LEGO ROBOTICS PRODUCTS BOOST STUDENT CREATIVITY IN PRE-COLLEGE PROGRAMS AT UMES

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Abstract *–. Two pre-college programs have been funded at University of Maryland Eastern Shore (UMES) to promote mathematics, science, engineering and technology (MSET) education among minority middle and high school students by the National Aeronautics and Space Administration(NASA) and the National Oceanic and Atmospheric Administration(NOAA) respectively. The programs are directed by the first and second author of this paper and are ably supported by graduate students in the Department of Mathematics and Computer Science at UMES who are also co-authors of the paper. In the NOAA - sponsored middle school program twenty, middle school students participate in a two-week summer activity at UMES. The program endeavors to introduce and generate interest among participants to pursue MSET majors. The NASA-sponsored "Summer Engineering Bridge Program (SEBP)" provides enrichment activities for fifteen to twenty high school seniors in transition to college. The program is five weeks long and is structured to improve the success of marginally accepted engineering majors at UMES during their freshman year in college. While the focus of SEBP is on promoting engineering, other interested MSET majors can also participate and benefit from the program.*

There are a variety of educational and recreational activities that are integrated in the programs. The focus in this paper is on activities incorporated in the programs using LEGO Mindstorm and LEGO DACTA products for design and embedded computer control of mobile robotic platforms as well as instrumentation and data acquisition using LEGO sensors. Teamwork and cooperative learning are promoted. A similar product suitable for embedded computing activities called MIT Handyboard is also introduced to the high school students.

Index Terms – Active-Learning, LEGO Mindstorm, LEGO Dacta, Pre-College.

INTRODUCTION

The NASA-sponsored Summer Engineering Bridge Program (SEBP) and the NOAA-sponsored NOAA-UMES summer camp were developed in recognition of the fact that the performance and retention of minorities, women and economically disadvantaged young adults in mathematics, science, engineering and technology (MSET) continues to remain low in the United States. The objective of both programs is to favorably impact these problems by recruiting fifteen/twenty high school students in transition to college for the NASA program and twenty middle school students for the NOAA program from the underrepresented groups and strengthen their academic preparation in the MSET fields. The NASA program includes five weeks of rigorous activities over the summer where as the NOAA middle school program runs for two weeks of summer. While follow up and tracking activities are performed throughout the year, the major thrust of both the programs is during the summer. The programs have been running successfully at UMES for the last two years based on projects developed for a three year funding cycle.

Both pre-college programs emphasize activities primarily based on mathematics, physics, engineering and Internet technology. Core activities involving physics and engineering are emphasized in both programs. Moreover, significant effort is devoted towards preparing the participants for the first college level course in Calculus in the NASA Pre-College program for the "would be" engineering majors. In the NOAA-UMES summer camp for middle school students web surfing and learning to use Frontpage / Netscape Composer to develop web pages, uploading them to the dedicated site[1], and providing appropriate hyperlinks have provided tremendous excitement among the participants.

Emerging trend in engineering education facilitated by the Engineering Criteria 2000(EC2000) developed by the Accreditation Board of Engineering and Technology (ABET) [2,3] is encouraging integration of design throughout the engineering curriculum. It is also promoting a holistic integration of 'soft' and 'technical' skills encompassing academic knowledge, civic responsibilities, and life skills consistent with the engineering profession. Industry and government enterprises such as NASA and NOAA naturally embrace this philosophy in their day-to-day activities and have strongly supported our efforts towards integrating team based design activities in the pre-college programs. In this regard, design activities involving modern software tools such as Working Model and West Point Bridge Design Software [4] as well as LEGO-Mindstorm and LEGO-DACTA products and their inspirational predecessor, the MIT-Handyboard, have been successfully utilized.

