Embedding LEGO Mindstorms in the Electromechanical Engineering Technology Curriculum

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Abstract:

The innovative use of LEGO as a tool for learning and exploring has leaped many boundaries. The use of LEGO is projected as a fun learning tool, while keeping the mind and the hands of the user engaged in creative activities. The degree of the diverse level of users captured by LEGO is practically boundless. The LEGO mindstorms is a fun learning tool for users from very young children to older adults. The kinds of activities that can be performed vary from designing and building to coding in languages such as NXT, Java, and C. The type of learning is intuitive and the inspiration for applying and advancing emerges from the users themselves. Many children who are fortunate to be exposed to the LEGO activity have the opportunity to participate in the competitions and are aware of the wider world of LEGO applications. However, there is an imbalance and many of the students entering college are not familiar with the LEGO environment. We propose to use LEGO as a tool for an inner city institution starting with the freshman class of students. LEGO serves as a perfect platform for these students who are enrolled in the Electromechanical Engineering Technology program. In this paper, we step through the process to employ LEGO as a tool in the Logic and Problem Solving course. We will also discuss the students' experience with LEGO as part of enriched learning. Finally, we conclude with the observations and recommendations of the efficient use of LEGO mindstorms in the curriculum.

Introduction

Active learning approach to engage students has been an area of study in multiple disciplinary areas [1-3]. Using LEGO Mindstorms as a tool to induce active learning in introductory and advanced courses has proved successful in the past decade [4-5]. Programming with LEGO has also been used to teach Math, Science, Pre-Engineering, and even Service learning courses [6-8]. LEGO Mindstorms is an ideal choice to keep students engaged in building, programming, and testing. It also invokes the multimodal perceptions for active learning. We include LEGO Mindstorms as a tool to teach the logic and problem solving course for the Electromechanical Engineering Technology program at NY City College of Technology. In this paper we elaborate and step through the approach used to instill critical thinking and problem solving through the use of LEGO robots. Robots provide a visual medium for collaborative learning and teaching. Algorithmic thinking can be implemented through simple structures and loops. The effectiveness of the problem solving exercises and programming the LEGO mindstorms are validated from the students' feedback. Finally, we conclude with observations and recommendations for future work.

By the very nature robots in the curriculum fits the associate degree (AAS) in Electromechanical Engineering Technology program. As goes by the famous Chinese proverb - I hear and I forget; I see and I remember; I do and I understand; the learning related activity is better absorbed in a hands-on environment. The retention capacity is proved to increase when the content under study is demonstrated or initiated by the student [9]. The learning pyramid shown in Figure 1 supports this theory. If the students can think for themselves and reason out their thought process to produce a clear path to their solution, they can apply these skills in any subject and pave their way for life long learning.

The logic and problem solving course lays the foundation for an important first step in the degree program. The content should serve as an ongoing living course in which students enrich their approach and streamline their thought process to solve problems as they move further up in their coursework. The students should be prepared to analyze the problem and tackle them from multiple perspectives. They should understand the context of the problem they are focusing in the global sense. Often times, students are lost while reading the problem and have no idea where to start. A systematic thought process should be developed and it is very essential that the students acquire the skills to move towards the solution in a logical and systematic way. It will be beneficial if these skills can be adopted at the very early stage of their course work and should be emphasized and practiced as the subject matter gets heavier. Collaborative learning skills must be brought into play. Other soft skills such as good communication, written and oral must be

gained. Thus this course could potentially seed a number of the above mentioned attributes laying a firmer ground for success in the coursework and career.

