Paper Session III-C - Using Space in Project Based Education

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ABSTRACT

The work described in this abstract is supported by an ARPA/TRF grant which is managed through the NASA management office at the Jet Propulsion Laboratory. The grant number is NAG7-1.

This paper discusses the Sierra College Small Satellite project, its impact on students and Space Technology curriculum development. Sierra's program has led to the development and implementation of a hands-on Space Technology curriculum that uses the design and manufacture of Get Away Special (GAS) projects as its focus. (NASA's GAS program allows educational institutions to fly a payload aboard the Space Shuttle for as little as $3000.) Students involved with this program have already flown a GAS payload which measured backscattered ultraviolet radiation. The students are currently designing a small satellite which will fly in early 1997. This innovative program requires students to manufacture their hardware designs. One of the primary goals of the program is to create a direct link between design and manufacturing processes. The students are gaining an appreciation of what it takes to create a sophisticated product on a real schedule. The inherent excitement of a space project is a great motivator.
Traditional Engineering Curricula

Over the past fifty years undergraduate engineering has been taught in this country with a heavy emphasis on analysis-based design. Manufacturing methods have been relegated to the backwaters of engineering education. In the early 1940's a mechanical engineer was expected to complete a substantial number of units in hands-on manufacturing. Currently a ME student pursuing a B.S. degree is typically required to take only a 1 unit course that involves hands-on manufacturing.

The reasons for the shift away from a hands-on approach towards an analysis-based approach are well documented. During World War II engineers were widely regarded as the plumbers of the physicist, because of an almost exclusive focus on manufacturing in the engineering degree programs of the 1930's. (1) It was clear to many engineers who left academia to work on complex systems such as RADAR that engineering education needed more of a grounding in science. It was also clear that scientific analysis of engineering problems would lead to better solutions. The manufacturing emphasis of engineering programs was gradually decreased as more time and effort was devoted to intensive training in math and science.

The pendulum has now swung completely away from manufacturing to our present state of engineering education. Undergraduate engineering students spend virtually all their time engaged in mastering complex mathematics used to analyze designs. Very little consideration is given to the relevance of the mathematics given the manufacturing methods available. Most undergraduates experience real design problems only during their senior project. The argument made for putting off working on a serious design is that the students don't have sufficient knowledge before they are seniors or graduate students. Our view is that this is very late for students to consider the problems encountered when a real product is manufactured.

One result of the analysis-based design focus of engineering programs is the creation of paper engineers, who design products with little knowledge of how they are to be manufactured. Designs generated by engineering departments are generally thrown over the fence into manufacturing only after the design is complete. When the designs for these products reach the shop floor, those responsible for fabrication are baffled by the engineer's approach.

We are not suggesting the abandonment of analysis-based design, instead we believe that undergraduate engineering students need to temper their analysis classes with course work in hands-on manufacturing techniques. We further suggest that a real and complex project should be at the core of an engineering curriculum. Current methodology usually has students take at least two years of math and physics before any application to real-world problem solving is attempted. The purpose of this course work is often a mystery to the students because the relevance of the knowledge to the process of engineering is generally ignored. Early involvement in manufacturing methods and project design allows students to see the practical application of the science and math skills they are learning. Pulling these disciplines out of the abstract realm gives students motivation to study. Focusing education around the creation of a project, with its firm deadlines and reliance on teamwork to achieve completion, teaches lessons that are extremely valuable to a future employer. Our experience using Space Shuttle experiments designed and manufactured by our students has been very positive in achieving these goals.

The Arguments for Space in Project-Based Education

There are several advantages to an education that has a space project as its central theme. The first of these advantages is that excitement is built into the program. Space seems to create a
strong interest in people without regard to the age group. We have presented aspects of our program to diverse groups ranging from second graders to middle aged adults and the response is always overwhelmingly positive. Our projects have received extensive newspaper and television coverage, which has generated enormously widespread enthusiasm in the community. In our students, the knowledge that they are working on an experiment destined to fly aboard the Space Shuttle is a very deep motivator. Students routinely work on the projects during holidays and breaks. On several occasions we have had to force students to go home and sleep. We know of no other project that motivates students as much as Space Shuttle experiments.

