AIRCRAFT ENGINEERING, AN INTERDISCIPLINARY MINOR MODULE

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ABSTRACT

Aircraft Engineering is offered as a minor module at the University of Twente. It consists of 3 courses and a project in which students make a conceptual design of an aircraft. Every year around 100 students of 12 different bachelor programmes participate. This means that prior knowledge of students differs and working in interdisciplinary teams is a new challenge. To overcome the differences in prior knowledge the project groups are composed with a maximum variety of students from different bachelor programmes. This way, students can help each other to master the knowledge gaps. A series of three workshops on interdisciplinary teamwork was developed for this minor module.
Results of these workshops are encouraging. The collaboration within the groups is good. In several groups the students helped each other with mastering the theory. Also students showed more concern for each other's knowledge development. The group reflection reports that were part of the final project report showed that students did appreciate the interdisciplinary teamwork. Students indicated gaining insight in interdisciplinary teamwork as well in their individual strengths and weaknesses.

KEYWORDS

Aircraft engineering, Teamwork, Interdisciplinarity, Skills education, Standards 5,7,8.

INTRODUCTION

The University of Twente is a university situated in the east of the Netherlands with approximately 10,000 students and 3000 staff members (support and academic). While the university is known as a technical university, both science and engineering programmes, as well as behavioural science and management programmes are offered. The link between technical solutions and human factors (High Tech Human Touch, De Boer & Drukker, 2011) is an important focus point for the university.
In 2013, the UT implemented a new educational concept for all bachelor programmes, the Twente Educational Model (TEM, 2018). In this model, all bachelor programmes are divided into 12 modules of 15 ECTS (420 hour study load) each.
Each module has a theme around some programme specific subjects/courses and a project. By applying new learned theory directly in a project, students are stimulated to look further than only their course books. In that way, the students learn to integrate and select course materials and information from the literature. Further different learning activities are used, such as workshops, lectures and feedback sessions with students.

The first eight modules represent the core of the programme. In modules 9 and 10 the students have elective space to choose modules for broadening or deepening their knowledge, for example with a so-called High Tech Human Touch (HTHT) module, a core module of another programme or study abroad. In the last two modules (11 and 12) students work on their graduation assignment and related subjects.
The HTHT modules were developed (in competition) at the UT with the goal to educate engineers that are aware of the social impacts of the decisions they make.
Aeronautical Engineering and Management was selected as one of these HTHT packages. It consists of the modules Aerospace Management & Operations (AMO) and Aircraft Engineering (AE). The AMO module takes the aircraft as the point of focus. Attention is paid to the technical and economic properties of the aircraft as well as its use and users, the regulations and constraints under which it operates and the ways its performance is assessed. This focus integrates the various technical, economic and social (human) subjects covered in this module.
The central theme in the AE module is the Conceptual Design of an Aircraft. In this design all knowledge gained during the lectures on Aircraft Technology, Aircraft Structures and Aerodynamics are applied and integrated. The conceptual design is done in groups of 6 to 7 students.
This paper focusses on the module Aircraft Engineering. Every year around 100 students of 12 different bachelor programmes participate. This means that prior knowledge of students differs and although all have experience in project lead education, working in interdisciplinary teams is a new challenge. To overcome the differences in prior knowledge the project groups are composed with a maximum variety of students from different bachelor programmes. This way, students can help each other to master the knowledge gaps. During the first year this did not work as expected. In general students did not exchange knowledge or help each other filling mutual knowledge gaps and even in the evaluation students proposed to exclude students from certain programmes because they did not contribute to the project. This result overshadowed the positive evaluation results on the theory courses, the organization, the availability of the lecturers and the challenge the students faced in designing an aircraft from scratch. Therefore it was decided to discuss this problem with the educational advisor of the faculty and to ask for a method to get a better interdisciplinary collaboration within the project groups in which the students see the inhomogeneity of the group as a benefit.
Another striking result was that although all students did follow eight project related modules (during the first two years of their bachelor programme) they complained of not having a tutor for safeguarding the process around the project. This problem was also taken into account in the method mentioned above and is presented in the remainder of this paper.

