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6.7 Mechanical, Aeronautical, and Aerospace Engineering

Some activities to examine Mechanical, Aeronautical, and Aerospace Engineering are:

1. Building a bridge out of popsicle sticks. Each group is given a fixed number of popsicle sticks and glue. They are to build a bridge which will span a fixed distance (6-12 inches) and support as much weight as possible. A set of fixed weights will be used to test completed designs for their strength.
2. Egg drop. Groups are given one egg and a shoe box and are asked to design a housing for the egg so that it will survive being dropped from as high a distance as possible. They can make use of any other materials that they can find. After designs are completed, testing consists of dropping the housings with egg from incrementally increasing distances until the eggs break.
3. Building a paper airplane to strike a fixed target. Each group is given a manila envelope containing markers, paper clips, plain paper, scissors, and tape. Their goal is to design a projectile out of only these materials which can be hand tossed and land as close as possible to a bulls-eye type target roughly 30 feet away. Distance to the target is measured from the projectile's first contact with the ground. Each group is allowed a fixed number of practice runs.

7 Future Plans

The plans we have outlined thus far must be developed in further detail. Our group will rely on the assistance of High School teachers and University Education faculty to develop materials suitable for freshmen high school students. We have found several science teachers at local high schools to assist in the curriculum development.

Of course, implementing such a project will require ample funding. We have approached the National Science Foundation with our ideas. We will also solicit funding from private companies, foundations, state, and local governments. Several Arkansas foundations have agreed to support part of this work, and these funds will be used as matching dollars.

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References

[1] Braukmann, James R., "Designing Technology Education Activities for Elementary Students," *The Technology Teacher*, Vol. 52, No. 8, pp. 23-26, May/June 1993.

[2] Carelse, Xavier F., "Technology Education in Relation to Science Education," *Innovations in Science and Technology Education, Volume II,* David Layton, Ed., UNESCO: Paris, pp. 101-112, 1988.

[3] Johnson, James R., "Technology Education: An Imperative," *The Technology Teacher*, Vol. 52, No. 2, pp. 3-5, November 1992.

[4] Lovedahl, Gerald G., "You Can Shape the Future," *The Technology Teacher*, Vol. 52, No. 7, pp. 18, April 1993.

[5] Mills, Jonathan W., "Stiquito: A Small, Simple, Inexpensive Hexapod Robot. Part 1: Locomotion and Hard-wired Control," Technical Report 363a, Computer Science Department, Indiana University, Bloomington, Indiana 47405, 1992.

[6] Nanjundan, Mohan and James M. Conrad, "A M68HC11 Microcontroller-based Stiquito Controller," in *Stiquito: Design and Implementation of Nitinol-Propelled Walking Robots*, ed. by J. Mills, IEEE Computer Society Press: Washington, D.C. (in preparation).

[7] "Math, Science, and Engineering Education : A National Need : Hearing before the Subcommittee on Postsecondary Education of the Committee on Education and Labor, House of Representatives, One Hundred First Congress, first session, hearing held in Kansas City, MO, May 1, 1989," U.S. G.P.O.: Washington, D.C., 1989.

messages, opening applications, and reading information from the Internet.

2. Students will operate a digital image capture setup, and "take a picture" of themselves. They can then transfer the image to their Sun workstation account, where they can view, edit, and print the image.
3. Using a breadboard and a Motorola M68HC11 microcontroller, students can assemble and run a Stiquito controller circuit [6]. The microcontroller would be pre-programmed to run certain walking gaits depending on control signal inputed by students.

6.5 Electrical and Materials Engineering

Electrical Engineers are concerned with applying scientific principles governing electrical phenomena to generate, distribute, and control electric energy. Applications range from the design of microscopic computer circuits to the development of large generating facilities.

Materials Engineers develop new compounds and examine their properties. Novel characteristics on new materials include superconductivity, the ability to transfer electricity, without resistance, at the speed of light.

Through facility tours and experimentation, students will gain a further understanding of the broad range of activities of an Electrical and Materials Engineer. Laboratory experiments can include:

1. A motor control experiment would acquaint the students with electrical circuits. Each student will control a fan by varying light on a solar detector. The basic principals of signal conversion, voltage and current will be discussed.
2. A digital logic experiment will be developed using "AND" and "OR" gates that implements a programmable alarm. A keypad will be included that will allow the student to key in an access code. If the access code is correct, a green LED will light up. If the access code is incorrect, a red LED will light up.
3. Concepts learned from the other two labs can be used to "control" the Stiquito robot, where the legs of the robot move faster if a solar detector senses brighter light.

