training missions and the Robotics Educator software, which was invaluable in educating the participants by providing example programs and robots. A combination of desktop and laptop computers running MS/Windows was also used to facilitate student access. Note that the ROBOLAB software also runs on MAC computers. The First Lego League competition mat and structures from the 2005 competition were used to provide challenges for the one of the camps. Additional miscellaneous items including masking tape, coffee cups, tennis balls, a stopwatch, and empty water bottles were employed to create the challenges. Finally, the RCX brick requires six (6) AA batteries and each robot exhausted at least two sets of batteries during each camp.

IV. Instruction for the camp

The instruction for the camp was designed using the 5-E Learning Cycle suggested by Roger Bybee and the Biological Science Curriculum Studies group. This cycle includes Engagement, Exploration, Explanation, Elaboration, and Evaluation.

A. Engagement

The first day of camp the participants were introduced to the LEGO™ Mindstorm™ kits. They were told that they would be building robots and programming them to compete in a set of challenges on the last day of camp. The LEGO™ Mindstorm™ Team Challenge kit comes with 828 pieces, including motors, wheels, touch and light sensors, gears, pulleys, belts, bushings, bearings and a large number of bricks. Prior to building a robot, students removed the pieces from the original packaging used for shipping and sorted the pieces into storage containers included in the kit. This activity allowed the campers to identify and explore the different pieces, while forming questions and ideas about their potential uses.

Initially, the students, working in groups of two, were directed to build the tankbot by using a step-by-step procedure outlined in the LEGO constructopedia that accompanies each Team Challenge set. Note that the instructions in the constructopedia contain only detailed pictures of the construction of the robots. There are no words in the book. This provides a challenge of its own as students must refine their spatial skills (the ability to locate objects in three-dimensional space using sight and/or touch) to follow the sequence of instructions to build this robot. However, an advantage to having instructions with no words is that the workshop could be offered to students for whom English is a second language. In fact, there is evidence that activities like these are beneficial in allowing those students to acquire language skills. This tankbot robot was used for the activities of the first day of the first camp but was clearly fragile as many groups struggled to pick up the robot and keep it in one piece.

Starting the second day of the camp, the groups were asked to create another tankbot with the instructions for this version coming from the Robotics Educator software. As with the constructopedia, the instructions were only graphic but incorporated extra LEGO bricks to produce a sturdier robot. Not only did this make handling the robots easier but also offered to the students a terrific lesson in how a few simple bricks could provide stability to the robot. In essence, it became a structural engineering lesson for the students.

The tankbot constructed using the directions from the Robotics Educator software was used as the base robot for the remainder of the camp. Basically, the tankbot is a moving vehicle with treads, two motors and the RCX programmable brick, which contains the six AA batteries. The electrical leads are configured so that the motors are connected to outputs A and C of the RCX, which also includes an output B and inputs 1, 2, and 3 (Figure 1). Typically, the programs downloaded to the RCX receive information from the inputs, usually sensors, and then direct the outputs based on the objective of the program and the information from the sensors. The exploration part of the camp, which was most of the first two days, involved the mechanics of using sensors and programming the robot. Eventually, the campers were encouraged to experiment with the tankbot by replacing the treads and wheels and modifying the gears. No

Figure 1.
The LEGO RCX brick with inputs at 1, 2, and 3 and outputs at A, B, and C. The RCX brick holds the programs downloaded from ROBOLAB. Also seen is the Program, On-Off, Run, and View buttons.

specific instructions on how to make these changes were provided, leaving the teams to learn on their own with minimal guidance from the instructors.

B. Exploration

To familiarize the participants with the ROBOLAB programming environment, the training missions included with the software were utilized. The ROBOLAB programming environment is divided into two main sections, namely pilot and inventor. Participants launched the software, selected "Programmer", and then selected "Pilot 1". After this selection, a simple program appears in the window which simply turns on one of the motors for 4 seconds. The program is shown in Figure 2. Participants then download the program to their tankbot by selecting the large white arrow, place the tankbot on the floor, and then press the green run button to run the program. Both the motor direction and amount of time on the timer can be modified and participants are asked to explore by changing both and observing the effect on the operation of the tankbot. While simple, this allows the students to see a program, to modify a program, and to perform the mechanics of successfully downloading a program from the computer to the robot using the USB infrared tower.

