DESIGNING FOR DIVERSITY: SOFT LANDINGS AND DEVELOPMENTAL PORTFOLIOS IN AEROSPACE EDUCATION

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ABSTRACT

Coordinating and executing an MSc program is accompanied by various challenges. To name a few: a) students joining the program means have diverse backgrounds which means varying levels of prior knowledge, and b) in a program that offers specialization into different profiles, it is important to ensure that every student attains the required breadth in foundation as well, which the program mandates. At the Aerospace Structures and Materials (ASM) Department in the Faculty of Aerospace Engineering at TU Delft, we are developing a core curriculum that encompasses the first education quarter (8 weeks, 15 ECTS), which aims to successfully tackle these challenges in order to train up future aerospace engineers with solid technical foundation, critical thinking ability and collaborative working spirit. The module starts with a "soft-landing" for the students and is followed by three content sprints that cover the essentials in the three principal domains of ASM – Materials, Manufacturing and Modelling. Engineering and consulting assignments have been embedded that tie the sprints together and offer inspiration and motivation for the students. In parallel, students get trained in transversal skills. A student facing dashboard will provide comprehensive feedback on learning progress and outcome. The dashboard will additionally support the transition towards a portfolio-based assessment. In this paper, we outline key features of the core curriculum along with the process that was employed for its development.

KEYWORDS

Curriculum Development, Portfolio assessment, Standards 4, 7,11, Optional Standard 1

INTRODUCTION

A common challenge in master's programs is integrating students from varied academic and professional backgrounds while ensuring they achieve an even foundational understanding essential for advanced specialization. For instance, in the year 2024/2025, at the TU Delft master specialization on Aerospace Structures and Materials (ASM), 44% of the students had done the bachelor in our faculty (See Figure 20).

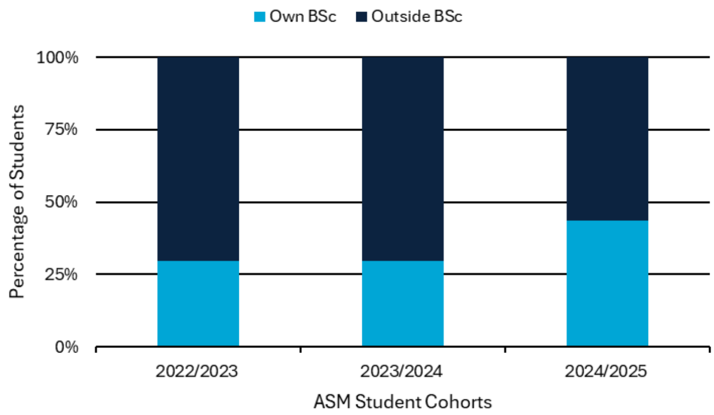

Figure 20 Percentage of MSc students with a background in the TU Delft Aerospace Engineering bachelor's program, by cohort

When restructuring the core module of the Aerospace Structures and Materials (ASM) master, the department decided to tackle these challenges. The new core module of the master would aim to cultivate “T-shaped engineers” by equipping students with a comprehensive understanding of the three key domains: Materials, Manufacturing, and Modelling, while also preparing them for success in their specific areas of expertise. To reach this goal, the core module was developed collaboratively through intensive workshops by multiple staff members. The development of the core module is aligned with the principles of the CDIO (Conceive-Design-Implement-Operate) framework (Malmqvist et al., 2020).

The core starts with a "soft-landing" phase, where the module first addresses knowledge gaps and familiarizes students with the expectations of the master's program. This is directly connected to the CDIO Standard 4: Introduction to Engineering. The “soft-landing” phase prepares students for the demands of engineering practice, giving them space and time to repair any content deficits at their own pace.

Then, three content sprints on Materials, Manufacturing, and Modeling follow the intro phase. Two aerospace specific projects combining transversal abilities with topic knowledge weave the sprints together. These assignments are guided and performed in teams. In this way, disciplinary knowledge is integrated with interpersonal skills development, promoting holistic learning as recommended by the CDIO Standard 7: Integrated Learning Experiences. Moreover, students engage in dedicated learning experiences throughout the sprints to build the skills needed to contribute to sustainable innovation in aerospace engineering. This aligns with Optional Standard 1 (Sustainable Development).

A key feature of the module is the introduction of a student facing dashboard, which provides real-time feedback on learning progress and supports the transition to a portfolio-based assessment system, in line with CDIO Standard 11 (Learning assessment). This system places the responsibility on students to demonstrate their achievement of the learning objectives, serving as an integrated tool to align what is taught with what is learned (Cain et al., 2018).