6.6 Industrial Engineering

Industrial Engineering applies the engineer's problem solving approach to situations involving people, materials, machines, equipment, and facilities. Industrial Engineers look at the "big picture" of what makes society perform best - the best combination of human resources, natural resources and man-made structures and equipment. Industrial engineers bridge the gap between management and operations, dealing with and motivating people as well as determining what tools should be used and how they should be used.

The instructive mechanism proposed for the "Introduction to Engineering Concepts for High School Teachers and Students" project would be the Stiquito robot. Industrial Engineering workshops for teachers and students would encompass the following functional areas:

1. Facilities Design - the participants would be required to do a location analysis, a plant layout, and a material handling analysis for the production of x number of Stiquito robots. The participants would utilize various software packages in this endeavor (e.g. FactoryCad, AutoCad). The basic concepts of all these areas would be addressed before the actual modeling ensued.
2. Human Factors/Ergonomics/Methods Analysis - the participants would design an efficient methodology to assemble the robots. The design would take into affect work physiology, workplace design, design of controls and displays, and environmental effects on performance.
3. Simulation - the computer would be used to physically simulate the factory assembly of the Stiquito robot.
4. Engineering Economy - an overview of cost estimation and forecasting would be done for the production of the robots. A discussion of the different economic analysis procedures would be addressed, and an economic analysis performed for the robot production (e.g. present worth, rate of return).
5. Engineering Administration - organizational theory and management methods will be discussed and a management plan developed for the pseudo company to put into practice.

tion of fresh produce, processed foods, and other industrial products. From these systems, students can learn about the principles of electromagnetic energy, electronics, and computing technologies. Because the weather does not always cooperate for some research, a Biological and Agricultural Engineer must develop equipment that can better control the outcome of an experimental procedure. Engineers at the U of A use a rainfall simulator to do just that. By participating in the experiment, students can learn how the intensity and droplet size of a rainstorm affects the soil and the growing plants and nutrients that it supports.

6.2 Chemical Engineering

Chemical engineering applies problem solving to the development to situations involving the transportation, separation and production of chemicals and pharmacuticals. Chemical Engineering principles can also be applied to a wide variety of fields including material science, environmental cleanup, microelectronics and bioengineering. Investigation into the development and separations of materials will encompass the following experiments:

1. Separation of Two Metals Using the Bio-Polymer Chitosan. One of the major concerns in the chemical industry is the cleanup of waste streams and removal of toxins from the environment. This project demonstrates the use of the separation technique adsorption to remove metals from a water stream. Have the group pack a small tube with the chitosan and prepare a solution of CuCl2 and CoCl2 in water. Note that both the biopolymer and the solutions are not toxic. Have the students pipet the solution into the top of the packed column and observe the removal of the metals from the solution. The initial solution will be a purple color and the packed bed will be beige. After the removal of the CuCl2 and CoCl2 the column will be blue and red and the solution will be clear.
2. Fiber Formation from Recyclable Plastics. Each group is given samples of several plastics which are commonly used for household packaging (i.e. HDPE for Milk Bottles), a hot plate, aluminum foil and wood splints. The students are asked to heat the plastic pieces on the hot plate to melt the plastics and use the wood splints to draw fibers of the plastics. Have the students vary the draw rate and polymer to obtain the longest fiber.

6.3 Civil Engineering

Civil Engineering research encompasses a number of diverse research topics including transportation, water treatment, structures, pollution control, and power generation. The Civil Engineer designs and builds projects coordinating natural and human resources for urban and regional development, such as: small office buildings, bridges, dams, highway systems, public water systems, and flood diversion controls.

Civil Engineering concepts can be demonstrated by several activities, including:

1. Strength of structures. Students will create concrete cylinders using metal support rods, plastic/resin support rods, and no support rods. They will then test the strength of the cylinders by applying pressure until the cylinders break.
2. Students will build dams of varying materials, thicknesses, and depths. They will then examine how well their structure hold water in a "simulated lake."
3. Students will design an interstate highway using computer simulation. They will then examine traffic flow based on varying simulated capacities.

6.4 Computer Systems Engineering

Computer Systems Engineers explore the potential of computers, seeking novel applications to increase productivity and quality of life. The design and implementation of computing systems emphasizes interface technology and a balance of hardware and software principles. Computer System Engineers are often asked to bridge the knowledge gap between Computer Science and Electrical Engineering.

