INTEGRATING DESIGN APPLICATION AND COMMUNICATION SKILLS INTO SENIOR DESIGN COURSES

James Helbling, Department of Aeronautical Engineering
Embry-Riddle Aeronautical University, Prescott, AZ

This paper recounts the evolution of a capstone senior design course taught at Embry-Riddle Aeronautical University in Prescott, Arizona. It will discuss the development of the application based learning objectives and the integration of a technical communication component into the course in question, and the challenges and negotiations involved in successfully implementing these changes in course content.

The content of this aircraft design course was conceived after a review of previous senior design briefings and of recent alumni surveys. The design briefings were shown to be lacking in any true understanding of physical application of analytical tools, while the alumni survey indicated that the students were given insufficient communication training during their tenure at the university. As a result, the course content was radically altered to address these perceived weaknesses.

To address the lack of application of analytical tools, both wind tunnel and structural testing of scaled aircraft models were introduced into the course. The wind tunnel models were used to verify the aerodynamic loading and stability predictions made during the preliminary design phase completed in a prerequisite design course. Structural testing was then completed to verify the design team's ability to predict structural response to load completed via finite element model simulation. Further design verification has recently been added in the form of flight testing of scaled flight test articles designed to fly with RC components.

The lack of communication training was addressed by introducing team-teaching with a communications instructor. This instructor provides lectures and additional guidance in the areas of technical writing, group presentations, and teamwork. The instructor is responsible for 30% of the grade for all written and oral communication submittals.

The integration of design application and communication skills has been very successful in preparing Embry-Riddle students for real world employment as evidenced by alumni comments. Senior students also enjoy being placed in a hands-on environment which allows verification of the theoretical learning they have been exposed to during their previous courses.

Introduction

This paper recounts a change in the senior capstone design curriculum at Embry-Riddle Aeronautical University (ERAU)/Prescott campus that involves the introduction of verification of analytical predictions via testing of physical models and a team-teaching effort between the Department of Aeronautical Engineering (AE) and the Department of Humanities/Communities (HU/COM). These changes address perceived gaps in student preparation as they transition to the workplace. This paper will define these perceived gaps in student knowledge, describe the implementation of curriculum changes, and evaluate the success of the new capstone curriculum.

The senior capstone Aircraft Detail Design course was selected for curricular change because it provides timely instruction just prior to graduation. Furthermore, this course is intended to be a stepping stone to professional life. Thus, curricular changes to bolster application of theory and communication skills, including teamwork and conflict resolution, have been implemented in order to better prepare senior students for professional challenges.

This paper begins by explaining the context that led to the curricular changes in the capstone course. The evolution of the Detail Design course is described in detail, followed by a discussion of the challenges and successes encountered in developing revised course content. The paper concludes with a recap of the recent physical enhancements in the course configuration and plans for further improvements in preparing ERAU graduates for their post-graduate life.

Context

ERAU/Prescott is a 4-year university in Northern Arizona with an enrollment of approximately 1,600 undergraduate students, with Aerospace Engineering (AE) being the most popular engineering major. Students majoring in AE take courses which have a strong emphasis on laboratory and design work to prepare the students for the senior capstone design courses.

AE majors must choose one of two design tracks: aircraft or spacecraft. The aircraft track culminates in a sequence of two senior design courses: Aircraft Preliminary Design and Aircraft Detail Design. Likewise, the spacecraft track also has two senior design courses: Spacecraft Preliminary Design and Spacecraft Detail Design.

In the Aircraft Preliminary Design course, students work in teams to conceptualize a complete aircraft design. These designs are developed in response to a set request for proposal (RFP) which defines mission requirements and aircraft constraints. In the Aircraft Detail Design course, teams have the option of pursuing a design, build, fly (DBF) design or selecting one component – typically a wing or tail section – and designing a scaled test article representative of that component which they will ‘design, build, and break’ (DBB).