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Overview of Design Projects

The six important attributes associated with the engineering profession that were emphasized to the students are:

- Creativity
- Capability
- Communication skills
- Cooperation and Teamwork
- Caution
- Character

The middle school students could readily appreciate how these characteristics related to engineering practice when they worked in groups to design truss structures for bridges. The students explored the West Point Bridge Design software (Version IV) to analyze their proposed design with respect to material, strength, structural aesthetics and cost. Photograph 1 shows one of the teams working on a bridge design using West Point Bridge Design Software

The students also built bridges using Popsicle sticks and Elmer's glue corresponding to their structural designs that were developed on the software for a certain span and height. The bridges were tested using a bridge-testing platform with progressively heavier loads until they had a structural failure. Photographs [2a & 2b] show the participants as they construct and perform load test on the bridges. Students developed some insight about design optimization with regard to structural strength and costing while iterating on their designs using a test load of a moving truck that was provided in the West Point Bridge Design software.

The overall experience not only gave the students a feel for the engineering design process but also helped develop valuable life-skills such as ability to work in teams and resolve conflicts.

The student-participants in the camp were divided into four groups and each group was given a RCX brick, an infrared transmitter, and an assortment of LEGO parts to build a tankbot (a mobile platform built like a tank using LEGO parts and an RCX programmable brick). One of the five kits was used for demonstration. Initial demonstrations included programming the tankbot to execute different motions without any sensors. Subsequently, the touch sensor and light sensor were used to demonstrate how the tankbot could interact with its environment. The touch sensor was employed to demonstrate obstacle avoidance capabilities whereas, the light sensor was utilized to track a trajectory marked in black over a white background using the tankbot.

The students worked in teams to build the tankbot. Photograph [3] shows one of the NOAA-UMES summer camp student teams discussing the tankbot construction from the kit. While they were building the platform the correspondence between LEGO parts and mechanical components used in real machines and mechanisms were pointed out to them. After a brief initiation the students could easily program heir tankbots using RCX code, an easy to use icon based programming language integral to the Mindstorm Kit. This visual programming environment allows one to drag, drop and stack commands and bits of code without explicitly writing any code following appropriate syntax. Photograph [4] shows a RCX code for the tankbot equipped with a touch sensor. Photograph [5] shows the tankbot in action as some of the program participants watch with interest.

The students were also briefly introduced to ROBOLAB a programming environment based on the popular instrumentation and data-acquisition software, LABVIEW, developed by National Instruments. ROBOLAB can also be used on RCX programmable brick for embedded computing applications as well as other applications that may be attached to desktop computers via a stationary input-output platform. Although coding in ROBOLAB is somewhat more difficult than RCX code, in the long run it is more suited for the educational environment, since, familiarity with ROBOLAB gives one a leg up with LABVIEW, a popular software in the engineering and science laboratories.

The UMES-NOAA camp students were given a demonstration of a ROBOLAB program that was used to monitor the data recorded by a LEGO temperature sensor dipped in water. The temperature was made to change by adding more hot or cold water to the container. A RCX programmable brick sensed the temperature and turned lights (LEGO lamps) on and off via the output ports at pre-specified temperatures. The data-logging capability of the RCX-brick was utilized to log and plot the variations of the temperature using the ROBOLAB Investigator. Photographs [6a-6c] show the ROBOLAB code, temperature sensor attached to an RCX brick, the data-acquisition experimental set-up and the graphical display of the logged temperature data.

It is expected that the brief exposure to structural design, mechanical design, sensing and instrumentation and embedded computing will spark the young minds and the creative energy of the middle school students to learn more about engineering design, robotic/mechatronic logic and design, instrumentation and data-acquisition. The LEGO Mindstorm kit can be used for a variety of creative endeavors. The interested NOAA-UMES summer camp participants will get an additional opportunity to work with them during follow up activities scheduled at UMES. Some students were even thinking of including a Lego Mindstorm in their Christmas wish list.