Students will be given a tour of the campus computing resources, including mainframe, mini, and microcomputer labs. They will be exposed to the technology available to businesses for document preparation, accounting, and research and development. Investigation into software and hardware-based disciplines will be achieved through several activities:

1. Students will be given login IDs and instructions on how to log into the Unix-based Sun workstations. Students will experiment with sending

tation, Stiquito recap, evaluation of workshop.

5 Student Competition and Workshop

The student competition will be conducted at the high schools by the teachers during the Fall 1995 / Spring 1996 school year. Teams of two students will build the robot and devise an innovative application for the robot. The winning team from each school of the competition will be invited to attend a one week summer workshop. High schools will be given autonomy in running their competition and choosing the winning team. It is our hope that the students selected will be judged on merit and creativity.

These student workshops will take place in five, one week sessions at the University of Arkansas, Fayetteville. During the workshop, the students will learn about engineering and the role of engineers in society. They will also meet in small groups and improve on their Stiquito design with the assistance of other students. University and High School Faculty will lead engineering activities, conduct tours, and provide assistance to the team Stiquito building.

The following topics will be discussed and the activities will be held during the Summer 1996 student workshops:

Sunday: Arrive on campus, campus tour, tour of engineering facilities, icebreaker activities, team building exercises, introduction of the program.

Monday: Discussion of Stiquito robot, group assembly of Stiquito robots, introduction of engineering workstations, women and minorities in engineering.

Tuesday, Wednesday, Thursday: Group discussions of each engineering discipline, including activities. Disciplines include Biological/Agricultural, Chemical, Civil, Computer Systems, Electrical/Materials, Industrial, and Mechanical/Aeronautical/Aerospace Engineering.

Friday: Applications of engineering, NASA presentation, Stiquito recap, evaluation of workshop.

Minorities and women are underrepresented in all engineering disciplines. The University and the faculty participants are in a unique position to involve minority students in this program. Our program includes two minority faculty participants. These faculty members will participate in the discussion on women and minorities in engineering, and serve as role models for others.

We will create 100 scholarships for minority students to attend the workshop. We also plan to visit the Arkansas Delta region (an area with a high concentration of low-income minorities) to interest students in attending the workshop.

Forty more high school teachers will be invited to participate to learn the program during the Summer of 1996. Sixty teachers from the previous summer will serve as team leaders and chaperones.

6 Engineering Activities

The highlight of the workshop will be the exposure to modern engineering and research facilities at the University and local companies. Hands-on activities at these facilities will help foster a better understanding of the Engineering disciplines listed below.

6.1 Biological and Agricultural Engineering

Biological and Agricultural Engineers use principles of both science and engineering to solve real problems involving biological, mechanical, electrical, hydraulic, and structural systems. These principles are used to solve problems and design new processes and equipment for food and agricultural industries. A Biological and Agricultural Engineer might design processing equipment for packaged foods, image analysis equipment for quality inspection of food and agricultural products, and suspension systems for vehicles that must cross levees in a rice field.

In order to help students understand what a Biological and Agricultural Engineer does, a demonstration of the principles of hydrostatics, which applies to many of these areas, was developed. Students can observe that by simply pouring an ordinary pitcher of water, weighing no more than five kilograms, into a small tube connected to a platform supported by an inflatable bladder, that they can lift a person weighing as much as 100 kilograms. Of course they must raise the pitcher to about two meters and the person is lifted only several millimeters.

Biological and Agricultural Engineers have also designed countless image analysis systems for inspecof high school students who are interested in engineering. We have targeted high school freshmen so that interested students enroll for engineering-preparatory courses later in high school.

3 Stiquito Robot

The vehicle for introducing engineering will be Stiquito. Stiquito is a small, simple, inexpensive ($3) hexapod robot developed by the Computer Science Department of Indiana University at Bloomington [5]. Even though the Stiquito is a small prototype originally designed to be used in research, it is used worldwide for educational purposes. This device employs several concepts from electrical, mechanical, and chemical engineering. Applications of the robot would encompass computer and industrial engineering concepts as well.

The hexapod robot Stiquito does not use motors for its movement. Instead it uses nitinol wire actuators [5]. Nitinol wire is an alloy of nickel and titanium. When current is passed through these wires, they heat and contract. When the current is interrupted, these actuators return to their original state. The speed these actuators can move each leg of the robot depends on the ambient temperature. The actuators can be activated individually or in groups to give the robot different gaits. The prototype robot does not lift its leg for motion but slides it as it moves. Other operating modes can be incorporated by additional actuators. A drawing of the Stiquito robot is shown in Figure 1.