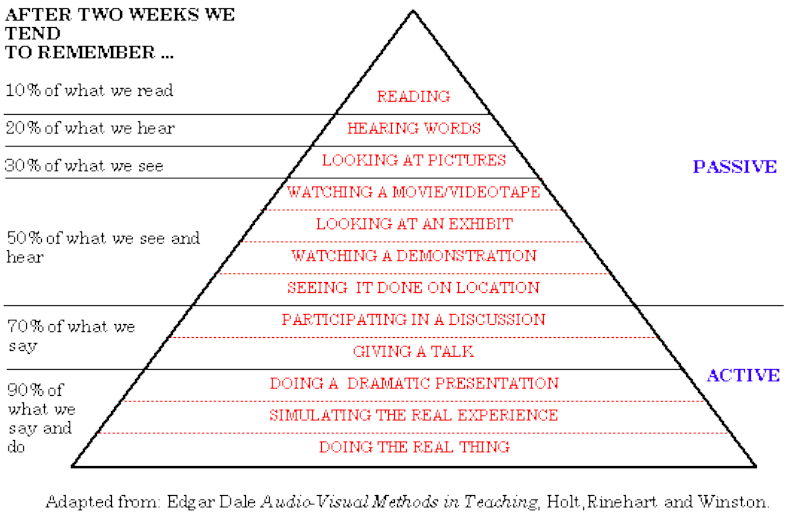

Figure 1: Retention outcomes with Active learning Methods in Teaching

The Environment

The students who enroll in the logic and problem solving course are generally freshman majoring in the Electromechanical Engineering Technology program. The mathematical level of the students' varies from remedial mathematics to Calculus. Many of these students have opted for this program because they like to tinker and enjoy the hands-on activities. They like to fix things better than writing code. As with the technology, only about 5% of the students use handheld electronic devices other than cell phones. About 2% of the students have experience with LEGO building and programming. In an institution like NY City College of Technology, for some international students this is the first course outside of their country. Many students support themselves in college and therefore, do not have much time to spare. Thus, achieving the balance for a sustained interactive and constructive learning atmosphere is critical.

The LEGO mindstorms introduced in the problem solving course can serve as a bouncing board for a number of other courses in the program as well. In the AAS degree program the students can extend their knowledge of gears and levers. They could also use LEGO in the data communication class to work with lab exercises involving different signal types and synthesizing sound signals. In the bachelors degree program in Computer Engineering Technology, LEGO can find its place in

the networking course to network multiple robots, to acquire data using different types of sensors in the instrumentation and data acquisition course, software engineering technology to translate the code in C and Java, and the feedback control systems course could interface with MATLAB toolbox to demonstrate different feedback instances. Last, but not least, LEGO can also be taken advantage of in the capstone course with extended project implementation and worked in conjunction with additional external circuits and embedded systems.

Problem Solving and Logical Thinking

The structure of logic and problem solving course was modified to include working with LEGO mindstorms NXT for implementing problem solving activities and team building exercises. Before diving into hands-on activities with LEGO mindstorms, the students were trained to look at the problem and streamline their thought process to step through the solution. They would start with reading and interpreting the problem, come up with strategies to find the solution, evaluate their results, and repeat the process until the goal of the problem was achieved. To accomplish this task the span of the semester work was divided into five phases. In the following section these five steps are described.

1. Critical thinking and Problem Solving

At the beginning of the semester the students were introduced to multiple critical thinking questions worded as problems. Two different strategies were used to solve the problems. In the first approach, the students were encouraged to think through and solve the problem on their own within a fixed time. After the initial effort by the individuals, answers to solution was sought from students and were discussed as a class. The students expressed their approach orally or demonstrated their solution on the board. With the second approach, the problem was read and dissected with the aid of student interaction. Students were shown how to translate phrases to arithmetic and logical expressions. Systematic thought process and strategic thinking to solve the problem at hand were brought into play. The students were guided in their thought process to formulate the solution. Systematic handling to step through the solution was emphasized and possible error spots were cited.

2. Use of Design tools

Once the solution was discussed the steps were laid out initially as a pseudocode. Multiple pseudocode examples were illustrated. Extension of the code was assigned for students to work by themselves. The next step in designing the

solution was the picturesque depiction of the solution using flowchart. Conversion from pseudocode to flowchart and vice versa was discussed. Common examples like hourly wage calculation invoking decision criteria and iterative loops were discussed. Logic and Boolean operation were introduced. Sample procedures to test run using the design tools were addressed. Examples of hierarchy charts were also illustrated in class.

3. Introduction to LEGO Mindstorms

At this stage of the course, the students are ready to read and interpret the problem and are familiar with the methods to progress with the solution using design tools. To realize their design models the LEGO Mindstorms was introduced. Students built structures using LEGO kits and used them to code and test. Since the class meeting times were limited to two hours, building the LEGO structures were encouraged outside the class period. Two sessions of LEGO building for interested and available students were planned. Many students were motivated to spend the extra hours they could in working with the LEGO. Meeting at the extra sessions outside the class hours was optional and was not mandatory. Students who did not participate in the LEGO building exercises worked with the already built models of the robots.