The NASA Summer Engineering Bridge Program (SEBP) exposed the participants to a variety of engineering activities. The participants learnt to prepare simple solid models and projection drawings using the popular solid modeling software ProEngineer. They also worked in teams to design a four bar linkage with the follower arm exhibiting 45 degree rocking motion using card boards and thumbtacks. They simulated their design using the MSC Working Model

2-D software environment before performing the actual construction. Photographs 7a & 7b show a SEBP team consulting the Working model software while designing a fourbar linkage. The participants also built an electric motor using bar magnets, paperclips, D cell battery, rubber band and magnet-wire coils wound over the cardboard core of toilet paper rolls. Instructions and information provided by the Beakman's Electric motor website[5] were found to be extremely valuable for the construction of the motors . The student participants worked in teams and experimented with the thickness of the magnet-wire, its shape and number of turns to design a motor with the highest revolutions per minute. The speed of rotation was determined using a Stroboscope.

The SEBP students were also engaged in team-based "mechatronic" design projects. The activities were designed not only to inspire the student creativity but also to prepare the students for the "Introduction to Engineering Design" course (ENES 100) that they will undertake during the regular semester in the subsequent fall term. The ENES 100 course has been developed at UMES largely following the structure of the course developed at University of Maryland, College Park.

The "mechatronic" design projects assigned in the SEBP involve student teams designing and developing mobile robotic platforms using LEGO components. The mobile robots use either the LEGO RCX brick as the controller or the MIT Handyboard [6]. Students cooperate in teams to build the robots using LEGO components that are comparable to components used in machines and mechanisms designed by engineers in the real world. The students also integrate sensors and motors with their mobile robots. The RCX brick and the MIT Handyboard are integrated with the robotic platforms for providing them with embedded computing capability. Photographs 8a & 8b show two SEBP teams with their LEGO robots using the RCX-brick. The students also experiment with developing and downloading programs to these devices, which enable the platforms to move and interact with the environment using appropriate sensors. Photographs [9a & 9b] show a Lego Mindstorm kit based mobile platform using the RCX and a MIT Handy Board based mobile platform. These platforms are used as demonstration devices during the SEBP. Although the mechanical design aspects of the LEGO projects performed in the SEBP parallels what the middle school students do during the NOAA summer camp, the SEBP students are exposed to more advanced programming concepts. The middle school students mostly use the RCX–code that is integrated with the LEGO Mindstorm package whereas the SEBP students are encouraged to compare programming approaches using the RCX-code, ROBOLAB as well as NQC (Not Quite C) –a C-like language that can be effectively used with LEGO RCX brick[7]. Photographs 10a & 10b show an RCX-Code and Robolab code for line tracking using a tankbot with a light sensor. Moreover, the SEBP students also experience working with MIT Handyboard using the Interactive C language.

The design projects engage students through all the four phases of Kolb's "Experiential Learning Cycle"[8,9], involving 'Concrete Experience', 'Reflective Observations', Abstract Conceptualization' and 'Active Experimentation' to provide a holistic learning experience which integrates knowledge from many different fields.

IMPACT AND OUTCOME OF PROJECT ACTIVITIES

Formal outcome assessments are being performed on a semester basis for the NASA, SEBP program for inclusion in the yearly progress reports to the agency. Middle school teachers collaborating in the project have reported anticipated outcomes for the NOAA-Summer Camp in terms of tangible quantitative measures have proven difficult. However, in their perception the student activities, interest and excitement generated after initiation of the camp are evidences to support the success of the program. Some of the significant impacts of the two programs are listed below :