This paper offers an overview of the ASM core module's design, highlighting its pedagogical innovations and the process behind its development. By addressing the diverse needs of incoming students and drawing on established educational frameworks, the core module aims to enhance the learning experience and better prepare students for advanced studies in aerospace engineering.

CORE SETUP

The ASM core is being designed to take place as a full-time study load over an eight-week period at the beginning of the academic year (see Figure 21). It will consist of several content-related 2-week sprints (content sprints) that cover key disciplinary knowledge needed by all students in the ASM track. To tie these sprints together and provide an engineering context for applying the knowledge, a pair of projects from an engineering design and consulting perspective will take place over the entire eight-week core. In addition to the main content sprints, elements related to digital skills and sustainability will be interwoven with the projects and reinforced over the entire eight-week core. Finally, to kick off the core and provide a soft-landing to incoming students, a two-week introduction & repair sprint is being designed. Further details of each of these elements will be elaborated on in the remainder of this section.

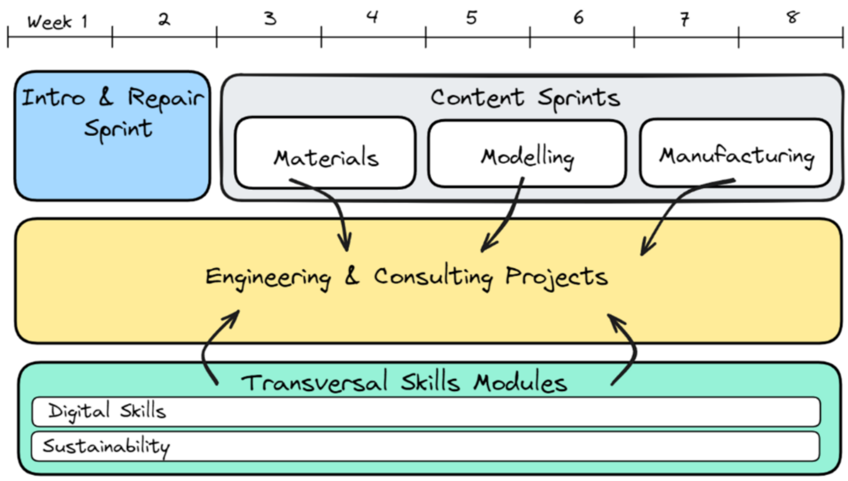

Figure 21: Concept map for the ASM core redesign

Engineering & Consulting Projects – A Common Context for Learning

The backbone of the new ASM core will be two aerospace assignments that interconnect and engage students with the content taught within the content sprints and transversal skills modules. The assignments will run in parallel throughout the whole core module. For instance, as seen in Figure 24, the student teams will have to work simultaneously on both projects during the manufacturing sprint.

Figure 22. Artist concept of projects during the Manufacturing Sprint

The first assignment, called the *Engineering Project,* has the aim of providing an open but scaffolded design project in which the student groups can apply the knowledge gained during the different sprints. The teams will have to identify critical material properties, use these properties to develop structural models to analyze and design the structure, and develop a manufacturing and production plan to realize their designs. The intent is for this project to be hands-on and permit failures and struggles without hampering the overall learning process.

The *Consulting Project* serves as a counterbalance to the *Engineering Project*. In the *Consulting Project*, students will have to review and evaluate work that has been done by a fictional company. Through critically analyzing data and models they will try to understand the material, modelling, and manufacturing choices that were made. In this way, the tasks here will focus on higher-level critical thinking and evaluation, and they will allow the staff to confront students with common errors and misconceptions that students often make.

Both projects are embedded in the aerospace context: The *Engineering Project* will be centered around the design of a liquid hydrogen storage tank for an aircraft, while the *Consulting Project* will be focused on an organic truss-like structure made with additively manufactured metals, such as the one found in the landing gear of a reusable rocket.

Introduction & Repair Sprint – Setting Students up for Success

The essence of learning is that it involves teaching learners to apply cognitive structures they have already developed. Because learners cannot learn to apply cognitive structures they do not yet possess, the basic cognitive architecture must first evolve on its own. Learning experiences that are designed to teach concepts that are clearly beyond the current stage of cognitive development are a waste of time for both teacher and learner. Designed to provide arriving students a "soft landing," the introduction & repair sprint is the first of our two-week sprints.

