FOSTERING CREATIVE COMPETENCE IN ENGINEERING STUDENTS

EMBEDDING STIMULI FOR CREATIVE BEHAVIOUR IN EDUCATIONAL PRACTICES

DELFT UNIVERSITY OF TECHNOLOGY
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Fostering Creative Competence in Engineering Students
Embedding Stimuli for Creative Behaviour into Educational Practices.

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ABSTRACT

In today's fast-changing world, creativity is essential for engineering students to succeed. As part of my master's thesis in Strategic Product Design at the TU Delft, I explored how to identify and stimulate creativity in engineering education. My research focused on the bachelor programs in Aerospace Engineering and Industrial Design Engineering at the TU Delft. I looked at the topic from four different perspectives: the literature, the industry, the education and the student.

To understand creativity in engineering students, I developed a model with five key attitudes: being imaginative, disciplined, inquisitive, persevering, and collaborative. Each attitude is linked to three creative habits that students can develop. I also created a student journey to give educators a clear insight into the student's perspective, based on interviews with students from the Aerospace Engineering and Industrial Design Engineering programs.

My research identified four main conflicts that can affect creativity in engineering students: the tension between freedom and structure, the balance between theory and practice, the lack of true teamwork, and the challenge of assessing creativity. For each conflict, I provided recommendations for educators to improve the stimulation of creativity in their students.

To put my findings into a broader context, I compared my study to similar research in England and Germany. My conclusions highlight the importance of considering the student's perspective and the need for educators to adapt their teaching methods to stimulate creativity. My report shows that creativity can be developed in engineering students by understanding their perspective and addressing the conflicts that affect their creative growth.

KEYWORDS

Creativity, Education, Engineering, Competence, Stimulation

PREFACE

And here we are, at the end of my own student journey. I've always been fascinated by topics related to creativity, which is why I dedicated my minor and elective courses to it. With this passion and interest, I dove into this project. Every conversation sparked new ideas, and sometimes it was hard to stay within the project's scope. I thoroughly enjoyed the experience and look back on it with pride.

I'd like to express my gratitude to my two supervisors, Eva Kalmar and Katrina Heijne. First, Eva, who supported me with a unique and extremely helpful connection to both the topic and the client. Her detailed feedback pushed me to think outside the box. I also appreciated her concern for my mental well-being and her compliments, which made me feel safe and valued in every conversation. Then there's Katrina, whose critical eye and sharp questions took me to the next level. She's the reason I'm so passionate about creativity. After a fascinating minor and elective courses, it was a no-brainer that I wanted her as my mentor. Thank you both for your support, valuable feedback, and trust, which enabled me to tackle this project with confidence.

I'd also like to thank my cleint Steven and all the participants in my research. I never expected to encounter so much enthusiasm, passion, and even frustration when discussing creativity in engineering education. Every conversation shed new light on the problem, and I'm grateful for the trust you placed in me, sharing your personal stories, which I will always treasure.

Of course, I'd also like to thank my family and friends. They were always there for me, offering new insights, a listening ear when I needed to vent, and a shoulder to cry on when things got tough. We shared delicious cups of coffee, took short walks to get some vitamin D, and forced me to take breaks from my screen. Without them, I wouldn't be where I am today.

Thank you!

Liefs en knuffels,
Mandy

GLOSSARY

TU Delft = Delft University of Technology
BSc = Bachelor of Science
IDE= Bachelor Industrial Design Engineering
AE = Bachelor Aerospace Engineering
IDEE = Innovation in Delft Engineering Education
FES = Future Engineering Skills
PaG = Problem as Given
PaP = Problem as Perceived
PO = Problem Owner
ToCA = Theory of Change Analysis
CPS = Creative Problem Solving

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CHAPTER 1
THE PROJECT

This chapter provides an overview of the research project of this thesis. It includes a description of the assignment, the key stakeholders, and the problems this research aims to solve. Additionally, this chapter outlines the structure of the report, offering a roadmap to help navigate the thesis. Finally, it defines the scope and limitations of the project, highlighting the boundaries and constraints of this thesis.

In today's fast-paced world, where technology is advancing rapidly and global challenges are becoming more complex, engineers must embrace creativity (Felder, 1987; de Vere, 2009). They play a significant role in shaping our future by providing innovative solutions and driving economic growth (Industry Agenda, 2016). However, the traditional perspective of engineering often prioritizes technical skills over creative thinking, neglecting the vital role that creativity plays in the profession (Cropley, 2015). By fostering creativity, engineers can develop unique solutions, challenge traditional thinking, and expand the boundaries of what is possible (de Vere, 2009).

This study investigates creativity within an engineering context, aiming to identify the habits and characteristics that define an engineer's creative competence, particularly focusing on students as creative individuals. The thesis sheds light on the current state of creativity among engineering students at Delft University of Technology (TU Delft). It also seeks to identify potential gaps in creativity, ultimately helping educators encourage and nurture more creative habits in their students, thereby fostering a new generation of innovative engineers.

PROJECT ASSIGNMENT

It's clear that we need creative engineers. However, the TU Delft Teaching Academy has noticed that there has not been much focus on encouraging creativity in the curriculum, even though teachers know how important it is. This realization inspired this thesis.
This observation was made by an initiative created by TU Delft's Teaching Academy: Innovation in Delft Engineering Education (IDEE). This initiative consists of academic staff, PhD students, postdoc researchers and learning developers, who join hands to drive innovation and research that will have a lasting impact on TU Delft's Engineering Education. They focus on various educational themes inspired by didactic and pedagogical challenges relevant to all engineering education disciplines at TU Delft (IDEE, n.d.). For this thesis, I am in contact with the research project on Future Engineering Skills (FES) within IDEE.

THE PROBLEM

At the beginning of this thesis project, discussions took place with the problem owner (PO) for this project. As a representative of IDEE FES on this topic, he presents the problem that is addressed through research and design in this thesis.

The project of this thesis explores, defines and solves the problem of recognising and stimulating creativity in engineering students. This problem is presented by a representative of the IDEE FES research project. As a Problem Owner (PO), he is my direct link to the problem of this project, and therefore, the final solution will also be directed towards him.

During the first conversation, the focus was on identifying the problem within the given context. To accomplish this effectively, the PO was asked a series of in-depth questions. The PO expressed dissatisfaction with the current state of creativity at the university, citing a demand for soft skills in all faculties, but little attention is being paid to it. The problem was identified as teachers' inability to integrate creativity into their teaching, and the PO expressed a desire for a vision on how to incorporate non-traditional engineering skills into educational programmes. This led to the formulation of the main question of this study, which serves as the research question of this thesis.

Research question:
How can we narrow the gap between understanding and implementing creativity in engineering education?

This research question outlines the conflict: an unwanted gap between understanding and implementing creativity in engineering education. To better understand this problem, I created a visualisation of the conflict, separating the different aspects of the problem and making it clear what needs to be focused on (Figure 1).

I then apply a problem-finding design process, which involves broadening the problem, creating an overview of the options, and refining the problem statement (Appendix 1). Through this process, I identify two main themes: identifying and stimulating creativity in engineering students.

I see these themes as crucial in addressing the problem because they provide a basis for understanding what creativity means in the context of engineering education and how it can be implemented effectively. I address the first theme, identifying creativity, by defining creativity specific to the context and breaking it down into recognisable elements for the teacher, thus reducing the likelihood of misunderstanding. I address the second theme, stimulating creativity, by mapping students' experiences and identifying what stimulates and blocks their creativity, so that concrete areas of focus can be identified. I formulate two sub-questions to guide my research:

Sub-research question 1:
What are the indicators of creativity in engineering students?

Sub-2esearch question 2:
How do you stimulate creativity in engineering students?

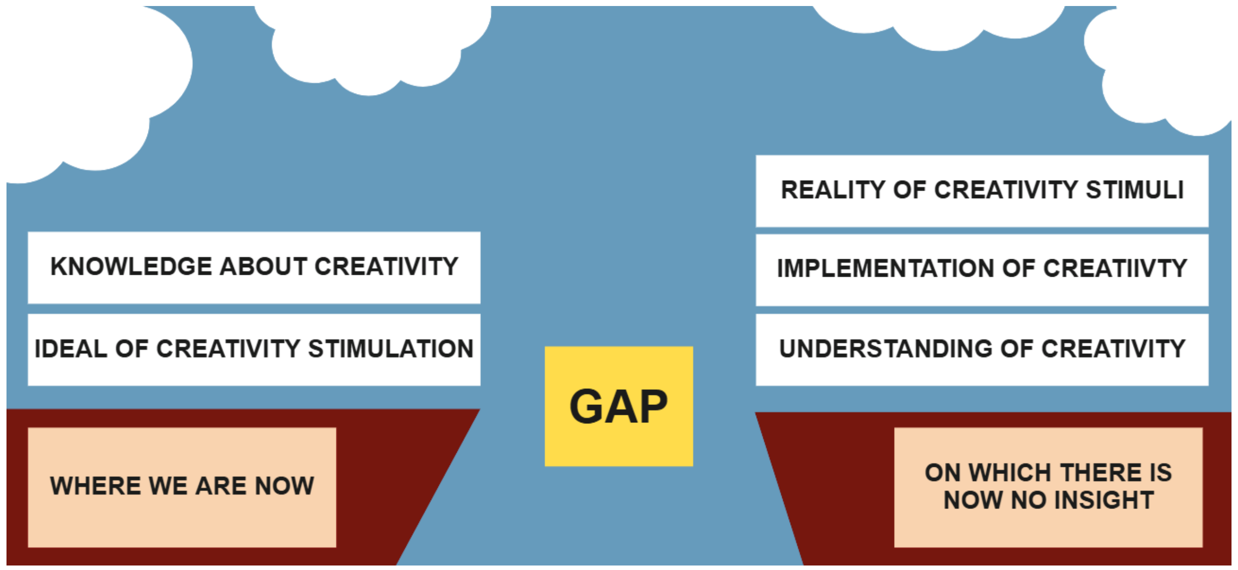


Figure 1: Visual representation of the conflict

PROJECT APPROACH

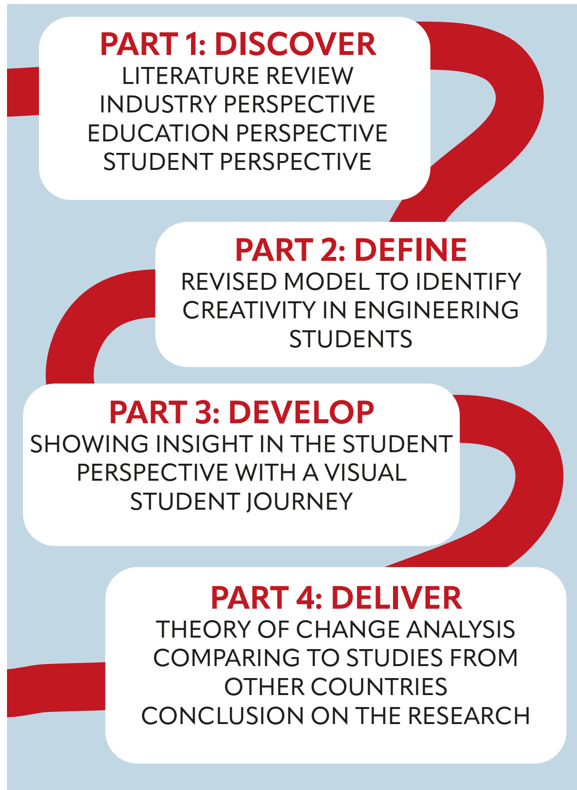
I begin by exploring the different perspectives on creativity for engineers. In Part 1: Discover, I delve into the literature, industry, education and students' perspectives in search of a better understanding of the complexity of creativity in engineering. Through a thorough analysis of existing research, interviews with professionals and surveys of students, I gather valuable insights into the current state of creativity in engineering. This part of the thesis is divided into four chapters, each focusing on one of the four perspectives. By the end of part 1, I have a rich understanding of the different views on creativity, which serves as a basis for the following parts of the thesis.

