# Undergraduate Capstone Projects Integrate Technology and Engineering Programs


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***Abstract*** - *The complex global economy requires a whole new set of skills from newly-graduated employees. Today, one of the most important components of technical curricula is national and international collaboration, which is becoming an important part of both the learning process and research in academia. Students must be able to handle not only the technical aspects of their jobs after graduating, but also learn 'soft skills' which range from simple tasks such as reading and writing, but also higher-level skills, such as decision-making and problem-solving. These skills have come to be known as "employability skills." The joint efforts of faculty members from Purdue University's Aviation Technology Department (housed in the College of Technology) and the School of Aeronautics and Astronautics (located in the College of Engineering) have successfully developed a model to better implement capstone projects. Students in the two departments are tasked to work as teams to find and implement the practical solutions to specific technical problems. This involves developing a feasible design solution, from concepts to three-dimensional models, drawings, process sheets and actual production and assembly of a product. The biggest challenge can be to find an appropriately-sized, task-oriented interdisciplinary problem in a course, the solution to which could be used as a prototype for other situations. The task must also be complex enough to challenge the students to use the knowledge they already have, and still be something that can be accomplished during a fifteen-week semester. Another important aspect of the assignment is the project and peer evaluation that helps students learn to objectively assess their own contributions and the contributions of others; these, too are important skills in both academia and the work world. In these capstone projects, students develop confidence in their abilities and learn how to perform in a multidiscipline collaborative environment. The paper will deal with the details of operating such a capstone course.*



***Index Terms –*** *Capstone project, collaborative project, engineering technology, hands-on, undergraduate*


## Introduction

While universities have considerable experience and expertise in the transfer of technical knowledge to their students, they have not always been as focused on helping students acquire and practice the hands-on skills that industry increasingly demands of recent graduates [1]. This includes important, but "non-technical," skills such as effective reading and writing, as well as an array of complex "employability skills," such as problem-solving and decision-making [2]. It turns out that it is often these basic employability skills that are more highly-valued even than traditional technical skills [3]. It's important to note that this is a problem that is becoming recognized across international borders, and not just in the United States; in a survey conducted by the Association of Graduate Recruiters in 2008, they found that the biggest companies in the United Kingdom complained that British students lacked sufficient literacy or numeracy to fill available vacant positions [4].

If the object is to prepare undergraduates to use both the technical and employability skills they will need for the jobs they will want in their areas of expertise, then the most direct and straight-forward way to do that is to give them actual work experiences that encompass all of the skill sets that future employers will require of them. In order to accomplish this, many universities are creating laboratory activities that incorporate requirements that mimic independent business ventures and real-world manufacturing situations. As an added benefit, universities are finding that such projects tend to attract better-prepared students [5] and keep current students interested in technology, which makes it less likely that they will change majors to a different area they find more engaging [6].

While it’s true that these projects have positive effects on student retention and the effectiveness of programs, there are substantial benefits for students as well. Participation in these hands-on programs exposes students’ to practical applications, giving an added dimension of understanding to what would otherwise be mere academic knowledge. Actually applying what they know helps develop work skills by providing actual experience, building confidence and giving students the opportunity to practice communication and interpersonal skills in a workplace setting. As students become involved in an active planning and decision-making situation, they also develop learning patterns based on experimentation and discovery, rather than just waiting to passively receive information through a traditional lecture approach. [7]

## Usage of Problem-Based Learning

This approach is based on problem-based learning, which was defined by Finkel and Torp as "a curriculum development and instructional system that simultaneously develops both problem solving strategies and disciplinary knowledge bases and skills by placing students in the active role of problem solvers confronted with an ill-structured problem that mirrors real-world problems" [8]. In addition to supporting the acquisition of specific skills, PBL helps to provide an environment in which students can learn important “soft skills; such skills might include effective ways to communicate, the ability to find existing information, leadership, understanding what is required to be a part of a team, social and ethical skills, critical thinking, and problem-solving skills. The effect of this approach is that the emphasis is shifted from “teaching” to “learning.” [9]

Barrows describes the main elements of PBL as:

1. Learning is student centered, which means students have an option on how and what they want to learn.
2. Problems are a tool for the development of problem-solving skills.
3. New knowledge is acquired through self-directed learning.
4. Problems guide the organizing focus and benefits of learning.
5. Teachers take role of facilitators.
6. Learning takes place in small student groups and encourages collaboration [10].

