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Comparison of an Introductory Engineering course with and without LEGO Mindstorms Robots

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Abstract

An introductory Engineering course was run in two concurrent terms, one without LEGO Mindstorms robots, and one with. A comparison was performed between the two approaches considering teamwork, leadership, and engineering problem solving. In both groups, the project covered the engineering design process from customer needs through a working prototype.

The first semester, student design teams were allowed to choose any toy related project. In the second, they were required to use the LEGO robots to navigate a maze, find a colored ball and return it to the start point. During the non-robotic semester, one or two members of each team tended to dominate the group with some members seldom contributing. With the robotics groups, leadership changed throughout the engineering process as expertise of different individuals became important. The students were involved throughout the project as prototypes did not work as expected and both mechanical and software changes were required. The robotics project required not just mechanical expertise, but also the ability to program. The LEGO system also introduced many of the students to programming for the first time through a graphical interface that allowed everyone to participate.

Introduction

An engineering class designed for incoming freshmen has been modified to be project based. The class, Introduction to Engineering Design, was administered in two consecutive semesters at Penn State University, Lehigh Valley campus during the 2009-2010 academic year.
The goal of the course is to expose students to the engineering design process, methods, and decision making. A team based approach was adopted with grades based on team presentations, written journals and a successful project. The course covers the design process in detail from customer needs to a working prototype as shown in Figure 1. Students are

required to generate presentations for customer needs, product specifications, concepts and intermediate and final prototypes.

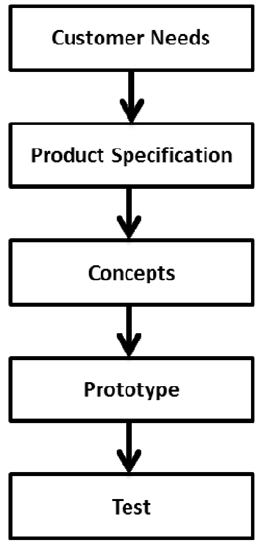

Figure 1. Design process

The scope of projects during the first semester was virtually unlimited. The only restriction was that it be a toy and be approved as a realistic project. One of the potential approaches to a project was to use the LEGO Mindstorms Robots[1].

During the second semester, projects were restricted to generating a robot to navigate a maze, find a red ball within the maze and bring it back to the start point. The robots also had to ignore any blue balls along the way. Each team was still required to define the form of the robot, method of movement, etc. and incorporate the customer needs.

Semester 1 observations

During the first semester, each team started with 4 members. Teams were generated based on the skill sets of the members of the class. All students were administered a survey to assess their mechanical, electrical and programming abilities [1]. Based on the survey results, teams were selected in an attempt to equilibrate skills across teams.

Each team was instructed to build a prototype of one toy. They had to decide on what toy they wanted to design and obtain customer input to determine the right product and customer needs for it. Requiring students to define the product proved to be an important step as they were asked to narrow down a broad spectrum of choices. The students used resources such as the Internet, visiting elementary classes and talking to people they knew. This portion of the project provided a good challenge to the students and produced relatively good results.

[1] LEGO® MINDSTORMS®, URL=http://www.lego.com/eng/education/mindstorms/default.asp

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Generating product specifications also worked well by forcing the teams to define all aspects of the selected toy. This activity held the attention of the majority of students and produced good results.

The concept phase was also successful in terms of results and participation of most of the students. However, as this phase unfolded, one or two students in each group began to take over as leaders. In each case, the leaders pushed the projects in a direction where they had some expertise. The toy project did produce some very good concepts since students were allowed to envision and develop what they were planning to build.

In the prototyping stages, the same one or two team leaders continued dominating the project in two thirds of the teams. While two of those teams did produce prototypes similar to their concepts, none of them worked as planned. One team did produce a working prototype, but it was lacking the full function prescribed by the concept.

The group that decided to do a LEGO robot project also fell short of their goals, but the dynamics of that group changed from the start to the final prototype. In the beginning, one group member was leading the group. Once the construction of the robot was completed, the leadership shifted to another member of the group during the programming phase. All group members of the robotic project were highly involved in at least some portion of the prototyping phase..

Semester 2 observations

Again, teams were generated in a similar manner as the preceding semester. When teams were divided, the first priority was programming experience. Next priorities were mechanical and other general skills.

