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INCORPORATING COOPERATIVE LEARNING ACTIVITIES INTO TRADITIONAL AEROSPACE ENGINEERING CURRICULA

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Abstract

Active learning is a term used to describe programs where students learn by doing. In active learning programs, students work on projects where they use their theoretical classroom knowledge in real-world, hands-on activities. The activities range from single person projects to larger, complex, team oriented programs. In many programs the students work on actual hardware and software, many times similar to those used in industry. Many of the methods and techniques in active learning, such as time management and cost control are also similar to that of industry. A benefit of these types of projects is that the students cannot look up the answer in the back of a book, but must innovate, discover, or invent solutions. This produces a better rounded graduate through a fun and exciting educational environment that encourages the student to learn through involvement.

Many universities are now incorporating active learning into their curricula. This trend is due to the reduction in degree requirements and easier access to materials. Also, it is seen that the traditional classroom education, by itself, does not produce the best graduates. Industry wants not just students who understand theory, but graduates who understand how to implement the theory in the real-world. Active learning is used to bridge the gap between theory and real-world implementations. This paper examines the general trends in active learning, and details the methods and challenges encountered when one such program was incorporated into the curriculum at the Department of Aerospace Engineering at The Pennsylvania State University.

Hands-on, group based education is now used extensively in many engineering programs. This paper examines how an education paradigm shift can benefit students and how hands-on activities can be integrated into a traditional aerospace engineering curriculum.

Hands-on learning can fall under many titles. Problem-based learning, active learning, group education, and cooperative learning are but a few of the terms used. Another term used extensively, and developed at Massachusetts Institute of Technology (MIT) is Conceive, Design, Implement, and Operate (CDIO) (Crawley et al, 2002). CDIO is used at MIT in many of their classes and has been quite successful. Hands-on learning allows the students to take their classroom knowledge and apply it to solving a real-world problem.

The traditional four year classroom education in aerospace engineering has been inadequate to the growing changes facing graduates. Aerospace engineers today must be more in tune with technologies than ever before. Today, computers and electronics are an integral part of any aerospace project. Aerospace engineers have pushed the limits of material and performance, finding effective solutions to ever increasing challenges. For example, today's fighter aircraft can perform beyond the limits of the pilot's body, guided missiles can pinpoint targets hundreds of miles away, and the increasing unmanned aerial vehicles (UAV) activity is spinning off technologies for many different applications. The trend today is the use of software and electronic solutions to increase performance. This applies to all ranges of aerospace development, from military to civil and commercial solution. The Boeing 777 aircraft, for example, was completely designed on computers before any part was machined (Norris, 1995). With the increasing speed of the microprocessor, clustering solutions to numerical problems are now routinely solved on computers. Students are given homework problems to solve on clusters that were cutting-edge research projects only a generation ago.

Miniaturization is also having a profound effect in the aerospace field. Today, a $10 microcontroller can exceed the capacity of the computer which guided the Apollo module to the moon. A typical home has about 50-100 of these microcontrollers. Piezoelectric and microelectromechanical system (MEMS) technologies have reduced the prices of sensors dramatically. More importantly to the aerospace field is the fact that these advances in technologies have also reduced the weight and increased the capacity, which allows microcontrollers and sensors to be placed in many locations in and on an aerospace vehicle. The emerging field of UAVs use microcontrollers and sensors extensively along with the fast computers and complex artificial intelligence required to autonomously control these UAVs.

In fact, no field is left untouched from the information technology revolution. These terms may look foreign to a graduating aerospace engineer, yet the individual will be exposed to these materials as well as many others in their career. To complicate matters further, industry today must adapt or perish. The multi-year Joint Strike Fighter competition between Lockheed Martin and Boeing was a good example of all the impact of technology on companies. The requirements asked for by the government were substantially more complex than previous development programs, with the main component being that the fighter must be compatible with multiple branches of the military. Additionally, each branch of the military had its own unique requirements. Cost control and performance were also major issues. Graduating engineer must think in terms of the whole picture, not just the task at hand.

Industry has repeatedly emphasized that graduates are not well trained to deal with the mind set required in today's world (Wilkerson and Gijselaers, 1996 and Boud and Feletti, 1998). Although graduates excel in understanding theoretical material, they lack real-world problem solving skills. The answers are not in the back of the book. Classroom theoretical knowledge will only contribute partially to the solution - industry requires innovative solutions to problems. This requires a combination of independent as well as group-oriented thinking. The ability to think of innovative solutions is a skill that is not taught in traditional curricula. Additionally, group activity is not always encouraged; most of the solutions in undergraduate and more so in graduate classes, are individual orientated. Students are inadequately prepared to use their "toolbox" of knowledge to solve problems. They are taught how to find a solution when all the steps are well defined. For them to think and use their knowledge independent of the "cookbook" approach is difficult. Industry also requires quick adaptation to changes in technologies as well as how the organization will change due to competition. Again, these skills are generally inadequate in graduates.

Graduates must also be multidisciplinary; they must have knowledge of theoretical aerospace topics but must also be exposed to computer technologies, electronic technologies and the myriad of other changes occurring due to the computer revolution. Everything in engineering is group-oriented work and traditional engineering curricula must adapt to this changing need. The ability to work in groups can be taught in the curriculum.