- Immediate outcomes of the SEBP are clearly evidenced from improved student performance in introductory mathematics, physics and engineering design courses.
- An SEBP participant have provided team leadership and significant number have participated and contributed to the ongoing NASA-UMES experiential learning project acronymned UMESAIR (Undergraduate Multidisciplinary Earth Science Airborne Imaging Research). The project involves flying an instrumented blimp to perform earth science related investigations using remote sensing. Some students have utilized and are investigating LEGO based design of some of the components onboard the instrumented payload for the project [10,11].
- Exposure to web surfing and webpage development using Frontpage and Netscape composer have generated a splurge of creative expression on the web among the middle school participants of the NOAA Camp. The participants have not only surfed the web with ease for information gathering but some have gone on to developing and maintaining their class website, developing websites for their school band and family business.
- LEGO based design and programming activities have not only provided excitement for learning among both SEBP and NOAA summer camp participants but will have given the students initiation into courses in Introductory Design, Introductory Computer Programming, Instrumentation Control and Data acquisition related courses which they are likely to encounter as MSET majors.
- Both programs have heavily utilized computers and computer software that is likely to benefit the students in the future. The software tools that students have been

exposed to include Powerpoint, Frontpage, Netscape composer, ProEngineer, Working Model, West Point Bridge Design, Robolab and Labview, Interactive C, RCX Code, and Not Quite C.

- Reports from the teachers of the middle school NOAA summer camp participants indicate that a large number of them are likely to pursue careers in MSET fields.

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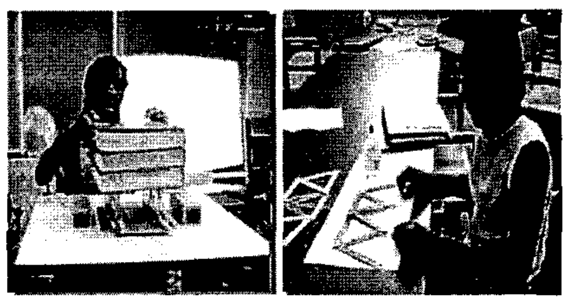
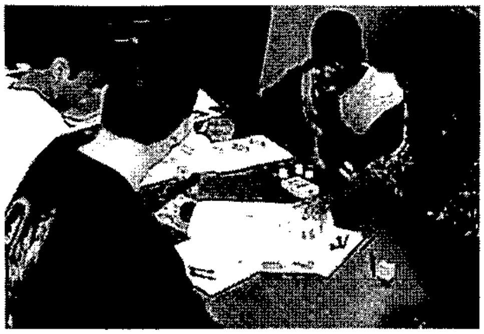
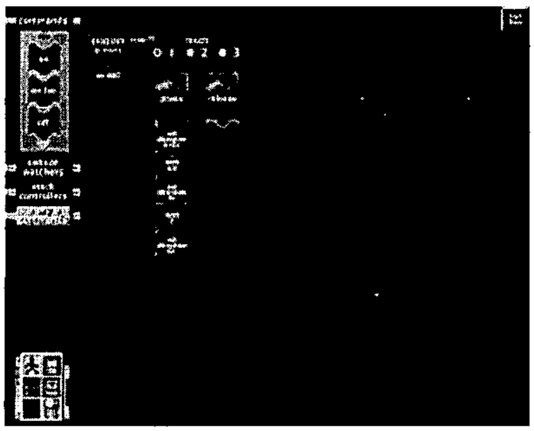
PHOTOGRAPH 1: NOAA Summer Camp students working on West Point Bridge Designer



Photographs 2a & 2b: NOAA Camp students construct and load test their bridges.

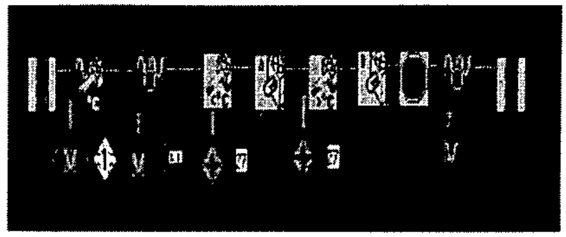


Photograph 3 : A team of students discussing tankbot construction from the kit (NOAA Summer