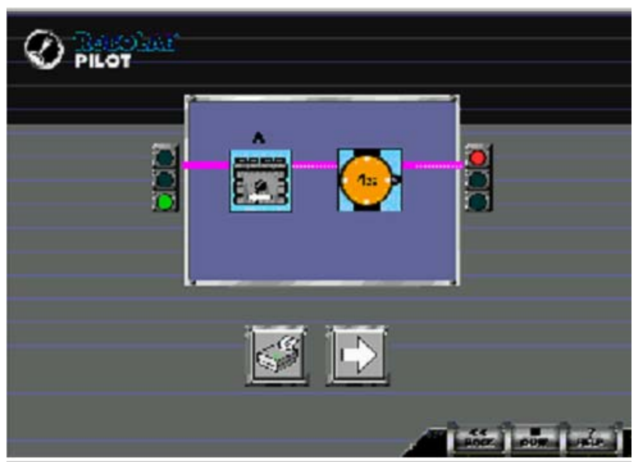

Figure 2. The pilot 1 training mission showing that motor A is to go forward for 4 seconds.

The "Pilot 2" training mission adds a lamp as an additional output in the "C" port and a touch sensor as an input in the "1" port. These items are easily added to the tankbot. The mission program also incorporates parameters (the "3" and the "5" in Figure 3) that vary the power of the motor and the brightness of the lamp. In this case, motor A runs at power level 3 while the lamp is at power level 5 – the brightest – until the touch sensor is activated. Again, participants were encouraged to make changes to the power levels, directions and even to the input port (shown as "1" in the figure) to investigate the various combinations possible for this simple configuration.

For both “Pilot 1” and “Pilot 2”, only one of the motors was activated, meaning that the tankbot simply rotated in a circle – nothing too exciting.

The “Pilot 3” mission simply added the action of the second motor and created a longer program that spun the tankbot in one direction for 6 seconds and then reversed the direction until the touch sensor was activated. Sticking with this concept, “Pilot 4” did much the same except that the timer was replaced by a light sensor, allowing the participants to examine how it worked. The program from “Pilot 4” is shown in Figure 4. The light sensor operates by providing to the program a number that is indicative of the intensity of the light it’s receiving. A value of 0 means total darkness and a value of 100 means total brightness. Operationally, though, the numbers only vary from about 35 to 65. As seen in Figure 4, this program tells the RCX to stop all outputs (the two motors and the lamp) when the light sensor in input port 2 sees a value greater than 55. The students were given masking tape to apply to a surface and were directed to move the light

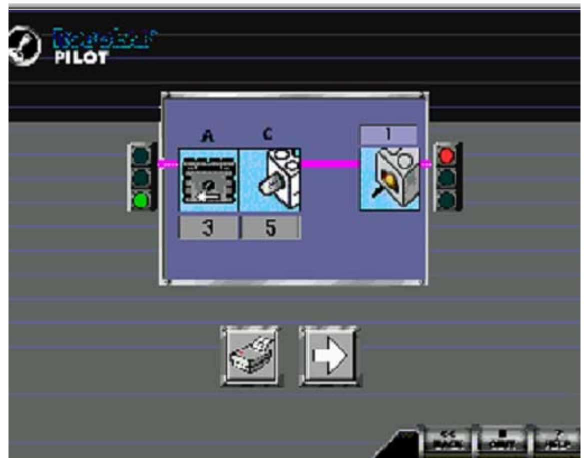

Figure 3. The pilot 2 training mission which adds a lamp as an output in the “C” port and a touch sensor as an input in the “1” port.