The technologies today will also allow us to change the way students learn. Using computers and creative learning theory, one can teach students new approaches that allow them to learn using active learning skills. That is, the student learns by doing not by listening. Cooperative learning theory states that learning can be enhanced when the student learns by constructing knowledge. They learn to apply knowledge, not just acquire it (Brodeur et al, 2002). Brodeur states that cooperative learning is more interesting and engaging. The students have a greater understanding of the core engineering principles because they find the information themselves and actively use the information to complete the project. Moreover with emphasis on real-world contexts, the students see the connection between the subject matter and their professional interests. Guidance is given only to encourage the acquisition of knowledge. This paradigm also aids the students because it is a natural way of learning.

A cooperative based learning project was implemented in the Department of Aerospace Engineering at The Pennsylvania State University. The Student Run Rocket Program (SRRP) allows the students to be involved in a project that is integrated into the curriculum through a number of established classes. Each semester, the goal is to build a rocket and all of its subsystems, launch and recover it, analysis the data, write a number of reports and give presentations about the project. Students can select how long they would like to be involved in the project by their selection of classes. A great deal of flexibility is offered to the student in this project.

The engineering goals are easy to define. Building a rocket will require a great deal of skill and will challenge the students to use their engineering knowledge extensively. But the students will learn much more than just engineering. The exact goals of the class are set by the students. However, students tend to be overly optimistic and unrealistic about

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goal setting, especially in projects where they lack experience. Therefore, some guidance is required from experienced faculty and staff when establishing these goals. Since each group works on a subsystem of the rocket, and since a rocket is a combination of interdependent subsystems, all the groups must work together and establish some form of communication to relay information. Since building and launching a rocket is extremely challenging to do in one semester, time management skills are also a must. This project forces the students into determining how to manage their time in and out of the classroom. More common than desired, in industry, the cost of engineering projects can also spiral out of control, therefore cost constraint issues will always occur. The students must find a good median between buying off-the-shelf systems and developing systems on their own. Additionally, they must trade off solutions which will optimize all the parameters.

Project management is also a skill that is indirectly taught. More importantly, the students are required to think differently. They must use theoretical classroom knowledge and apply it to solving a real-world engineer problem. The students are encouraged to develop solutions on their own. The incorporation of active learning into the curriculum enhances the quality of the educational experience and ultimately produces better rounded engineers.

Background

In the past decade there has been much research and implementation of cooperative education in universities across the U.S. The implementation has been across many different fields from engineering to biology. This literature review looks specifically at cooperative education in engineering.

Problem-Based Learning in Aerospace Engineering Educations

The Massachusetts Institute of Technology (MIT) is one of the innovators in cooperative education, with a number of programs using problem based learn (PBL) in their many capstone implementations. Some of the programs in Problem-Based Learning (PBL) in Aerospace Engineering education at MIT are discussed in Brodeur et al (2002). The need for PBL came from industry, which stated that graduates need problem-solving skills for a lifetime of learning. In PBL, students must learn to apply knowledge, not just acquire it; they learn by doing instead of just listening.

PBL is established from three main theories:

1. Learning is a constructive process; the project the students are involved in must be ones that the students can use their existing knowledge base and apply it to solving a given problem. This method allows the student a learning experience by discovery, as they examine the problem, research its background, analyze possible solutions, develop a proposal, and produce a final result (Delisle, 1997).
2. Knowing about knowing (metacognition) affects learning; the process of knowing when one is learning or not learning and how to adapt in order to attain that knowledge. PBL can give a student the opportunity to monitor his or her learning and assess their progress.
3. Social and cultural factors affect learning; the given problem must be setup so the student has some familiarity with it. It should emphasis what the student will work on when graduating and be relevant to what the student has studied. Additionally, it should be close to real life situation (Delisle, 1997).

Barrows (1996) describes the main features of PBL as:

- Learning is student centered, i.e., students make choices about how and what they want to learn.
- Learning occurs in small student groups, which promotes collaborative learning.
- Teachers are facilitators or guides or coaches.
- Problems form the organizing focus and stimulus for learning.
- Problems are a vehicle for the development of authentic problem-solving skills.
- New information is acquired through self-directed learning.

Good Problem Statement

A good problem statement is essential for a successful Problem-Based Learning implementation. No one knows the full solution to the problem at the beginning of the work, so by identifying what the problem is, and what the goals are that need to be reached, the students can create a "route" to the destination.

Gijselaers (1996) suggests these guidelines in designing problems:

1. Effective problem descriptions focus on student-generated issues and do not include lists of questions to be answered.
2. Problems are complex, multi-faceted in which there is no single best answer.
3. Effective problems should result in motivation for self-study.

Delisle (1997) also has some good suggestions for PBL. He suggest that the problem statement should be grounded in student experience, be curriculum based, allow for a variety of teaching and learning strategies and styles, be unconstrained, focus on a question, and be assessable.