In Part 2: Define, I take the model of creativity from the literature and refine it based on the insights and observations from the other three perspectives. This ensures that the model is tailored to the specific context of my thesis and provides a solid framework for developing practical solutions. By adapting the model to the needs of the target audience, I create a tailored tool that can be used to stimulate creativity in engineering students.

With the refined model in hand, I move on to Part 3: Develop, where I design and create practical elements for the target audience. One of the key outcomes of this part is the creation of a student journey, a visual representation of students' experiences in bachelor's IDE and AE programmes. This journey offers teachers a unique insight into their students' creative learning process and highlights strengths and weaknesses. I also identify the agreements and conflicts, based on the four perspectives. Based on these conflicts, I create recommendations for educators to stimulate the creativity in their engineering students.

In the final part of the thesis, Part 4: Deliver, I critically evaluate the research done and the outcomes produced. I use a Theory of Change Analysis to make an overview of the relations and impacts of my research. I highlight the assumptions and external influences that might affect the success of my research. I also make a comparison between my research and two similar studies, based on different countries. With this, showing the relevance of my research. To close off, this part finishes with a conclusion chapter.

By following this structured approach, I offer a clear and comprehensive exploration of creativity in engineers, with practical solutions and insights that can be used to improve creativity in the Faculty of AE and IDE at TU Delft.



SCOPE & LIMITATIONS

This project is carried out as a graduation project for the master's degree in Strategic Product Design at the Faculty of Industrial Design Engineering at TU Delft. For this thesis project, the faculty has determined that 100 working days are available. This has therefore been a very decisive factor for what could and could not be included within this time frame during this project.

A focus on the Bachelor of Industrial Design Engineering (IDE) and Aerospace Engineering (AE) was chosen. The reason I chose the faculty of IDE is convenience. I am familiar with this faculty, and can therefore make an easy connection to educators and students, which is reinforced by the fact that both my supervisors are also from this faculty. To contrast with IDE, I chose to use the bachelor AE as a comparison. This is an international bachelor's with very different students, educators and courses. However, the bachelor's also have a lot of similarities, for instance, they are both expected to be creative, have similar companies they work with, and both students will be awarded the title 'Engineer' at the end of their master's degree. Due to the time frame of this project, it was decided to only look at the bachelor's, and not include the master's in the study as well.

READING GUIDE

The target audience of this report is educators at TU Delft, including teachers, lecturers, coaches, course coordinators, and education-related staff members, such as those working in the teaching lab.

This report is build up in four different parts. Each beginning of a new part is indicated with a dark blue page, showing the title and a small introduction to what can be expected in that part. Each chapter has a similar indication, only this time in red and without an introductory text.

The report follows a strict design, with hierarchy between headings visible by colour and size.

HEADER 1

HEADER 2

HEADER 3

Regular text

PART 1
DISCOVER

The first part of this project is to explore the context. This involves a thorough literature review, investigating a wide range of research papers and books on creativity in general, as well as in the context of engineering and education. In addition to the literature review, a market survey was conducted, as well as a study on the perspective of education, to gather insights into how engineering professionals and educators perceive the current and desired status of creativity in their field of work. These three studies collectively form the "Discover" phase, providing a solid basis for the next parts of the project.

CHAPTER 2
LITERATURE REVIEW

This chapter reviews the existing literature on creativity, with a focus on the complexity of creativity and its relevance to engineering. According to Rhodes (1961), creativity can be understood using the 4P framework, which includes the person, the process, the product and the press (Figure 2).

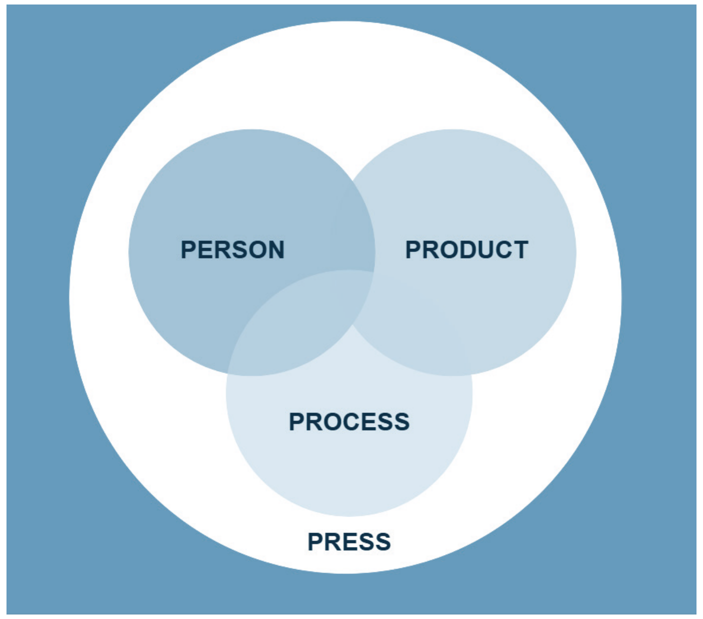


Figure 2: The 4P framework

The creative person is a crucial aspect of this framework, and research has identified several traits and characteristics associated with creative individuals, such as high intelligence, originality and good imagination (Tardif & Sternberg, 1988). Furthermore, Chen and Hsu (2006) identified characteristics important for creativity, including a willingness to explore, curiosity and a non-conformist attitude. Motivation also plays an important role in unlocking creative potential, with intrinsic motivation driving creative expression (Henriksen, 2017; van Straten, 2024). A creative personality can be defined as someone curious, possesses the necessary skills and can persevere (van Straten, 2024).

This thesis focuses specifically on the creative person, rather than the product, process or press. As Zhou (2012) notes, the student can be seen as the primary output of education, and understanding how to stimulate creativity in students is essential for teachers. The process and product are not the main goal of education, and therefore, a focus on the creative person is more relevant (Zhou, 2012). By focusing on the creative person, this thesis explores the traits, characteristics and motivations that enable an engineer to think and act creatively.

In addition, the press is also an important factor, but it depends on many different factors beyond just the target group of this study, making it less feasible to focus on. This chapter reviews the existing literature on creativity, with a particular emphasis on the creative person, and examines the concept, its components and meaning in the context of engineering.

SEARCH STRATEGY

For the literature review, the available content with the TU Delft Library license in the digital search engine Google Scholar was used. This was browsed using a combination of the search terms [creativity], [engineering] and [education]. The most recent search was on 18 February 2025.

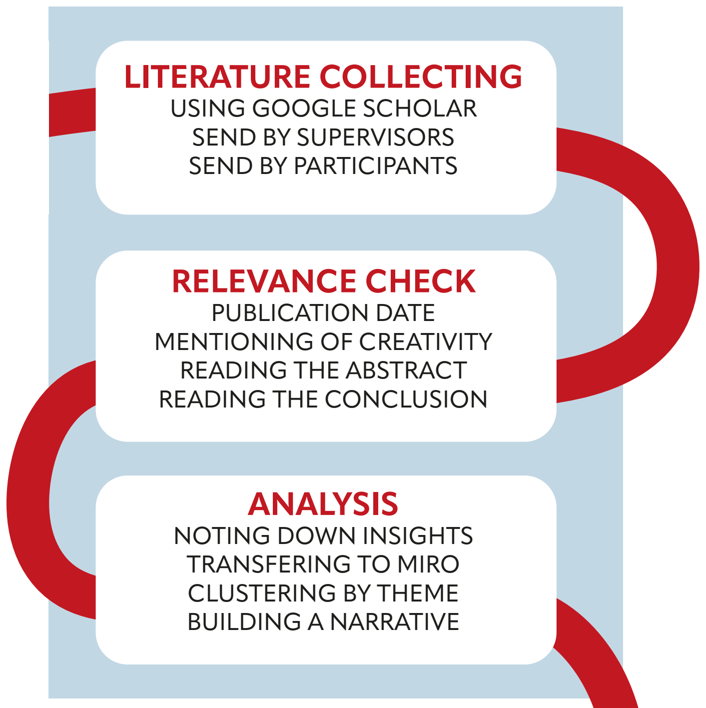
At the beginning of the search for relevant literature, using two of the abovementioned search terms was sufficient. However, as the search became more in-depth and focused, it was important to use more specific search terms, by giving a context. Thus, [education] was specified to university education, and [creativity] was enriched by addressing creativity as a competence, or divided into one of the five dimensions of creativity (Imaginative, Disciplined, Inquisitive, Perseverance and Collaborative). Some articles were also immediately dismissed, either because the connection to the topic was too far or the article was too old to be relevant. Each article was analysed manually, reading first the title and abstract, followed by the conclusion if relevant, then chapters or in some cases the entire article if relevant.

The literature was enriched with articles suggested by my supervisors and participants. As such, relevant articles and books were forwarded or lent, which they believed had a close connection to the project's research. These articles were then manually analysed in the same way as the articles from the digital database. These articles were last used for this project on 10 March 2025. In the end, a total of 44 articles were relevant and included in this project.

The articles had to be written either in English or in Dutch, as those are the only two languages I am good enough in myself to go through on an academic level. Furthermore, it was important that the word 'creativity' was mentioned either in the title or in the abstract. The results were filtered based on relevance to the search terms. I scanned through the results one by one, selecting the articles I found relevant to the context of this thesis: creativity, engineering and education.

While foundational papers on creativity may be older, papers on current practices in engineering education were selected from 2010 or later. A total of 41 articles were relevant and included in this thesis.

I did a thematic analysis on the selected articles, highlighting and noting down the insights from each article. I transferred these insights to an online whiteboard program, MIRO. Here, I clustered them by theme, making it easier to identify connections between the different articles.



LITERATURE REVIEW

CREATIVITY IN THE ENGINEERING CONTEXT

The engineering world is closely associated with technological expertise and analytical thinking. Yet creativity is seen as an essential competence of the 21st century (Spencer & Lucas, 2025). Therefore, it is important to consider whether the traditional engineer still meets the requirements of the 21st century, or whether we need a new kind of engineer (de Vere, 2009).