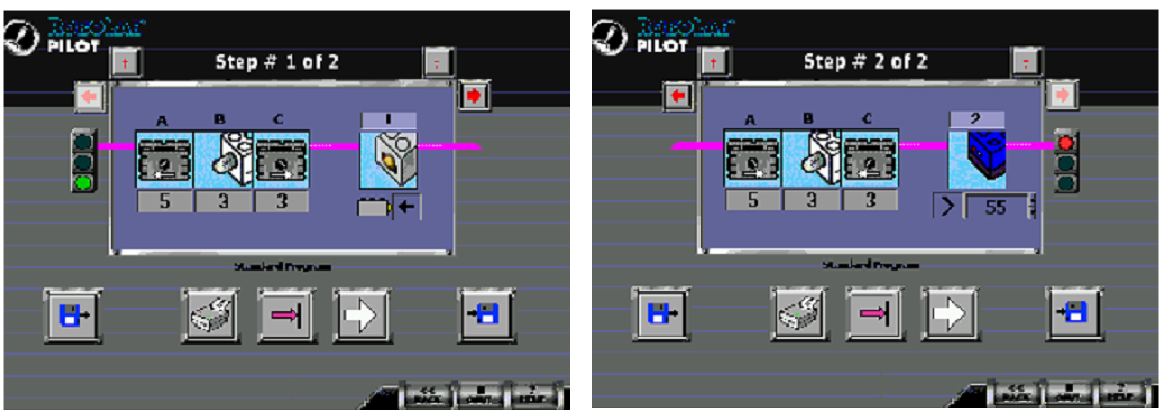

Figure 4. The pictures above display the two steps in the Pilot 4 mission. For this example, all three outputs (A, B, and C) are used while inputs “1” and “2” are used for the touch sensor and the light sensor.

sensor over the surface and the tape to investigate if there was a difference. If so, they were told to modify the program below to fit their situation. Again, the students were instructed to make several variations of this program to help them understand the logic. Simple changes like modifying the power of the lamp or motors, switching directions of the motor(s), altering the input ports of the two sensors, and changing the touch sensor so that releasing the sensor rather than depressing it moved the program into step 2.

These “training missions” are provided within the ROBOLAB software and proved to be an excellent way of introducing the software to the camp participants. Having completed these missions, the groups were asked to complete a challenge by programming their robots to move in a square. Using masking tape, the square was outlined on a carpeted floor and the students worked the last part of the first day and the initial couple hours of the second day to complete this challenge.

C. Explanation

In this phase of the camp, after the students had completed programming their tankbots to move in a square, the groups were asked to program and download a few more advanced programs from the Robotics Educator software. This software, also available as a site license, is an outstanding resource for educators. It contains curricula, lesson plans, assessment sheets, tutorials, a curriculum guide, describes relationships to standards, a quick-start guide and short videos showing real industrial robots. Additionally, there are example programs that are categorized by sensor and equipment and were used in the camps to introduce more advanced programming as well as to get the participants to ponder, discuss and explain the operation of the robot as they had programmed it.

To do this, the students were shown a program and asked to duplicate the program on their computers and download it to the robot. After watching their robot's behavior, groups were asked to explain what was happening. In some cases, such as a program demonstrating loops using only motors and timers, the explanation was quite simple. Others were not so simple. Examples used for this portion were:

1. Motors/Timers – Programming with Loops
2. Touch Sensor – Wait for Push
3. Touch Sensor – Wait for Let Go
4. Touch Sensor – Bug Bot (advanced program using multitasking)
5. Light Sensor – Wait for Dark
6. Light Sensor – Wait for Light
7. Light Sensor – Line Track
8. Light Sensor – Line Track with a Timer (advanced program using jumps, lands, and nested forks)

Since the first camp had a smaller number of participants, they could be easily divided into four groups and could then explore the use of the rotation sensor (only four were available). Due to this limitation, the rotation sensor was not introduced during the second camp.
Most of these examples presented more advanced programming techniques. Some of those included loops, forks (a conditional statement similar to an "if-then-else"), jumps and lands (similar to "go-to" statements) and initialization statements (setting variables equal to zero). A couple of the examples even used nested forks with nested jumps and lands. These examples gave the participants valuable experience in programming that would be needed for the challenges presented in the final two days of the camp.