This sprint gives students the time and space to adjust to our department's particular instructional approach and to fill in any knowledge gaps. Establishing a basis of knowledge and abilities necessary for success on the ASM track is the main goal of this sprint.

Figure 23. Artist concept of the Intro Sprint

A challenge of doing this well is that each student has different strong and weak areas. For instance, on a discipline level, a student with a materials background might struggle with the aerospace terminology (see Figure 23. Artist concept of the Intro Sprint). On a digital skills level, students from different programs might be used to different programming languages and/or software and may need support in that area. On the interpersonal skills, students from different cultural backgrounds may not be used to the expected independence and collaborative environment and will need time and mentorship to be able to adjust.

The Intro Sprint activities will include a formative entry test to identify content deficiencies, which will be followed by personalized feedback and online materials that can be followed to repair the identified weaknesses. During this sprint, the students will be introduced to the structure of the core and working teams will be formed. The goal would be to balance each team with different academic and cultural backgrounds so the individuals can learn from each other. Finally, the students will be introduced to the research done in the department through standalone lectures which will serve as a motivational tool for the rest of their master.

Content Sprints

The content sprints replace the three core discipline courses covered in the previous course design. Topics have been consolidated into the domains of material science, modelling & structural analysis, and manufacturing, resulting in the three content sprints of the same disciplines. What is unique about the new setup is that students focus on one domain over a condensed period of time and explore it through a combination of teaching activities interwoven with the engineering and consulting projects previously mentioned. How this is done for one of the sprints – the material sprint – will be used as an example of how this is done for all of the sprints.

The materials sprint immerses students in the study of aerospace materials, encompassing the fundamental understanding and application of metals, polymers, ceramics, and composites. It is built on the materials engineering philosophy tailored specifically in the context of aerospace materials.

The curriculum emphasizes a pedagogical blend that integrates teacher-led theory instruction, hands on experimentation and collaborative classroom experiences, and self-directed student exploration. In the first week, lectures establish the foundational knowledge of diverse materials to be employed in aerospace systems, highlighting their mechanical/thermal/physical/chemical properties, processing/manufacturing techniques and limitations in the context of *Engineering Project*. By the end of the first week of the sprint, students will be able to grasp and design their own Ashby-type plots regarding aerospace materials. Case studies presented in lectures, such as short historical analyses of aerospace failures (e.g., the Space Shuttle Challenger and Columbia), encourage students to connect material science principles with practical engineering decisions and safety considerations. So the students would Understand the importance and strategic impact of research and technological development on society

Active learning is central to the sprint, in the second week, students are offered lab session opportunities to directly engage with materials in *Consulting Project*. Hands-on lab activities such as mechanical test of metals, microscopy analysis of metal and thermal expansion calculation of given metal part will set an important base on analyzing some key material features. Such activities enable students to observe material behavior and compare the results to supplied technical report, reinforcing critical thinking by experimental understanding.

To enhance self-directed learning, the sprint incorporates student-paced activities, such as independent research on emerging aerospace related materials in groups. Group projects are integral, fostering collaboration and teamwork as students design, evaluate, and present material solutions for specific aerospace challenges, such as sustainable composites, corrosion resistant coatings or ultra-high temperature ceramics for thermal protection system applications. These activities allow students to explore specialized topics at their own pace, promoting critical thinking, innovation, the ability to integrate multidisciplinary knowledge and share their findings in a concise way.

Transversal Skills Modules

To complement the knowledge centered content sprints, the core is also designed to have two skills-based modules – Sustainability and Digital Skills - that run throughout the entire core module. Currently, the sustainability module is further along in its design. It begins by introducing students to the complexity of the current climate crisis by engaging students in the interactive Climate Fresk workshop (Widmann, 2024), promotes discussion and discourse on sustainability related topics through organized debates, and concludes with an introduction to the more engineering approach of Life Cycle Analysis for quantifying sustainability in an engineering design and decision-making process. The digital skills module is not currently well defined but is expected to be centered around analyzing and organizing data and the FAIR principals for data management (see Figure 24).

Figure 24: Artist concept for the Digital Skills module

DEVELOPMENT PROCESS

The core module was developed collaboratively through intensive workshops by multiple staff members (592 man-hours throughout a period of 14 months) based on the **D**elft **A**pproach for (**R**e)designing **E**ducation design methodology. Inspired by the Carpe Diem methodology and Gilly Salmon (Salmon, 2023) for (re)designing, developing, implementing and evaluating (blended) subjects within higher education, DARE was developed by the blended team of Teaching and Learnings Services of the TU Delft. It has the following underlying principles: constructive alignment, backward design, team based and modular.

