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Attracting k-12 Students into the Engineering Pipeline Early

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Abstract

This paper addresses some of the American Association for the Advancement of Science and the National Science Teacher's Association's concerns about science and engineering education in America, especially in the K-12 grades. The preparation of our American K-12 students for engineering universities continues to be a problem. This paper presents specific actions that can be taken by ASEE members and other engineers and scientists to ensure that students will be entering the "Engineering pipeline" for future generations. The lack of motivating experience and hands-on projects in the early K-12 grades in the American public school system turns students away from careers in engineering. The paper presents a national award winning, after-school program where students 4th grade through high school become engineers and scientists, by building robots, bridges, boats, cars, airplanes, towers and scores of other hands-on projects. The Future Scientists and Engineers of America (FSEA) curriculum consists of over 50 hands-on projects. Engineers, companies, universities and communities, team with teachers and schools to motivate and excite students with hands-on science, mathematics, engineering and technology.

Introduction

There are many indications that suggest that the American K-12 education system is failing to provide students prepared and motivated for the science and engineering "pipeline". The views frequently expressed by middle and high school students are that science and mathematics are hard and boring and not fun and exciting. The enthusiasm and excitements evident in a large percentage of elementary school children disappears in most middle and high school students. The concerns about K-12 education are expressed by universities with decreasing engineering enrollment and with students lacking basic skills. The National Science Board states that the number on native-born science and engineering graduates entering the workforce is likely to decrease unless the nation intervenes to improve success in educating S&E students from all demographic groups.

The purpose of this paper is not to rehash all the studies that show a change is needed, but to discuss a program which is based on some well established methods of capturing the excitement of students early and maintaining that attention and excitement throughout K-12. This program is not a simple magical "silver bullet", but rather one which is based on a systematic approach which involves the entire community in a shared responsibility rather than a "blame game". It is

well known that "doing science" results in basic understanding and long term retention, and yet there has been a steady movement away from "hands-on" to lecture and ineffective memorization.

Goals

There are four major goals for this model K-12 program.

1. To provide for these needs with a program that has the potential for being available in every public and private school in America.
2. To make a systemic change both in participation and in assumption of responsibility in teaching Science, Mathematics, Engineering and Technology, (SMET). It is imperative to get local colleges, universities, businesses and community to participate since they are the beneficiaries of the effort.
3. Introduce excitement and fun into learning SMET and parity for girls and minorities in numbers and participation**.**
4. Finally, the goal is to use informal science so it will be a major supporter of formal SMET education in filling the pipeline for colleges, universities and the future technical workforce.

The Need

According to the National Science Teacher's Association, the Third International Mathematics and Science Study Repeat TIMSS-R validates the results of the 1995 TIMSS study "that after 4th grade, students in the United States fall behind their international peers as they pass through the school system[1]". A recent study by the Organization for Economic Cooperation and Development (2003) shows American 15 year-olds ranked 19th in mathematics and 14th in science.[2] In this same study Education Secretary Rod Paige is quoted as " I don't think we have come to grips with the urgency of the situation". Even though the U.S. spends substantially more than other countries, a number of studies and experiments have shown the money is not the ultimate solution.

A recent poll, titled Facts of Science Education IX: Americans' Views on the Role of Science and Technology in U.S. National Defense, respondents said improvement in K-12 math and science education should be a national priority.[3] The study commissioned by Bayer as a part of Making Science Making Sense MSMS program, showed that 90 percent said that science and technology is critical for national defense, 80 percent for terrorist threats and 75 percent for homeland security. Ninety percent of the respondents believed that students do not have the necessary math and science skills. Eighty percent believed that elementary school teachers are underqualified to teach science. Eighty six percent said that textbook-based education should be replaced by hands-on science learning.

Businesses, colleges and universities in southern California are all experiencing the severe shortage of technically trained personnel in science, computer science, and engineering. The effect is so critical that some businesses curtail their growth and tend to focus their efforts on

immediate fixes, such as importing foreign workers or paying exorbitant salaries for luring employees from other companies.