D. Elaboration

After two days of instruction, the participants were presented with challenges to solve within their teams. All groups had a Mindstorm Team Challenge set and a computer with ROBOLAB and Robotics Educator software. The various challenges are described below.

1. Speed Challenge

This challenge included start and finish lines with a third line in the middle. The robots were required to stop at the line in the middle for at least one second and then proceed through the finish line. Robots were timed using a stopwatch from the start line to the finish line. The top finisher was awarded 20 points with second earning 18 points and so on.

2. NASCAR Challenge (Oval Track)
   An oval track was configured with masking tape on a carpeted floor and the groups are challenged to completely navigate the oval in 3 minutes. Robots were not allowed to have either wheels or tracks touch the tape. Again, the top finisher received 20 points with fewer points for the rest. This proved to be a difficult challenge.
3. Line Follower to Knock Ball off Coffee Cup
   In this challenge, 4 cups of differing heights with foam tennis balls placed on top are placed in an area. A starting line was marked with tape. Tape was also used to create a winding path to each of the cups, allowing participants to use a line follower program to reach the cups. The groups had two minutes to knock off as many of the four balls as possible. Robots were required to be started from behind a starting line and participants couldn't step beyond the line to retrieve or redirect the robot. Either the robot must travel from cup to cup with one program or it could retreat back to the starting line after knocking down a ball on one cup.
4. Knock Cup out of Circle
   Clear plastic water bottles were configured in a circle with a small gap on one side. A white plastic bottle was placed in the center of the circle. Again using a starting line, groups were challenged to direct their robot to travel through the gap to knock down, drag or retrieve the white bottle in the center. 20 points were awarded for retrieving the white bottle past the starting line. Fewer points were awarded for knocking down the bottle or dragging it a short distance. Penalty points were subtracted for knocking over the clear plastic bottles (2 per bottle).
5. Bump Cup, Back Up, Knock Ball Across Line
   This challenge utilized one coffee cup and a single foam tennis ball. Starting from behind a line, the groups were to program their robots to touch the cup, back away from the cup, and then proceed to knock or drag the ball to a specific area. Points were awarded for touching the cup. The destination area of the ball was divided, with more points awarded for having the ball reach certain areas.
6. Release Dolphin, Capture Shark
   This challenge was taken from the 2005 First LEGO League competition, which focused on marine and subsea activities such as releasing fish, capturing fish, connecting pipelines and dragging a protective structure over some critical equipment. In this case, the boat from that challenged was used with groups challenged to push or capture a shark near the back of the boat and proceeding on to push or release a dolphin back into the water. A single program was required to perform this task within a 2 minute time limit. Varying points were given for accomplishing only one of the tasks.

Only four of the six challenges were used in each camp. The NASCAR challenge was replaced in the second camp because groups clearly had difficulty with it. All the other challenges worked well during the camp. The last afternoon of the camp (camp hours were 9-2:30) parents, siblings and other friends and relatives were invited to witness the official competition. Team members chose a name for their team and points were summed for each team for all the challenges. All participants received a prize with the top point scorers having the first choice of the LEGO Bionicles available.

E. Evaluation

The first of the week-long camps included participants that were invited by the authors. Most had previous experience with LEGOs and some even had experience with the Mindstorm robots. These campers were shown more advanced programming techniques including containers, which are used to store sensor outputs during the execution of a program and then are recalled later in the program. The challenges used for the first group (1-4 from above), particularly the NASCAR and Knock the Cup out of the Circle challenges, proved to be difficult. Not all groups were able to successfully complete these challenges.

The second of the camps was specifically targeted to free and reduced-lunch students from schools around the county. These young people had little idea what they were going to do during the camp. It's unlikely that they had any experience with robotics and programming. For that reason, the pace of the camp was necessarily slower yet the enthusiasm of the campers seemed greater. The challenges for these groups included 1, 2, 5, and 6 from above, although the NASCAR challenge was dropped when groups were clearly having difficulty with it.

