ADVANCED AERONAUTICS DESIGN: PROJECT BASED ENGINEERING EDUCATION AT WPI

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Abstract

One element of WPI's project-based curriculum is its interdisciplinary Advanced Aeronautics Design Program. Students participating in the program are involved in the design, construction, and flight testing of non-traditional aircraft such as an ultralight solar-powered vehicle, microwave-powered long endurance aircraft, or a flying oblique wing. The WPI project philosophy and character are described and illustrated using examples from the AAD program.

I. INTRODUCTION

Improving the design component in undergraduate engineering education has been an immediate and pressing concern for educators, professional societies, industrial employers and agencies concerned with national productivity and competitiveness. WPI addressed this need when its faculty revised the entire engineering curriculum and implemented a radically new project-based program called the WPI PLAN which has been widely heralded as revolutionary in its scope and execution. The PLAN provides what the 1982-1983 New York Times Guide to engineering education calls "unique engineering education" suggesting that students interested in science and engineering explore WPI and "be prepared for a shock--of delight".

Under the WPI PLAN, students complete a number of projects to satisfy the graduation requirements. The Major Qualifying Project (MQP) is a minimum of nine credit hours of faculty-directed engineering design outside the classroom on real-world, multi-disciplinary problems requiring realistic solutions. Students normally conduct MQPs as a major portion of their activity throughout the senior year. They work in teams, often with liaisons from off-campus organizations, to synthesize their classroom experience into the design and testing of an idea or product in the environment of real world constraints.

A second nine credit project, the Interactive Qualifying Project (IQP), is designed to make the students aware of the importance of technology and its impact on society. Like the MQP, it encourages team formation and coordination and external sponsorship of real-world topics. The IQP however, is distinctly different from the MQP in investigating an interdisciplinary topic involving both technology and the analysis of how that technology affects societal systems and values. Students typically devote a significant portion of their junior year to their IQPs.

II. PROJECT BASED DESIGN

Following this same spirit of innovation in education and of state-of-the-art research, WPI established an Aerospace Engineering Program as part of the Mechanical Engineering Department. Through a series of five courses, MQP and IQP projects, the students receive a sub-specialization in aeronautics and aerospace engineering. Since its inception in 1986 the program has experienced unprecedented success and expansion. The undergraduate population has risen steadily from an initial 18 students to a total student population of approximately 330 for the 1992-1993 academic year (33% of the Mechanical Engineering Student body).

At WPI, aerospace project activity is mainly organized within two programs- Advanced Aeronautics Design and Advanced Space Design. These programs are supported

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by the National Aeronautics and Space Administration, NASA, through the Universities Space Research Association, USRA. NASA/USRA supports undergraduate design education at selected universities. The objectives of the NASA/USRA Advanced Design Program are in concert with our own curricular objectives and, for several years, have provided a strong foundation for WPI's aerospace projects.

The central activities of these two programs typically involve design of non-traditional aircraft and spaceflight experiments. Ancillary activities to these two programs are a number of other MQP or IQP projects dealing with various aerospace issues and problems. All of these projects rely upon input from engineers working in government agencies and industry as consultants and participants in periodic critical design reviews. It is important to note here that because the design projects are multi-disciplinary we recruit students, faculty and practicing engineers from all engineering disciplines. In some cases students have the option of completing their projects away from campus and at a company or research center. In this way, the design project activities are given "real-world" importance.

In both programs, accomplishment of significant goals is emphasized. In the case of the Advanced Space Design Program a GAS payload was flown aboard the Space Shuttle Columbia during the STS-40 mission. The payload included experiments in crystal growth, fluid mechanics and acceleration measurement. In the case of the Advanced Aeronautics Design Program the central theme is the design, building, and testing of non-traditional aircraft such as ultralight solar-powered aircraft, microwave-powered long endurance ozone sniffer aircraft or a flying oblique wing. The underlying idea in the selection of these projects is to challenge the students with projects requiring innovative designs which they cannot extract from existing applications. The Advanced Aeronautics Design Program shall be our focus in the remainder of this paper.

Based on the experience gained during initial advising of projects in the Advanced Aeronautics Program, and utilizing prior experiences of the Advanced Design Program, it became clear that the construction and flight testing of a prototype was an important part of the final design. Therefore, the scope of our projects was expanded by requiring the addition of this element to the design process. A "design it, build it, test it" philosophy lies at the core of the Advanced Aeronautics Program.

During the 1990-91 and 1991-92 academic years, project teams developed a solar-powered remotely controlled aircraft. In the first year, students designed and built the first lightweight plane. In the second year, new students developed an evolutionary version of the aircraft utilizing an entirely different configuration. This particular project is quite challenging due to the strict design constraints related to the low efficiency of the available solar cells, the availability of solar power and the need for an ultralight design. Details of the final configuration which is shown in Figure 1 can be found in Ref. 1.