Engineering is based on applying scientific principles and findings to create useful products and services (Shaw, 2001). Engineers are true problem-solvers, focused on identifying , solving and preventing complex problems (Charyton & Merrill, 2009). Furthermore, engineers must be able to go beyond analysis, they must be able to synthesise, combining different elements to make something new or innovative (Zhou, 2012).

However, considering the problems of the 21st century, more than solving problems is needed, engineers must be able to add value and make real change (de Vere, 2009; Ghosh, 1993). The future engineer must be flexible, adaptable, well-rounded and innovative professionals (Stouffer et al., 2004). It is therefore not surprising that creativity is seen as one of the nine key attributes of future engineers (The National Academy of Engineering, 2004) as well as being one of the eight attitudes according to the CDIO (2022).

Thus, future engineers need to be creative. They need to go beyond the boundaries of traditional engineering. They need to look at both past, present and future to redefine, analyse and collaboratively approach problems in a solution-finding process (Sheppard et al., 2009; Sternberg & Dess, 2001; Williams, 2002). As such, a creative engineer must be driven by intrinsic motivation, they must be able to apply existing knowledge and skills uniquely with passion to their work (de Vere, 2009; Blicblau & Steiner, 1998). All this must be done simultaneously while the engineer maintains a critical and analytical mindset (Shaw, 2001). Overall, a lot is expected of a creative engineer, but are they prepared and trained for this in education?

CREATIVITY IN THE ENGINEERING CONTEXT

Despite its importance, creativity is often overlooked in engineering courses, which traditionally focus on structured learning, predefined solutions and efficiency. If we want to produce engineers capable of tackling complex global problems, we need to rethink how creativity is stimulated and facilitated in engineering education.
The structure of modern education is still largely influenced by the Industrial Revolution, which prioritised uniformity and efficiency over individual creativity (Van Straten, 2024). In general, engineering education follows a rigid format of lectures, homework and exams, teaching students to find the only correct answer as quickly as possible (Felder, 1987; Zhou, 2012). This approach encourages accuracy and speed but discourages exploration, experimentation and original thinking (Blicblau & Steiner, 1998).

Furthermore, engineering curricula in general are often highly theory-based, leaving little room for practical experience or open-ended problem-solving (Vere, 2009). Creativity thrives in a flexible, non-linear learning environment, but engineering curricula are often rigid and structured (Pappas, 2002). Soft skills and creative problem-solving are often dismissed as unimportant in engineering fields (Corazza & Agnoli, 2016). Moreover, creativity is rarely a formal requirement in curricula, even though it is recognised as valuable at the national policy level (Lucas, 2016).

THE IMPORTANCE OF CREATIVITY IN ENGINEERING EDUCATION

In essence, engineering is about designing and solving problems, not just memorising theories (Dym et al., 2005). Without creativity, engineers can be highly competent but cannot innovate and develop new solutions (Corazza & Agnoli, 2016; Eekels, 1987). Yet, creativity is absent from most engineering curricula, resulting in engineers who often lack essential creative skills (Spencer & Lucas, 2025).

Studies show that integrating creativity into teaching leads to greater student engagement, higher achievement and better learning outcomes (Hattie, 2009; Office for Standards in Education, 2010; Cooper et al., 2011). Creative projects and practical design tasks make learning more exciting and meaningful, allowing students to see how scientific and engineering principles apply to real-world problems (Vere, 2009). Moreover, when students are encouraged to take risks and reflect on their learning, they become more confident in their creative abilities (Green & Kennedy, 2001).

THE ROLE OF EDUCATORS IN STIMULATING CREATIVITY

If creativity becomes a core element of engineering education, educators must play an active role in nurturing it. Teaching creativity does not mean abandoning engineering knowledge, but rather integrating creative behaviour into problem-solving. Engineering professors should go beyond simply providing content and instead help students develop a mindset that embraces exploration and originality (Felder, 1987).

An important aspect of this is helping students recognise and overcome creative blocks (Christiano & Ramires, 1993). Many students enter university with the belief that engineering is purely analytical, and it is the responsibility of teachers to challenge this perception (Felder, 1987). Encouraging students to take different approaches, think critically and experiment with unconventional solutions can lead to a more dynamic learning experience (Richards, 1998). However, there is often a gap between how teachers view their teaching and how students experience it. Although many teachers believe they support creativity, students often report that creative thinking is not encouraged or assessed (Kazerounian & Foley, 2007). Addressing this gap is essential for real change.

To create an environment in which creativity can thrive, teachers should focus on facilitating an atmosphere that encourages creative exploration. This means giving students the freedom to experiment, make mistakes, develop their ideas without fear of failure, and recognise and reward creative approaches, rather than just correct answers (Felder, 1987).

One effective method is to integrate more opportunities for creative problem-solving into the curriculum. Encouraging students to participate in open-ended design challenges, project-based learning and real-world problem-solving allows them to apply both technical knowledge and creative thinking (Vere, 2009). Teaching systematic approaches to problem-solving can also help students better understand how to activate their creativity (Liu & Schonwetter, 2004). In addition, structuring the curriculum to support rather than suppress creative development can significantly enhance students' creative abilities (Chen & Hsu, 2006).

BARRIERS AND CHALLENGES TO STIMULATING CREATIVITY

Despite the benefits of creativity in engineering education, several barriers remain. A big challenge is the pressure on students to work quickly and efficiently, which can discourage in-depth research and creative risk-taking (Kazerounian & Foley, 2007). Some teachers may also be biased against creativity, seeing it as an excuse for a lack of precision or discipline (Kazerounian & Foley, 2007).

There is also a strong belief that engineering is purely technical and that creativity is unnecessary or impossible to teach (Kazerounian & Foley, 2007). These assumptions limit how far creativity is being integrated into engineering courses. Moreover, engineering education's highly structured and precise nature makes it more difficult to introduce open, creative learning opportunities compared to disciplines such as arts or social sciences (Lucas, 2016).

CREATIVITY AS A COMPETENCE

Creativity is described as essential 21st -century competence (Newton & Newton, 2014; Spencer & Lucas, 2025). This not only highlights the relevance of creativity in today's society, but also that it is more than a skill (Davies et al., 2017). Thus, a competence consists of cognitive elements, such as using theories, concepts and knowledge. But also functional aspects that allow the person to turn their ideas into action, further, a competence also consists of personal attributes and values (Ananiadou & Claro, 2009; Davies et al., 2017). These three elements can be seen as a person's knowledge, skill and attitude which together form the three dimensions of a competence for a person (Figure 3).

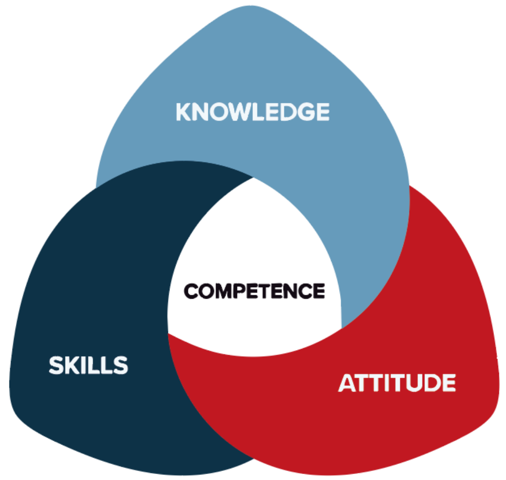


Figure 3: The three dimensions

KNOWLEDGE

Knowledge can be seen as the database of all the experiences, information and insights a person has had in their life, ready to be used at any time (Sheppard et al., 2009). Despite knowledge being a component of competence, it can also be contradictory, as having a lot of knowledge can also block creativity by making it harder to think outside the box (Ramires, 1993).

SKILLS

Here, knowledge is applied through training and methodologies, which ensures that a person can, for example, explore boundaries, discover new things or cause creative breakthroughs (Henriksen, 2017). Skills provide the tools and techniques needed to be creative as a person.

ATTITUDE

A creative mindset is essential in fields such as engineering (Martin, 1991). Attitude addresses a person's mindset, personal point of view, openness and values (Davies et al., 2017). A positive attitude for creativity can ensure experimentation with ideas and risk-taking, and is developed through knowledge, experiences, beliefs and feelings (Basadur & Basadur, 2011).

THE CREATIVE HABITS OF MIND

The three dimensions of creativity as a competence- knowledge, skill and attitude -are connected. For example, knowledge can be developed into a positive attitude by applying one's skills (de Vere, 2009). It is therefore important to pay attention to all three dimensions if a person's creativity is to develop further. Creative attitude is difficult to develop as it is closely linked to a person's self-image, but can be addressed by developing the other dimensions as well (Basadur & Basadur, 2011). Here, it is important to have the person's environment support this development.

Knowledge, skill and attitude together form the reasoning behind a person's creative behaviour. Lucas (2016) has divided this creative behaviour into 'Habits of mind' (Figure 4), the way of thinking and doing. These habits are visible in a person's behaviour and are closely linked to someone's creative attitude.

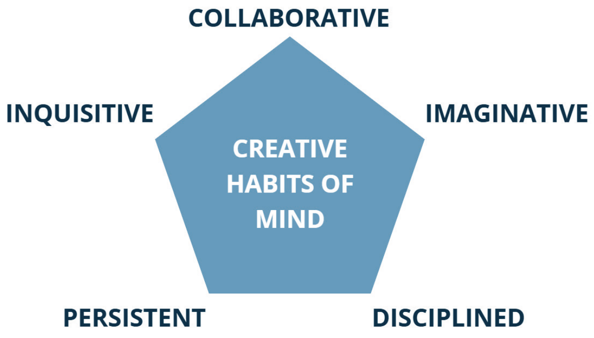


Figure 4: The five creative attitudes of the habit of mind (Lucas, 2016)

The Habits of Mind are categorised in five dimensions. These five dimensions - Imaginative, Disciplined, Inquisitive, Persistent & Collaborative - can be seen as the five attitudes associated with the competence. What makes Lucas' (2016) framework unique is the addition of Persistent, Disciplined and Collaborative, which is left out in many definitions of creativity.

Within the five attitudes of creativity, Lucas (2016) defined three sub-habits each. Together, these formed the wheel of creativity (Figure 5 & Table 1).