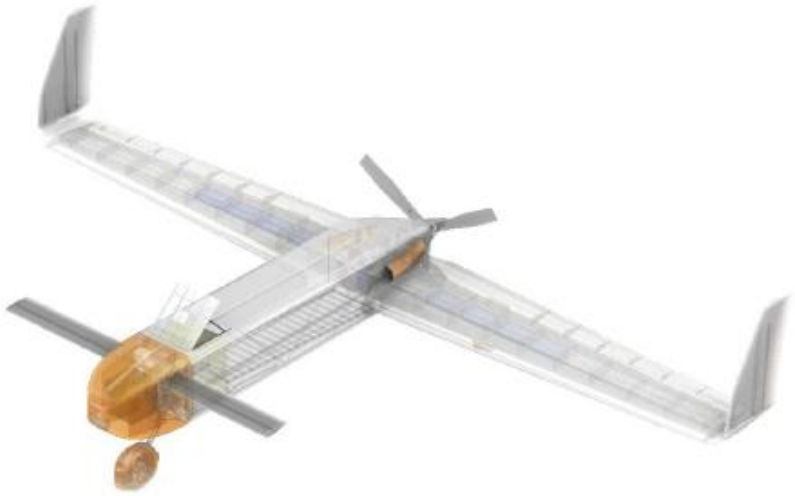

Fig. 1. Conceptual design of unmanned aircraft for dropping goods in disaster areas

THEORETICAL FRAMEWORK

To design our solution for the problem described above, we used a team development model from Tuckman & Jensen (2010). In his paper he describes five development phases that a team have to go through in order to become a well-performing team during a project or other cooperative activity.

1. *Forming*
   At this first orientation stage, there is no team yet, but only a number of individual students. During this phase, what needs to be discussed are the aims and goals of the group, the different roles that members will take on and who will be the leader. Rules for cooperation are set here.
2. *Storming*
   During this second phase, the group members grow closer to each other, but also differences in personalities and perspectives become visible. Conflicts may also arise as members of the group challenge the leadership and rules that were set during the first phase that they originally consented with.
3. *Norming*
   During the third phase, conflicts are settled and (new) working methods and rules are set for the group. The cooperation becomes more constructive and task oriented. The team starts to develop an identity and is able to work more independently than before.
4. *Performing*
   In this fourth phase, the team is a unity, has common goals which everyone is working towards. There is energy in the team focussing on the project and clear decisions are made.
5. *Adjourning*
   The fifth and last phase of ‘saying goodbye’ starts when the project task is completed and the team can be dissolved.

Tuckman & Jensen claim that a group cannot be fully effective and acting independently until the performing stage is reached (see figure 2 development of team effectiveness).

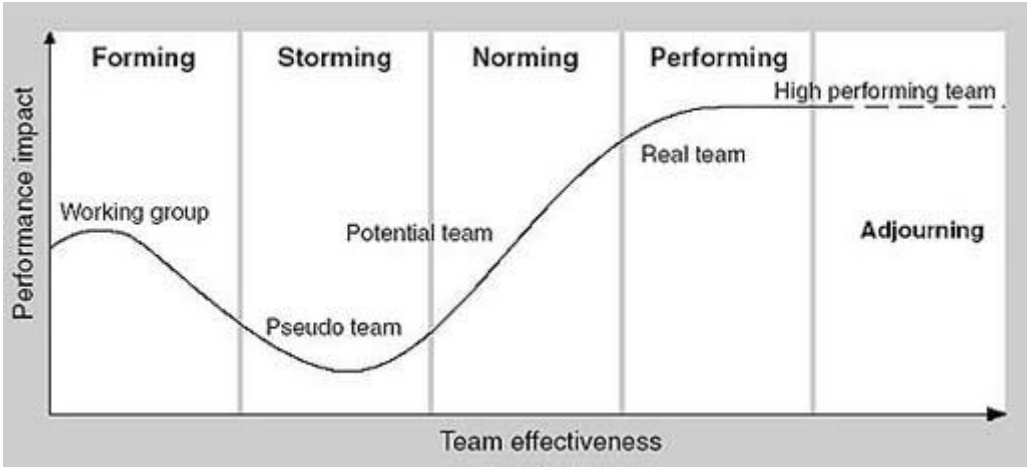

Fig. 2. The 5 phases of teamwork and team effectiveness (Groups and teamwork, 2018)

Based on these five phases of team development, a series of workshops was developed. The setup and contents of these workshops is discussed below.

METHOD

To support the interdisciplinary teamwork of the students and help them to become more effective as a team, a series of three workshops was developed.

Workshop 1. The life boat

The first workshop, offered to students during the 1st week of the module was aimed at the forming phase. During this time in the module, the student teams with 6 to 7 group members have just started working and getting to know each other and are orienting on the project assignment they received. In this case their project assignment is to develop a concept design of a 'small unmanned cargo aircraft for disaster relief'.