Problem-Based Learning at MIT (Crawley, 2002)

PBL is integrated into MIT's larger CDIO based curriculum. CDIO is based around a full product life cycle in which the product development goes through the conceiving, designing, implementing, and operating phases. It is set in a real world engineering context, with PBL integrated throughout the program. A major curriculum reform was initiated around 1997 with CDIO integration. New goals were identified, teaching and learning methods initiated, laboratories and workshops were built or rebuilt, and major resources, such as time and funding, were committed to the program. The program can be categorized into four levels:

- Level 1 Problem Sets: traditional, structured problem sets found in theoretical classes where solutions are usually known.
- Level 2 Mini Labs: structured labs where a specific engineering phenomena or data are observed. Students work in small teams and the task lasts a class period or two.
- Level 3 Macro Labs: complex problems where investigation lasting a couple of weeks to a semester.
- Level 4 Capstone CDIO Labs: this level includes all the other levels. They are complex projects, lasting three semesters and require significant support from instructors.

PBL fits into levels three and four, as they are less structured, require active student participation and are highly motivating to students.

Implementation of PBL

Problem-Based Learning is implemented at MIT through a number of classes:

1. Introduction to Aerospace and Design: students design, build, and fly a radio controlled lighter than air vehicle.
2. Unified Engineering: second year students do traditional theoretical classroom analysis, but also use this knowledge when assembling and flying an electric radio-controlled airplane.
3. Aerodynamics: students design and perform aerodynamic analyses including both computational and experimental methods.
4. Experimental Projects Lab: experiments are carried out and are assessed through laboratory notebooks, design reviews, technical briefings, and written reports.
5. Space Systems Engineering: students design complex space systems, in which they are assessed on their design reviews, technical briefings, written documents, teamwork, project organization, and integration of more than one discipline.

As can be seen from MIT's implementation, CDIO can be incorporated into existing classes, and does not require the creation of new classes or programs.

Larger Active Learning Programs

Examples of larger active learning programs are listed in Mason et al (2004), Frederick et al (2002), among others. Active learning is the primary focus of these programs. The programs are implemented in many ways at each university; some universities integrate the active learning into existing classes, while other universities have chosen to offer it as an independent class. As detailed in these example references, the active learning can be a single class project with students divided into groups; it can be an interdepartmental project, such as mechanical and aerospace departments; or they can be international programs where many different universities are involved.

More students are involved in larger active learning classes. Because of the scale of the program, this form of active learning requires more time, money, preparation and support. The possibility of not meeting the goals is a real possibility due to the complexities involved. Larger groups require more teamwork, and the ability to communicate between groups is even more important. The program can be divided among different groups to delegate similar tasks to each group. This puts a strain on the professor, for they will require more knowledge on each topic. Additionally, the professor requires more from each student, from leadership to gaining more knowledge of that group's tasks.

Even with these complexities, large active learning classes have substantial advantages. The students can get involved in something they are really interested in. The costs are divided among many students, so this type of program can be offered more economically, as opposed to a single independent study class where the cost may not be justifiable. These larger projects also teach students to think, communicate and develop skills, such as project management, which they cannot pick up in traditional classes or small independent classes. The larger classes can also be modeled after industrial processes, so the students can understand how industry does things, what skills are required in industry and help them develop some of these skills in a non-industrial, learning setting.

These examples demonstrate that there are many approaches that can be offered. Additionally, the students

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also have flexibility when involving themselves in such projects. Overall, the universities who have made a commitment to active learning programs have benefited with a better educational package that is offered to their students.

Requirements

Active learning requires more effort and creativity for a successful implementation. Support must come from not just one professor but from several. Active learning requires a conscious commitment to do things differently from the traditional method of classroom lectures, which must be supported by everyone involved in the program. Additionally, successful implementation requires more department resources, so the department's support is essential.

The requirements should be established by asking questions, such as what, why, who and where. This is an iterative process as the answers to some of these questions will require a reassessment of the other answers.

In order to establish what requirements are need to support active learning, several items must be addressed. First, what will be the active learning project? This, then, can establish how the project fulfills and benefits the overall curriculum. Next, the year or semester goals must be established. Once these goals are established, many of the requirements fall into place as they define the program, its benefits, and the roles it fulfills. Third, one can answer who is required to carry out the project. There are many different ways of implementing the goals. For example, a professor can teach all or part of an active learning class. Another effective technique is to have the weekly interactions with the students carried out by a teaching assistant (TA), and have the higher level management carried out by the professor. Thus, the requirements vary widely depending on the method used, but never the less, each method carries with it a certain set of needs that must be fulfilled.

In addition to professor and TA support requirements, what additional staff members are required? If the project needs machining, is a staff member available to support the needs, or can a student fill this gap? If there are electronics involved, who will be assigned to support this need? Where will the program be conducted, does it require a large space, or can it be carried out in a classroom? Does the classroom provide secure storage for program hardware and support equipment? Is additional equipment easily accessible, e.g. tools, machine shop? Does the professor have enough previous experience with active training type projects? If not, the professor must learn from others and experiment with various techniques.

The structure of active learning may seem to be less rigorous than classroom teaching, but increased structure may be required to make sure the educational goals are met. Active learning classes inevitably take more time and effort from everyone involved. This comes from the fact that the students learn from asking questions and finding the answers, which will lead them to many different paths including the wrong path. It will be the professor's responsibility to help steer them onto the correct path.

Funding is another requirement of active learning. The amount and kind of funding will depend upon the type of active learning. If active learning is a simple question and answer session in class, then additional funding may not be required. On the other hand, if the active learning is a semester long project requiring hardware, software, tools and equipment, additional staff and expertise, then funding will be required.