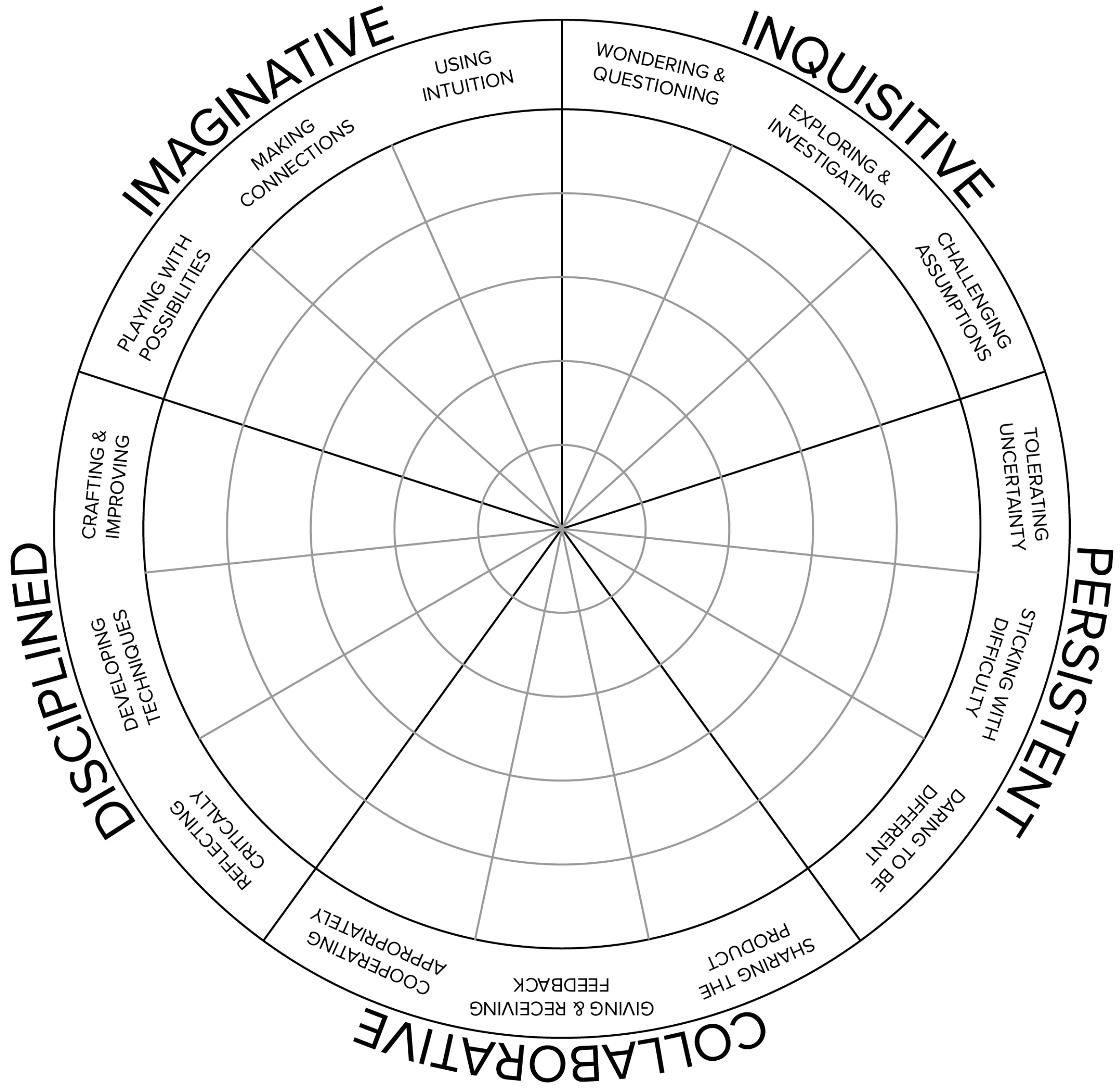


Figure 5: The Wheel of Creativity (Lucas, 2016)

ORIGINAL WORD	ORIGINAL DESCRIPTION
Imaginative	At the heart of a wide range of analyses of the creative personality is the ability to come up with imaginative solutions and possibilities.
Playing with possibilities	developing an idea involves manipulating it, trying it out, and improving it.
Making connections	the synthesising process brings together a new amalgam of disparate
Using intuition	the use of intuition allows individuals to make new connections tacitly that would not necessarily materialise given analytical thinking alone.

Disciplined	As a counterbalance to the more intuitive side of creativity, there is a need for knowledge and craft in shaping the creative product and in developing expertise.
Developing techniques	Skills may be established or novel, but the creative individual will practice to improve.
Crafting & improving	Taking pride in work, attending to details, and correcting errors indicate people whose creative skill is of the highest order (Berger, 2003; Ericsson et al., 1993).
Reflecting critically	Once ideas have been generated, evaluation is important. Such “converging” requires decision-making skills.
Inquisitive	Creative individuals are good at uncovering and pursuing interesting and worthwhile questions in their creative domain.
Wondering & Questioning	Beyond simply being curious about things, questioning individuals pose concrete questions about things to help them think things through and develop new ideas.
Exploring & investigating	Questioning things alone does not lead to creativity. Creative individuals act out their curiosity through exploration and follow up on their questions by actively going out, seeking, and finding out more
Challenging assumptions	A degree of appropriate skepticism is important; not taking things at face value without critical examination.
Persistent	Creative individuals do not give up easily. Given the complexity and challenges inherent in much creative acts (Koestler, 1964), being able to persist in the face of difficulty is essential
Tolerating uncertainty	being able to tolerate uncertainty is important when actions or even goals are not fully set out.
Sticking with difficulty	persistence in the form of tenacity is important, enabling an individual to get beyond familiar ideas and come up with new ones.
Daring to be different	creativity demands a certain level of self-confidence as a prerequisite for sensible risk-taking.
Collaborative	In today’s world complex challenges—for example, unraveling DNA, understanding climate change—require creative collaboration. Creative individuals recognize the social dimension of the creative process. While there has long been a socioconstructivist strand of thinking about learning (Vygotsky, 1978), with creativity we have tended to focus on individuals and not on groups. Yet creative advances in the fields of science, technology and management today almost always stress the social components (Amabile & Pillemer, 2012; Laudel, 2001).
Giving & receiving feedback	the propensity of wanting to contribute to the ideas of others, and to hear how one’s own ideas might be improved.
Cooperating appropriately	the creative individual co-operates appropriately with others. This means working collaboratively as needed, not necessarily all the time
Sharing the product	creative outputs matter, whether they are ideas or things and create impact beyond their creator

Table 1: Habits with their corresponding description (Lucas, 2016)

ENGINEERING HABITS OF MIND

Towards the end of this project, it was brought to my attention that Lucas’s (2016) framework has undergone a revision for the engineering context. This revised framework has a core, describing the engineering mind: ‘Making “things” that work and making “things” work better’ (Spencer & Lucas, 2025). From this follow six Engineering Habits of Mind, surrounded by seven Learning Habits of Mind (Figure 6).

In the paper by Spencer and Lucas (2025), they do not try to define the habits, but rather to find out which interactions help develop the habits. For this, a four-step plan has been drawn up, as also shown in Figure 7 (Spencer & Lucas, 2025).

Step 1: Understand the habits.
The teacher needs to understand what the habit is and how it is expressed within the courses

Step 2: Select appropriate strategy.
The teacher has to select the right strategy, which can be curriculum design, but also pedagogical strategies, design processes, assessment strategies and professional learning.

Step 3: Establish the culture.
This is seen as one of the most important steps. The teacher needs to find out to what extent the current culture encourages creativity and what the required knowledge and skills are.

Step 4: Develop learner commitment to habits.
Here it is important to consider the student’s role in their own learning, feedback and assessment methods and the extent to which the school itself prioritises habits.

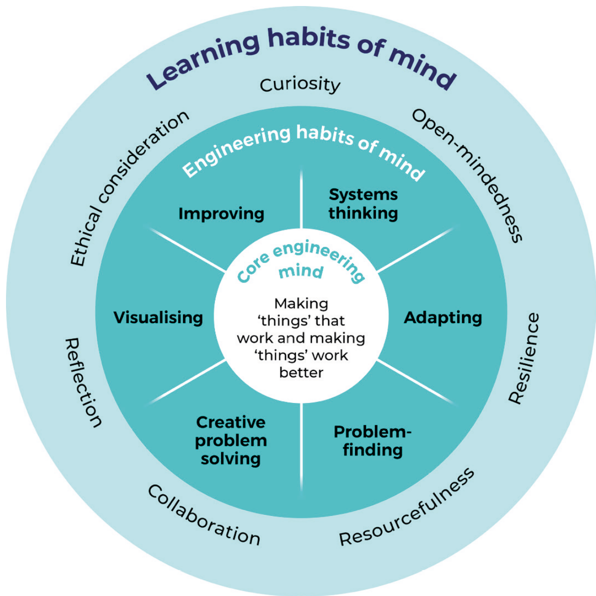


Figure 6: Engineering Habits of Mind (Spencer & Lucas, 2025)

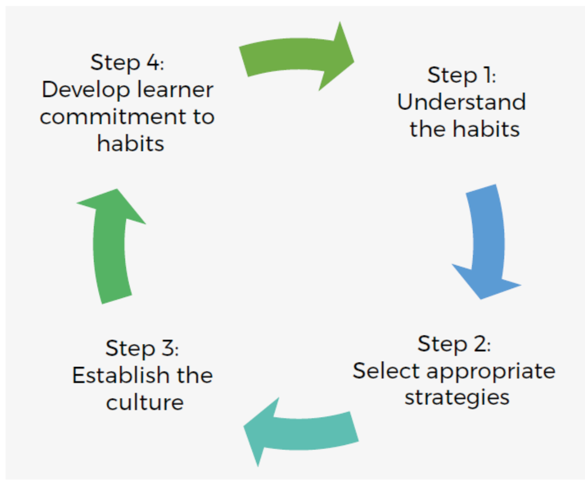


Figure 7: A four-step process of cultivating habits in engineering and creativity (Spencer & Lucas, 2025)