Each team was instructed that they were to build a toy, but that it had a specific task to perform. It was to navigate a maze and capture the red ball, bringing it back to the start. This had to be accomplished using the LEGO robotics set provided. Teams were also allowed to build additional parts if required.

During the customer needs phase, students had some difficulty compared with the previous semester when given free reign over what to build. In this case, teams were not nearly as imaginative and did not do as well at surveying potential customers.

The product specification phase was also weaker during the second semester, possibly due to the lack of excitement of building ideas of their own. Two of the six groups had reasonable product specifications, but the other four did not on the first attempt.

Once the specifications were completed, teams were introduced to the LEGO sets. At this point, they began developing their concepts. The concepts did follow ideas obtained from customer needs and developed relatively well. Some of the ideas generated were concerned with locomotion – tracks vs. wheels and how to configure them. Other issues dealt with how to capture the ball. One item that all the groups missed was documenting concepts on how to program the robot.

Another interesting learning situation occurred once students were given the LEGO sets. Many teams began building prototypes as opposed to generating as many concepts as possible. This did help them quickly narrow down the final concept that they presented, but most made fairly major changes to the designs as they progressed into the testing phases. The presentations for this phase were strong. Students could visualize what they were going to design/build and had pictures as well as text in their slides. During this phase, one or two leaders of each group essentially controlled the direction.

During the prototyping phase, the same leaders of each group led during the mechanical build phase. In two thirds of the groups, the leadership changed once the robotics programming began. Students that had been fairly reserved and not significant contributors to this point became the leaders of the group. Other team members were still heavily involved since all groups had unforeseen mechanical issues as well as continued software modifications.

The programming used a drag and drop graphical interface shown in Figure 2, so it was not beyond any of the students. This eliminated the need to learn a sophisticated syntax for the language and students could focus on the problems and algorithms. The benefit of graphical programming has been reported by multiple authors [2-4].
On several occasions, the main programmer would be missing for a portion or all a class. Teammates would pick up and make updates to the programs. In some cases, these team members had no prior programming experience.