The size of the class has an impact upon effective active learning. This is dependent on the professor's time and management ability as well as the complexity of the project. Although small manageable size is very important, large projects can actually benefit from large groups. These projects will inevitably be divided into smaller sub-projects; thereby the students can be divided into subgroups. Each subgroup can work as a team on that particular group task. If the division of labor is distributed correctly, each group may actually have less to do and produce better results than if a large project was given to a small group. If each group produces good results then there is a better chance that the overall goals will be reached. However, larger groups require better interactions. The overall project requires interdependency between the groups, so working together in interdependent groups can build communications skills through better understanding of the other group's requirements and what is required from each group to satisfy everyone's task.

Students bring to the project a large and diverse set of skills. The professor must be able to gauge each student's ability and know how to exploit each student's strength as well as how to handle the student's weakness. In large groups, students will naturally migrate to the subgroups which they are good at, but care must be taken if all the tasks of the project are to be accomplished effectively. Most certainly, there will be tasks that no one will want to do, yet these must still be distributed within each group. Attention must be given so these tasks are faithfully finished. Another important ability is to gauge the students' abilities to perform tasks autonomously. The professor cannot be around to help each student all the time, which would also be detrimental to the student's ability to benefit from active learning. Instead, the students can be guided with goals and asked to develop solutions and let them implement the solutions, with the professor acting as a guide instead of a participant.

It may seem that the professor is the main person for the success of the active learning. In reality, it depends upon how the program is carried out. The main interaction with the students can come from a professor, a teaching assistant, a staff member or even a group of people. Whoever it is, this person or group of people will have a disproportionate amount of responsibility for the program's success. The ability to choose the correct person or group is also a requirement.

Challenges

Whenever things are done differently, one encounters many challenges - active learning is no exception. How well these challenges are attacked and surmounted determines the rate of success of the program. The main challenge is trying to manage the complexities required of the program. Obviously, the task will be substantially easier if a well organized plan is implemented. Using a top-down approach, one where the goal is defined and the method needed to attain the goal is implemented, will help to understand the complexities. One approach is the methods outlined previously, but the flexibility of active learning will allow many different approaches, with equaling level of challenges.

Some of the additional challenges are:

1. Resistance by others at the new method of education
2. Finding a method to implement the program in an effective way
3. Involving students
4. Time management
5. Keeping with a schedule throughout the semester
6. Ordering the required parts and equipment
7. Keeping within a cost model
8. Finding the resources required for the program
9. Funding the program

There will always be resistance to something new. Active learning is a unique way of teaching but it cannot replace traditional classroom education. Instead, it can be used to enhance the student's overall education. Therefore active learning should be implemented to supplement classroom learning, not replace it. Resistance can further be reduced by keeping the program, at least at the beginning, simple. As experience is gained and the program is successfully integrated, more complex projects can be initiated.

The methods to implement active learning stated previously and the implementation results are only one of the methods available to carryout active learning. Each implementation will bring about its own challenges and cannot be examined here. The professor must study the methods properly and implement it as well as possible. Keeping it simple, especially at the beginning, will always help increase the likelihood of success of the program.

To involve students, one must advertise the program. One method is to integrate it into a class, or to advertise it as a separate class or project. As stated in Brodeur et al (2002), Delisle (1997), Mason et al (2004) and Frederick et al (2002), there are many methods to involve the students in the program. The more exciting it sounds to the students, the more will join. As the program succeeds, more students will join from word of mouth. At this point there may be a need to reject or limit the number of students involved, to allow the quality of the educational experience to remain high.

Time management is a major key to the program's success. A one semester active learning class is very challenging, due to the fact that active learning programs themselves require more time than traditional classroom education. Proper planning of the activities and students' time is critical. Additionally, the students themselves will underestimate the time required, partially due to enthusiasm and partially due to a lack of experience in determining the required time. The professor or TA must help the students in time management.

Keeping with a schedule is equally important. Many things affect an active learning class. One cannot move at the pace of a normal class. Students are used to theoretical classroom education - it is instilled into them since entering school - as most of the classes are textbook-based, where the pace can be maintained. Like many real-world programs, active learning programs can slip from the established schedule. The reasons are many, the openness of the program requires the students to invent or discovery the solution, it's not laid out for them. This discovery process will inevitably lead them down many paths before a solution is decided upon. Additionally, as new solutions are created, new methods to implement these solutions must also be created or carried out. A lot of this cannot be planned and in many cases should not be planned. Since active learning educates by the students' experience, strictly planning an inflexible schedule will be detrimental. Instead, time must be allocated in the schedule for such experiences and the schedule must take into account the many factors and diversity of the student, such as experience, enthusiasm, and talent, among others.

Certain active learning classes will need parts and supporting equipment. Parts will usually need to be ordered before the classes begin, especially if the length of the class is only one semester. Proper planning can define what is needed. More importantly, time is needed to figure out how a certain part works (whether it is software or hardware). Debugging hardware and software can take a considerable amount of time. Integrating these into other equipment will also take a considerable amount of time. Testing hardware is also time consuming. Many times, hardware does not work as advertised, or will need to be modified when it is integrated. Examples of this are seen in robotics programs, where the computer hardware and software is bought from one vendor and the robot hardware is bought from another vendor. Integration time can be reduced if the components are bought together from one vendor. Unfortunately, this can limit the flexibility of the program. Another approach is to buy off the shelf components at the start of a program and then more customized solutions can be integrated as experience is gained in the program. These are just some of the techniques to reduce time while keeping the quality of the active learning class high and staying on a realistic schedule.