CONCLUSION

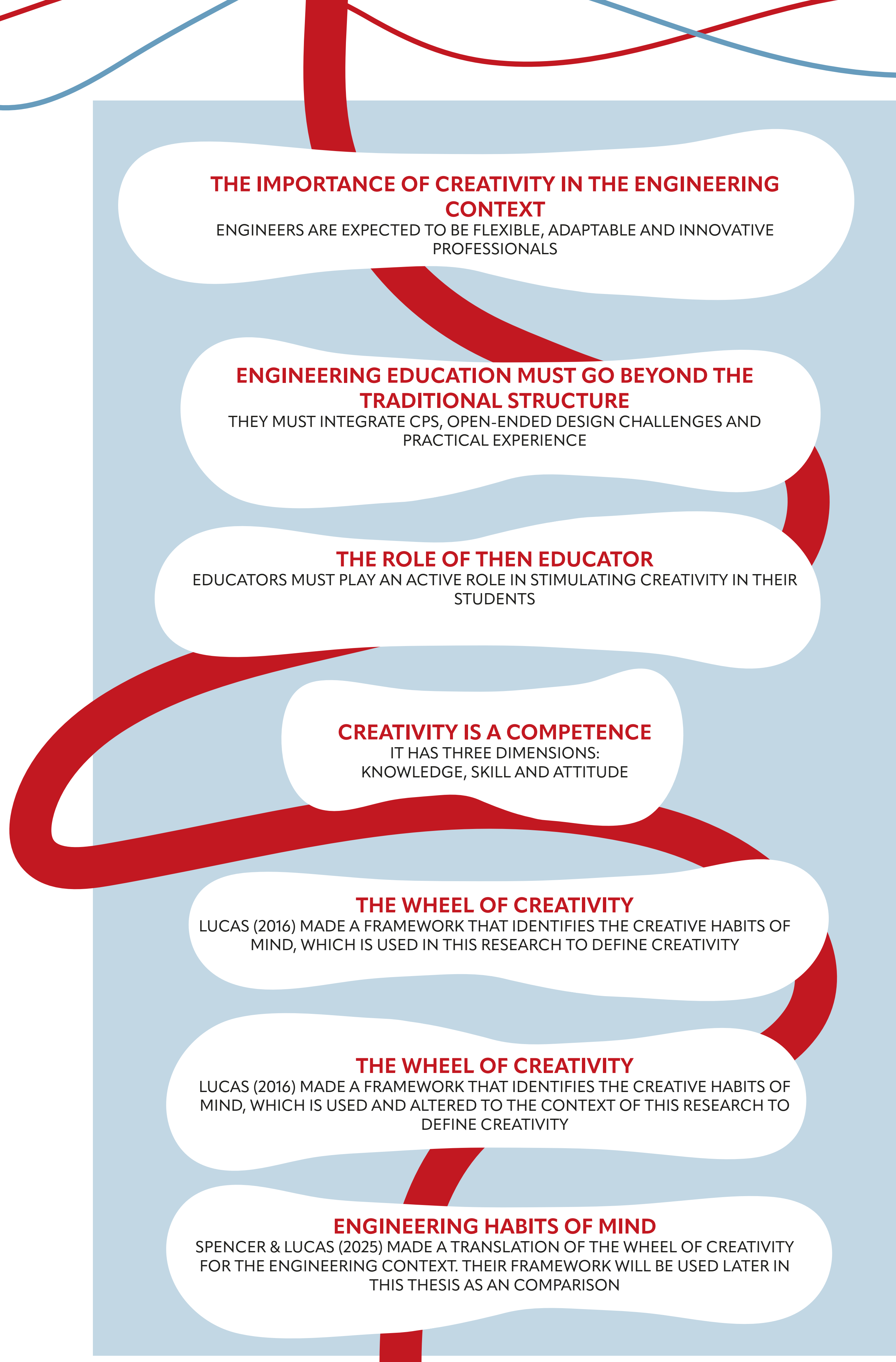
In conclusion, this review highlights the importance of creativity in the engineering context, where engineers are expected to be flexible, adaptable and innovative professionals (Stouffer et al., 2004). To achieve this, engineering education must go beyond traditional structured learning and integrate creative problem solving, open-ended design challenges and practical experience (Vere, 2009). The creative person is a crucial aspect here, and teachers must play an active role in nurturing creativity by facilitating an atmosphere that encourages creative exploration (Felder, 1987).

The concept of creativity as a competence is particularly relevant in the context of engineering education (Ananiadou & Claro, 2009; Davies et al., 2017). The three dimensions of creativity - knowledge, skill and attitude - are interconnected and the development of one dimension can have a positive impact on the others (Basadur & Basadur, 2011). The wheel of creativity, as proposed by Lucas (2016), provides a framework for understanding the creative habits of mind, including imaginative, disciplined, inquisitive, persistent and collaborative attitudes.

This framework is especially useful in the engineering context, as it emphasises the importance of perseverance, discipline and collaboration in creative problem solving (Lucas, 2016). The revised framework for the engineering context, as proposed by Spencer and Lucas (2025), further emphasises the importance of making 'things' work and making 'things' work better, surrounded by six engineering habits of mind and seven learning habits of mind.

The four-step plan proposed by Spencer and Lucas (2025) provides a practical approach to cultivating these habits of mind in engineering education, including understanding the habits, selecting appropriate strategies, creating a culture that encourages creativity and developing student engagement with the habits. By using the wheel of creativity and the framework of engineering habits of mind, teachers can better understand how to encourage creativity in engineering students and prepare them for the complex challenges of the 21st century.

This review provides a basis for further exploration of the role of creativity in engineering education, and the wheel of creativity is used as a framework for analysing the creative habits of mind in the context of engineering education. By exploring the link between creativity and engineering education, we can better understand how to prepare engineering students for success in an increasingly complex and innovative world.



CHAPTER 3
INDUSTRY PERSPECTIVE

To establish a connection between the literature and the current engineering job market, this chapter explores the industry perspective. To do so, I investigated the current and desired state of creativity among engineers just entering the engineering job market. This chapter addresses the small-scale study, explaining the methods, results and conclusions. The purpose of this study is to get a better understanding of the industry's perspective on creativity in engineers.

METHOD

Since the purpose of this research was to get a small-scale insight into some opinions in the market, it was not worth the time investment to conduct face-to-face interviews. Also, parallel to this research, the literature review was ongoing. Therefore, to increase efficiency, it was decided to use an online questionnaire. This questionnaire was created in the online programme Qualtrics, a programme approved by TU Delft. This questionnaire started with the following description as shown in Figure 8.

CONSENT

The survey started with a description of the project, its purpose and any risks involved in participating in this project. Following this, the question was whether the participant had read and agreed with this text. In this way, consent was handed over. In case the participant answered 'no' to this first question, participation in the study ended. In case the participant had filled in 'yes', the questionnaire went on to the questions.

RELEVANCE

The recruitment of participants was done using the online networking platform LinkedIn. Even though this platform includes a variety of different engineering disciplines, a verification of their relevance and connection to the engineering industry had to be checked. For this purpose, the first part of the questionnaire focused on the person's connection to the engineering industry. This question asked whether the participant himself considered his views to be relevant to the perspective of the engineering industry, and to which engineering discipline they belonged.

Thank you for participating in my graduation project research study titled:
Exploring Creativity in Engineering: why it matters and how it shapes the future.

The purpose of this research study is to get a better overview of the perception of creativity in the engineering industry and the need for creative engineers in this industry, and it will take around 5-10 minutes to complete. The data will be used to create insight into the market perspective on creativity in the engineering context.

As with any research activity, the risk of a data breach is always possible. We will prevent this with the best of our ability and your answers in this study will remain confidential. We will minimize any risks by only sharing data with my supervisors if needed, and deleting all data after processing. Also, I will keep the interview completely anonymous, as I will not use your name or any other personal data.

Your participation in this study is entirely voluntary, and you can withdraw at any time. You are free to omit any questions.

Figure 8: Introduction text questionnaire

If any of these questions reflected an irrelevant connection, this participant was excluded from the study and their answers were not included in further analysis.

NEED FOR CREATIVITY

Following this was the question of whether the participant experienced a need for creative engineers in his industry. A 0-5 scale had been drawn up for this question, with 'Totally disagree' at 0 and 'Totally agree' at 5 (Table 2). A 0-5 scale was deliberately chosen for this study, as it does not contain an answer exactly in the middle. This pushes the participant to choose a side. This question was followed by an open-ended question asking why they needed creative engineers (Table 3).

ATTITUDE SPECIFIC

Next came five similar sections. Each section addressed one of the five attitudes Lucas (2016) used to describe creativity (Table 4). Within each attitude, the three corresponding habits were used. To avoid repetition, we will cover the five sections of the questionnaire in general.

0	1	2	3	4	5
Fully disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Fully agree

Table 2: 0-5 scale labels

Question or statement	Format
'In our industry, there is a need for creative engineers'	0-5 scale
Why do you need creative engineers in your industry?	Open question

Table 3: 'The need for creativity '- questions

The attitude section started with three statements, to which the participant could answer with a 0-5 scale for each statement. Again, 'Totally disagree' was set at 0 and 'Totally agree' at 5. The format of the statements was the same for each habit and attitude: 'In my industry, we need engineers to be [habit]'. This was followed by three more statements with the same 0-5 scale, but this time the statements were about the reality of the situation. The format of the statements here was: 'In reality, my industry receives engineers that are [habit]'. As the last question of each section, participants were asked to explain any differences between the wanted and the realistic situation (Table 5).

ATTITUDE	HABITS
Inquisitive	• Wondering & Questioning • Exploring & Investigating • Challenging assumptions
Imaginative	• Playing with possibilities • Making connections • Using intuition
Persistent	• Sticking with difficulty • Daring to be different • Tolerating uncertainty
Collaborative	• Sharing the product • Giving and receiving feedback • Cooperating appropriately
Disciplined	• Developing techniques • Reflecting critically • Crafting & Improving

Table 4: The five attitudes with the habits made by Lucas (2016).

Question or statement	Format
In my industry, we need engineers to be [habit] (3X)	0-5 scale
In reality, my industry receives engineers who are [habit] (3x)	0-5 scale
In the case of a difference between need and reality, what do you think is the main reason for this?	Open question

Table 5: Attitude-specific questions

By researching both the current and desired state of creativity in engineers from the industry perspective, I was able to identify gaps and areas of improvement. It also helped me to understand the industry's needs and expectations. Using the wheel of creativity (Lucas, 2016) as a framework for this study, I could contextualize the findings in a theoretical understanding of creativity. This helped me to gain insights into how the different aspects of creativity are perceived and valued in the industry.

After these five sections, the participant had reached the last section of the questionnaire. In it, the participant was thanked for their participation and had the opportunity to leave their email address so that we can potentially schedule an appointment to dive deeper into the questions together.

ANALYSIS

To analyse the data, the completed scale questions were treated quantitatively. I compared the data by plotting them by habit and by attitude. The open-ended questions provided direct insights into the market and were treated qualitatively. Thus, each open-ended question was carefully reviewed and compared with the other answers. This produced a list of insights, clustered by attitude.

RESULTS

A total of 15 responses were collected, with 7 meeting the requirements to be included in the analysis. Of these 7 responses, the participants were employed in six different engineering-related industries. These industries were: Electronics, Telecommunication, Finance, Naval Design, Mechatronics and Maritime. Within these industries, two participants were working in the naval design industry. All six of these different industries met the requirements to be taken into account for the engineering perspective.

Looking at the question of whether they need creative engineers, the answers were very positive. On the 0-5 scale, the minimum was 3 and the maximum 5, giving a median of 4 (Table 6).

For the attitudes section, it is important to look at individual responses. With this, desired differences can be made visible between the current and the desired state of creativity in their engineering sector. To look at this in detail, both a graph and a table were prepared for each attitude. The graph shows the responses of all participants, categorised by habit and by state. The median and mean are also noted here. The table shows the individual responses, noting whether the participant would like to see an increase or a decrease in habit. The numbers can be between -5 and +5, with all negative numbers and all numbers of 3 and above highlighted.

	Fully dis-agree	Disagree	Somewhat disagree	Somewhat agree	Agree	Fully agree
Amount of answers	0	0	0	1	3	3

Table 6: Distribution of answers on the need for creativity

INQUISITIVE

For the attitude 'Inquisitive', it can be seen that in all cases, the median is higher in the desired compared to the current state (Figure 9). Looking at Table 7, it can be seen that 'wondering & questioning' is desired higher by all participants, with one person indicating a desired increase of 3. For the habit of 'Exploring & investigating', every participant would also like to see this higher in the desired state. Of these, two participants also indicated that they would like an increase of 3 or higher.