Utilizing materials and challenges from previous First Lego League competitions worked well in the second camp and is a strategy that will likely be continued. The teachers involved in the second camp were also from most of the elementary schools in the county and they and the students were encouraged to initiate and seek support from their schools for forming a First Lego League team. All were notified of a First Lego League Qualifying tournament that is held annually in Columbus during the fall semester.

V. First Lego League

An additional emphasis of the camps was to encourage teachers/students to compete in the yearly FIRST Lego League competition in our county. Portz (Portz, 2002) in his discussion of bringing robotics to middle school, states his belief that for a learning activity to be successful in the middle school classroom, "it must meet three criteria: the learning must be relevant, fun, and develop employability skills. The FIRST Lego League robotics fills these requirements in every measure." (Portz, 2002, p. 17) The FIRST organization (For Inspiration and Recognition of Science and Technology) was started by Dean Kamen, who invented the gyroscope-controlled Segway, among other inventions. Kamen says "Our culture celebrates one thing: sports heroes. You have teenagers thinking they're going to make millions as NBA stars when that's not realistic for even one percent of them. Becoming a scientist or an engineer is realistic." (Portz, 2002, p. 17)

Teams of students, ages 9 – 14 years old, together with adult mentors are supplied with the same LEGO robotics set and programming software. While part of the competition requires the team to solve various challenges with a robot, other parts include a presentation about the yearly theme (in 2007 this is alternative energy), a presentation explaining the design of the robot and how it's programmed, and teamwork. FIRST also sponsors other competitions for high school students and for children from 6 – 8 years old. All of FIRST's activities emphasize "gracious professionalism". A quote from the FIRST website says "In FIRST, one of the most straightforward interpretations of gracious professionalism is that we learn and compete like crazy, but treat one another with respect and kindness in the process." According to Portz who served as a coach for a team, "FIRST Lego League is one of the most effective extracurricular technology activities I have ever seen. It is really exciting to see so many students, so motivated, do something so challenging and educational." (Portz, 2002, p. 19) In Portz's experience, the middle school students needed more help dealing with personality conflicts and teamwork issues than with robot design and programming.

VI. Real World Applications

The final connection of these activities is to relate LEGO robotics to real world applications. A similar paper (Deal, 2006) discussed the similarities between LEGO robotics and industrial robots. In particular, both receive information from sensors and then perform a function based on that information. The LEGO programming software, ROBOLAB, is"drag and drop" software and is very similar to programmable logic controllers. "Programmable logic controllers employ Windows-based programming software that is visually oriented and uses the drag and drop capabilities of a graphical software interface. The conceptual similarity between programmable hardware used in technology education laboratories, such as LEGO Mindstorms and ROBOLAB, and that found in industry is a bit amazing." (Deal, 2006, p. 16) The skills of logical and critical thinking are enhanced using LEGO Mindstorms and the skills are transferable to other situations. As Deal says, "The significant points are that the design and construction of automation and control technologies require critical thinking and problem-solving skills, and there are common connections between low-cost educational equipment and industrial programmable hardware." (Deal, 2006, p. 17)

VII. Connection to Standards

The activities in this camp address several of the National Science Education Standards, standards regarding the teaching, content, inquiry, as well as concept and process. Teaching Standard B, and Content Standards A, B, & E are also covered. Science inquiry is an organizing principle for all science instruction and the selection of students' activities. The standards emphasize the need for students to engage in open-ended inquiry and develop understanding about the process of scientific inquiry. In many instances, camp participants have asked "What will happen if I do this?" Instead of answering the question, the adult helpers simply suggest that the campers should investigate further and find their own results. In other cases, campers are provided advanced programs and invited to predict what will happen if the program is loaded on their robot allowing them to form predictions. They are then encouraged to load the program and see what happens giving them the opportunity to test their predictions. Campers also conducted investigations by running the robot for 2 or 4 seconds to determine how far it would travel and then extrapolate to establish the time required to move a greater distance. Student experience the nature of science and discover inquiry-based instruction throughout the camp.