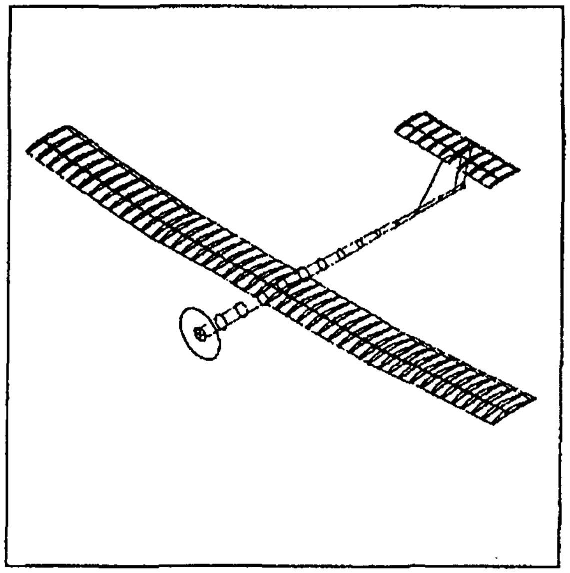

FIGURE 1: SOLAR-POWERED AIRCRAFT

During the 1992-93 academic year the focus shifted to the design, fabrication, and testing of a remotely controlled flying wing aircraft. This non-traditional configuration, with its inherent stability and fabrication problems, challenged the students to extend their classroom experiences. In responding to this challenge the students incorporated a custom-designed airfoil, and the use of composite materials into the final design. State-of-the-art carbon fiber fabrication techniques were utilized. Interdisciplinary aspects were emphasized through the design, construction, and testing of a ground-based telemetry system for the aircraft by students and faculty advisors within the Electrical and Computer Engineering Department at WPI. A final configuration is shown in Figure 2 and detailed in Ref. 2.

The requirement of final construction of the designed planes has provided significant impetus to the project. More importantly, however, it has transformed the students attitude towards design. While conceptual design projects did not require the students to prove the accuracy of their analysis through construction and flight testing, the addition of a prototype requirement confronts the students with the viability of their design. This has been an invaluable experience and a confidence booster for the students which cannot be easily quantified.

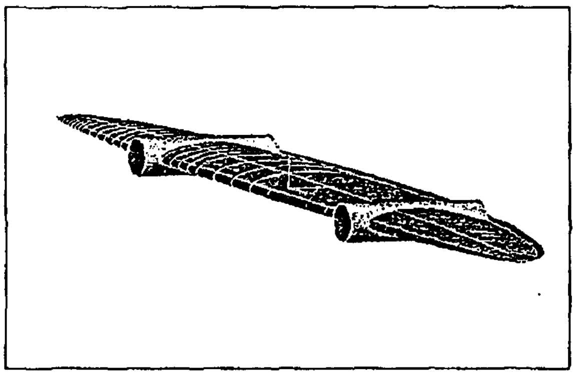

FIGURE 2: FLYING WING AIRCRAFT

Our experience indicates that the design projects are pedagogically superior to classroom work in at least three ways:

1. Projects are realistic. They necessarily involve the what, why, when, where, and how questions and require the student to synthesize previous course material in a practical problem.

2. Projects require state of the art practice and challenge students to match wits with the needs and offerings of current technology rather than classroom pedagogy.

3. The burden of decision making is placed squarely on the student team members who must invoke planning, leadership, and scheduling skills. Conflicts frequently occur and must be resolved by the teams; faculty members play the role of consultants and advisors.

The Advanced Aeronautics Design Program provides an organizational framework to coordinate project activity by faculty and students from various disciplines with common interests in aeronautics. However, this "project" approach is not restricted to those areas alone. Truly interdisciplinary projects such as those described above become the catalysts for significant capstone design experiences which significantly affect the students' perception of engineering design. Students of various backgrounds and disciplines are brought together in a manner that encourages close interaction in order to meet their design objectives. The high visibility and expectations of the projects emulate the pressures in a "real life" design team. During weekly meetings all the students are required to report on their progress both in written form as well as orally. The weekly meetings also serve as brainstorming sessions and provide major problem solving opportunities. At the end of the academic year the students are required to produce a detailed project report, written by the team, which is part of their graduation requirements.

The participating faculty have made a conscious effort to promote integration and to challenge societal prejudices among the students. As part of the attempt for integration the groups choose the individual team leaders and select the person responsible for conducting the weekly meetings and direct the progress of the project. The organization and execution of individual tasks are performed in a non-hierarchical climate. As a direct consequence of this policy, the programs have progressively attracted more minority and female students than the campus norms. Currently, the female students are equally represented as males, and many of them are team leaders, while a large portion of the students are minority students.