The second major benefit we have found in project-based education is the teamwork requirement. Space Shuttle experiments are so complicated that no single person can understand the details of every subsystem. This requires students to learn to communicate effectively within their team and with teams working on other aspects of the design. In addition, students must learn to work with individuals majoring in disciplines as diverse as physics and photography. Engineers are often criticized for a lack of communication skills. A project-based approach to their education builds their interpersonal and presentation communication skills.

Firm deadlines, with pressures from outside the college, are another great advantage of using space in project-based education. Students often view their course work as a series of contrived problems with little relevance to the world beyond college. Pressure from an outside agency, such as NASA, gives the student's work additional intensity. They realize the project they are working on must meet a schedule in order to make a particular flight, and that pressure makes the learning experience close to that of a typical industry setting.

Manufacturing knowledge and skills are naturally discovered by the students as the project progresses. Students are very motivated to understand and master manufacturing techniques since their designs must actually be built. This takes our students several levels beyond the "let's build a hammer" attitude we have witnessed in typical manufacturing courses. The students involved with our program are intrinsically motivated by the project.

The realization that knowledge is unified and not a group of separate disciplines is also made clear to students who work on the project. Our Space Shuttle experiments draw knowledge from virtually every engineering and science discipline. Students must apply the knowledge they have acquired from lectures and readings. The application of knowledge is where deepest learning takes place.

Our methods are not without one major drawback, and that is the time required by the instructional staff. Project-based learning is not easy to direct. There are always unexpected twists, turns, and setbacks in a complicated project. This invariably takes more instructor time than a tried-and-true lesson plan. Hypothetical problems with previously determined solutions make a teacher's job relatively easy, but they can't touch the excitement of a real project. Instructors must be highly motivated and willing to make the extra effort that quality education demands. They must also have the support of like-minded faculty members and a forward-thinking school administration. A new approach to education that requires extra work and a change of the status quo will not be met with universal enthusiasm, but we believe the results are well worth the effort.
History of Our Program

Get Away Special

NASA's Get Away Special (GAS) program allows educational institutions to fly experiments aboard the Space Shuttle for as little as $3000. This fee covers the launch and associated services for a 2.5 cubic foot, sixty pound, fully self-contained payload (see figure 1). Even though the cost of flying educational payloads is very low, few schools have taken advantage of the GAS program. There are two most probable reasons for the small number of school payloads. The first is the time required to manufacture the support equipment as well as the actual experiment. The second is the very demanding safety process that all GAS payloads must go through before they are qualified for flight.

GET AWAY SPECIAL
SMALL SELF-CONTAINED PAYLOADS
CONTAINER CONCEPT

Another possible reason is a general lack of awareness of the GAS program. The Sierra College program got its start as the result of a happy accident. During the Summer of 1989 a call was made to Goddard Space Flight Center looking for some information on fault tolerant computers used on-board spacecraft. It was anticipated that this would be a nice peripheral topic for an introductory computer science course. A telephone transfer error connected GAS Technical Liaison Officer, Mr. Larry Thomas, who proceeded to explain the GAS program. The first GAS class was offered at Sierra College in the Fall of 1989. A physician in Fresno, California, Dr. Ronald Nelson, donated his $500 reservation with the stipulation that Sierra College students design, manufacture and fly an insulin-tag experiment.

Figure 1: GAS Payload Concept (2)
With a $17,000 grant from the California Community College Chancellors Office, Dr. Nelson’s reservation, and forty eager students, we began to create a Space Shuttle payload. Our first step was to meet with Dr. Nelson and discuss his process for tagging insulin. It was clear from the beginning that our task was non-trivial. The process involved mixing three fluids and a dry powder, and then washing the mixture through dialysis. One of the fluids was flammable, which created a very serious safety problem. The students came away from this meeting with a block diagram of the mechanism and a time sequence for the process.