These are current needs and issues, but even more critical is the shortage of technology focused students in the K-12 pipeline. Children need to be motivated by hands-on project experience, by having access to technical companies in the area and to research activities at the colleges and universities. Starting in elementary school children are being turned off by the lack of opportunity to experience the fun of science and technology. Technology is changing so rapidly that children and teachers are unaware of university research and workforce needs. The need is growing exponentially and it will take an integrated effort of the entire community to meet the 21st century needs. In California, and many other states, this challenge can only be met by including a much higher proportion of groups currently under represented in technology: specifically women and minorities.

Hands-on

Hands-on activities are acknowledged by almost everyone as superior to lecture or reading. Figure 1[4] indicates how powerful hands-on experience is in retention of things learned. Doing science however has many other even more powerful benefits. Discovery, where a complete step-by-step procedure is not provided, is one of the most important features of hands-on activities. The opportunity to fail in the discovery, hands-on approach is a powerful learning tool. Many facts in science and engineering can only be understood by hands-on projects. Hands-on projects that result in practical applications have the added benefit of demonstrating the importance and value of science and mathematics.

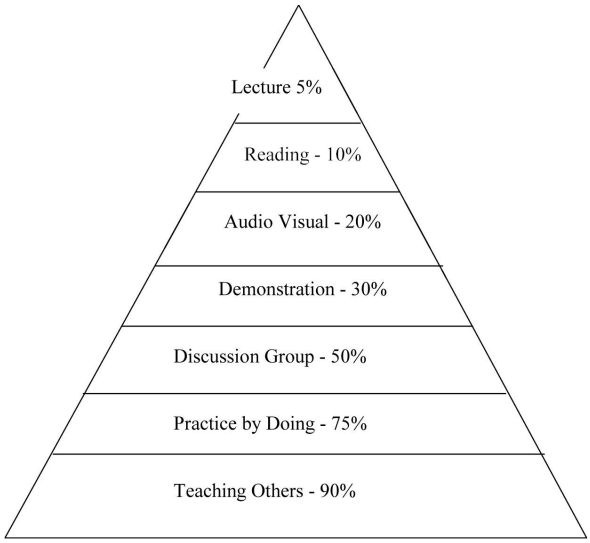

Figure 1 Learning Pyramid, National Training Laboratories, Bethel, Maine, 1998

The Need for Emphasizing Technology Education

There is a problem of scientific and technological illiteracy in the United States with a majority of the population, as concluded and documented in national surveys by Jonathan Miller. The National Science Commission states that the general public should have both science and technology knowledge and facility with problem solving strategies so they can cope adequately with their personal lives, their work and their role as decision makers in our technological society.

The U.S. Labor Department, concerned about changes in the world of work examined the changes and implications for learning. The Secretary's Commission on Achieving Necessary Skills (SCANS) produced a two part report[5] defining competencies, and a foundation of skills and personal qualities needed for employment, focusing on "responsible employees comfortable with technology and complex systems, skilled as members of teams, and with a passion for continuous learning."

Another often-stated need is the recruitment and training of enough competent scientists and engineers to maintain the leadership necessary for the nation's economic well being. Students need to be interested and involved in science and engineering in their early school years in order to make decisions about technology related careers. The U.S. labor force is changing and is soon expected to be comprised of over 70 percent of minorities and females. Minorities and females are not choosing to follow science, engineering and technology paths and receive little encouragement from home or school.

FSEA: Learning About Technology Education in an Informal Setting

FSEA provides an opportunity for teachers, parents, and the community to understand the importance of technology education and the preparation their children are receiving for a range of career opportunities.

An FSEA project begins with a problem to be solved in a real context. Students explore alternative solutions to the problem before designing and building a prototype. The opportunity to integrate mathematics and science in an informal setting enables them to select and test the proposed solution to the problem. Experimenting with the developing prototype engages them in math and science concepts and explanations. A review of technology and engineering projects reveal that FSEA is unique in offering students a program that is developmental from grades 4 through 12 and a system of achievement, with certificates that can be filed in their personal assessment profile, as endorsed by the SCANS Report of the U.S. Department of Labor.

Needs Met by FSEA

- Students see the need for mathematics and science through the hands-on projects and are motivated to learn.
- Students and teachers have contact with colleges, universities and industry, especially as it relates to science, engineering, and technology. FSEA brings industry into the classroom.