Figure 1: The Stiquito Hexapod Robot

The uses and applications of the Stiquito robot are limited only by one's imagination. One example discussed in class is cleaning floors of a building. Imagine that hundreds of these robots are left to roam the halls of an empty building at night. These Stiquitos could sweep a small portion of the floor, and return to a safe "garage" before employees return the next morning.

4 Teacher Training

The teacher training workshop will take place in two, one week sessions during the summer of 1995. One high school teacher from each of the state's 330 schools will attend one of the one week workshops at the University of Arkansas, Fayetteville. During the workshop the teachers will learn about engineering concepts, the Stiquito robot, and the student design competition. They will also be exposed to technology used in engineering companies which they may not otherwise see.

A workbook of suggested engineering lectures and activities will be provided to the high school teachers. Teachers will work on several of these activities during the week, but many more will be detailed, since time will not allow completing all activities.

The following topics will be discussed and the activities will be held during the Summer 1995 teacher training sessions:

Sunday: Arrive on campus, campus tour, tour of engineering facilities, icebreaker activities, team building exercises, introduction of the program.

Monday: Discussion of Stiquito robot, group assembly of Stiquito robots, discussion of the design competition within high schools, application procedures for additional women and minority student scholarships, women and minorities in engineering.

Tuesday, Wednesday, Thursday: Group discussions of each engineering discipline, including suggested classroom activities. Disciplines include Biological/Agricultural, Chemical, Civil, Computer Systems, Electrical/Materials, Industrial, and Mechanical/Aeronautical/Aerospace Engineering.

Friday: Applications of engineering, NASA presen-

Introduction to Engineering Concepts for High School Teachers and Students*

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1 Introduction

The future of the United States lies in the ability to use its resources to build a technological economy. Our most important resources are the young men and women still in secondary schools. Our objective is to introduce engineering and technology to Arkansas high school students. This objective would be accomplished with the assistance of high school teachers. Initial plans include: high school teacher training, summer of 1995; high school competition, fall/spring of 1995-1996; and high school student workshop, summer of 1996. This paper describes the organization of this pilot program, and discusses the nature of engineering topics and activities presented in the workshop.

The vehicle for introducing engineering will be Stiquito, a small hexapod robot. This inexpensive ($3 each) device employs several concepts from electrical, mechanical, and chemical engineering. Applications of the robot would encompass computer and industrial engineering concepts as well.

The teacher training workshop will take place in two, one week sessions. High school teachers will attend a workshop at the University of Arkansas, Fayetteville, and learn about engineering, the Stiquito robot, and the student design competition. The student competition will be conducted at the high schools by the teachers. Teams of two students will build the robot and devise an innovative application for the robot. The winning team from each school of the competition will be invited to attend a one week summer workshop at the University of Arkansas, Fayetteville. During the workshop, the students will learn about engineering and the role of engineers in society, and participate in engineering activities.

*Contact James M. Conrad for information about this program. Addresses are at the end of the paper.

2 Audience and Goals

Many have written of the need for technology education in primary and secondary schools [1, 2, 3, 4, 7]. At a hearing before the Subcommittee on Postsecondary Education of the Committee on Education and Labor, U. S. Congress House of Representative, educators, businessmen, and politicians discussed the importance of science and technology to the future of the United States [7]. One startling statistic is that, in a study of 1982 high school seniors, only 23% were interested in science and engineering disciplines. As high school sophomores, only 24% of these students were interested in science and engineering.

The policy options to improve science and engineering education include recruitment - enlarging the pool. Specific options include [7]:

- Intervention programs: increase interest and readiness for science and engineering majors; transfer the lessons from successful programs; encourage sponsorship from all sources.
- Informal education: increase support of science centers, TV, fairs, and camps.
- Opportunities for women: provide special support and intervention.
- Opportunities for minorities: provide special support and intervention.

Although the State of Arkansas has a healthy economy, it is mostly agriculturally-based. It is obvious that Arkansas is not a high technology state, but it needs to become so if it is to advance into the twenty-first century. What is needed is a way to infuse excitement of engineering into high school curriculum. One effective way is to "teach the teachers," and have them reach the high school students.

The major goal of this project is to enlarge the pool