Middle School Students get Introduced to Fundamentals of Engineering at the UMES-NOAA Summer Camp

Abhijit Nagchaudhuri, Gurbax Singh
University of Maryland Eastern Shore
Princess Anne, MD 21853

Abstract

National Oceanic and Atmospheric Administration (NOAA) have funded an outreach program at University of Maryland Eastern Shore (UMES) to promote mathematics, science, engineering and technology (MSET) education among minority middle school students. The first and second author of this paper direct the program with support and assistance from graduate students in the Department of Mathematics and Computer Science at UMES. Twenty middle school students identified from selected schools in Accomack County, VA, in the Eastern Shore of Delmarva peninsula participate in this two-week summer activity. Two school teachers accompany, chaperone, design and direct some of the student activities during the camp. They also try to include some of the scientific and engineering related projects that they get exposed to during the camp to the students during the regular school year. The overall objective of the program is to generate interest among participants and other school students to pursue MSET careers.

I. Introduction

It is imperative to inspire more students to pursue MSET careers to sustain the nation's economic growth and vitality from all cross-sections of the society and in particular, from among the women and minorities[1]. NOAA summer camp is a two-week program held at UMES to initiate early intervention at middle school level for a group of students to broaden their perspective with regard to career choices. The program is directed by Physics and Engineering faculty at UMES and is designed to provide hands-on project based learning experience to twenty middle school students from Accomack County schools in the lower eastern shore region of the Delmarva Peninsula every year. Accomack County is in an economically depressed area with a significant minority population. The students for the summer camp are recruited with the help of school administration from the low performing schools of the region. The students are chosen so that there is a mix of both high and low performing students and racial diversity in the group. The program endeavors to provide a positive experience for the participants so as to inspire them to prepare for MSET related fields in college. Also, it is hoped that the participants themselves will act as messengers and advocates of the program and program objectives among their siblings and peers.

The program incorporates a variety of project based learning and design activities in physics, engineering and information technology fields along with recreational activities in the UMES Athletics center and the newly built student center. The activities pertaining to the physics education aspects incorporated in the program have been reported elsewhere[2]. In this paper team based engineering design projects and information technology projects that are included in the program are highlighted. The activities are elaborated along with a discussion of the program outcomes.

II. Overview of the Information Technology and Engineering Design Components of the Summer Academy

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

- 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:

i. Design truss structures to develop a feel for engineering design process in general and bridge design in particular.

ii. Design, construct and calibrate the *Moment Machine* (a simple weighing machine that introduced the students to fundamentals of levers, mechanical advantage and engineering mechanics).

iii. Construct and program mechatronic devices and robots using the LEGO MINDSTORM kit.

The design projects not only provided an exciting learning experience for the participants but helped in establishing that for a successful engineering design activity, life-skills such as ability to work in teams and resolve conflicts as well as learning to communicate effectively were as important as cognitive skills of mathematical and scientific analysis.

The summer camp students were also introduced to the internet technology and web page development using "Microsoft Frontpage" and “Netscape Composer”. The students not only learned to surf the net to find information related to NOAA and their basic educational needs, but also with regard to the assigned design projects.

The activities were strongly inspired by the "experiential learning paradigm" offered by Kolb[3].

In the following sections the details of the above projects will be elaborated:

III. Design of Truss Structures for Introduction to Bridge Design

The students built bridges using Popsicle sticks and Elmer's glue corresponding to their structural designs that were developed on the West Point Bridge Design Software[4] for a certain span. The bridges were tested using a bridge-testing platform and progressively heavier loads until they had a structural failure. 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. Photograph[1] shows NOAA summer camp students working on the West Point Bridge Design software and Photograph[2] shows one of the summer camp students performing a load test on a bridge constructed by her team using popsicle sticks and glue.

Learning Outcomes

- Simulation as a tool to gain insight prior to real construction
- Design as a constrained optimization process
- Appreciation for teamwork
- Appreciation for safety, failure, and it's consequences
- Some idea of material selection and cost estimation.

IV. Design and Construction of a Moment Machine

The NOAA Summer Camp students worked in groups of four to design and build "Simple Machines" that were capable of weighing items between 0 and 500 grams. Photographs[3 and 4] show one of the groups painting and testing their "Moment Machine".