- FSEA clubs have a high female and minority representation in elementary schools and the opportunity to continue through middle and high school. Girls also express surprise at their own abilities in these areas.
- FSEA offers colleges, universities and industry an opportunity to impact elementary, middle and high schools in a structured program with hands-on projects.
- Hands-on learning is provided in the areas of science and technology, which meets the needs of educators by providing models.
- FSEA is the only national structured program which provides elementary through high school advancement in science and technology, paralleling job lines in industry from Technician to Engineering Specialists or Senior Scientists.

FSEA Clubs

FSEA clubs consist of 25 students in elementary, middle or high school. Elementary school clubs start in the 4th grade. The clubs can be a single grade or span several grades since FSEA is an advancement program spanning grades 4-12. A school may have several clubs in order to accommodate as many interested students as possible. Participation in FSEA is voluntary and special effort is made to encourage female and minority students to take advantage of this exceptional opportunity.

Sponsors

Each club is sponsored by a local organization. Typical sponsors include small and large businesses, technical societies, colleges, universities, civic organizations and parent-teacher organizations. FSEA provides a unique opportunity for an organization to become effectively involved and share responsibility in the local education process.

Sponsor responsibilities include:

- Provide the funding. ($60 per year per student, $1500 for 25 students)
- Provide or help recruit mentors
- Recruit students from local college or university.
- Add the company or organization identity to the club
- Promote FSEA in other schools and businesses until it is available in every K-12 school

Hands-On Projects

FSEA projects are designed to stimulate the process of technical inquiry and by doing so stimulate interest in mathematics, science and technology. FSEA projects have many unique characteristics including:

- Hands-on, not just demonstration
- Creativity, discovery and problem solving
- Grade levels 4-12
- Designed for teams of 2-4
- Performance criteria, including cost trade-offs

- Many areas of science, mathematics and engineering
- Complete package provided including project material, write-ups, videos, certificates, and awards.

Schools

FSEA club meetings take place at the school.
School responsibilities include:
- Adopt FSEA as a sanctioned after-school activity and publicize it with other school activities.
- Provide a teacher to participate in the club.
- Provide a meeting place.
- Provide a place to store project material.
- Recruit a parent coordinator.
- Help to recruit student FSEA members.
- Assist in recruiting mentors and sponsors.

Mentors

A team of volunteers – two mentors, one teacher and a parent coordinator, conduct each FSEA club. The mentors can be employed or retired engineers, scientists, technicians or people with other technical backgrounds, as well as engineering college students and professors. For elementary school projects a technical background is desired, but not required. Parents should be encouraged to volunteer as mentors.
Mentor responsibilities include:
- Present the project goals and objectives at the weekly one-hour FSEA club meeting.
- Answer questions and suggest possible research sources. FSEA provides most background material.
- Provide direction and assistance as required.
- Relate projects to personal work experience when possible.
- Describe sponsoring organization's activities and products.
- Evaluate teams' performance and select winners.

Teachers

Each FSEA club must have a teacher who is present and participates in each FSEA meeting. The training obtained by the teacher(s) in FSEA sessions can provide for more hands-on activities in the regular classes.
Teacher responsibilities are:
- Select a place to meet.
- Secure parent approval slips. (See Student Application forms)
- Collect the $5 membership fee. (Scholarships are provided if necessary to waive fees)
- Maintain discipline

Regional Directors

An FSEA region can consist of a few schools, a school district or larger geographical area. The Regional Director provides guidance for FSEA clubs in the area.
The responsibilities include the following:

- Promote and publicize FSEA.
- Recruit sponsors, schools and mentors.
- Conduct workshops.
- Sign off partnership agreement between the sponsoring organization and the school.

Evaluation Summary

In conjunction with a National Science Foundation grant, Science Learning Incorporated, SLI, completed an evaluation of the Future Scientists and Engineers of America program. This evaluation study was designed to determine the effectiveness of FSEA clubs in creating positive changes in participants. Participants in this study included teachers, industry sponsors/mentors, and students. Data were collected over a six-month period in 1997 using a methodology, which combined written questionnaires and semi-structured interviews.

A second evaluation of FSEA was conducted in 2002 by Marybeth Song PHD and funded by the Boeing Corporation.