During the workshop, students are asked to sit together with their project group and receive a short and clear explanation about the goals of the workshop, what it means to work in an interdisciplinary team and the advantages and challenges of interdisciplinary teamwork.

After the introduction, students were asked to participate in a so called 'lifeboat game'. In this game students receive a case describing 10 different people on a sinking ship with a lifeboat that can only carry six people. Based on the descriptions, students have to make a list of six people that will have a place in the life boat (and thus also that will stay behind on the ship). The criteria for making these choices are not set. Participants will have to set their own. During the workshop, students first spend ten minutes making an individual list. Then the group has to reach consensus about a group list and negotiate about choices for 20 minutes. Afterwards, the groups are asked to reflect on the process, different criteria that group members used and their experiences with each other. The goal of this exercise is to serve as an 'icebreaker' to get the conversation between students started and also as a way of getting to know more about team members and their underlying values. Examples of lifeboat exercises can be found in different variations online (LIFEBOAT Activity, 2018).

After this introductory activity, students are asked to look at their own project team as a 'life boat'. Like the people in the lifeboat, the members of the project group also have their unique characteristic skills and disciplinary knowledge, but also their pitfalls that they each bring into the group. First, students reflect on their own contribution to the team's assets individually,

using a predefined format. In this format, the student is also asked what he or she would like to learn from other group members. Then, the group looks at the total overview of team assets and challenges in light of the project assignment and discusses how to make the ideal 'lifeboat' for this task: Who can learn from who? Who should work together and what knowledge or skills are missing in the entire team?
Based on this discussion, a group contract is made with agreements about the division of tasks and roles, working methods, responsibilities and dissemination of knowledge and skills between group members.

Workshop 2. Evaluation of individual and team performance
With the agreements made during the first workshop, teams start to work on their project assignment. During these weeks, students often find out that things are not exactly working out as they pictures during the introduction phase and the first disputes or silent irritations arise. This is the phase described by Tuckman as the 'Storming phase'.
To help students move on to a next stage in becoming an effective team, in week 4, a workshop is organised that focusses on the 'Norming phase'. During this workshop, team performance as well as individual performance is evaluated.
Similar to the first workshop, this workshop starts with a short explanation of the goals and the activities that will take place. After this, students receive instructions about giving and receiving feedback in a safe and constructive manner.
After this introduction, students are first asked to make an individual evaluation of the team performance looking at aspects like: cooperation, project organisation, exchange of information, learning from each other, progress on the project assignment and quality of the work. After this individual evaluation, project groups sit together and compare their evaluations. Based on this, the agreements in the group contract are adjusted or additional agreements are made formulated as SMART (Specific, Measurable, Achievable, Realistic, Time-bound) goals to be reached during the weeks ahead.
The second part of the workshop focusses on individual performance. During this part, students are asked to fill in a form, scoring every team member (including themselves) on different aspects (see table 1 below). Besides this, students are also asked to write down at least one strong point and one suggestion for improvement for each team member.

Table 1. Scoring form for contribution of individual team members

Name group member (yourself)					
Cooperation	1	2	3	4	5
Project organisation	1	2	3	4	5
Communication	1	2	3	4	5
Coaching	1	2	3	4	5
Effort	1	2	3	4	5
Content	1	2	3	4	5

Indication of scores: 1 = very low, 2 = low, 3 = moderate, 4 = high, 5 = very high

After filling this in, the results are discussed within the project team starting with one volunteer until all students have been evaluated. Because discussing individual performance of yourself in a group can be confronting for students and could easily get out of hand if not guided properly, several staff members and student assistants are present during this workshop to supervise the discussions and step in if necessary.

Workshop 3. Final sprint & reflection

After the second workshop, groups continue to work on their project assignment, now with more clarity on common goals and points for improvements. In the Tuckman model, this is described as the 'Performing phase' where the team efforts are more focussed on the project and decisions are being made. To support students in this process, a third workshop is organised towards the end of the project, in week 8. During this workshop, students are asked to make an inventory of all tasks that need to be done in order to finalise the project and estimate the amount of time needed to finish these tasks. The degree of detail that is asked is a task size of ± half a day's work (four hours) for one group member.

After this inventory is made, project groups place these tasks on a timeline with names and deliverable deadlines and thus make a detailed planning for the last two weeks of the project.