4. Problem Solving with LEGO

Programming with LEGO mindstorms to fulfill specific tasks were assigned in-class. LEGO Mindstorms NXT-G programs were demonstrated initially for a quick start. Coding with NXT-G is straight forward and is icon-based. The in-class exercises started with simple problems to move the robot to using the sensors and motors. Arithmetic challenges were then added to move the robot with mathematical manipulations. These exercises included analyzing the problem more carefully and manipulating the parameters of the input and output devices arithmetically. For example a problem might require the group to calculate the number of rotations or the power of the motor to be adjusted to reach a distance in a specified amount of time. Use of sensors found useful implementation of decision supported activities and this addressed the logical aspect of problem solving. Each exercise was worked with teams of 2 - 4 people. Simple and straight forward exercises involved two group members and more complex tasks combined groups to make four members per team.

5. The LEGO Challenge

With the hands-on experience gained through the exercises, the students are now ready to take up challenges and compete amongst themselves. The classical robot

race and robot as sketching tool were given as challenges for the group to compete against each other. The criteria for the final project included all the concepts learnt thus far and to extend the features of the robot creatively. Each group is allowed to come up with variations of this protocol. A project report submitted includes the detailed discussion of the problem, steps to implement the solution, and the test procedures, along with the role of the individual group members. Details of the debugging and testing carry weights towards the final grade. Each of the projects is demonstrated by the group on the day of the presentation.

Performance and Evaluation

The students were enthusiastic in working with LEGO mindstorms and were eager to get started. Introduction of design tools earlier in the semester and reinforcing the problem solving approach during the LEGO implementation trained their thought process. Questions to recap and guide the overall context of the problem proved helpful. Alternate approach to solving a problem at hand was encouraged. The competition for the slowest, fastest, most efficient, and shortest solution made the group brainstorm and come up with modifications in the code. This sometimes led to mastering the intricacies and deeper analysis of the solution.

The effectiveness of this approach was studied with a feedback from the students. Two sets of questions are reported. One set of questions for the problem solving approach and the second set of questions included the LEGO experience. The feedback received was generally positive. A cohort of 16 students participated in the survey. In the first set of questions on problem solving questions on the interests in critical thinking and importance on the approaches to solving a problem was addressed. The response from the students on the importance of the strategic approach to problem solving is shown in Figure 2. In the second set of questions students were asked to respond on their LEGO experience. The summarized details on the results of the feedback are shown in Figure 3.