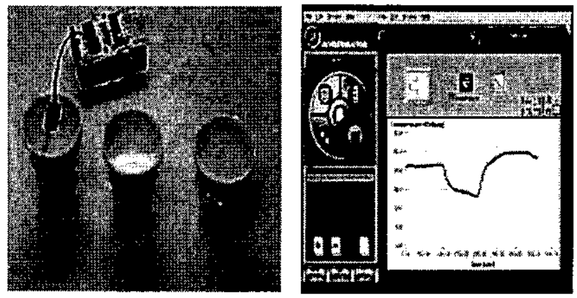


Photograph 4: RCX Code using touch sensor

PHOTOGRAPH 5 : NOAA Summer Camp student watch their tankbot execute the RCX-code.



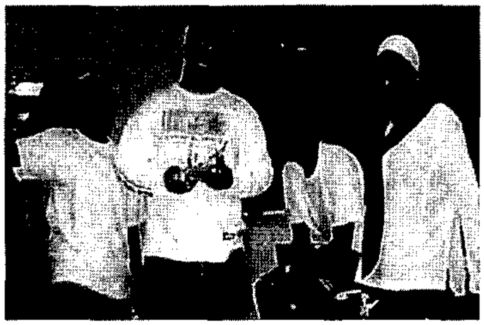
Photograph 6a: Robolab Code for Temperature Data Acquisition for water with varying temperature.



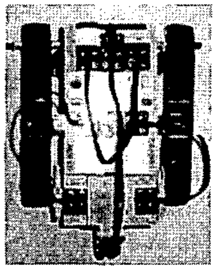
Photograph 6b & 6c : Lego temperature sensor, output lamps and hot and cold water cups and the temperature data recorded as the sensor is dipped in the cups.

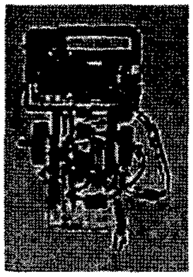
Photograph 7a & 7b : NASA SEBP students use Working Model to design and construct a 4 bar linkage.

Photograph 8a : A NASA SEBP student team display their LEGO Robot.

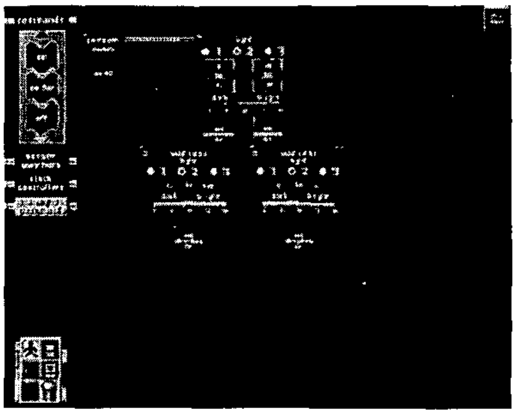


Photograph 8b : A NASA SEBP student team display their LEGO Robot.

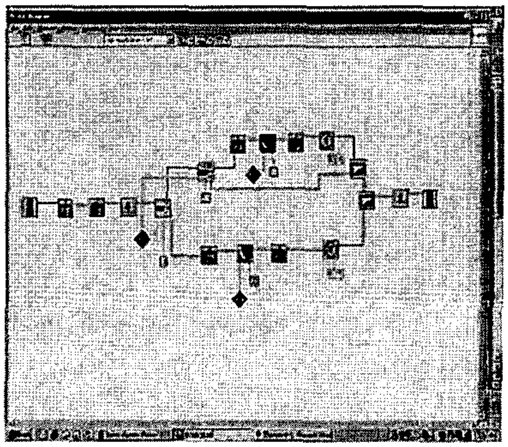




PHOTOGRAPH 9 (a) and (b)
(a)Lego-mindstorm based mobile robot platform
(b)MIT Handyboard based mobile robot platform



Photograph 10 a: RCX-Code for a line tracking code using light sensor.



Photograph 10 b: Corresponding Robolab program for the line tracking code in 10a above.