As a final assignment, students are asked to write individual reflections on their learning experiences and more specifically on how working in an interdisciplinary team influenced their learning and project work. These reflection reports can be used by project groups as input for the reflection on the group process as part of their final report.

Award ceremony

After the project is has been finished, there is an award ceremony where an award (certificate and cake) for the best airplane design is handed out (see figure 3). This final meeting after all the work is done supports the 'Adjourning phase' from Tuckman's model.

Fig. 3. Aircraft Engineering award ceremony

Qualitative data collection

For this study, we chose to focus on qualitative data, since so many factors are influencing group work and quality of their output that it is very difficult to express this in quantitative data and draw solid conclusions from this. An increase in final grades for example, could be caused by better teamwork, but also by changes in teaching or in a cohort of students that is better than the year before. Asking students about the impact of the workshops would be

very subjective, since they do not know how it would be without this support. Therefore, we chose to use the reflection reports about the group process (part of workshop 3) as qualitative data from students, supplemented with experiences from the lecturers of this module.

RESULTS

Student experiences

From the group reports we took some individual reflections and group reflections about interdisciplinary learning experiences and growth during the project.

“Outside of my own discipline I learned better how to work together with other disciplines and about their approach. Some parts of a project fit better to different kinds of students with different backgrounds, because they have for example a more analytical approach. Working in an interdisciplinary group led to that sometimes I had to explain some concepts other students were not familiar with. That resulted in that I had to overthink what I was going to say, so my first thoughts were not always right. I will take this with me to a next module, so I always will overthink before I give a (wrong) conclusion someone has to continue working with if I’m not corrected.” *(Mechanical Engineering student)*

“In this project I was the chairman. In this position I learned a lot about combining skills from different disciplines and learning people with different working styles. I stepped outside my comfort zone of applied physics to work on the business case and think of the pro’s and con’s of the canard configuration.” (*Applied Physics student*)

“As a biomedical engineering student I had the feeling I had the fewest prior knowledge of everyone in this group. In the beginning I felt a little intimidated, what gave me the tendency to stay quieter in discussions about the project. During the rest of the project I learned a lot about airplanes and I learned that sometimes I know more than I think. This gave me more confidence, which resulted in me joining the discussions again.” (Biomedical Engineering student)

Fig. 4 Conceptual design of a 90-seat regional airplane’

“I learned how to apply knowledge from my field into a project that does not seem like an industrial design project at first. I also learned how to go through the design phase in a more

technical way. Furthermore, I learned how to communicate with people outside of my own discipline. People from other disciplines tend to think in a different way and usually tackle a problem differently. It was sometimes difficult at first to adjust to this and be able to work together, but I got better at this during the project. This is definitely something that I will take with me to later projects, even if they are only with people form my own discipline," *(Industrial Design Engineering student)*

"As a group we worked together a lot. In each new phase of this project an overview was made of the different tasks and they were divided between the group members. This distribution took the individual talents, interests and disciplines into account. When somebody was not able to complete the task itself within the given time, others would always help or a distribution of the tasks was made. In the final weeks of the project we got used to the different working styles, knowing better how to encourage, coach, communicate and be critical to each other" (*group reflection*)

"Working in a multi-disciplinary group gives opportunities for learning new skills. As each discipline has their own specific skills set. In our project group we wanted to learn skills from each other. Therefore we decided to divide our project into four different departments: Aerodynamics, Structures, Performance and Business. In each department one or more persons of one or more disciplines would work together."*(group reflection)*

Project Tutoring

Although all students did follow 8 project related modules (during the first two years of their bachelor programme) there was a need for a tutor for safeguarding the process around the project. From discussions with students it was concluded by the module team that several bachelor programmes have different approaches of organizing a project. In some cases a project is a practical in which certain experimental skills have to be mastered without having much freedom because the availability of the lab space is limited. Other projects are supervised by lecturers with much knowledge on the content and can immediately answer questions concerning the theory needed in the project which discourage the students of searching the answers by themselves. The latter can be avoided by guiding the project groups only on the process the so-called tutors. In summary, students have different experiences in doing a project.

For the module Aircraft Engineering it was assumed that all students were aware how to run and organize a project. During the 10 weeks of the module, plenary sessions with all complete project groups were organized twice to keep track of the progress of the project groups. Further students knew that the minor team was always available for answering questions. However in the last week it went out that several groups were behind schedule and groups did not act as a unity.