Controlling costs is very important in any program. The main challenge of controlling cost comes from the unknowns of active learning. Since the program stresses learn as you go and experiment, sometimes it may become difficult to accurately determine all the costs up front. Equipment purchased may not fit the requirements, especially if the requirements themselves change. Additional costs may occur as the program is under way. All these factors should be included in the cost analysis.

Aside from hardware, software, and equipment, additional resources might be needed. Room for the program activities, remote locations for testing, access to department facilities, for example, need to be located and secured. Many times access to resources is limited and advanced planning is required. Sometimes the program schedule itself needs to be modified to accommodate access to resources, e.g., access to a remote launch site may require a rocket program to work around the launch site's schedule.

Funding in any program is very challenging. There is no one way to do this and it can vary immensely depending on the way the active learning is implemented. Accurate cost estimates are very crucial. Enough funding needs to be established for both the costs and for additional unforeseen costs overruns which may occur. As experience is gained, cost estimates will improve.

Proper planning cannot be over emphasized in dealing with all the challenges that will arise in any active learning programs. These challenges are just some examples of many that can occur. The challenges will vary extensively and some will be unique. Many of the challenges, such as funding, are critical; others can be less critical. Because active learning is a process by which the students learn by doing, mistakes will inevitably occur. These mistakes should be viewed as part of the learning process. Part of the success of the program is that one will learn as much or more from the mistakes as from their success.

Implementation Results

The Department of Aerospace Engineering at Penn State University embarked on a new active learning program in the Fall of 2001. The department already had a number of active learning programs in aeronautics, so a new active learning program that would interest students interested in astronautics was initiated. A project that fit the requirement was to build a complete rocket and launched it in one semester.

There were a number of goals that this first offering of the program would need to fulfill. The goals could be divided into managerial or upper level goals and student or project goals. Managerial goals were established to gauge the success of the program. Additionally, managerial goals were to estimate the total cost to the department, how much effort and resources are needed from the department, how could the program be funded, and what the requirements for getting funding are.

The main managerial goal set for this first semester was could such a program be implemented in the department? In order to succeed, a division of labor was established and each resource need was identified. Figure 1 shows the division of labor as well as the requirements needed.

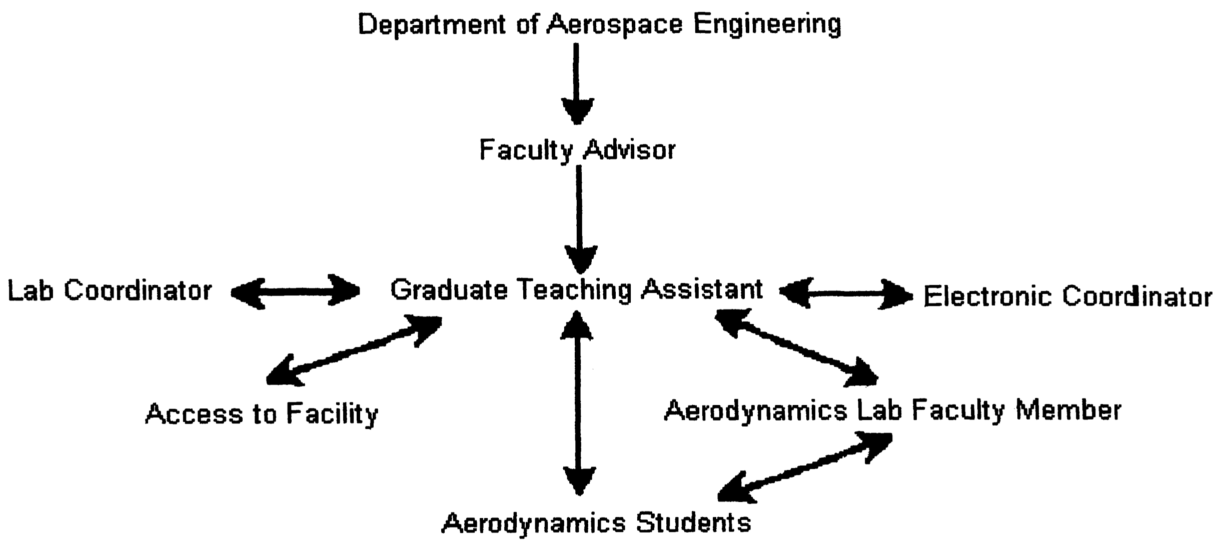

Figure 1. Division of Labor during the First Semester Rocket Program

The College of Engineering and the Department of Aerospace provided the funding. The faculty advisor wrote the initial funding proposal and worked with the graduate teaching assistant to implement the program. The program was implemented through one of the established courses in the department, AERSP 405, the aerodynamics laboratory course. The faculty member responsible for the class was contacted and the managerial group worked closely with him to integrate the program into the structure of the class. As can be seen from figure 1, the graduate teaching assistant (TA) was the main contact point for the program; this person would interface between the upper level managerial group and the lower level student groups. Additionally, the teaching assistant was responsible for interfacing with the aerodynamics lab faculty member as well as finding the needed resources required by the project. This included student access to facilities, such as machine shops, and arranging for use of small equipment such as tools. The TA also worked with the Lab Coordinator, who gave access to the labs and facilities. The Electronic Coordinator was an important part of this program. Since there are a good deal of electronics components in this program, the access to someone who had a very good understanding of real world electrical engineering concepts was invaluable. Fortunately our department had someone with over 20 years of experience in this area.