All teams fabricate full aircraft wind tunnel models for the purpose of verifying the aerodynamic loading and stability characteristics of their designs that they predicted in the Preliminary Design course. All teams also perform structural testing to verify finite element simulations of their designs. The DBF teams test to 80% of design limit load, while the ‘design, build, break’ (DBB) teams test their selected component test articles to failure. These design and test results are then presented by each team at a formal briefing at the end of the semester. This formal briefing is open to the university and is scored by a panel consisting of faculty and members of the university’s Industrial Advisory Board (IAB).

All of the senior design courses have significant technical writing and team presentation components. To prepare for these senior design courses, all AE students must take (and pass) a Technical Writing course and a Speech course. These writing and speech courses are offered by the HU/COM department.

Six years ago the Aircraft Detail Design course underwent a curricular update to better prepare AE students for professional life. The results from annual internal reviews were documented in preparation for a program review by the Accreditation Board for Engineering and Technology (ABET) in addition to the results from alumni surveys. These results indicated that AE graduates required more intensive and timely preparation in two primary areas: application and communication.

The impetus for a more application-based curriculum came from a change in faculty at the Detail Design level. The new design faculty had many years of industrial and managerial experience prior to joining the ERAU staff and understood that typical undergraduate training does not emphasize the application of theory. To address this need, the Aircraft Detail Design course added the fabrication of test models to allow verification of analytical predictions. The Detail Design instructor now also engages in team-teaching with his Preliminary Design counterpart to ease the transition from the more theoretically-based curriculum to his application-based course.

To address the lack of adequate communication instruction, the AE faculty reached out to the HU/COM faculty. After a series of discussions and negotiations, the AE and HU/COM faculty decided to implement communications team-teaching in selected senior capstone courses. This arrangement is explained more fully in the following section.

Aircraft Detail Design Course Evolution

The ERAU senior design courses are required 4-credit classes, taken in the senior year, that allow students working in teams of typically 6 to 8 members to design an aircraft or spacecraft and then test one component or set of subsystems. Extensive written reports and formal oral presentations are required in each course.

Prior to the curricular changes discussed in this paper, the Aircraft Detail Design course involved minimal wind tunnel testing and the limited involvement of an HU/COM instructor who served in strictly an advisory role. The change in the course content addressed perceived weaknesses through: 1) additional verification of analysis via test and 2) an increased emphasis on communication skills.

The first curricular change required students to select a single component from the aircraft they developed in the preliminary design course and concentrate on the design of that component alone. They were first required to fabricate and test a wind tunnel model of the selected component, with the intent of determining coefficient data that would allow verification of the aerodynamic coefficients derived during the preliminary design process. The students then used the coefficient data to verify loads predictions for the component being designed.

Concurrently, students designed a scaled structural model of their chosen component to critical design loads (verified by the wind tunnel results). Since the structural model was scaled, an emphasis was placed on verification of analytical method versus design of the full-scale component. Students were required to simulate their structural model as it was actually built and constrained using a Finite Element Model, and then verify their ability to predict structural

failure by comparing strain and deflection measurements obtained from the actual model to those predicted by the computer simulation.

The second curricular change adopted a team-teaching approach utilizing HU/COM faculty to provide lectures to students on proper technical writing style and the expected content of written submittals. This collaboration has been shown to benefit students in at least two ways: 1) to provide supplementary instruction in communication skills and strategies that are immediately contextualized making them more easily grasped [2], and 2) to present the rhetorical tools that allow students to master the genres specific to their discipline (e.g., design proposals) which AE instructors have mastered but may have difficulty articulating [3].

The HU/COM faculty member scored both written and oral submittals and also provided lectures on improving team interaction skills, which had always been a problematic issue within the design teams. She also developed a Code of Conduct and Conflict Resolution Plan, which were adhered to by all teams, and which have proven to be very effective in eliminating unprofessional behavior and promoting a healthy environment within the teams.