In the habit of 'Challenging assumptions', something interesting happens. Five of the seven participants would like to see an increase, but Participant 6 would like to see a decrease. Looking at the personal comments, participant 6 indicated here that many people have a 'not invented here' syndrome, so they challenge too much and explore too little. This reasoning explains the wanted decrease in 'Challenging assumption'.

Furthermore, for the attitude 'Inquisitive', comments were made about the lack of practical knowledge among engineers, being stuck with a traditional way of thinking and doing things, and that engineers just out of college do not dare to go beyond the limits they were taught at school.

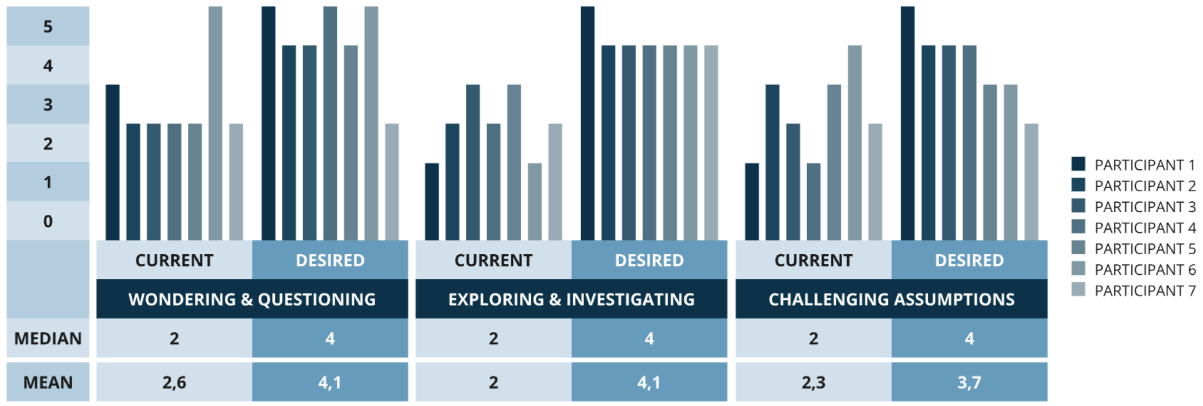


Figure 9: Responses from the attitude Inquisitive

INQUISITIVE		Part 1	Part 2	Part 3	Part 4	Part 5	Part 6	Part 7
Current	Wondering & Questioning	3	2	2	2	2	5	2
Desired	Wondering & Questioning	5	4	4	5	4	5	2
Difference		**2**	**2**	**2**	**3**	**2**	**0**	**0**
Current	Exploring & investigating	1	2	3	2	3	1	2
Desired	Exploring & investigating	5	4	4	4	4	4	4
Difference		**4**	**2**	**1**	**2**	**1**	**3**	**2**
Current	Challenging assumption	1	3	2	1	3	4	2
Desired	Challenging assumption	5	4	4	4	3	3	3
Difference		**4**	**1**	**2**	**3**	**0**	**-1**	**1**

Table 7: Desired change per participant for the attitude Inquisitive

IMAGINATIVE

For imaginative, the same applies as for inquisitive, for all habits both the median and mean are higher in the desired state than in the current (Figure 10). Furthermore, as seen in table 8, for the habit 'Playing with possibilities', five participants would like to see an increase, of which one person wants an increase higher than three. In the habit of 'Making connections', three participants would like to see an increase, one of them higher than three. In this habit, however, it is notable that four participants find the current state of this habit sufficient, and thus do not wish to see an increase or decrease.

The habit of 'Using intuition' shows something striking again. Here, participants give very different answers. Three participants would like to see an increase, two of whom wish for an increase higher than 3. Three participants are satisfied with the current state and participant 6 would like a decrease of -2. His remark on this attitude discusses trusting the calculations being made, for which, according to Participant 6, intuition would get in the way.

Other comments address the fact that imaginative takes time, and that time costs money. As a result, there would be too little room for it in the market now, despite it being desirable. It was also stressed that engineers would not be open enough to learn new technologies. Furthermore, the dominant role of a manager was also emphasised, whereby the manager is overruling in decision-making, thereby overriding the engineer's imagination.

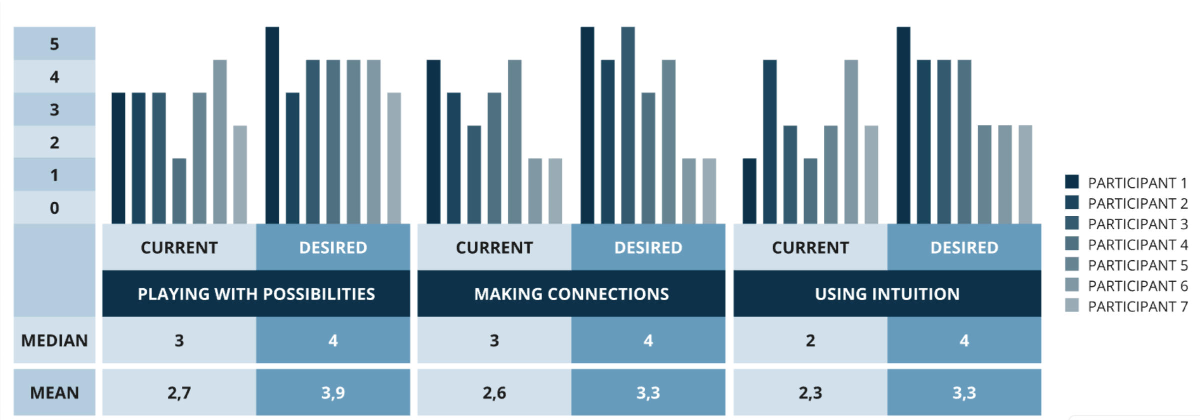


Figure 10: Responses from the attitude Imaginative

IMAGINATIVE		Part 1	Part 2	Part 3	Part 4	Part 5	Part 6	Part 7
Current	Playing with possibilities	3	3	3	1	3	4	2
Desired	Playing with possibilities	5	3	4	4	4	4	3
Difference		**2**	**0**	**1**	**3**	**1**	**0**	**1**
Current	Making connections	4	3	2	3	4	1	1
Desired	Making connections	5	4	5	3	4	1	1
Difference		**1**	**1**	**3**	**0**	**0**	**0**	**0**
Current	Using intuition	1	4	2	1	2	4	2
Desired	Using intuition	5	4	4	4	2	2	2
Difference		**4**	**0**	**2**	**3**	**0**	**-2**	**0**

Table 8: Desired change per participant for the attitude Imaginative

PERSISTENT

The differences between the habits are larger for the habit of 'Persistent' than for the previous two attitudes (Figure 11). Despite both median and mean being higher for the desired state than the current state, it can be seen that for the habit of 'Tolerating uncertainty' there is a much smaller difference than for the habit of 'Daring to be different'. This can also be seen in Table 9, where the desired changes of the habit of 'Tolerating uncertainty' are close to each other, with three participants wanting a small increase, three participants satisfied with the current state and one participant would like a decrease of -1. The comments mainly mention that uncertainty is scary and can even impact your career. From this, it can be extracted that the participants feel that as an engineer, you should move to a more certain state, which requires little to no change in this habit.

For the habit of 'Sticking with difficulty', six participants indicated they wanted an increase, one of them also higher than three. One participant also indicated a decrease of -1. This could result from the participant's indicated barrier in asking others for help. The last habit of this attitude is 'Daring to be different'. Here, all indicated they would like an increase, with two also indicating they would like an increase higher than three.

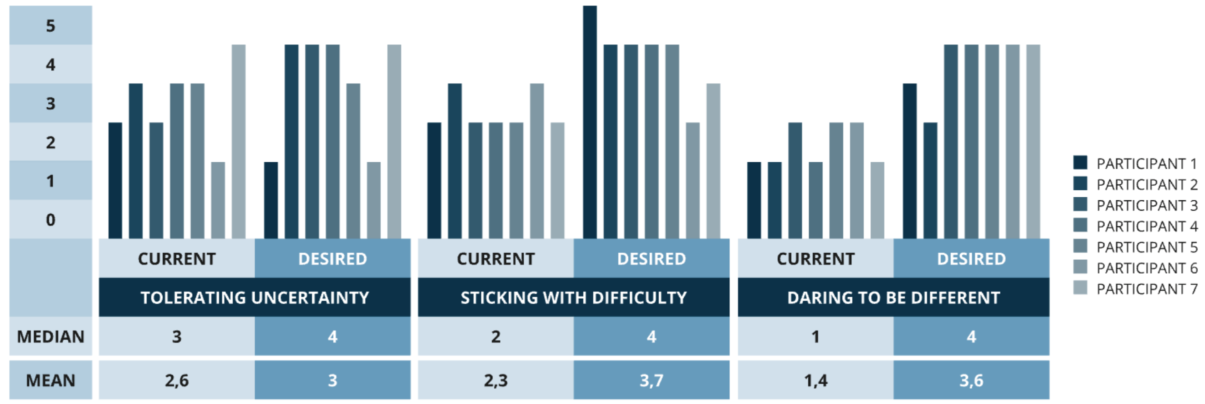


Figure 11: Responses from the attitude Persistent

PERSISTENT		Part 1	Part 2	Part 3	Part 4	Part 5	Part 6	Part 7
Current	Tolerating Uncertainty	2	3	2	3	3	1	4
Desired	Tolerating Uncertainty	1	4	4	4	3	1	4
Difference		**-1**	**1**	**2**	**1**	**0**	**0**	**0**
Current	Sticking with difficulty	2	3	2	2	2	3	2
Desired	Sticking with difficulty	5	4	4	4	4	2	3
Difference		**3**	**1**	**2**	**2**	**2**	**-1**	**1**
Current	Daring to be different	1	1	2	1	2	2	1
Desired	Challenging assumption	5	4	4	4	3	3	3
Difference		**4**	**1**	**2**	**3**	**0**	**-1**	**1**

Table 9: Desired change per participant for the attitude Persistent

COLLABORATIVE

For the Collaborative attitude, all participants are quite unanimous. All medians and means are higher in the desired state (Figure 12). There is also no habit where a decrease is desired. However, it is quite striking that Participant 1 wants an increase of 3 or higher for each habit, while Participants 4, 5 and 6 indicate that they are satisfied with all three habits and do not wish for any change (Table 10). In his comments, participant 1 indicates that he suffers from many NDAs, which means that a lot has to be kept secret. Therefore, his desire for a high increase in the Collaborative attitude might come from the desire for more collaboration without the danger of sharing secrets. Participant 4, 5 and 6 give no reason for their scores.

A different comment on this attitude is about the project-based working that engineers learn at university. It is indicated here that there is too much focus here on the end goal, which is preferably achieved as individually as possible. Effective group work would be seen as a necessary thing, rather than being about getting the best out of individuals, by having them move together towards an end goal.