It can be a challenge to develop a suitable task-oriented interdisciplinary problem for a class to undertake. The situation requires that the problem be complex enough that students have to drawn on and use their knowledge of the subject so they get relevant practical experience; it’s also important to choose a project that can be satisfactorily completed during a fifteen-week semester.

## Advanced Materials and Manufacturing Processes Capstone Course

Over the last few years, the Aviation Technology Advanced Materials and Manufacturing Processes course at Purdue University (AT 408) has undergone some basic, but important, changes. The course was originally structured as a “Design/Build/Test” course for aviation technology students, but in 2008 ABET established and accredited a new Aeronautical Engineering Technology (AET) program, and the course became an advanced manufacturing course that is required for the new degree.

Using a simulated “real world” project tends to take the focus off short-term learning of required curriculum and shifts students into a mode of searching out and discovering information and techniques that will support and advance the successful completion of their assignment. The context in which the work is done forces students to develop effective communication not only among themselves, but also with their customers, their upper management, and their sponsors. Similarly, they learn and develop problem-solving skills and practice them using a variety of management tools, such as brainstorming, the 6-3-5 method, and the Decision (Pugh) Matrix.

The characteristics of a good project are as follows:

1. The project must be significant, not only to make the learning experience worthwhile to students, but also to build their confidence.
2. It is important that the assigned project be task-oriented, both to help focus students on a finite project, but also to give them an opportunity to develop the technical skills and applications they’ve been studying.
3. If possible, the project should interdisciplinary, which would have the effect of not only introducing students to a new area of study, but would also force them to interact with and rely upon students with whom they have probably not worked before.
4. Problems that have more than one possible solution give students more latitude to be creative and to develop their own ideas; this is a much more realistic approach to problem-solving than the typical academic exercise in which the goal is to arrive at a predetermined solution by a standardized process.
5. In order for the exercise to be an effective learning experience, the problem must be complex enough to challenge students to draw on and use the technical knowledge they have already acquired in their studies.

6. Finally, the project must be simple enough and manageable enough that students can complete the assignment during a fifteen week semester.

While the final two items on the list seem to be incompatible, both requirements must be met if the project is to be effective. The project must both provide a challenge to students and be capable of being satisfactorily completed. Assignments that are too easy are viewed by students as unimportant and uninteresting; extremely difficult projects appear to be impossible to complete on schedule.

Using problem-based learning in a classroom can provide significant learning opportunities for students, but often increases instructor workload since planning and overseeing student learning activities, teamwork requirements, facilitation, preparation, and assessment are all demanding and time-consuming. On another hand, in this time of decreasing state support for public universities, PBL provides opportunities to involve undergraduate students in research that might increase chances of securing funding from industry or governmental agencies. In addition, exposure to research might have the effect of an increased number of students to elect to continue their studies and pursue Master and Doctorate degrees.

The process of developing and promoting projects with industry is likely to help establish contacts and long-term relationships between the university and industry. As companies learn more about university programs and find ways to both contribute to those programs and benefit from them, it is likely that those companies will become long-term partners and/or sponsors of those programs. That kind of a relationship would not only provide an inexpensive way to experiment with new ideas and approaches, but would also give them the opportunity to work with and eventually hire their choice of students for permanent employment or internship experiences.

The possibility of such a relationship with industry is not just a case of wishful thinking on the part of the universities. Over the course of the last three years, the new Advanced Manufacturing course has evolved from merely offering hands-on projects to be tackled by student teams into a program that provides students with a genuine problem-solving experience through exposure to and participation in solving complex engineering problems. In the fall semester of 2007, the instructor tasked the students to create mock-up parts for the Pratt and Whitney PW4098 Turbofan Engine used as a visual aid for the Aviation Technology Powerplant Laboratory. The engine was missing many of the components needed if it was to serve as a good tool. Student teams were asked to research those missing parts and assemblies, gathering information not just concerning geometrical dimensions and physical sizes, but also concerning the functions and requirements of the actual functional system or component. By the end of the semester the engine was better suited for its educational purpose [11]. From then on, projects grew in complexity.

## Design of Aerospace Structures Course

AAE 454 (Design of Aerospace Structures) is a technical elective offered by the College of Engineering School of Aeronautics and Astronautics to provide background and experience in technical issues associated with structural design, including failure criteria (fatigue, fracture, buckling, corrosion, etc.), design constraints, materials selection, manufacturing issues, joints and assembly methods, stress analysis, and nondestructive inspection. The course is intended to supplement other capstone design courses in the Aeronautics and Astronautics curriculum by emphasizing structural and manufacturing issues. The senior level students have a strong background in engineering mathematics and computer usage, and have completed several other introductory courses in aerospace engineering, including stress analysis, materials behavior and design concepts.