Recently, the course took on a different track by introducing the DBF option. This option is now initiated in the Preliminary Design course where two design teams are provided identical RFP's in the form of a design competition which culminates in the Detail Design course as a wind tunnel 'fly-off'. The two Preliminary Design teams combine to form a single team of 12-16 students in Detail Design. The two former teams become 'design groups' which continue to develop their designs through the fabrication of full aircraft wind tunnel models making use of rapid prototyping wherever possible [4]. The models are then tested using identical procedures and the results are submitted to a faculty panel which then selects the design which appears to have the most promise as a flight test article. Teams which choose this option still have the requirement to perform structural test of a selected component (typically a wing) to verify a finite element simulation, however they do not test to failure. The DBF teams instead perform a 'proof' test to 80% of the predicted limit load so that their component can be used for their flight test article. It should be noted that the flight portion of the design is purely optional, with the potential of 'bonus' grade points being part of the incentive provided to students to complete the flight test.

Introducing this option created new challenges in terms of communication and conflict resolution. With the combination of two teams into one, the design groups were forced to collaborate in the writing of their report sections so that a uniform product was submitted. There was also the obvious feeling of loss that one design group was forced to experience when the project that they had been dedicated to for over four academic months now had be 'left behind'. These factors made the need for communications and conflict resolution assistance offered by the HU/COM co-instructor even more essential to the successful completion of the project.

Based upon the improved quality of student written work, positive feedback on student course evaluations, positive comments received from ABET auditors, and improved alumni survey results, the curriculum changes cited above have become engrained in the Aircraft Detail Design course. However, implementing this curricular change did not come without its challenges, which are further documented below.

Challenges

Two critical challenges resulted from the implementation of this curricular change, primarily in the area of HU/COM team-teaching. The first critical challenge was student resistance to having an HU/COM professor in their AE class. When the HU/COM instructor was first introduced to the students in the team-teaching position, the students were uncertain of her role. They were unsure as to the relevance of her presence and what value she would add to an engineering course.

Despite providing a course syllabus which highlighted communication and teamwork objectives and activities, and despite the HU/COM instructor's lectures that were designed to ease the documentation process, in the first semester of the curricular redesign process AE students did not see the value of having a communication instructor in the classroom. Some even argued that her lectures on documentation and presentation were taking time away from the real work of the class, which they perceived was solving, designing and testing, not documenting. Students felt this way despite both instructors' consistent emphasis during class time on the need for strong communication and conflict negotiation skills if students were to be successful in industry,

The source for this lack of respect given to the HU/COM instructor was traced to lack of grading authority. In a traditionally team-taught course, grading authority is negotiated between instructors and is dependant upon the content and context of the course. In this case, team teaching was new to ERAU and so the HU/COM instructor did not immediately negotiate any grading authority; without such authority, however, students did not perceive the communications faculty as being a "real" teacher in the class, which lead in turn to student resistance to lecture material and instructor comments and requests for revision.

Therefore, in response to this challenge, the two instructors re-negotiated the syllabus so that the communications faculty would help assess every assignment and would then assign some percentage of the total points for that assignment. As a result, while the majority of the assignment grade would still be based on content and technical accuracy, a lesser percentage would be allocated to format, coherence, and grammatical accuracy.

Student response to this change in policy has been very positive. Once they realized that the communications instructor was grading the quality of their work, students began to treat her as a useful resource. Team teaching was subsequently introduced in the Aircraft Preliminary Design which made students even more accepting of the team teaching arrangement in Aircraft Detail Design. In fact, after a few semesters, students have begun to expect HU/COM instructors in their senior design courses, and first-year engineering students already know which HU/COM faculty is teaching in which AE senior design course.