VIII. Conclusions

During the summer of 2007, several similar camps were offered. The camp in Columbus, Indiana, served 20 teachers and 35 students, which included 5 teachers and 5 students who had previously attended a camp during the summer of 2006. Three other camps were offered to students only in Southern Indiana. Two camps were conducted in Scottsburg, Indiana with a total of 35 students attending. In Shelbyville, Indiana a single camp served 21 students. All used LEGO™ Mindstorms and featured challenges similar to those described herein.

Surveys were conducted after the camp in Columbus. Some of the important results are summarized below.

- 14 out of 15 teachers said they agreed or strongly agreed that they now have a better understanding of scientific content connected with Indiana science academic standards.
- 15 out of 15 teachers agreed or strongly agreed that they learned how to put science lessons into action with students.
- 15 out of 15 teachers agreed or strongly agreed that they learned how to teach science through inquiry.
- 15 out of 15 teachers agreed or strongly agreed that they learned inquiry-based teaching strategies.
- 14 out of 15 teachers agreed or strongly agreed that they learned how to modify current science lesson plans to be more student directed.

One teacher commented that "This is a phenomenal camp with both students and teachers practicing inquiry, the best I've been to."

- 26 out of 30 students graded the camp either A(excellent) or B(very good) with only 1 F(needs improvement)
- 27 of 34 students said they would go to more camps like this.
- 28 out of 34 students gave the Lego robotics an A or B grade.
- 20 of 33 students said they at least learned "a little" about what scientists and engineers do.

Parent and participant reaction to the camps was outstanding. Several of the parents shared their stories about their children's experience with the camp. Those stories are below.

1. *"Last night my son began talking when I picked him up. He had stories of everything he had done, seen and built. He talked to me while I prepared dinner, through dinner, while I did laundry and continued through his usual pre-bed time routine. He was up early this morning ready to learn even more. I was ready to have him be quiet for a while."* Mother dropping off her son on day two.
2. *"We arrived at Walt Disney World early and could not check in to our room, so we went to Downtown Disney to fill some time. The first store we came to was the LEGO store. Richie walked in to find a display of the new Mindstorm sets. He walked over to the man doing the demonstration and proceeded to tell the man everything he had learned at camp. He then had to correct a couple of mistakes the man was making before asking his dad when he could get a Mindstorm of his own. This was a first for Richie to take the*

lead and show his family something cool that he knew and the rest of us did not. He absolutely glowed." Mother of camper from week one of the camp after returning from the family vacation.

3. *"My son Christian took the class the second week and loved it. He said he won the competitions and I didn't discuss how to do the robots with him." This came from a teacher who participated in the first week of camp. His son when on to say, "on the first day of camp he felt camp was going to be just horrible." By the end of day two "something just sprang. It was like, Whoa, this is fun." And that the "fun overrides the learning. It's like, you don't even know you're doing science and math. If you try it, you'll see that it's the funnest thing ever. It's better than Kings Island."* Kings Island is an amusement park in the Cincinnati, OH area.

During these camps, young people and teachers worked together to grow their understanding of STEM topics. Many of these lessons learned were rooted in the National Science Education Standards as well as state based educational learning standards. The fun and excitement of these activities could easily expand from summer or after-school activities to classroom activities. The teachers involved in the camp were encouraged to do this. Twenty robotics sets identical to those used in the camp may be "checked out" by the teachers to use in their classrooms. At least two teachers who attended the camps did use the equipment in their classrooms.

Campers and teachers were also encouraged to participate in FIRST Lego League activities as team members and coaches/mentors. After the first summer of camps, six rookie teams from the area competed in the regional competition. Two of those teams earned a trip to the state FLL tournament with one of the teams finishing 10^{th} out of 48 teams.

IX. References

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