It consists of 8 steps that allow an educational advisor to guide teaching teams in a structured way through the entire design process. In March 2023, a week-long workshop was implemented for the team (8 people) to give aspirations of the course such as what they want to achieve through core, combined with the course analysis. This is called the *blueprint* step. During the course analysis, constructive alignment between learning objectives, learning activities and assessment is particularly scrutinized in this step. From April to May in 2024, more staff members were gathered in 4 different full day workshops to move on from the blueprint to the desired evidences and finally the instructions and materials. This is the storyboarding step. With the desired outcomes in mind from the blueprint step, the storyboard is a visual representation of the subject design. In this step, the constructive alignment, backward design and the blend of learning activities are most visible.

During the story boarding step, we also made the innovation by having an artist on board during the workshops who visually created drawings as he was eavesdropping the discussions in the room. This way, a representation of the concepts the teachers try to communicate through words could be visualized in a more intuitive and concrete way, e.g., Figures 3-5 are examples of artistic representation of proposed concepts. The storyboard is the basis of the subject design and is further elaborated during the prototype phase. During the prototype phase, the course team creates prototypes of the learning activities. Using a template, they write the first outlines of the learning activities. This helps to get a more concrete picture of what the course will look like. This is where we are right now.

FEEDBACK AND ASSESSMENT

Feedback via an interactive dashboard

For the core module, the idea to develop a framework as a Learning Analytics Dashboard to supplement traditional grades with quantitative visualizations, showcasing student understanding across various topical areas, their affinity towards different skills, and their disposition towards assessment types. This will enable feedback and assessment over the breadth of the module.

By providing such a comprehensive snapshot of the learning process and progress, this approach aims to empower both the teachers and students. Teachers gain deeper insights to identify blind spots, while students gain the self-awareness necessary for effective learning strategies. An illustration of the student dashboard is shown in Figure 25.

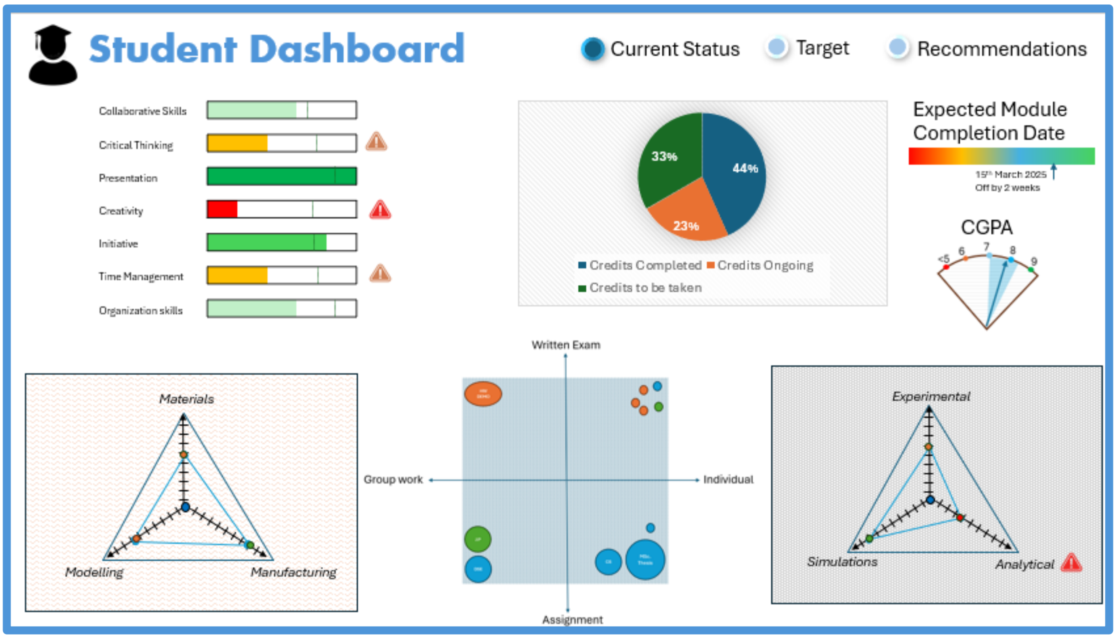

Figure 25. Illustration of a sample student dashboard.