The TA was also the individual who worked with the students directly on a day-to-day basis. Using the structure outlined in figure 1, the success of the program resided in the teaching assistant's ability to motivate the students, manage time properly and be very organized. The TA's project management ability would make or break the program.

Fall 2001 Rocket Project

On the student level, the rocket project would encompass many aspects in Aerospace Engineering. In this first semester, the project would require the students to build a commercially available rocket airframe and integrate this to a commercially available solid rocket motor. The rocket also contained a flight computer that recorded acceleration load in the vertical direction and controlled the parachute deployment system.

The first semester this project was offered, the goal was to simply launch the rocket with the motor and payload, as the department had little experience in a space related active learning program. By keeping the goals simple at the beginning of the program, there was a greater chance of success and continuity.

Eight students selected the project from the AERSP 405 class. Initially, the students relied on the TA for guidance, goal definition, what materials were required, what to order, and to develop a general road map of the project and how to go about attaining the stated goal. Once the materials came in, the students started to build the vehicle and integrate the flight computer. The students were required to integrate their classroom knowledge into the project. They were required to theorize various parameters. One common parameter required in model rocketry is the altitude the vehicle would reach. This was the first time the students were actually asked to apply their classroom knowledge to

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a real world problem. After some research, the students wrote a two degree-of-freedom computer program to estimate the height the rocket would attain. These values were compared against results obtained from a commercially available software program.

The rocket was launched at the end of the semester. Since the rocket contained a flight computer, various flight parameters were gathered. These actual data points were compared to the theorized points from the students' program. There was a 15% error between the actual values and the theorized values. The students needed to justify why there were errors and rework their assumptions in the theory.

In order to fulfill the requirements of the AERSP 405 class, the students presented their findings both orally and in a written report at the end of the semester. This was the first time the students had to go through a complete engineering cycle, from concept, design, fabrication, to actual use of the product. Since the students viewed the project as fun, they were eager to work to complete it. Additionally, the knowledge gained in terms of time management skills, project management skills, budget constraints, how projects come together, could only be taught in a real-world setting.

Spring 2002 Rocket Project

With the success of the 2001 project, the spring 2002 project introduced 12 more students the program. The goal was to build a larger rocket (double in size), incorporate two flight computers, have a dual recovery scheme, incorporate a wireless camera and use a larger, more powerful engine. Since the rocket was more complicated, two flights were proposed, one to test the vehicle and one to test the whole setup with both flight computers.

There was much pressure to have another success, and the aggressive goals established would be more impressive when we succeeded. The larger rocket was built very quickly by the middle of the semester. Unfortunately, during the first launch, the rocket crashed, destroying the whole vehicle.

Since there was not enough time to build another rocket by the end of the semester, the project seemed to be a failure. But the project changed direction, from launching a rocket to accident investigation. Although the vehicle was completely destroyed, there were some data and video of the flight, especially of the wireless video feed from the rocket. After some investigating, it was determined that the dual deployment did not work as designed and caused the crash.

The spring 2002 semester taught a number of lessons. Success is not always guaranteed in the real world. It also taught the students how to use their engineering skills to find out what went wrong and how to fix the problems. These skills cannot be taught in the classroom, they must be learned by experience.

From a managerial point of view, we learned to not set goals that were too ambitious, requiring too much commitment from the department and too much of everyone's time. These lessons served the program well as it continued into the next semester.

Summer 2002 Rocket Project

The program was now very popular with the students. During the summer of 2002, work continued on the project, this time two classes were involved, AERSP 405 and AERSP 496, an independent study class. The students in AERSP 405 were to design a new recovery mechanism and the one student in AERSP 496 was assigned to develop a test stand.

The managerial members had decided to go to a new propulsion unit, a hybrid rocket motor. The solid rocket motors were easy to operate, but the trend in the program was to use larger motors. Also, solids require more safety and handling procedures. The hybrids were the safest motors available so it was decided to invest in this technology. Additionally, this technology seemed to be the center of a renewed interest in the aerospace industry and would excite the students by introducing them to a cutting edge technology. The test stand would allow us to gather actual thrust curves and demonstrate to the students how actual rocket motors functioned.

The AERSP 405 students designed and built a recovery subsystem and fulfilled the requirements of the class; writing and presenting their findings. The test stand was designed by the AERSP 496 student and built by the department. A hybrid motor was tested on the stand and the student wrote a report fulfilling the AERSP 496 class requirements.

Fall 2002

The program continued into the fall 2002 semester. This semester the program expanded into two classes, AERSP 405 and AERSP 406, the Structures and Dynamics Laboratory. Ten students from both classes joined the program.

The AERSP 405 goal was to test fire hybrid motors on the test stand developed in the summer of 2002. They needed to calibrate the stand and load cell, as well as learn how to integrate a computer data acquisition system into the test firings. Figure 2 displays one of the results of the test firings.

