An example of active learning in Aerospace Engineering

6. Do senior staff members participate?

From the beginning of the program in 2001, we were happy to experience an increasing number of senior staff members joining the program; they appear to feel the need to improve and are therefore intrinsically motivated to work on their teaching skills. Especially so, because this program focuses on a teaching method they are very familiar with: the lecture. Furthermore, the program is something new: experienced teachers feel that it is something advanced instead of basic, and, advanced courses appear to be more attractive for experienced teachers.
Compared to our regular program more participants were associate and full professors and even Deans of Faculty.
One important side-effect of the program is that participants feel more comfortable to follow other staff development programs as well. Moreover, the verbal advertising by senior participants (associate and full professors, Deans of Faculty) has a percolating effect in the participant's faculty community.

7. Conclusions and future plans

Our experience up till now is that training teachers in theatre skills has a positive effect on student appreciation and quality of lectures. Furthermore, relatively more experienced teachers appear to participate in this course compared to other courses and they consider the course to be very valuable.

For the future we plan to increase the length of the course and add a program that explicitly deals with structuring content from a story point of view. Recent experience shows that the effectiveness increases even more when story construction is taken into account.

Literature

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Part 4:
Good Practice of Active Learning

Chapter 20
AN EXAMPLE OF ACTIVE LEARNING IN AEROSPACE ENGINEERING

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SUMMARY
This paper is a showcase for an on-going active learning capstone design project in the BSc. programme at the Faculty of Aerospace Engineering at Delft University of Technology. In multi-disciplinary teams supervised by tutors from different backgrounds students work towards an Aerospace (related) design. In the exercise students learn about applying knowledge, working in teams, sustainable development, project management, reporting, presenting and design in a semi-professional environment.

KEYWORDS
Design education, Project-based learning, Aerospace, Active learning

1. Introduction
Delft University of Technology (TU Delft) began offering Masters and Doctoral degrees in aeronautical engineering in the early 1940s. By the 1960s design of aircraft and spacecraft became a major topic in the teaching activities at TU Delft. Right from the start, attention focused both on the teaching of engineering science as well as on engineering practice. The latter because it was realized that engineers need more than pure technical knowledge to find good and viable solutions to the complex technical problems they are facing. For this reason design exercises were held wherein the students were required to actually perform a 'paper' design of an aerospace vehicle and/or component. This resulted in the publishing of the book "Synthesis of Subsonic Aircraft Design" (Toorenbeek, 1982).
In the 1990s the educational program was restructured to allow for team design projects (Rothwell, 1995, 1996, Saunders-Smits et al., 2003). It was felt that such a team project would provide a vehicle for attaining other educational objectives (Faculty of Aerospace Engineering 2004), such as the ability to work in teams, communications, documentation and configuration control and to improve their presentation and report-writing skills. It also resembles the team-design environment typically found in the aerospace industry.
This lead to the current design/synthesis exercise, a 360 hours design project conducted by teams of 10 students, in the third year of the study for aerospace engineering at TUDelft acting as the BSc. capstone project. The whole of the design exercise takes up 9 full weeks of 40 hours each in the fourth quarter of the third year of the study. The design exercise has now

run for 8 years averaging 12-14 projects per year. A large variety of projects have been conducted including the design of an ultra-long range reconnaissance aircraft, several unmanned aerial vehicles, wind farms, rocket launchers, solar power stations, airport adaptive regional transporter aircraft, micro-satellites, microgravity platforms etc. (van Baaren et al. 1998, 2001, Bergsma et al. 2001, Melkert 2001-2004). This paper aims to provide information on the current exercise, how it is set-up, organized and graded as well as how its quality is monitored. It also reflects on the challenges that lie ahead.