The apparatus consisted of the following:

(i) A wooden support platform
(ii) A long rod with an off-centered fulcrum
(iii) A counterweight and weighing pan to the left of the fulcrum
(iv) A sliding weight that slides on the rod with appropriate calibration marks to the right of the fulcrum
(v) Miscellaneous items such as rocks, stones, batteries etc. for counterweight and sliding weight adjustments
(vi) Standard calibration weights of 10, 20, 50 and 100 grams
(vii) Several Apples, Bananas and Oranges for items to be weighed.

The activity was designed to demonstrate moment of a force, fundamentals of lever mechanisms, Newton's first law of motion, basic comprehension of calibration of measurements and it's relation to resolution and accuracy as well as principles of engineering design. The activity also encouraged participants to work in teams, develop interpersonal skills and appreciate aesthetics and the role it plays in design and marketing of products.

Fundamental Guiding Principle

A body continues in its' state of rest or of uniform velocity motion (translation or rotation) unless it is acted upon by an unbalanced system of forces or moments.

Mathematically, the statement is equivalent to:

$\sum F = 0$ and $\sum M = 0$. (The sum of all force and moments acting on a body at rest is zero).

For the "Moment Machine" the moment balance equation can be written as:

$$\sum M = 0 \Rightarrow W_c L_c + W_u L_u - W_a L_a = 0 \qquad (1)$$

where,

W_c, W_u and W_a are the weight of the counterweight (constant), the unknown weight to be measured (variable) and the sliding weight (constant) respectively,

L_c, L_u and L_a are the distance of the counterweight (fixed), distance of the weighing pan or unknown weight (fixed) and distance of the sliding(variable) from the pivot or the fulcrum, respectively.

The counterweight and the weighing pan (unknown weight receptacle) are to the left of the fulcrum and are closer to it on the balance beam (rod). The adjustable weight slides on the longer portion of the beam (rod) to the right of the fulcrum to balance the moment due to the weights to the left of the fulcrum.

Design Procedure

In the interest of time the platform with an appropriate pivot for the "Moment Machine" was pre-fabricated and provided to each of the student teams. Each student team was also provided with a rod (balance beam), weighing pan, a disc with a circular hole which fit the diameter of the rod so that it would slide easily over the rod (the sliding disc could be modified to include additional weight if necessary), bundle of strings to hang the weighing pan and the counterweight and plethora of small items such as rocks, batteries etc. for the counterweight and sliding weight.

Student teams were allowed to experiment with the location of the fulcrum on the rod, the counterweight and the adjustable weight so that:

(i) With no weight on the weighing pan the adjustable weight could be slid quite close to the right of the fulcrum to balance the beam in the horizontal position.

(ii) With 500 grams standard weight on the weighing pan the moment balance is achieved when the adjustable sliding weight is close to the end of the rod to the right of the fulcrum.

Following this procedure the students could not only accommodate the specified range but also had enough space on the rod to provide calibration marks on the rod for 100 grams, 200 grams , 300 grams and 400 grams as well as 5 subdividing marks at increments of 20 grams between every 100 grams mark. While experimenting with the weights the students not only developed insight of the engineering sciences but also about resolution and accuracy of measurement.

Moment Machine in Use

After design, construction and calibration phase, each student team weighed an apple and an orange individually, and noted their individual weights. Subsequently they put the apple and orange together on the weighing pan and observed that the sliding weight balanced the rod at a position that indicated that the combined weight was the sum of the individual weights as expected.

Learning Outcomes

- Ability to work in teams,
- Understanding the engineering design process and it's relationship with " natural sciences (Physics in this case)" and mathematics,
- Aesthetics (the student teams painted the wooden platforms and the rod) to make their " Moment Machine" visually appealing,
- Fundamentals of metrology.

V. Robot Construction and Programming using LEGO MINDSTORMS

The popular activity using the LEGO MINDSTORM's Robotics Invention System that was introduced in the summer of 2001 was repeated during the 2002 UMES-NOAA Summer Camp. The LEGO system/kit is the result of research collaboration between LEGO and the Massachusetts Institute of Technology. The kit is easy enough for middle school children to work with but powerful enough as a learning tool for high-school or even university level students.

Five kits of Robotics Invention System were used during the 2002 Summer Camp. Each kit contained 727 LEGO parts, including the RCX "programmable brick", an infrared transmitter for sending programs to robots, the Mindstorms software CD-ROM, a full-color builder's guide (Constructopedia), two motors, two touch sensors, one light sensor and an assortment of LEGO bricks, connectors, wheels and gears.