In addition to these technical issues, AAE 454 also seeks to develop other “enabling” skills needed for the successful designer, including technical communications (oral and written), technology assessment, teamwork issues, economic considerations, creativity and problem-solving techniques, engineering ethics, case histories, and personal development skills. Development of these latter topics has involved several years of experimenting with cross-department projects with the Department of Aviation Technology [12, 13]. Typically these projects have involved a “Design/Build/Test” type theme, with integrated teams of engineering and technology students.

These engineering/technology student teams are quite different from normal student teaming arrangements in that students come from two different classes taught by two different departments. It should be emphasized that these are independent engineering and technology courses with different educational goals and content, but which collaborate on a common design-build-test type project. The students have significantly different academic backgrounds, and in many cases do not know each other before hand. Thus, the non-homogeneous nature of the student pairings represents the types of ad hoc teams found in industry, where members with widely diverse backgrounds and experiences combine for a specific purpose. Moreover, the fact that the engineering and technology departments are located approximately one mile apart on the Purdue University campus requires development of organizational and communication skills since students can’t simply depend on casual meetings between classes during the day. The projects have been successful in that both groups of students are exposed to the types of interdisciplinary teams common to the modern aerospace industry.

## Evolution of Collaborative Projects

AT 408 has had a strong connection to School of Aeronautics and Astronautics from the very beginning. Initially, students from both departments worked in teams to design a structural component to fulfill specific requirements, construct it, and test it to those requirements [12]. Ideally, if a component failed a test, students would re-design the structure and go through the whole cycle again. With changes in AET program, collaboration with the School of Aeronautics and Astronautics changed as well over last couple years. As projects requiring high-level engineering became more complex, the need for effective collaboration between students became even more pronounced. For example, in the fall semester of 2009, AET students designed and fabricated critical components for the Purdue University student rocket team, including a combustion chamber and an injector base. The goal of the team was to propel a vehicle and payloads of up to 5 pounds to an altitude of 25000 ft. In another example, students needed to improve specific Purdue University Grand Prix race cart functions; this involved redesigning paneling surrounding the kart for aerodynamics and aesthetic appeal, reengineering the engine to achieve increased performance, more horsepower, and improved fuel intake, designing and fabricating heat shields/guard applications for safety, and making other performance and safety improvements. Students also designed components and fixtures to support the research of the department's faculty members.

For their part, engineering students from the School of Aeronautics and Astronautics were able to provide necessary "consulting" support to AET students; their expertise was extremely helpful because of the increased complexity of the projects [13]. Through this project, the engineering students got the opportunity to get practical experience in the area of client communication, as well as in the areas of problem-solving and preparation. The intent of the collaboration was to model consultant/client relationships in industry with the engineering students acting as a consulting company for the Aviation Technology "clients" to deal with highly complicated engineering tasks. To further enrich the learning experience, both groups were required to prepare a variety of supporting documents, such as Requests for Consulting Services, Statements of Work, detailed reports, etc., making the arrangement beneficial for both the engineering and technology students. Overall, sponsors (faculty members and industrial partners) received usable products without significant investment of time and money on engineering products, while the academic departments involved will be generating important research and collaboration funds, which is even more important during a time of economic distress.

## Conclusions

Under the new "consulting- clients" model, laboratory projects have been based on a "Design/Build/Test" approach. To make the experience even more useful, the program has integrated the contributions of teams of engineering and technology students. In this model, both groups of students were exposed to the types of interdisciplinary teams commonly found in the modern aerospace industry. Students not only got practical, real-world experience by participating in the capstone project, but were also able to develop confidence in their abilities, learn employability skills, and work a project from the initial assignment through to its actual completion. This arrangement has also been beneficial to faculty members, who have received practical support from the program, and aerospace and aviation-related companies, because they have been able to develop answers to engineering problems without the commitment of company time or engineering assets. The goal of the program in the future would be to establish long-term relationships with such companies, hoping to provide engineering services to them on regular basis. Finally, from an educational and institutional perspective, universities and university departments will benefit because of the additional outlets for research and collaboration, and the opportunities to expose undergraduates to real research, which, over time, is likely to interest more of them to continue their education and pursue graduate degrees.

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