Improving Student learning by Assigning Functional Engineering Roles and Employing Industry Style Performance Evaluations in The Capstone Design Course

Sirish Namilae
Aerospace Engineering, Embry-Riddle Aeronautical University, Daytona Beach, FL, 32114

Abstract

Aircraft detail design capstone course in Aerospace Engineering at Embry-Riddle Aeronautical University employs group projects of four to six students and is designed to provide real world experience in structural design process, by designing and analyzing and documenting an aerospace structure. This paper reports on a few innovations in the course to provide industry like experience to students namely (1) Assigning functional engineering roles and (2) Industry style performance evaluations to inform grading. Survey and observations indicate that students found assigning of engineering roles to be helpful in enhancing their experience, but did not benefit much from performance evaluations as implemented.

Keywords

Capstone design, Engineering Roles, Performance Evaluations.

Introduction

Undergraduate degree in aerospace engineering department is capped by Aircraft Detail Design course (AE421). The course is expected to provide students with real world experience in structural design process, by designing and analyzing a real problem, e.g. Wing of a general aviation aircraft. The projects are generally structured to have 4-6 students working together in a group designing and analyzing the structure. Their results are documented in a project report which is expected to include details of the design to functional requirements, materials selection, and stress analysis.

According to the literature [1-3], some of the common problems instructors encounter during capstone design projects are laggards doing little work and getting credit for group results, inadequate planning and documentation, student time scallop, i.e. increasing the effort exponentially as the deadline approaches), inadequate practical exposure in the conceive, design, implement and operate (CDIO) process.

The objective of this work is to address the above problems by introducing aspects of industry practices. We address the issues of laggards by assigning specific functional engineering lead roles corresponding to an aspect of the project to each student. This also addresses planning and documentation to some extent. We focus on the issue of time scallop by incorporating industry style performance evaluations for grading. We also introduce a two-week mini-project involving correlation between design, analysis and manufacturing in the CDIO process to introduce the students to various engineering roles. The paper presents survey results and anecdotal findings regarding implementation of these practices in Detailed Aircraft Design course over two semesters.

Assigning Engineering Roles to Students

In the industry, detailed design of any large aircraft component is performed by team of engineers with specific functions. The engineering teams in aerospace structural detailed design typically include lead engineers responsible for (1) Design, (2) Structural analysis, (3) Manufacturing, (4) Materials and Processes, (5) Systems/project engineering. These lead engineers are supported by staff engineers, whose numbers vary depending on need through the conceptual, preliminary and detailed design phases of the project. For example, consider the detailed design of a commercial aircraft component like main landing gear door; the initial phase is design heavy and may need more design engineers developing design concepts with possibly one engineer from other functions supporting the development. Once the preliminary loads are available the focus shifts to structural analysis requiring more engineers in this function for detailed sizing of the parts. Once designs are finalized, the work is centered around manufacturing and materials engineers with other functions supporting. We wanted to bring this team dynamic to the design course by assigning specific functional roles to the students participating in the design projects.

The students were introduced to these various roles during a mini-project in the beginning of the semester. The two-week mini-project was presented as a design competition for lightest weight design that met given loading conditions. It involved designing a cantilever beam with fixed outer dimensions that is capable of bearing a specified distributed load (see Figure 1). The groups had to design the interior structure of the beam (e.g. stiffeners, honeycomb etc), analyze it for bending and buckling loads, and fabricate the structure using aluminum foil and glue only. The intention of the mini-project was to introduce the different engineering roles as well as coordination between design analysis and manufacturing.

For the main design project following the mini-project, students will be asked to self-identify into one of the four roles related to design, stress analysis, materials /manufacturing and system/project engineering. Without an actual build there was relatively less work on manufacturing, therefore that function was combined with materials and process engineering and the students. Each student in a project had two roles, one as a lead engineer for one of the four functions, which was their main responsibility. They also had another role as a staff engineer on the other functions where they are expected to perform the tasks assigned by the lead for that function. This process assigned individual responsibility to each student

Figure 1. Design and fabrication of cantilever beam using aluminum foil for the mini-project.

and also give them exposure to different aspects of detailed design and structural analysis.

The student assigned as lead for systems/project engineering was held responsible for requirement gathering, project schedule, and coordination with other sections (represented by instructor), monthly communication reports and planning/implementation of the final project report.

The design engineering lead was responsible for modeling of the design in catia, part notes that reflect all the requirements, coordinating with manufacturing lead to make manufacturable design, coordinating with stress lead to make structurally sound part.

The manufacturing/materials lead was responsible for ensuring that the design can be manufactured. He/she would identify the manufacturing process and assembly required and contribute to the manufacturing and assemble sections of the final report. They were also responsible for collecting the materials allowables and detailing any plans for required testing.

Stress engineering lead the structural analysis of the components using finite element modeling and hand calculations. They were responsible for structural integrity of the design and stress notes in the final report.