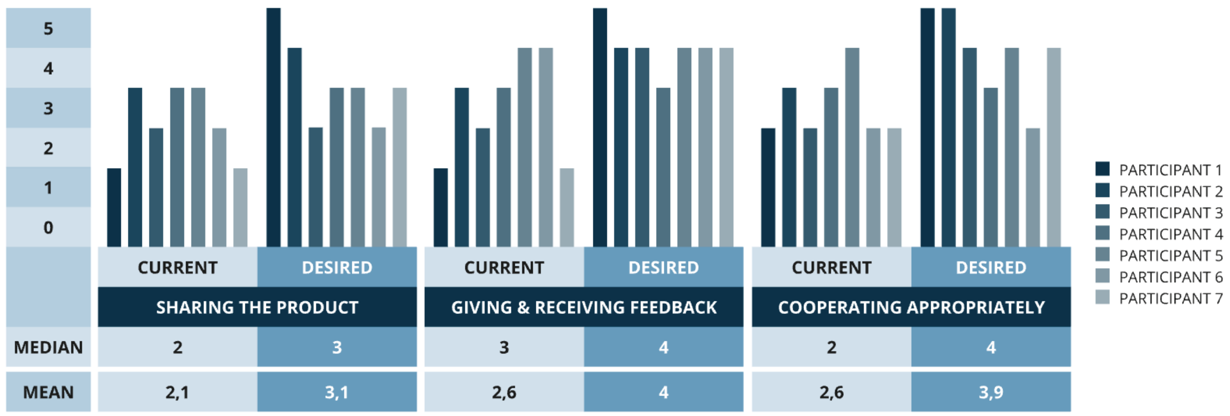


Figure 12: Responses from the attitude Collaborative

COLLABORATIVE		Part 1	Part 2	Part 3	Part 4	Part 5	Part 6	Part 7
Current	Sharing the product	1	3	2	3	3	2	1
Desired	Sharing the product	5	4	2	3	3	2	3
Difference		**4**	**1**	**0**	**0**	**0**	**0**	**2**
Current	Giving & Receiving Feedback	1	3	2	3	4	4	1
Desired	Giving & Receiving Feedback	5	4	4	3	4	4	4
Difference		**4**	**1**	**2**	**0**	**0**	**0**	**3**
Current	Cooperating appropriately	2	3	2	3	4	2	2
Desired	Cooperating appropriately	5	5	4	3	4	2	4
Difference		**3**	**2**	**2**	**0**	**0**	**0**	**2**

Table 10: Desired change per participant for the attitude Collaborative

DISCIPLINED

The last attitude from the questionnaire is 'Disciplined'. In this, again, all medians and means are higher for the desired state (Figure 13). For the habit of 'Reflecting critically', there is a general satisfaction; three participants indicate that they do not want any change, and the other four wish only a slight improvement (Table 11). The habit of 'Developing Techniques' is more diverse. As such, six out of seven participants want an increase, two of which want an increase higher than 3. In addition, participant 1 indicates that he wants a decrease of -1. Unfortunately, there is no clear explanation for this in the comments.

On the last habit of 'Crafting & improving', an increase is desired by all, with participant 1 indicating a desire for an increase of 4. Comments indicate that critical reflection can be confrontational, for which little time is often set aside. There is also the comment that intellectual curiosity is a rare quality these days. On this, participant 4 expresses that it is highly desired but unfortunately too rare.

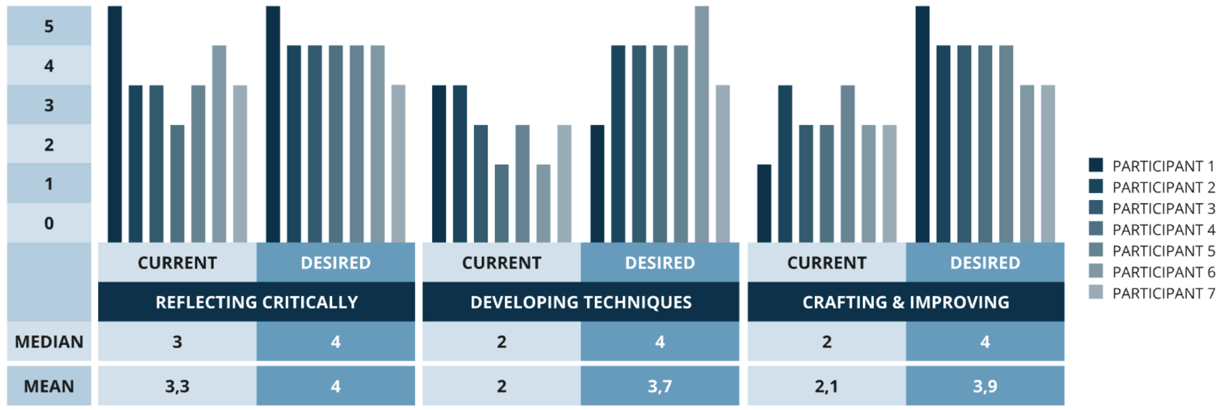


Figure 13: Responses from the attitude Disciplined

DISCIPLINED		Part 1	Part 2	Part 3	Part 4	Part 5	Part 6	Part 7
Current	Reflecting critically	5	3	3	2	3	4	3
Desired	Reflecting critically	5	4	4	4	4	4	3
Difference		**0**	**1**	**1**	**2**	**1**	**0**	**0**
Current	Developing techniques	3	3	2	1	2	1	2
Desired	Developing techniques	2	4	4	4	4	5	3
Difference		**-1**	**1**	**2**	**3**	**2**	**4**	**1**
Current	Crafting & improving	1	3	2	2	3	2	2
Desired	Crafting & improving	5	4	4	4	4	3	3
Difference		**4**	**1**	**2**	**2**	**1**	**1**	**1**

Table 11: Desired change per participant for the attitude Disciplined

DISCUSSION

Some results are more surprising than others. For example, it was expected that the industry would be hesitant towards tolerating uncertainty, given the associated risks and potential for costly errors. However, a more surprising finding was the extent to which legal restrictions limit industry practices.

Similar to the literature (Amabile, 1996; Lucas, 2016), the participants desired an increase in collaboration. Yet, legal constraints, such as NDAs, prevent the sharing of knowledge and outcomes, significantly hindering opportunities for collaboration. This was a limitation I did not expect.

Similarly, the industry's perspective on intuiting was unexpected. The literature shows intuition as a way to make connections beyond formal logic (Cropley, 2015). But some participants desired a decrease, as they expressed a need for data-driven decision making. This reflects a notable scepticism toward intuition, particularly in fields that require precise calculations.

CONCLUSION

The analysis of the seven participants, working in six different engineering-related industries, reveals a consistent desire for increasing creativity, with both the median and mean being higher in the desired state compared to the current state for all five attitudes. This finding is consistent with the literature, which highlights the importance of creativity in engineering education (Lucas, 2016). The participants' comments and desired changes also underscore the need for a culture that encourages exploration, innovation, and critical thinking, while acknowledging the challenges and barriers engineers face in the job market. Notably, the results show that legal restrictions, such as NDAs, can significantly limit opportunities for collaboration, which is a key aspect of creative engineering (Amabile, 1996; Lucas, 2016).

CONCLUSIONS

THERE IS A CONSISTENT DESIRE FOR INCREASED CREATIVITY IN ENGINEERS

A CULTURE IS NEEDED THAT ENCOURAGES EXPLORATION, INNOVATION AND CRITICAL THINKING

OPPORTUNITIES OF COLLABORATION ARE LIMITED BY LEGAL RESTRICTIONS

ACTING ON INTUITION IS NOT ENCOURAGED IN INDUSTRIES WITH PRECISE CALCULATIONS

TRADITIONAL ENGINEERING EDUCATION LIMITS CREATIVITY IN ENGINEERS

Furthermore, the industry's perspective on intuition was found to be more nuanced, with some participants expressing a need for data-driven decision making, reflecting a scepticism toward intuition in fields that require precise calculations. The results also highlight the importance of addressing the limitations of traditional engineering education, which can leave engineers too stuck in their way of thinking and doing things, lacking practical knowledge, and struggling to work effectively together.

By identifying these desired changes and limiting challenges, this study provides valuable insights for focusing efforts to better stimulate the creativity of engineering students and address the industry's needs for more innovative and collaborative engineers.

CHAPTER 4

EDUCATION PERSPECTIVE

This chapter discusses the approach, results and conclusions of the interviews conducted with educators from the faculty of IDE and AE at the TU Delft. As the problem owner of this project noted a problem in the implementation of stimuli for creativity, the goal of this study is to verify the existence of this problem.

By conducting interviews, I wanted to gain insight into the perspective of educators on creativity in engineering education. I also wanted to find out how they perceive and stimulate creativity in their students. I chose to conduct interviews, as I wanted to get a deeper understanding of how educators approach creativity in their teaching practices. Furthermore, I wanted to identify any unique structures or approaches that are used to promote creativity. By talking to the educators, I aimed to gain a better understanding of the research question of this thesis: How to stimulate creativity in engineering students?

APPROACH

INTERVIEWS

A total of 13 TU Delft teaching staff were interviewed for this study. Each interview started with signing the consent form, as shown in Appendix 3. To ensure that I could fully focus on the conversation during the interviews, I had chosen to record the entire conversation. As such, this had to be indicated in the consent form. The recording was started as soon as the form was signed.

The conversations were to be open discussions, where there was no set question-answer structure. With this, the conversation was guided by the participant to follow and emphasise their concerns. To ensure that a comparison between the different interviews would still be possible, a few fixed questions had been prepared, which were asked to push the conversation in a direction (Table 12). In questions 5 and 6, the participant is asked to fill in the wheel of creativity, as created by Lucas (2016). The template for this model can be found in Appendix 4. The educator was asked to fill it in based on their current and desired state of creativity in their corresponding bachelor's. This wheel has a 1-5 scale, with 1 representing a very low focus and 5 representing a very high focus

	Question
Q1	How would you describe creativity for an engineer?
Q2	Do you consider creativity a competence?
Q3	How do you see knowledge, skill and attitude reflected in your teaching?
Q4	How does your teaching balance knowledge, skill and attitude?
Q5	Would you like to fill in the wheel of creativity based on the extent to which you think there is a focus on a certain habit in education at your faculty?
Q6	Would you like to fill in the wheel again, but based on what you would find the most desirable situation?

Table 12: Questions asked in the interview

ANALYSIS

All 13 interviews were recorded. To extract the insights from these recordings, each recording was transcribed. I used this transcription, in combination with the audio, to note down quotes and conclusions.

The separate insights that emerged during the interviews were noted down in a separate document. After this, all the insights were placed on their post-it. The online whiteboard programme MIRO was used for this. Next, all post-its were clustered by topic. This created a huge board on which all insights were structured by topic.

In addition, the participants filled in the wheel of creativity, giving a score between 1 and 5. By taking the mean of these scores, categorised per faculty, a quantitative comparison can be made between the two different faculties.