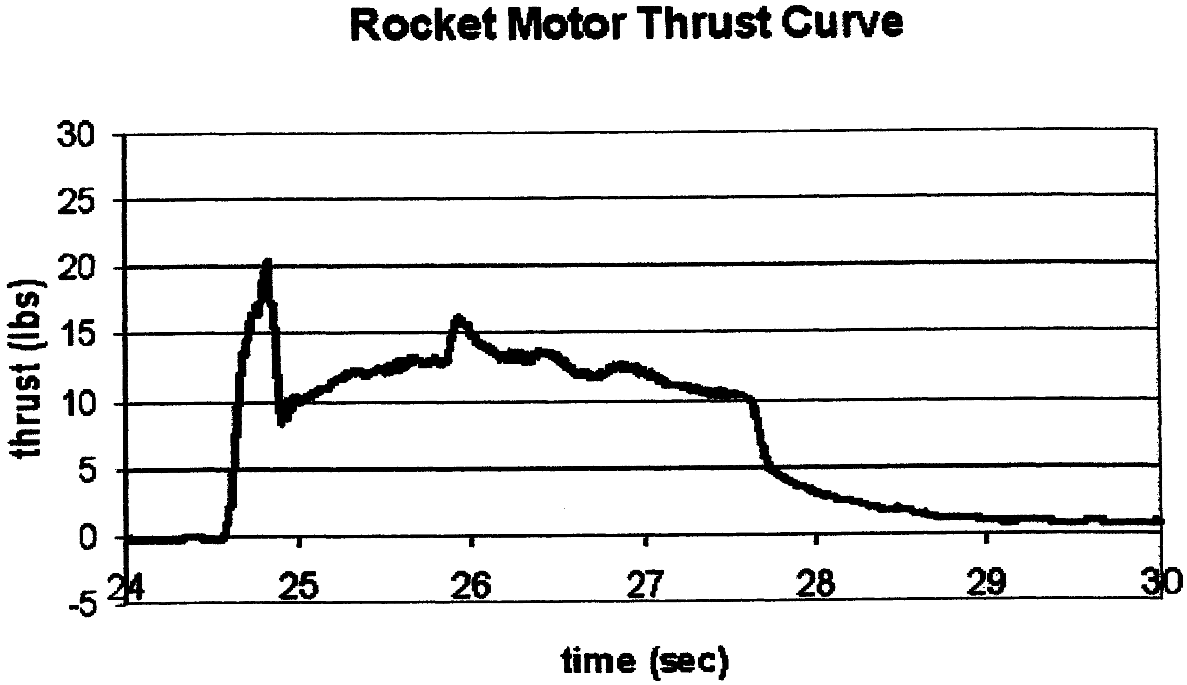

Figure 2. Hybrid Rocket Motor Thrust Curve

The AERSP 406 students' goal was to gather calibrated data for the sensors on the flight computer. The 406 students had to develop various tools to test the flight computer, which contained an accelerometer and a pressure transducer. In one of the experiments, the flight computer was placed on a rotating disk and the value from the accelerometer sensor was measured for different rotational speeds. This was compared to theoretical values. The graph of the results from one such test is shown in figure 3.

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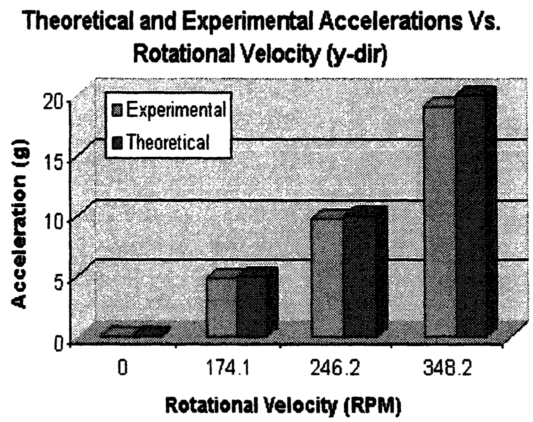

Figure 3. Theoretical and Experimental Acceleration vs. Rotational Velocity

The experiments were simple but it gave the students confidence in the data and the relationship between theory and experimental data. Both classes fulfilled their class requirements by writing reports and presenting their results.

The program was now well established in the department. The lessons learned from the spring failure were now being integrated into the program. The program now moved away from building and launching each semester and started to offer more detailed development of the program by making sure that each component was tested to meet the requirements of the program. Additionally, by simplifying the goals, the chances of success were greatly increased as was the likelihood that the program would continue.

Spring 2003

This semester, the managerial team decided to try to launch a rocket and asked the department to support such a goal. The decision was made from the fact that we had matured from the failure of the previous year and that we had researched and tested enough configurations since spring of 2002 to be confident that we could be successful. Additionally, a new graduate assistant was added to the program to help achieve the goal.

The program was integrated into AERSP 405 and AERSP 406 again. Twelve students, six from each class, selected the project. The rocket selected was the same as the one used the previous year, with a flight computer and a wireless video camera. The main difference between the previous rocket and this one was the use of a hybrid motor. Although this motor was more complex than a solid, the safety and non-hazard condition of the motor allowed for easier integration into the rocket. The AERSP 405 students were responsible for the airframe and propulsion and the AERSP 406 students were responsible for the flight computer and deployment subsystem.