The design lead and stress lead had higher load with this structure, therefore a project of six students would have two design leads, and two stress leads each with unique responsibility. For example aft and forward sections of a design, or finite element and hand calculations in stress analysis.

The instructor served as consultant/interfacing section representative/management in this project team structure. Below figure 2 illustrates this project structure.

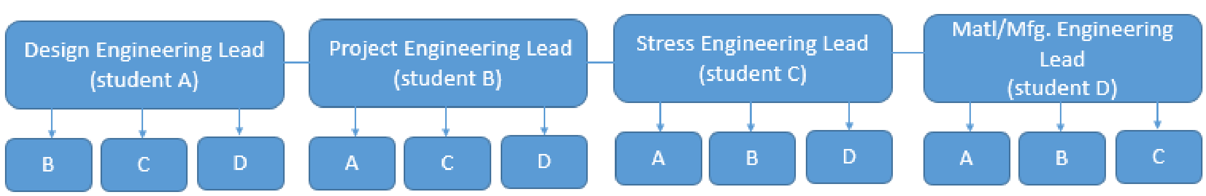

Figure 2. Design project structure.

For one of the semesters the final project was on 'Design and analysis of main landing gear door for a commercial aircraft'. Four groups of 5-6 students with self-identified lead engineers for design, stress, manufacture/materials and project engineering participated in the projects. The groups choose different concepts and aircraft model for designing the landing gear door. Figure 3 shows two of the concepts, a small door for Boeing 737 and a large landing gear door assembly for Airbus A-380.

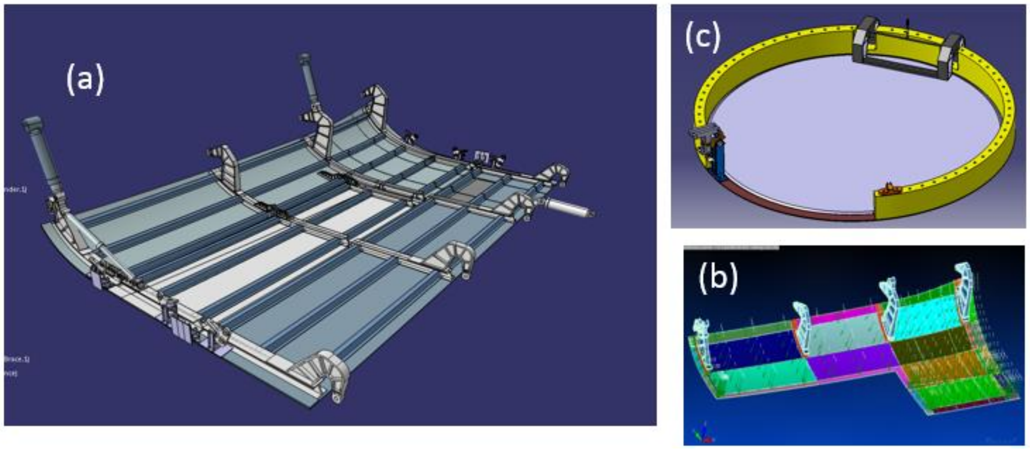

Figure 3. Student design of main landing gear door for (a) Airbus A380, (b) corresponding finite element analysis and (c) design for Boeing 737.

Q1- Use of different engineering roles in design project has helped me in acquiring/improving **engineering skills**. **Agree – 75% Disagree - 20%**

Q2- Use of different engineering roles in design project has improved my capability to **formulate problems.** **Agree – 70% Disagree - 20%**

Q3- Use of different engineering roles in design project has improved my capability to **work in a group.** **Agree – 70% Disagree - 15%**

Q4- Use of different engineering roles in design project has improved **communication within the team.** **Agree – 75% Disagree - 10%**

Q5- Use of different engineering roles in design project has improved my **overall engineering skills.** **Agree – 80% Disagree - 15%**

Q6- Should we continue assigning engineering roles in design projects? **YES – 70% NO - 20%**

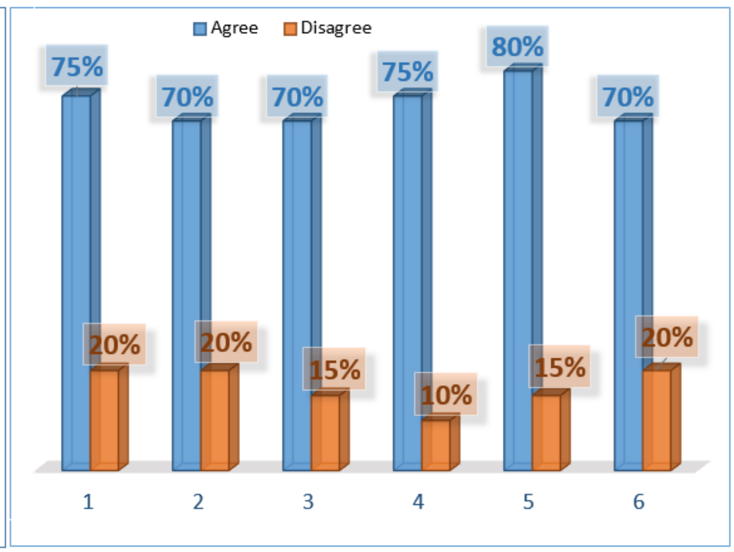

Figure 4. Survey questions and results indicates success of the research approach.