2. Objectives of the exercise
In the design project, the students must demonstrate that they have the basic knowledge and skills necessary to accomplish a successful 'paper' design of an aerospace system. By completing the project, the student will demonstrate:
Technical competence or applying knowledge
- Apply basic sciences, mathematics and engineering sciences to convert resources optimally to a stated
- objective
- Model a variety of physical systems and use the models to predict system behaviour
- Use the modern tools of the trade in analysis and design of engineering systems

Design competence:
- Perform conceptual design of an aircraft or spacecraft system
- Integrate life-cycle issues in the design

Effective communication skills:
- Plan, prepare, deliver, and assess oral presentations
- Plan, prepare, deliver, and assess written reports
- Prepare & maintain documentation of the design process

Professional attitude:
- Work in multi-disciplinary teams
- Manage their work
- Perform peer and self reviews
- Understand contemporary & societal issues in their work from sustainable development point-of-view
- Exhibit life long learning attitudes and abilities

The objective is not to attain a flawless final technical product, able to compete with industrial standards. However, students must be aware of weaknesses in their design and whether their design is feasible within the timeframe defined in the project assignment. A fundamental limit to the current design project is that the students are unable to verify their solutions themselves. This, however, is dealt with in several other exercises in the degree.

2.1 Sustainable development
Within the exercise students are also required to analyse how their designs

contribute to a more sustainable world. There are two ways to facilitate the above. To explain the two approaches first a definition of sustainable development is given (Brundtland, 1987): "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs".
Within the exercise one of two approaches can be used: the first approach is looking into radical changes towards new (transport) systems; the second approach is looking at improvement of the current (transport) systems. Examples of radical changes are the development of:

- Solar powered aircraft
- Completely new transport vehicles based on renewable energy
- Examples of improvement of current systems are:
- Reduced emissions
- Lower noise production
- De-orbiting plan for a satellite at the end of the operational life

The aim for the assignment is to have SMART requirements, which can be met by the students and validated afterwards by the tutor.

3. Organization of the exercise

Staff members initiate most topics of the exercise, however, students are also encouraged to come up with their own project ideas. Every research group within Aerospace engineering is asked to volunteer one or more principal tutors (PT). They will take the lead in writing the assignment and lead the group of tutors. In total they are required to spend some 220 h on the project, including the preparation of the assignment. Each principal tutor is assigned two project coaches (PC), which must come from different research groups to ensure multi-disciplinarily support. They are each allowed to spend some 70 h on tutoring the project. Every project is therefore guaranteed tutoring from at least three tutors. They offer supervision, guidance and assistance during the exercise, though the group has to operate independently as much as possible, thereby introducing their own ideas and program. The assistance of PT and PCs is limited to reinforcing the team's ideas and project plan in close cooperation with the project team and giving feedback (both activating and motivating) at project meetings, reviews, reports on progress, content, procedure/approach, organization, communication, and cooperation

Table 1: Summary of phases, activities, reviews and deliverable items in the design exercise.

Project phase	Activity/step	Milestone	Deliverable Item
Phase O	1: Organization and planning 2: Requirements generation 3: Set up design options	Baseline Review	Project Plan Baseline Report Baseline report
Phase A	4: Analyze options 5: Trade and select best option	Mid-Term Review	Technical Design Report (mid-term)
Phase B	6: Detailed design & analysis	Final Review	Technical design report (final)
Symposium	7: Present project	Symposium	

Students are asked to express preference for a project, although teams may be adjusted to accommodate all the students in the class. Each project is defined by three phases. In these phases a number of activities has to take place, see table 1.