The RCX brick has three input ports and three output ports. The input ports can be attached to sensors such as light, touch etc. to acquire information from the surroundings and the output ports can be attached to lamps to turn on and off as well as motors to turn on and off in forward or reverse at any of the 8 pre-set speeds. The RCX uses an 8-bit Hitachi H8/3297 micro-controller running at 16MHz that works as the "brains" of the overall system/robot into which the RCX brick is integrated. The Hitachi chip has 16K ROM, 512 bytes of SRAM(for firmware) and 32K of external SRAM for downloaded programs. It features a fully multi-tasking operating system that can sustain upto 10 simultaneous tasks. The brick also houses six AA batteries for power requirements.

The student-participants were divided into four groups and each group was given a RCX brick, an infrared transmitter, 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 purposes. The demonstration included programming the tankbot to make different motions without any sensors. Subsequently the touch sensor was used to demonstrate how the tankbot could determine when it encountered an obstacle and react appropriately (back up). 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. 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 their tankbots using RCX code. RCX code is an easy to use, icon based programming language. This visual programming environment allows one to drag, drop and stack commands and bits of code without actually writing any code following appropriate syntax. Photograph [5] provides a collage of the campers designing, programming and testing their tankbots. Photograph [6] shows sample RCX-code developed by the students for downloading and testing on their tankbot.

It is expected the brief exposure to mechanical design, sensing and instrumentation and embedded computing will spark the interest of the young minds and wake up the latent creative energy of the middle school students to learn more about robotic/mechatronic logic and design, instrumentation and data-acquistition. The LEGO Mindstorms kit can be used for a variety of creative endeavors and the interested students will get an opportunity to work with them during follow up activities held at UMES or at other places like their school or home where the kit may be available.

Learning Outcomes

- Ability to work in teams.
- Creativity and exploration of engineering innovation.
- Ability to integrate knowledge and information from several different fields.
- Learning to appreciate synergistic integration of mechanical design, electronics and instrumentation and computer control in fields such as “robotics” and “mechatronics”.

VI. Personal Web page for participants and Summer Camp Website

The students surfed the world wide web every morning to search for information based on a NOAA related theme. They were also asked to identify their favorite websites.

A web page was also developed for the UMES - NOAA activity[5]. The website is hyperlinked to the main page of both UMES and NOAA. Hyperlinks have been provided for the pages developed by the NOAA camp students during the year 2000 and 2001 activity as well as the activity during the summer of 2002.

The website includes a hyperlink that shows photographs of each participant as well as a hyperlink to a page that was developed by the student-participants. On this page each students provides some of their personal information with hyperlinks to their favorite sites. As part of the summer camp the students not only learned to surf the web for information gathering but to actually develop and post information on the web using Microsoft FrontPage.

The UMES-NOAA website also provides hyperlinks to popular internet sites for:

- Biology, Chemistry, Physics and Environmental Sciences
- Computer Science and Mathematics
- Engineering and Technology.

It is expected that the summer camp participants will visit the UMES-NOAA Summer Camp website on a regular basis and utilize the internet resources for school project activity and self directed learning.

The website also contains pictures of highlights of the Summer Camp which were put together as a power-point presentation.

Photograph [7] is a screenshot of the main UMES-NOAA summer camp webpage. Photograph [8] is a screenshot of a sample webpage developed by one of the campers.

Learning Outcomes

- Ability to surf the web to find specific information using various search engines.
- Exposure to FTP (File Transfer Protocol), uploading files, updating information and creating hyperlinks).
- Ability to use FrontPage and Netscape composer at a basic level and a rudimentary understanding of the underlying HTML code.

VII. Impact and Outcome of Project Activities

Middle school teachers collaborating in the project have reported that, 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 programs are listed below:

- 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.

- The design activities involving the moment machine and bridge design have provided the students with an understanding of the basic framework for engineering design process. This may well provide the foundation for creative design and project activities that the participants may participate in at the high school level.
- LEGO based design and programming activities have not only provided excitement for learning among 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.
- The NOAA Summer camp activities have heavily utilized computers and computer software that are likely to benefit the students in the future. The software tools that students have been exposed to include Powerpoint, FrontPage, Netscape composer, West Point Bridge Design, Robolab, RCX Code, and Not Quite C. The campers have continued to use computers effectively during the regular school year.
- 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. The teachers have also reported improvements in grades of some low performing students who participated in the camp.
- The schools involved in the camp have invested in setting up Lego based Robotics Laboratory and Science Workshops for the middle school students.