In the second year it was decided to organize a weekly progress meeting with all leaders of the project groups. In the first workshop on interdisciplinary teamwork during the first week it was emphasized to appoint a project leader within each group. At the first meeting in the second week all project leaders were present and joined the meetings in all other weeks. In this way the module team had a good overview of the progress of the (16) project groups and could push project leaders to hurry up if necessary. Another advantage of these meetings was that project leaders became aware of the progress of other groups and could compare that with the status of their own group. This way of tutoring turned out to be very efficient for the module team. It took only 2 hours a week for the 4 module team members and a lot of questions could be answered and discussed plenary. To get a feeling on the collaboration within the groups during one of these project leaders meetings all complete project groups were invited. During this meeting the module team discovered that a few project leaders

were too optimistic about the progress of their project group. Nevertheless most groups realized their planning and delivered complete conceptual designs.

Lecturer observations

At the kick-off of the aircraft engineering module the module team faced negative reactions on the announcement that interdisciplinary workshops were scheduled. Students denoted that they already had 2 years of experience in working together and, in the case of some students, even in working together with students from one or two other programs. However, the module team forced the students to join the workshops by stating that it was an obligatory session. To show the students that the workshops were taken seriously by the lecturers in the module team, the coordinator of the team joined the first part of the workshop. Afterwards students indicated that they were positive about the workshop and the lecturers experienced that in several project groups 'master-pupil' couples were focusing on a certain part of the project e.g. aerodynamics, structural mechanics, aircraft performance or the business case. On the other hand, there were also still project groups in which couples were formed of students with expertise in a certain area. In most cases in these groups students did not want to leave their comfort zone for mastering a certain new area and focused on (only) a successful finishing of the module.
Another benefit of the workshops was that at the first project leaders meeting all project groups were represented. During the module most of them really represented the group very well with posing questions on behalf of their team and making notes. Too late, the module team discovered that a few project leaders were too optimistic about the progress of their project group.
The 3rd workshop 'Final sprint and reflection' was organized in the middle of week 8 (less than one week before submitting the final project report). It went out that this was a bit too late in the project. The lectures on the courses are in the first 6 weeks which means that from week 7 on the students can work almost full time on the project. Further week 7 starts after a 2 week Christmas holiday and is really the start of a final sprint. Some groups waked up after the 3rd workshop (1.5 week after the re-start) and realized that they were behind schedule.
During the module, 6 students (6%) decided to stop because it took them too much effort. This meant that the number of project group members of 6 of the 16 project groups was reduced with 1. However, the project groups solved this by themselves and did not complain. One student was requested by the group itself to withdraw because he was not motivated well enough to significantly contribute to the project. With the skills the students learned during the workshops they solved this problem to mutual understanding without intervention of the module team.
In the evaluation of the module the students were positive about the workshop. They showed this in an indirect way by stating that they learned a lot on interdisciplinary collaboration which had a positive effect on the project. Further there were no complaints about the contribution of students from the different bachelor programs.

CONCLUSIONS AND RECOMMENDATIONS

The introduction of three workshops on interdisciplinary collaboration is a very valuable addition to the module Aircraft Engineering. Before the students started most of them did not see the necessity to follow these workshops. However, already after the first workshop students denoted that they learned a lot and in comparison with the year before (without the workshops) most project groups act as a unity rather fast.
The weekly project leaders meetings were a good way to monitor the progress of the project groups and answer questions in a way that is also efficient for the module team. Next time

however, attention has to be paid to methods to prevent that a project leader is not honest or realistic about the progress of his/her project team.
The topics that are covered in the 3rd workshop are important for the (re-) start of the project in week 7 and therefore it is better to plan this workshop at the beginning of week 7.
Although all students at the University of Twente have 2 years of experience with working in project groups it is still necessary to support the students in case of a different collaboration method. In this module it is shown that with a relatively small effort (3 workshops of around 3 hours) a lot of added value can be gained.
Finally it can be concluded that the 100 students of the module Aircraft Engineering mastered to design a complete aircraft while working in a real interdisciplinary team. Something, of which most students are very proud at the end of the module.

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BIOGRAPHICAL INFORMATION

André de Boer is head of the research chair 'Structural Dynamics, Acoustics and Control (SDAC) within the department of Mechanics of Solids, Surfaces and Systems (MS3). He is also specialisation coordinator for education for the MS3 department. Until July 2017, André the Boer was programme director of mechanical engineering. His current research focusses on multibody dynamics, buckling of structures and acoustics and also on educational topics concerning student motivation and knowledge retention.

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