Step 1. Organization and planning is key to a successful project. During this activity, the team members are introduced to the project. Next, team members learn about their (technical and managerial) strengths, weaknesses, and interests, with an eye toward how team members will be allocated to solving the design problem. The students are then asked to organize themselves. Usually one team member is chosen as project leader for organizational and contact purposes, but all team members are expected to contribute to all components of the project. The students must decide on the various roles in their team and who is serving in what role. The team must also prepare a complete road map of how the team plans to develop the design through studies and analysis and perform the necessary scheduling.
Step 2. Starting from the top-level requirements, students are to analyze the functions that the design (the product) must be able to perform to allow the intended use. Next, requirements are to be generated that specify how well these functions shall be performed. Attention should also be given to non-functional requirements and constraints that relate to operations, cost, manufacturing, testing, reliability, availability, maintainability, safety, etc.
Step 3. In step 3 the students are to set up a number of design options. This step is usually the most creative part of the exercise. As a rule any solution initially is fine. Only because the time for analysis of the design options is limited, each team must decide which options they feel fit for further analysis. As a minimum it is required that at least two options are selected which must be worked out in further detail in step 4. The trade-offs are mostly based on known (from literature) advantages/disadvantages with respect to (functional) performance, costs, etc.
Step 4. The designs selected in the previous step are analyzed with respect to how well they can fulfil the requirements. Analysis methods used are mostly fairly simple methods (parametric analysis, engineering experience, similarity comparison, etc.) that allow developing sufficient detail to estimate the performance and other characteristics of each option so that each option can be assessed in a comparative way.
Step 5. In step 5 the students must compare and rank the various design options analyzed and select the most promising design for detailed design
Step 6. In the detailed design analysis phase, the team works out the design selected in the previous step in more details. Students become 'specialists' in their team. Typical engineering disciplines included are aerodynamics, structures & materials, flight performance, stability and control, propulsion, manufacturing, cost estimation and RAMS.
Step 7. As in any real life project the students have to communicate their project and its outcome to their fellow workers, knowledgeable people as well as to people who are totally unfamiliar to the project. In this final step, the students must prepare for a presentation to be held at a one-day

symposium at the end of the project. They are also asked to write a 10-page summary of their project, which is published in a book (van Baaren et al. 1998, 2001, Bergsma et al. 2001, Melkert 2001-2004).
Throughout the project, major emphasis is put on certain milestones marked by briefings, and reports. Students should consider these milestones equal to an examination. For all briefings technical content is the most important factor. Management content should not take much time in the briefing. It is required that every student must give a formal briefing at least twice during the project.

4. Supporting Courses

Imbedded in the exercise are three supporting courses: one in Systems Engineering and Project Management, one in Oral Presenting each of a workload of 40 h per student and a library course.
The Systems Engineering and Project management course aims to equip students with the tools to structure their design process and time management.
The oral presenting course aims to make the students more confident in presenting and communicating their ideas to others. The course is a combination of lectures and practice sessions during the design exercise. The design reviews of the exercise are videotaped and assessed by the oral presentation lecturers from the department of Technology, Policy and Management of Delft University of Technology.
The library course aims to help students finding their way through a library and how to use all the options open to them to find the literature they need.
The introduction of imbedded courses was done to enable students to immediately apply the knowledge and skills learned in the short courses in the design exercise.

5. Facilities

During the 9 weeks the students spend on the exercise dedicated project rooms are made available. Each project room contains 5 PCs, meeting tables, swivel chairs, whiteboards etc. Also the students are given the necessary office equipment and access to photocopying and printing. A total of 22 of such rooms are available. Besides the existing library at TUDelft, the exercise has developed its own library of design and other related literature ensuring enough copies are available for all groups.

6. Tutor training

The guidance of 10 students during the 10-week design project demands special skills from the lecturers. To guarantee the quality of the exercise and prepare the lecturers for this function, each tutor has to qualify for his position of principal tutor by completing an in-house tutor training.
Every year new tutors and coaches are trained by a professional lecturer of the Institute of Technology and Communication of TUDelft, in a setting that is tailored to the design synthesis exercise in aerospace engineering.
The training is built up of three modules: Project Design, Project Tutoring, and Project Evaluation. To achieve the optimum learning effect, the modules

are synchronized with the design synthesis exercise itself. This means that the module Project Design is scheduled prior to the exercise, when the tutors have to define the contents and scope of their project; the Project Tutoring module is scheduled around the kick-off of the project; and the Project Evaluation module is given at the end when grading and feedback is appropriate.
Each module contains a 4-hour workshop and a 2-hour feedback session. In the workshops the lecturer teaches the aspirant tutors the basics in an interactive way by various simulations and scenario analyses. Each feedback session is planned after the tutors have gotten their first experiences in each respective area. In these sessions the tutors reflect on their real-life experiences.