Our next step involved multiple iterations of the design. It was during the design iterations that the microgravity environment of space forced our students to think in a very different way. The temptation was to think in terms of a design that could use gravity to assist with fluid transfers. The microgravity environment is a great way to make students think creatively and seek innovative solutions.

Once a design for the primary experiment was agreed upon, we started to manufacture the necessary stainless steel containers with their intricate o-ring sealed pistons that would pump fluid out of one vessel and into another. We all went down to the manufacturing area with its manual lathes and milling machines where we were greeted with reserved enthusiasm. Several students spent the Spring and Summer sessions of 1990 learning how to operate the various machines.

The lack of any team members with manufacturing experience was immediately obvious in the results of our metal shaping efforts. We had designed a great deal of hardware that couldn’t be built with the available equipment. Although the team had plenty of energy and creativity, the lack of experience in actually building things led to impossible designs. It was realized at this time that manufacturing experts must be part of the design team. We had made a classic error in our organization—we had built a wall between manufacturing and engineering. (3)

People with knowledge of manufacturing methods were recruited to the team, including students, faculty members, and advisors from outside industry. The designs became more simplified, and a completed payload was integrated at Kennedy Space Center in February, 1993. The experiment flew on STS-57 and was very successful.

**ARPA TRP Grant**

After the flight of our first GAS payload, an application was made for an ARPA TRP grant in the area of manufacturing engineering education. At the core of the outlined proposal was the development of a microsatellite by students and staff at Sierra College with assistance from a group of displaced aerospace engineers. This would be the project that students would use as the focus of their studies. The grant was awarded in November of 1993.

The ARPA grant, which is managed by the NASA management office at the Jet Propulsion Laboratory in Pasadena, California, has three major goals. The first of these goals is the creation of a multitrack Space Technology degree and transfer program. Students earning a heavily interdisciplinary Space Technology degree will use a project as the focus of their studies. The second goal of the grant is to create standard flight-qualified GAS hardware including a support structure, computer, and battery box. This standard hardware will allow other schools or industry users to create Space Shuttle experiments with minimal effort. The final outcome required for the grant is the design, implementation and flight of a microsatellite. The satellite will use a spectrograph to measure the ozone layer and take digital images to characterize the target area.
We are coming to the close of our first year of the three year period of the grant. To date we have created a four track Space Technology curriculum and we have created a standard 2.5 cubic foot GAS structure. The structure was flown, along with prototype versions of the instruments we plan to use on our microsatellite, aboard the Space Shuttle Discovery in September of 1994. The payload performed flawlessly, recording over 30,000 spectrograph readings. A follow-up GAS flight is scheduled for October of 1995. It will test improved versions of the instruments and make use of a standard computer developed for use in GAS experiments and the microsatellite.

Concurrently, the small satellite technology class has worked on the design of the satellite. In the Fall, 1994 semester the class was divided into design teams, each of which created a mock-up of their satellite design. The best elements of the designs were combined to create a preliminary structure, which will be built in the Spring of 1995. The Spring, 1995 class has been divided into specialized teams to develop prototypes of the various satellite sub-systems. The project is proceeding on schedule, and the students are participating with genuine enthusiasm.

Summary/Conclusion

To be effective, education must constantly adapt and evolve to match the needs of a rapidly changing world. Advances in technology and changes in the world economy require today's engineers to have an understanding of manufacturing processes as well as the ability to work as a member of a diverse team. Students are best served by an early exposure to this knowledge and type of working environment. We believe this is most effectively accomplished through project-based education, and the most exciting type of project is a space project. Although resistance to change will always be an obstacle, the rewards certainly make the effort worthwhile.
References