Three students from AERSP 405 built the airframe while the other three students test fired the hybrid motor. The motor was tested a number of times so the students would be comfortable with the procedures required to operate it. The AERSP 405 students also modeled the rocket on a computer and established various important parameters, such as maximum altitude and deployment time. The AERSP 406 students worked with the flight computer, a wireless video camera, and tested various deployment schemes. They chose to use a single parachute instead of the more complex dual deployment scheme. This was tested extensively to establish the exact time for the deployment.

This deployment time was established from the computer simulation done by the 405 students.

During the semester, many challenges were overcome by the students. Their enthusiasm and positive attitude kept them challenged. Additionally, the thought that they might actually launch the rocket kept them on track. One major problem was the location of the launch. One of the main problems the program faced was to secure a safe launch area. Previous semesters relied on launching at Tripoli events (Tripoli is an amateur high powered rocket club which meets and launches rockets throughout the year). Complicating the process, these launches required insurance and qualifications. More importantly however, the Tripoli events occurred at inconvenient times which forced the students to finish a rocket early or launch it after the semester was over. In order to solve this problem, the department contacted National Aeronautics and Space Administration (NASA) to see if they could help. NASA was more than happy to help out and offered a launch field at NASA's Wallops Island Flight Facility, as well as other safety equipment. Worries about liability were alleviated since we were using NASA property. NASA's involvement required the students to work even harder, as NASA required extensive documentation and safety analysis of the vehicle and flight path.

All the effort and hard work paid off on the actual launch day. The launch occurred on the first attempt with no delays or problems. The students learned many things this semester. Teamwork, budgeting, time management and a positive attitude all contributed to making this semester the most successful in the program.

Fall 2003

The fall 2003 semester saw the largest number of students choosing the rocket project, 16 total. A new TA was added to the program, bringing the TA total to three. It was proposed to build a larger rocket. Since this was new territory for the department, we chose to proceed cautiously. This semester, the students went back to component testing of the rocket. Various teams were chosen to test the fins, a new flight computer, a fiber wrapped airframe, and a new motor mount. These tests were analogous to concept cars - although the car itself may never be built, some of the technologies in the concept car would make it into a final vehicle. Additionally, these tests allowed us to see if the proposed materials could survive and withstand the stress on the vehicle.

The coordination and work required was also extensive. Even though three TAs were involved, the student size was a little too large to effectively build a large vehicle in a short semester timeline. Choosing simpler goals helped the semester run smooth. The lessons learned at the managerial level are that the ideal size of the program for the implementation chosen in the program is about 7-12 students.

Spring 2004

The program moved into a new direction in the Spring 2004 semester. This was the first semester that the initial TA was not directly involved in the program (but was available for consultation). The crossroads in such programs are when the original creators leave or are less involved and the program gets a life of it own. How well a program survives and thrives without the creators is a measure of it continuity and success. The initial people involved must find a mechanism to continue the program by incorporating and transferring their knowledge to others.

Since the program relied on teaching assistants for the major interactions with the students, maximizing the knowledge transfer is vital for success. The new TAs were allowed to conduct the class as they saw fit, as long as they went about achieving the stated goals of the semester. Additionally, having the experienced TA available to ask questions became an invaluable tool for information.

The semester goals were simplified so the TAs could successfully take over the class and not feel overwhelmed. This semester, one student team performed static motor test firings while the other team tested the strength of a newly designed motor mount on a materials testing machine. These were tasks that were done before in previous semesters and so the TAs could rely on previous data and methods to help guide them this semester. However, the experience was still new to the students and so they still enjoyed their time and learning experience. Additionally, doing the same thing helped the managerial team improve the class by incorporating the lessons learned in the previous semester to this class. The semester was a success, due to teamwork, not only by the students, but also by the managerial team.

The Way Forward

The program continues each semester, with new students and teaching assistants being involved. Although the height of the program may have been the launch at NASA Wallops in the spring of 2003, the continuity of such a program is not on spectacular launches, but on a steady, well thought out plan. The goal of the program is not to do out of the world things, but to offer the students an exciting, educating and rewarding experience, which the department can truly support. The rocket project has developed into such a program.

Conclusions

This paper examined active learning in general and the implementation of it into a traditional aerospace curriculum. As a growing number of universities incorporate active learning into their curriculum, expanding the educational experience of the students, this shift towards hands-on education is due to a number of factors. The computer revolution has reduced the cost of hardware, which has allowed universities to offer many exciting projects to students relevant to their fields. In addition, the software to operate and program the hardware is much easier to use than

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ever before. The students gain exposure to industrial materials, methodologies, and real-world experience. These programs enhance the students' overall education and industry gains a more experienced graduate.

Implementing active learning poses many challenges. This paper summarized some of the experience of those in the reference as well as the once experienced when the student-run rocket program was implemented. There are many challenges when doing something so different and unique, but the benefits to students, faculty, and the department are well worth the challenges. In addition, the program offers learning in a fun environment.

More time and funding is required for hands-on learning. These programs need to be well thought out and support must be secured from many sources. The criteria for success of the program can be measured in many different ways and the program is very flexible, allowing it to be experienced by a wide variety of students. Active learning enhances the student's classroom knowledge and overall produces a well rounded graduate.✈

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