Digital Learning Environments provide a convenient platform to record scores and grades on multiple criteria over time, and also seamlessly capture student interactions and activity. These interactions have the potential to add valuable insight to learning strategies and can form the base for actionable feedback to learners. It has been shown that awareness of learners about the learning process increases through visualizations. Sense-making is drastically improved by meaningful presentation of information. It is important to ensure that Dashboards are not just student-facing but also student focused, providing awareness, reflection, prediction and recommendation (Kuosa, 2016).

The aim is to develop a Dashboard designed to assist learners in managing their study plans, tracking goals, and monitoring progress. The dashboard will provide a detailed breakdown of progress, moving beyond simple grades to offer insights into affinity, knowledge areas, and disposition. It will also evaluate learners' development in transversal skills and provide predictive analytics and personalized recommendations. Additionally, the platform will facilitate peer comparison and help identify knowledge gaps and missing prerequisites, offering a comprehensive tool to enhance the learning experience.

The dashboard will also support staff with curriculum portfolio and course management. This can be also used to extract effectiveness in different teaching methods.

Assessment: Moving from grades to Portfolio

One of the requirement of the dashboard design is to facilitate portfolio-based assessments of the module. Such a portfolio can be used to demonstrate learning achievement for assessment purposes (Assessing by Portfolio, 2025). Moreover, a student portfolio offers many advantages with respect to self-regulated learning – registering performance, reflection on learning, setting up study plans, archive of experience and more (Cain, 2018).

The portfolio approach also addresses broader challenges in assessment practices. By enabling continuous feedback and progress tracking, it ensures alignment with intended learning objectives, as highlighted by Kovacs et al. (Kovacs et al., 2023). Additionally, moving away from traditional grades to a portfolio system acknowledges the findings of Willems et al.

(Willems et al., 2024), who noted that grades can either encourage or hinder students' willingness to innovate. By focusing on developmental feedback and reflective learning, the module fosters an environment where students are motivated to explore, experiment, and innovate.

The digital dashboard eases the process of data archiving and makes the maintenance of a student portfolio less tedious. Challenges with respect to mandated vs voluntary use, scaling module portfolio to program and job search, assessment consistency and cross faculty buy-in need to be addressed.

CONCLUSION

The core curriculum redesign in the department of Aerospace structures and Materials at TU Delft has been a departmental effort aiming at providing the next generation aerospace engineers with more customized and empowered learning experiences. The curriculum was designed to enable soft-landing upon boarding to tailored feedback dashboard, and eventually to the final certification at the end of the core module. Group teaching and group learning are promoted to foster collaborative environment with a focus on fundamental concepts that are necessary for the program while keeping the aerospace context. As we continue to venture into this redesign, we are on the way of prototyping and creating course material content, while continuing to seek insights and suggestions on portfolio management and assessment control.

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Ines Uriol Balbin is a lecturer at Delft University of Technology's Faculty of Aerospace Engineering. Her research focus is in structures and mechanisms for space applications. Since 2021, she coordinates a master profile on Structures for Space, which is one of the specializations of the Aerospace Structures and Materials master discussed in this paper.

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Prem Sundaramoorthy is an associate professor at the Faculty of Aerospace Engineering at TU Delft. Prem has been involved in education for close to fifteen years in primarily three universities – TU Delft, TU Eindhoven and University of Bologna. His educational research interest is in improving feedback mechanisms in education and developing frameworks that will assist students in reaching their planned and intended goals effectively.

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Mahsa Sajedi is an educational advisor and curriculum designer at Delft University of Technology. In 2017, she was awarded the Teach For Australia scholarship through which she completed her Master in Education, while working as a teacher. Her experience includes working in Australian universities and bridging programs and high schools. She is passionate about designing programs that work well for students and teachers, applying educational sciences and evince-based practices, and bringing educators together to work in interdisciplinary ways of teaching and assessing.

Calvin Rans is an Associate Professor at Delft University of Technology's Faculty of Aerospace Engineering. In 2007, he received his PhD in Aerospace Engineering from Carleton University for his work on fatigue crack growth in riveted lap joints, and he has since continued his research in structural failure and safety. Calvin is an educator at heart. In addition to his research, he strives to be innovative in his teaching methods, both online and on campus, and is a master of video and animation. He distinguished himself as a teacher by being named Best Lecturer TU Delft 2018 and Docent van het Jaar in the Netherlands 2019.

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