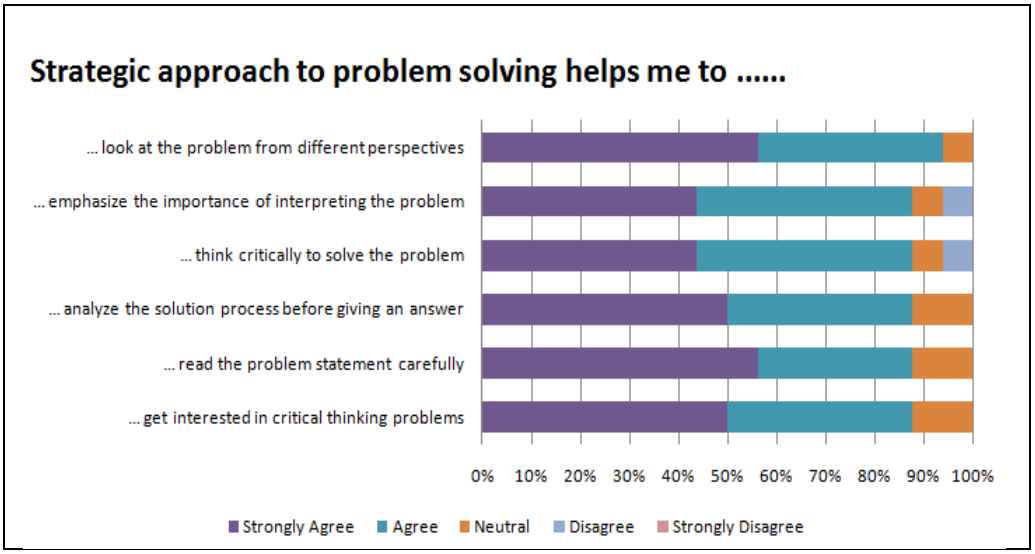

Figure 2: Student Response to Problem Solving Approaches

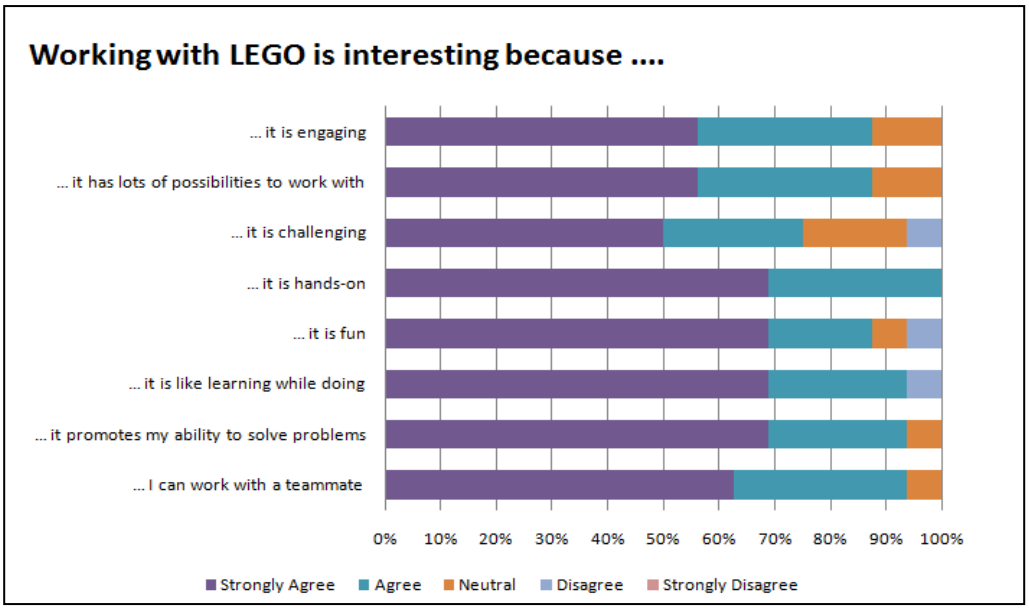

Figure 3: Student Response to LEGO Experience

Observations and Recommendations

The first phase of the course with critical thinking problems was certainly an ice-breaker and proved very useful for the class. Majority of the students tend to be interested in the brain teasers and were involved in the discussion. There were some requests from the students to have more critical thinking problems for discussion. Some students specifically requested for more word problems because they find the interpretation of the problem difficult. The use of design tools was

improved by the reinforced use of these techniques. Emphasizing the problem definition, strategies, and solutions for every task implemented proved useful.

In working with the LEGO mindstorms, the students were looking forward to building and trying out new ideas. The creativity, persistence, and visual outcome of their code came into play. The students greatly enjoyed the competition between the groups. Extra credit points for enhancing the robot operation gave an opportunity to rethink the design and implementation. Overall, directing the thought process to enable problem solving using a step by step approach was brought to life through programming. Programming with LEGO mindstorms made it easier to create event driven programming with structures and loops. The immediate response of the implementation and the ability to test for different outcomes, made the use of LEGO a tool for active learning.

- Weekly problem could be assigned to be worked outside the class with some extra credit points. This would alleviate students' interest in problem solving.
- The class officially met only two hours per week. The students needed more time to discuss, assimilate, design, and exercise their ideas.
- From the survey it can be observed that some students needed more challenging exercises. This seemed difficult since the prerequisites for this class were none. However, bonus points for additional challenging efforts can be awarded.
- Given more time this course could be aligned with middle and high school children to participate in the LEGO competitions.
- Extending the use of LEGO experience with other courses in the program would enrich the project ideas on a known platform. By this way the students can concentrate on the additional module that links to the LEGO framework.

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