To promote participation of public secondary school students, an outreach aeronautics and space education program has been started. In this program we either recruit students from public schools to help out with the projects on campus or we have our own students help out with teaching or advising similar projects at secondary schools. For example, a high school senior was recruited and worked on the solar-powered aircraft project. He was partially responsible for tasks such as the wind tunnel testing of the motor propeller assembly for the solar plane and the evaluation of the experimental results. Additionally, IQP students are developing curriculum elements involving aerospace subjects in association with public school science teachers. In this program, during summers, provision is made for disadvantage students to work side by side with project students and graduate students.

Another significant impact of the NASA/USRA Advanced Design Program has been the unification of all the aerospace related project work into two programs. Project work at WPI encourages interdisciplinary working groups learning in a synergistic environment. The impact of the programs among the student population has been tremendous. In the past two years the majority of the students who worked in these programs have opted to continue their education at the best graduate Aerospace/Aeronautics programs in the country. The majority of those who chose to work in industry are currently employed by aerospace companies. The program has also affected the students in many more subtle ways. The close interaction with the faculty has provided the students the opportunity to participate in the design process as practicing professionals.

III. PROJECT ORGANIZATION

Major Qualifying Projects typically begin at the end of the junior year or the beginning of the senior year. In the case of long-term projects the students are encouraged to join a particular team during the last term of their junior year in order to ensure proper continuity.

At WPI, project topics can be originated by students, faculty, or outside industry. In the first case, students must define the project and search for an appropriate advisor; there are no guarantees or obligations on the part of faculty members other than to carry a fair share of the project advising load. In the second case, faculty define projects they are willing to advise by providing written descriptions disseminated to students by several means. Students then "shop" for projects and advisors using their own selection criteria. In the Advanced Design Programs described here, all projects are pre-defined by the faculty advisors. Students complete an application to be admitted to the program stating their qualifications, rationale, and preferences for available projects.

Once project teams are formed, proposals are developed by the students focusing on what, why, where, when and how, work will be performed. For the most part, faculty roles are confined to teaching, advising, and facilitating, although if the work is closely related to the faculty research, a more collegial relationship quickly develops. Typically, project meetings between faculty advisors and the entire design team are scheduled for one hour per week. In addition, student project teams are expected to meet separately to ensure continuous progress.

One frequent problem arises when scheduled milestones are not achieved. In this case, it is imperative that students determine an acceptable resolution and establish a new time-line. Another frequent problem arises from the interdisciplinary nature of the teams. Students naturally tend to compartmentalize tasks according to discipline. Faculty advisors need to become involved in this situation to maintain involvement of all students in all problems. Only with full participation of the students does the value of the interdisciplinary aspect of the team benefit the members. Since the project report will likely be the first major technical report prepared by the students, it is important that all contribute approximately equally and that writing difficulties be identified and corrected early. Veteran faculty advisors often use the project proposal for this purpose and to set the expected standard.

The critical design reviews which are conducted with the participation of practicing engineers and professionals from industry are important elements of the projects. The reviews are conducted during January at which time substantial work has been accomplished but changes can still be made. Review teams consist of engineers from local aerospace industries or NASA, and usually consist of three to five individuals. Critical design reviews provide unparalleled opportunity for students to defend their design decisions and to acquire a glimpse into industry practices. It is imperative that such sessions be viewed as constructive criticism and that the reviewers understand that they are reviewing student work. The review team prepare a written critique for the student team. Such sessions provide many new, good ideas from the experiences of the review team members. At the end of each academic year the students are also required by the terms of the NASA/USRA Program to participate at a NASA/USRA sponsored student conference. In this conference the students present their design project to a large audience of other students, faculty and NASA engineers. The students presentation and project are critiqued by practicing NASA engineers.

Part of the project scheduling must include a reasonable period of time for faculty to read and edit project reports. Since we have firm deadlines for completion of degree requirements, draft reports must be completed with reasonable time for faculty review. The consequences are that a student or students will not graduate on-time. It is important that such responsibility resides with the students.

IV. CONCLUSIONS

Project based education has proved extraordinarily effective with regard to integrating engineering design into WPI's curriculum. Within this framework we have been able to incorporate, in a realistic manner, important elements of design experiences typical of those encountered in industry. The project approach to design education deviates substantially from the traditional design classroom courses. It is our belief that the design process cannot be learned in the traditional sense, but rather, must be acquired by practice. However, the final project is not a substitute for a constant attention to design issues throughout the students' education. It is important while teaching the fundamentals of engineering education to also nurture sensitivity and attention to design issues. Furthermore, the project based approach emphasizes that engineering design is a general concept that encompasses all engineering disciplines. By stressing interdisciplinary projects and by bringing together students with various backgrounds, the project work fulfills the integrative function of a capstone experience.

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