While the first critical challenge was classroom related, the second critical challenge is more administrative in nature. To understand the nature of this challenge, one must also understand that as an undergraduate teaching institution, ERAU has many degree programs but none that are housed in the HU/COM department. Rather, HU/COM is a service department, teaching general

education courses such as freshman composition, speech, journalism, literature, values and ethics, mythology, and basic humanities courses to approximately 1600 students. As such, this department offers a broader range of courses and more sections of courses than any department on campus except the flight department, and accomplishes this feat with a limited number of full-time faculty and adjuncts.

Obviously, faculty resources can become a bit stretched, and HU/COM faculty have at times been asked to stop team-teaching with the AE faculty in order to teach general education courses instead. As of this semester, department chairs in both departments have been able to juggle faculty and course loads to satisfy administrative requirements so that HU/COM may continue to support the AE students' professional development. And many administrators see the value of the continuing collaboration between departments, for both teaching and research. Nonetheless, varying levels of administrative support for team teaching is a continuing challenge for ERAU/Prescott, one that might be side-stepped by in the short term by mini-grants or adjunct hires, but one that must be addressed each semester that this curricular redesign continues.

Successes

Although a quantitative assessment of the success of the capstone curriculum change is difficult at this time due to limited data, a qualitative appraisal is possible based upon student course evaluations, senior exit interviews, feedback received from a recent audit performed by ABET, and recent alumni feedback.

The percentage of positive student comments documented in course evaluations has increased steadily every semester since the capstone curriculum change was introduced in Fall 2003. Initially students were frustrated by the changes made to the course and the workload required to achieve the course objectives. This frustration resulted in less than 50% of the comments regarding the course content being positive. During the last 8 semesters, however, 80 – 90% of the comments are routinely supportive of the course.

Regarding the application-based learning content, student comments during the first two semesters were directed toward the time 'taken away' from analysis and design work by forcing them to manufacture test articles. Many of these comments referred to the fabrication tasks as non-engineering work. However, comments received during the last 8 semesters have embraced the learning experience inherent in manufacturing a test article, and the design 'lessons learned' obtained through fabrication and test. The positive comments now routinely outnumber the negative responses in excess of 10:1.

In terms of team-teaching, originally only one or two students would provide positive comments regarding the communications instruction given. Those comments now routinely number 10 or more for class sizes ranging from 15 to 30 students. Originally there were many comments asking why time was being 'wasted' on communications skills that could be provided adequately by the engineering instructor. The comments now typically state the students' gratitude for the work ethic shown by the HU/COM instructor in improving their communication skills.

Overall, students greatly appreciate the opportunity to perform application-based engineering, and enjoy having a faculty member dedicated to improving their HU/COM skills. There have been many positive comments on the structure of the course and the HU/COM instructors' willingness to provide almost immediate feedback on written assignments, and on how incorporating that feedback into report sections throughout the semester makes the final compilation of design reports much less difficult and stressful. Seniors have also voiced their overwhelming approval of the structure and learning environment present in the Aircraft Detail Design course in senior exit interviews documented since the curriculum change.

The ABET auditors were impressed with the AE Department's strategy in addressing application-based engineering and in adopting team-teaching to further improve communications skills, which was documented as a perceived weakness in recent alumni surveys. The ABET criteria require engineering programs to show that graduating students have computer simulation and experimental experience as well as communications and ethics skills and have demonstrated the use of that skill set to enhance the technical content of their curriculum. The application-based engineering approach and team-teaching with communications faculty as a part of the senior design experience certainly helps to fill these requirements, and the auditors whole-heartedly endorsed the process.

Additionally, alumni surveys have shown a reversal of the previous trend showing dissatisfaction with technical writing and project management skills acquired at Embry-Riddle's Prescott campus, as shown in the following table.