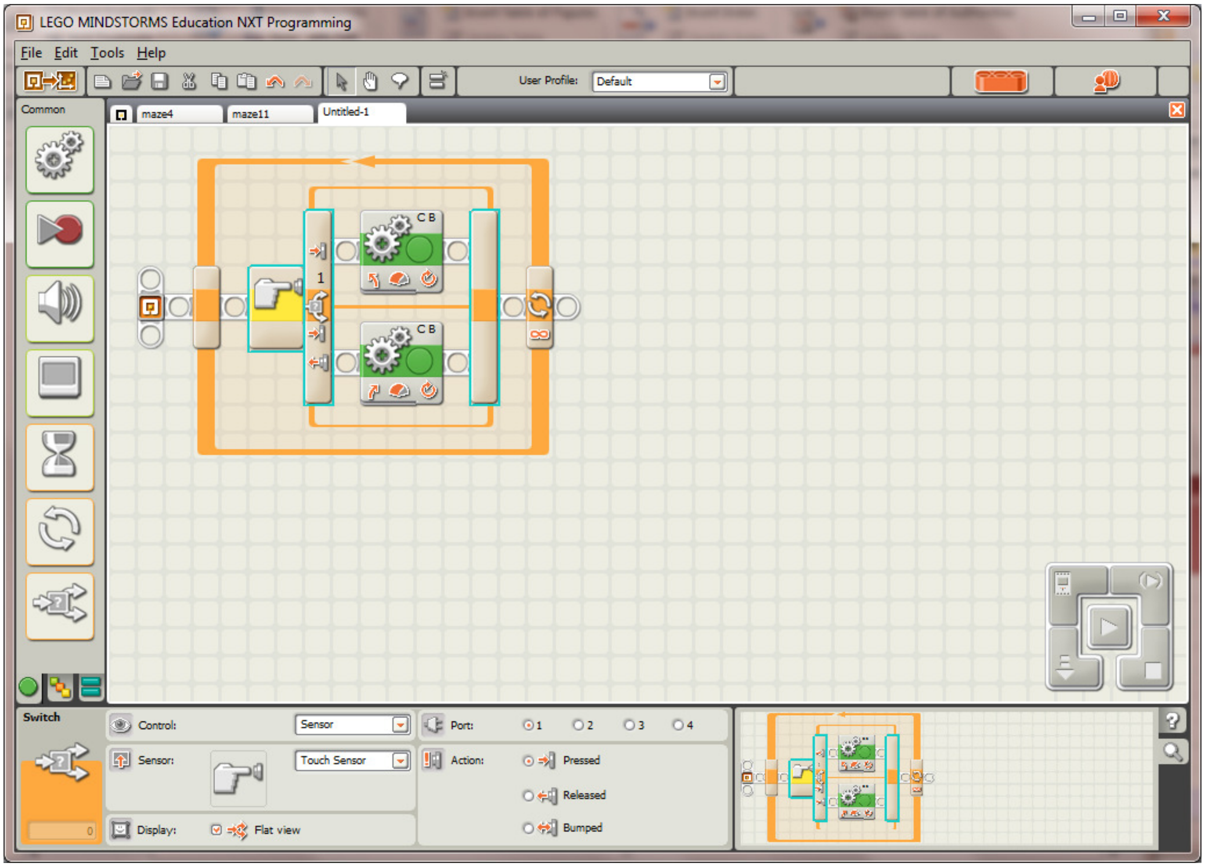

Figure 2. Graphical drag and drop programming interface and program. Program demonstrates a continuous loop with a conditional statement that turns left if the button is pushed otherwise it turns right.

Size constraints arose as unexpected issues faced by the groups. The maze was rather constricting compared the size of the robotics. This caused numerous redesigns with all the groups. They also encountered stability issues where the robot would tip over while cornering or when striking a wall. Also, teams realized that the “simple” mechanism originally planned for capturing the ball was not as easy as it first appeared.

The teams met with multiple challenges in developing the software. A simple gap in the outer wall of the maze would cause robots to turn into the wall. Navigating in a straight line would not work as planned since the motors of both wheels did not always turn at the same rate. Most of these issues required including feedback or damping the reaction to a sensor change.

Besides learning engineering skills during this phase ,students learned to work together as a team. Each team member had different skills to bring to the project at different points. Also, the time to build and program the robots was sufficiently short to instill a real sense of urgency.

At the end of the project, one group successfully navigated the maze and captured the red ball. All of the groups were able to navigate the maze with varying degrees of sophistication. A better measure of success, however, was that all groups worked together as teams and made good progress towards a goal. The last day of class, the maze and robots were on display in a central area of the campus where the final projects were demonstrated for students, faculty and staff.

Comparisons

Allowing students the freedom to choose any project definitely produced more interest during the initial phases of the project. Up through the concept phase, non-robotics students were more enthusiastic and creative than students with a robotic project.

However, the non-robotics groups bogged down during the prototyping stages, and in all but one group seemed to lose track of what they were trying to accomplish. Contributing to the confusion was the fact that the goals set out when defining product specifications were more difficult than envisioned. As freshmen, they did not have the appropriate skills to actually complete the projects as specified. On the other hand, the robotics students showed increased enthusiasm as they started working with the LEGO robots during the concept development phase.

The robotics teams knew it was possible to build a robot to do what was being asked of them, and could see other groups getting closer to the solution. Since each team had the same raw materials available, it put them on equal footing. This definitely helped them to focus and work hard to get their projects to function.

Participation in the non-robotics group stagnated with one to two people from each group leading from start to finish. The robotics groups however saw at least three of thefour members take control at some time in all but one of the groups.

Conclusion

Using the LEGO robotics provided an attainable engineering challenge for freshman engineering students. They were reasonably engaged during the customer needs and product specifications phases. During the concepts and prototyping phases, the vast majority of students were heavily engaged in solving the many problems associated with the project.

Many more students were involved in leading their respective teams with the robotics than with the non-robotics projects. This was due to the variety of work that had to be accomplished in a relatively short time.

Acknowledgments

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Biography

HAROLD SCHOLZ is currently an instructor in Physics and Engineering at Penn State, Lehigh Valley. Dr. Scholz has over 26 years of experience in integrated circuit design, research and development at Bell Laboratories, Lucent Technologies, Agere Systems and Lattice Semiconductor as both an engineer and manager.

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