A mid-term and final survey were conducted to measure the effectiveness of assigning engineering roles towards the final success of the project. The survey questions and the results of the survey are shown in the figure 4. The class size for this sample was 24 students and all of them participated in the survey. As can be seen most students found the assigning of distinct engineering roles to be useful for their overall experience. Significantly, 80% of the students agree on “Use of different engineering roles in design project has improved my overall engineering skills” and 70% agree on “Should we continue assigning engineering roles in design projects?”.

Some qualitative observations regarding the approach, firstly, there were fewer complaints from groups about xyz student not contributing to the team. Secondly, high performing students contributed larger share of work, both as leads for their function and as staff engineers in other functional roles. While the mini-project before the main design project, helped students identify the engineering roles, there were at least two instances where the students wanted to change their assigned role middle of the project creating imbalance in the team. This aspect needs to be addressed in further iterations of this approach.

Incorporating Industry Style Performance Evaluations

Table1. Target goals for performance evaluation generated by one of the student teams

	Exceed Expectations	Meet Expectation	Meet some expectation
Schedule Compliance	➢ All tasks are completed by the set completion date with no changes to schedule.	➢ All tasks were completed on time but pushbacks were needed. ➢ If not completed, team worked to complete task as soon as possible	➢ Tasks were not completed on time and no effort was made to complete after missing deadline.
Analysis Tasks	➢ All final designs were under the prescribed strain limits. ➢ Fasteners and hinges were analyzed and met limits. ➢ Failsafe analysis met limits of effectiveness. ➢ Models were clean logical and results were justifiable.	➢ Designs met most criteria for strain limits. ➢ Analysis met limits, but required further work. ➢ Model had some errors/was messy and could have been refined to improve results.	➢ Model failed to run/results generated indicated and ineffective aircraft horizontal tail.
Design Tasks	➢ Model was competitive with existing composite designs in terms of weight limits. ➢ Design provided easy access to perform NDE.	➢ Model was effective but needed further refinement to be competitive with existing designs. ➢ Potential integrity and access issues.	➢ Model was unrefined and was missing key components. ➢ Wing box existed and was tested but could have used additional items.

One of the objectives here is to help students quantitatively assess their contribution in a group project. Additionally, an essential part of real world industry experience the course intends to provide, involves shifting from traditional grading to industry style performance evaluations. We implemented an industry style performance evaluation that informed the eventual grade in the course. This provides students with an understanding how their work will be assessed once they leave the university and start engineering careers.

The performance evaluation system we used was a modified version of the one currently followed at the Boeing company. The criterion used for performance evaluations were based on (1) Schedule compliance, (2) Analysis tasks, and (3) Design tasks.

When the students start their group project, they were asked to come up with target goals on each of the above three criterion. The instructor and students met one-on-one to refine and specify these target goals for the above mentioned criterion. The performance of the students to various levels of the goals resulted in evaluation of: (1) Exceed Expectations (EE), (2) Met Expectations (ME), (3) Met Some Expectations (MSE), and (4) Did Not Meet Expectation (DNM)

An example of rubric one of the student group came up with is shown in Table 1. Student input was sought as to how they graded their team performance according to these preset rubric. This student group was working on detailed design of horizontal stabilizer.

Some qualitative observations regarding this practice were following: Overall students did not like this approach to grading compared to the default system of instructor coming up with a grade based on group performance. In spite of repeated assurances to the contrary, they assumed that EE would result in A grade and DNM would be an F grade. Most students were looking for means to get to EE, by changing the rubric or interpretations of the rubric they themselves devised. This made objective evaluation with student input a difficult task. A quantitative survey was not used to measure the efficacy of this approach because of these anecdotal observations. One way to possibly improve this process is by not correlating performance evaluations to grading, or correlating only a small percentage of grade. We will modify this approach for the next iteration.

Summary and Conclusions

This paper reports on a few innovations in the capstone aircraft detailed design course which include; assigning functional engineering roles and industry style performance evaluations. Assigning functional engineering roles helped define individual roles for student team members and was well received by students. Improvements in the process are needed to effectively use performance evaluations for course grading.

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Sirish Namilae

Dr. Sirish Namilae joined Embry-Riddle Aeronautical University in 2014 after a six-year career at Boeing where he worked in airframe structure analysis on several platforms like 787-8 & 9, 777-9X and rotorcraft. He teaches materials and design courses at Embry-Riddle’s Aerospace Engineering Department. Dr. Namilae’s specializes in solid mechanics and materials science. His current research interests funded by NSF, DOT and NASA are in the areas of computational modeling of active particles, and nanocomposites.