Skill Preparation	**1999 - 2002 % Very Good Responses**	**2004 % Very Good Responses**
Technical Writing	28.4	50.0
Planning, Scheduling and Carrying-out Project	22.0	57.4

The table shows the percentage of 'One Year Later' alumni respondents who indicated they received a 'very good' preparation for the two general skills most closely linked to the curricular change implemented in the capstone design course. The center column shows the results for a compilation of the surveys taken for the three years prior to the curricular change, while the right column shows the results for the year following the initial curricular change (which is also the latest available data for this type of survey). These results show a dramatic improvement in perceived alumni preparation which is likely attributed to the timely communication and team-building skills emphasized in the capstone course. However, it is understood that these data are provided for a limited time period and scope, and further verification of these results is required.

While no formal survey data are available for more recent years, a qualified assessment of the curricular changes is available through alumni feedback via email transmissions. Since 2004, a semester has not gone by without several alumni contacting both the engineering and communications instructors of the Aircraft Detail Design course to personally them for exposing the alumni to analytical verification methods and 'forcing' them to learn proper communication skills. These students often cite the documentation and presentation requirements of industry,

and state how much better prepared they are for those requirements versus recent grads from other institutions.

Planned Improvements

As stated in previous paragraphs, the Aircraft Detail Design course allows students to gain first-hand knowledge of analysis verification via test. This environment has been greatly enhanced with the recent addition of an Aerospace Fabrication and Experimentation building which allows for structural testing using industry standard equipment [5]. This new building also includes separate fabrication areas for both the aircraft and spacecraft design teams placed on either side of a refurbished machine shop with computer-numeric-controlled machining capability. These facilities allow students to fabricate and test their designs more efficiently and with a higher level of fidelity than was ever before possible. However, even with these physical enhancements to the ERAU/Prescott capstone experience, several improvements are planned which will allow future students to become even more prepared for their post-ERAU futures.

The curricular changes described in this paper are planned for implementation into the Spacecraft Detail Design course in the Fall 2009 semester. Once this course has undergone curricular modification, all four senior design courses will provide AE graduates with timely instruction on application of engineering theory and with a stronger set of team, communication, and ethics skills. Because these objectives will be present in all four classes, and because all four courses will use the same delivery method (i.e., team-teaching), these classes will form a coherent curriculum. Students will have established the required skills in their preliminary classes and can thus transition more easily into their detail courses where these skills will be refined in preparation for professional life.

Finally, it is planned that follow-up alumni surveys and additional quantitative data be collected which will be used to assess the success of this curricular modification. This information will also be used to identify additional skill sets that could be incorporated in future curricular modifications intended to better prepare AE graduates for professional challenges.

References

[1] Helbling, Jim, David Lanning, Ron Madler, Angela Beck, and Patric McElwain. “Integrating Communications into Team-Taught Senior Design Courses” Proceedings of the 2005 American Society for Engineering Education Annual Conference and Exposition, Washington DC: ASEE, 2005.

[2] Bereiter, Carl and Marlene Scardamalia. The Psychology of Written Composition. Hillsdale, NJ: Lawrence Erlbaum, 1987.

[3] Kokkala, Irene and Donna A. Gessell. “Writing Science Effectively.” Journal of College Science Teaching 32 (2003): 252-257.

[4] Helbling, Jim, and Lance Traub. "Impact of Rapid Prototyping Facilities on Engineering Student Outcomes" Proceedings of the 2008 American Society for Engineering Education Annual Conference and Exposition, Pittsburgh, PA: ASEE, 2008

[5] Helbling, Jim, David Lanning, Ron Madler, Darin Marriott, and Karl Siebold. "Impact of New Facilities on Engineering Student Outcomes" Proceedings of the 2007 American Society for Engineering Education Annual Conference and Exposition, Honolulu, HI: ASEE, 2007.

Biography

JAMES F. HELBLING, M.S.A.E.

Currently an Associate Professor of Aerospace Engineering at ERAU/Prescott where he teaches structural analysis, computer aided design, and aircraft detail design courses. He has 21 years of industry experience with McDonnell Douglas (now Boeing) and Northrop Grumman Corporation where he specialized in structural fatigue loading and served as manager of F-5/T-38 Engineering.