7. Grading of the Exercise

The principal tutor is responsible for the grading of the design project. Grading a project team is a difficult matter but should be practical at the same time. Recognition must be given for both the achievement of the team as a whole as well as the individual contribution to the team result. Each student is graded individually. The grade should be a good reflection of how the student evolves during the design project. Hence the input to grading has to be collected at several moments such as the reviews and the technical reports. Also the results of self-evaluations and peer reviews that are done around the two critical reviews in the project, provide valuable information on the attitude, performance and functioning of each team member. Tutors are recommended to attend a review from a different project to "calibrate" the performance of their own team.

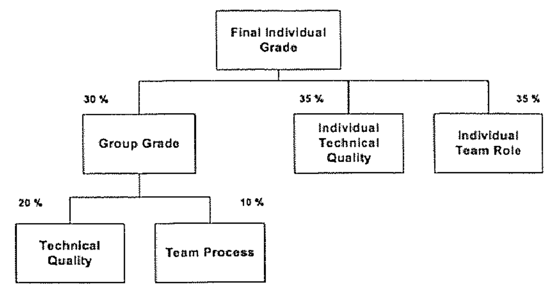

Figure 1: Grading of the design exercise

The individual grading is done in two stages: 1) Grading the group and 2) Grading each student individually. Each grading is based on two main performance aspects: Technical Quality and Team Organization Aspects (commitment, attitude, initiative, management of resources and communication). The Final Individual Grade is composed from weighted contributions as shown in figure 1.

8. Quality Control

In order to maintain high standards of the design synthesis exercise, an elaborate quality control system is used. In this system, the quality of the assignment is the shared responsibility of the organizing committee, and the principle tutor. The tools that are used to facilitate these responsibilities are described below.

8.1 Tools used before the exercise:

- Choice and division of coaches: Principle tutors must have completed the tutor training and have been a project coach before preparing an assignment. Experienced coaches are assigned to less experienced tutors and vice versa. Secondly, coaches are placed such that their expertise provides the best possible match with the project.
- Template for the project description: Principal tutors use this template to assure that all project descriptions are written in a uniform manner to the same levels of detail.
- Quality control and improvement of the project descriptions: A committee of faculty members and external experts verifies all assignments prior to kick-off against set criteria: Relevant Subject, Multidisciplinary and SMART objectives. Experienced staff members support tutors in improving the assignment if the quality review commission judged the quality as insufficient.
- Manual for Principal Tutor and Project Coaches: A compact set of instructions, guidelines and hints for the definition, monitoring and control of the Design/Synthesis exercise.

8.2 Tools used during the exercise:

- Project guide: Students and coaches use a project guide in which all important data on the assignment can be found
- Review milestones: The review milestones are used to give feedback to the students about the quality of their work and their 'virtual grade' that will become real if work is continued at the same level.
- Peer reviews: Tutors have access to student peer reviews to find any problems in the group that need their attention.

8.3 Tools used after the exercise:

- Student, tutor and coach evaluations: All participants are asked to complete a survey to enable the evaluation of the assignments and organization and thus to improve the exercise (Brügemann, 2004).
- Verification of completed points of improvement: Just before the exercise starts again, a check is made against the list of planned improvements to see if those improvements have been realised.
- Timekeeping: The students have to log their time spending to the Design Synthesis Exercise. These logs serve to gain insight for students about work load distribution and for tutors and organisers to gain insight about the study program and to improve their estimates for the future.

9. Added value of the exercise

Over the years, the projects received great enthusiasm and appreciation from the participating students. They demonstrate this by working well over the required number of hours and organizing activities during the exercise.

One reason for this is that in most projects representatives of industry are involved in the projects as clients and as evaluators in the formal design review presentations during and at the end of the exercise. Feedback from industry representatives as well as from faculty staff is also very positive.
Since 2002 international design projects are also run (Melkert et al., 2002). Partners are Queen's University Belfast and Royal Melbourne Institute of Technology.
In the future the exercise expects to be able to maintain its ability to challenge students to go above and beyond themselves working on more ambitious projects whilst at the same time maintaining the quality of teaching design.

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