Teachers

The majority of teachers and principals felt that a student's participation in FSEA positively impacted his or her knowledge of and attitudes toward science, mathematics and technology. Results indicated stronger agreement among teachers that FSEA had improved student attitudes toward science than for improving student knowledge about science. Teachers reported that FSEA participants had become more empowered, confident problem-solvers as a result of FSEA participation. Some teachers specifically noticed this change among girls.

Nearly all of the teachers and principals felt that FSEA would positively impact technical education if implemented throughout the school district, positively impacting more students' scientific knowledge and skills, as well as, increasing their interest in and enthusiasm for science. These views should be encouraging to FSEA to further expand the program.

The mentors were considered critical in improving student understandings of work and career. Mentors' direct discussion of their work and career were useful to students, as was their ability to model positive qualities such as cooperation, teamwork and problem-solving tenacity. In addition, FSEA activities were seen as enabling students to more fully appreciate science and engineering careers.

Almost half of those surveyed described that, in addition to FSEA, their schools collaborate with local industry through their science curriculum or science-based extracurricular activities. This collaboration consisted mostly of invited guest speakers, school field trips to businesses, school-based competitions facilitated by professional engineers, material donations and advice given by

experts. The teachers agreed that the student experience in FSEA went way beyond the experience the students were provided in the classroom.

Industry Sponsors and Mentors

Industry sponsors and mentors regarded students' participation in FSEA as an opportunity to expose students to careers, duties and the working world of scientists and engineers, as well as, an opportunity for them to develop the youth of the nation and potential employees.

Industry sponsors and mentors felt that students learned important work-related skills or information such as teamwork skills, problem-solving and planning skills, and thinking, analytical and communication skills.
Sponsors felt that the FSEA collaboration with schools allowed them to contribute back to the community; motivate and/or inspire students to pursue science careers; help teachers in their teaching of practical skills; and help others understand the importance of what they do as a company. Furthermore, it was felt that such collaboration would ultimately provide a better future workforce; build better community relations and better image for the company; and improved company morale and personal satisfaction among employee. Sponsors and mentors felt positive about their experiences with FSEA and believed that they had gained an increased appreciation for the nature of student learning and students' interests, and the roles and duties of the teachers. However, they did not feel particularly empowered to influence K-12 education in general, but sensed a greater level of impact on their local schools through their participation in FSEA.

Industry sponsors and mentors almost entirely agreed that business had a responsibility toward educating students which included fostering and investing in the future scientists and engineers of the American workforce and to promote education and/or support education generally.

Students

Students thought that they learned from their participation in FSEA in terms of increased and improved knowledge of science, increased and improved cooperative learning skills, improved teamwork skills, and improved thinking and design skills.

The things students liked about FSEA related to opportunities to learn new things, the fun nature of the program, opportunities to make things, working in teams and the positive relationships they develop with teachers and mentors. Overall student attitudes toward FSEA were very positive changes in students' understanding and attitudes toward math, science and FSEA were positive. All students developed a greater appreciation for teamwork as a result of their participation in FSEA. Elementary school students gained increased appreciation for what engineers do and for why science and engineering are important.

Many students also claimed that they felt somehow different or special compared to other students because of their participation in FSEA. Students considered it to have been a privilege to be selected to participate in FSEA and thought that they learned more things than other students due to their FSEA participation.

Overwhelmingly, students were of the view that engineers build, design and improve things. Other themes relating to students' views on what engineers do related to improving life, solving problems, making things work/or repairing things and inventing new things. The majority of students considered science and technology to be important because it improves life and/or helps people.

Teachers and principals perceived FSEA to have empowered students by motivating them to pursue careers in science and engineering, as well as helping them to better understand science and engineering careers. Many teachers believed that students gained insights into the duties, responsibilities and attributes of scientists and engineers and that the students see the relevance of FSEA activities to real-world engineering problems. Industry sponsors and mentors believed students benefited through their exposure to the careers, duties and the working world of scientists and engineers. Students, particularly those in high school clubs, felt that FSEA had inspired them to pursue science and engineering-based careers.

In conclusion Future Scientists and Engineers of America is a program that makes a difference. FSEA can inspire, motivate, and excite students to pursue engineering and technology careers. FSEA can and does form significant partnerships between education and business helping to bridge the gap between learning and earning.

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