IX. Conclusion

It seems intervention at the middle school level with enrichment programs such as the one reported here is highly effective in terms of positively impacting the students' career choices. Some of the electives the students pursue during school helps prepare them for MSET majors. Without proper exposure, advice and motivation the school students do not realize the importance of these choices and fails to take full advantage of the school years to prepare themselves for MSET majors.

The campers are being monitored by the participating school teachers as they progress through school and start making choices for their electives. While the teachers have not provided us with statistical data on the students but they have provided several anecdotal evidences that goes to show the summer camp has and continues to have tremendous impact on the middle school students.

VIII. Acknowledgment

The MSET summer camp would not have been possible without the leadership of Ms.E.Cropper of NOAA and W. Richard Bull, Jr., Division Superintendent, Accomack County Schools, who had the vision and the interest of children at heart. The interest and support of two Principals – David Elebash (Principal, Parksley Middle School) and Chris

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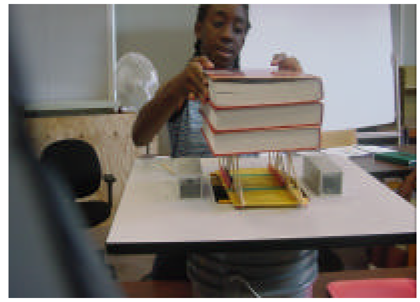
ABHIJIT NAGCHAUDHURI

Abhijit Nagchaudhuri is currently an Associate Professor in the Department of Engineering and Aviation Sciences at University of Maryland Eastern Shore. Prior to joining UMES he worked in Turabo University in San Juan , PR as well as Duke University in Durham North Carolina as Assistant Professor and Research Assistant Professor, respectively. Dr. Nagchaudhuri is a member of ASME, SME and ASEE professional societies and is actively involved in teaching and research in the fields of engineering mechanics, robotics and systems and control. Dr. Nagchaudhuri received his bachelors degree from Jadavpur University in Calcutta, India with a honors in Mechanical Engineering in 1983, thereafter, he worked in a multinational industry for 4 years before joining Tulane University as a graduate student in the fall of 1987. He received his M.S. degree from Tulane University in 1989 and Ph.D. degree from Duke University in 1992.

GURBAX SINGH

Gurbax Singh is a Professor of Physics in the Department of Natural Sciences at University of Maryland Eastern Shore. He earned a doctoral degree in the area of Quantum Electronics from the University of Maryland College Park in 1971. His current research deals with the trace detection of energetic materials using laser photo-fragmentation coupled with LIF or REMPI. His earlier work dealt with nuclear radiation effects on solid state devices, device physics, optical pumping of cesium with diode lasers to study light shifts and to make miniature atomic clocks, and nuclear instrumentation.

Photograph-1



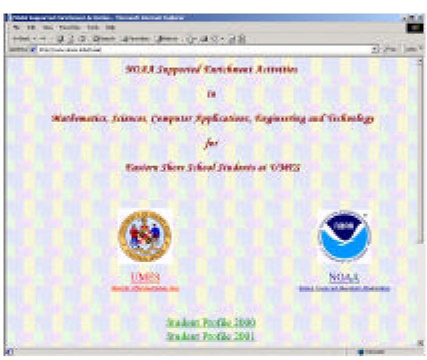
Photograph-2

Photograph-3

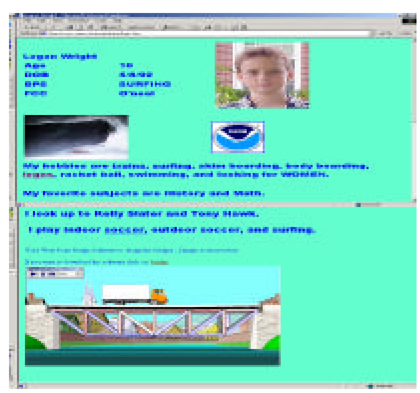
Photograph-4

Photograph-5

Photograph-6



Photograph-7



Photograph-8