Participant	Relation to creativity	Faculty	Code	Wheel completed?
1	Module manager	AE	AE 1	Yes
2	Course Coordinator	IDE	IDE 1	Yes
3	Faculty Management	IDE	IDE 2	Yes
4	Faculty Management	IDE	IDE 3	Yes
5	Department chairman	IDE	IDE 4	No
6	Master Coordinator	AE	AE 2	Yes
7	Course Coordinator	IDE	IDE 5	Yes
8	Teacher of the Year	AE	AE 3	Yes
9	Course Coordinator	IDE	IDE 6	No
10	Department chairman	IDE	IDE 7	No
11	Course Coordinator	IDE	IDE 8	Yes
12	Course Coordinator	AE	AE 4	No
13	Course Coordinator	AE	AE 5	Yes

Table 13: Overview of participants and their connection to the university

RESULTS

Five of the 13 teaching staff interviewed were from AE faculty and eight from IDE faculty (Table 13). Due to the free structure of the interviews, not every participant completed the framework with Lucas' (2016) wheel of creativity. However, each participant did provide relevant insights. As a result, for insights, all thirteen participants will be included. A total of ten times the framework was utilised, nine of which were also completed in full. One of the participants had only filled in the current state of the framework. For this reason, only nine out of thirteen frameworks were used for the analysis of this study.

THE WHEEL OF CREATIVITY

To provide a comparison between the different participants and the two faculties, Tables 14 and 15 list all responses. For each participant, a column representing the difference between the current and desired state was also added. In these columns, the numbers above the two are coloured blue and the negative numbers are red. By doing so, it is immediately visible where there is an increase and where a decrease is desired.

Participant IDE 3 indicated that he did not want to talk too negatively about the current status, because the person felt that they are already working on it a lot at the faculty and are proud of where they are now. This could be a reason why the current and desired states are closer to each other than in the market survey.

IMAGINATIVE

For both IDE and AE participants, everyone either wants an increase or is satisfied with the current state. For AE, the highest desired improvements are only an increase of 2, while for IDE, improvements of 3 are also wanted. None of the participants indicated that they wanted a decrease in attitude Imaginative.

INQUISITIVE

For the AE faculty, participants indicate that they are generally satisfied with the habits within the attitude 'Inquisitive'. As such, all answers vary between 0 and 2 (N=12). For IDE, opinions are more diverse. IDE 1 indicated that he would like a considerable increase in the habits of 'Wondering & questioning' and 'Exploring & investigating'. Participant IDE 5 indicates to be reasonably satisfied, but wants a small decrease in the habit of 'Exploring & investigating'. The other three participants are between 0 and 1.5 and are therefore moderately satisfied or would like a small improvement.

PERSISTENT

The participant IDE1 again indicates the need for a big improvement, with the habit of 'Sticking with difficulty', even wanting an increase of 4. As participant IDE1 is involved in the first courses of the bachelor's degree, her opinion may come from the fact that she mainly interacts with students who are still used to how everything happened in high school. Participant IDE 3 sees the attitude Persistent in a different way, and would like a decrease of -2 in the habit of 'Tolerating uncertainty'. Apart from that, this participant is satisfied with the current state.

COLLABORATIVE

Among IDE participants, there is an overall satisfaction where only once an improvement of up to 1.5 was wanted. Among AE participants, there was more improvement desired, with an increase of two wanted twice for both 'Sharing the product' and 'Giving & receiving feedback'. The difference between IDE and AE could originate from the amount of collaborative tasks that occur in the bachelor's. For instance, IDE has a lot of project courses with collaborative assignments, so there might be the opinion that students are already learning to collaborate rather well.

DISCIPLINED

In the last attitude, opinions diverge somewhat further. Among the IDE participants, four out of five agreed reasonably, varying in response between 0 and 2, with three wanting an improvement of 2. Participant IDE 8 was of a different opinion from the rest in this attitude. For the habit 'Developing techniques', a decrease of -0.5 was wanted and for the rest, there was either contentment or a minimal increase wanted, of only +0.5.

Among the AE participants, there was also an overall satisfaction, except for one participant. The latter indicated to want an increase of 2 for the habit 'Reflecting critically', but a decrease of -1 for the habit 'Developing techniques'.

		IDE 1			IDE 2			IDE 3			IDE 5			IDE 8		
		C	D	Diff	C	D	Diff	C	D	Diff	C	D	Diff	C	D	Diff
Imaginative	Playing with possibilities	2	5	3	4	4	0	4	4	0	3	3	0	2,5	4	1,5
	Making connections	2	4	2	4	4	0	4	4	0	2	5	3	2,5	4	1,5
	Using intuition	1,5	2	0,5	3	3	0	3	3	0	2	3	1	2	4	2
Inquisitive	Wondering & Questioning	1	5	4	3	4	1	4	4	0	3	3,5	0,5	2,5	3	0,5
	Exploring & Investigating	1,5	5	3,5	2	3	1	4	4	0	4	3,4	-0,6	2,5	4	1,5
	Challenging assumptions	1	2	1	2	3	1	4	4	0	2,5	4	1,5	2,5	3	0,5
Persistent	Tolerating uncertainty	1	3	2	3	4	1	5	3	-2	3	3	0	2	3	1
	Sticking with difficulty	1	5	4	3	4	1	3	3	0	4	4	0	2	3	1
	Daring to be different	1	2	1	3	4	1	3	3	0	3	4	1	2	3	1
Collaborative	Sharing the product	3	4	1	4	4	0	4	4	0	4	4	0	3,5	4	0,5
	Giving & receiving feedback	3	3,5	0,5	3	4	1	4	4	0	2,5	4	1,5	3,5	4	0,5
	Cooperating appropriately	3	3,5	0,5	4	4	0	4	4	0	5	5	0	3,5	4	0,5
Disciplined	Reflecting critically	2	3	1	3	4	1	2	3	1	3	4	1	2,5	3	0,5
	Developing techniques	2	3	1	2	3	1	2	4	2	2	3	1	3	2,5	-0,5
	Crafting & improvising	2	5	3	3	3	0	2	4	2	2	3	1	2,5	2,5	0

Table 14: Desired change per participant of IDE

		AE 1			AE 2			AE 3			AE 5		
		C	D	Diff	C	D	Diff	C	D	Diff	C	D	Diff
Imaginative	Playing with possibilities	3	3	0	2	4	2	3	4	1	4	4	0
	Making connections	3	4	1	4	4	0	3	5	2	3	4	1
	Using intuition	3	3	0	3	4	1	2	3	1	2	3	1
Inquisitive	Wondering & Questioning	4	4	0	4	5	1	3	4	1	4	4	0
	Exploring & Investigating	4	4	0	4	5	1	3	4	1	3	4	1
	Challenging assumptions	3	4	1	5	5	0	2	4	2	3	4	1
Persistent	Tolerating uncertainty	3	4	1	3	4	1	3	4	1	3	4	1
	Sticking with difficulty	4	4	0	2	1	-1	3	4	1	5	5	0
	Daring to be different	3	3	0	3	3	0	3	4	1	2	3	1
Collaborative	Sharing the product	2	4	2	5	5	0	3	5	2	4	4	0
	Giving & receiving feedback	2	4	2	4	4	0	3	5	2	4	4	0
	Cooperating appropriately	3	4	1	3	4	1	4,5	5	0,5	3	4	1
Disciplined	Reflecting critically	3	4	1	3	5	2	3	4	1	3	4	1
	Developing techniques	3	3	0	2	1	-1	3	4	1	4	4	0
	Crafting & improvising	4	4	0	2	3	1	4	4	0	3	4	1

Table 15: Desired change per participant of AE

		IDE 1	IDE 2	IDE 3	IDE 5	IDE 8	MEAN	MEDIAN	IDE 1	IDE 2	IDE 3	IDE 5	IDE 8	MEAN	MEDIAN
		C	C	C	C	C			D	D	D	D	D		
Imaginative	Playing with possibilities	2	4	4	3	2,5	3,1	3	5	4	4	3	4	4	4
	Making connections	2	4	4	2	2,5	2,9	2,5	4	4	4	5	4	4,2	4
	Using intuition	1,5	3	3	2	2	2,3	2	2	3	3	3	4	3	3
Inquisitive	Wondering & Questioning	1	3	4	3	2,5	2,7	3	5	4	4	3,5	3	3,9	4
	Exploring & Investigating	1,5	2	4	4	2,5	2,8	2,5	5	3	4	3,4	4	3,88	4
	Challenging assumptions	1	2	4	2,5	2,5	2,4	2,5	2	3	4	4	3	3,2	3
Persistent	Tolerating uncertainty	1	3	5	3	2	2,8	3	3	4	3	3	3	3,2	3
	Sticking with difficulty	1	3	3	4	2	2,6	3	5	4	3	4	3	3,8	4
	Daring to be different	1	3	3	3	2	2,4	3	2	4	3	4	3	3,2	3
Collaborative	Sharing the product	3	4	4	4	3,5	3,7	4	4	4	4	4	4	4	4
	Giving & receiving feedback	3	3	4	2,5	3,5	3,2	3	3,5	4	4	4	4	3,9	4
	Cooperating appropriately	3	4	4	5	3,5	3,9	4	3,5	4	4	5	4	4,1	4
Disciplined	Reflecting critically	2	3	2	3	2,5	2,5	2,5	3	4	3	4	3	3,4	3
	Developing techniques	2	2	2	2	3	2,2	2	3	3	4	3	2,5	3,1	3
	Crafting & improvising	2	3	2	2	2,5	2,3	2	5	3	4	3	2,5	3,5	3

Table 16: Mean and median for each participant of the IDE faculty

From all responses, the mean and median were also calculated for each state (Table 16 & 17). In all cases, in the desired state, both the mean and median are equal to or higher than the current state. However, it is striking that, of the Collaborative attitude, all habits are rated highest in both the current and desired state, for both IDE and AE participants.

		AE 1	AE 2	AE 3	AE 5	MEAN	MEDIAN	AE 1	AE 2	AE 3	AE 5	MEAN	MEDIAN
		C	C	C	C			D	D	D	D		
Imaginative	Playing with possibilities	2	4	4	3	3,25	3,5	5	4	4	3	4	4
	Making connections	2	4	4	2	3	3	4	4	4	5	4,25	4
	Using intuition	1,5	3	3	2	2,38	2,5	2	3	3	3	2,75	3
Inquisitive	Wondering & Questioning	1	3	4	3	2,75	3	5	4	4	3,5	4,13	4
	Exploring & Investigating	1,5	2	4	4	2,88	3	5	3	4	3,4	3,85	3,7
	Challenging assumptions	1	2	4	2,5	2,38	2,25	2	3	4	4	3,25	3,5
Persistent	Tolerating uncertainty	1	3	5	3	3	3	3	4	3	3	3,25	3
	Sticking with difficulty	1	3	3	4	2,75	3	5	4	3	4	4	4
	Daring to be different	1	3	3	3	2,5	3	2	4	3	4	3,25	3,5
Collaborative	Sharing the product	3	4	4	4	3,75	4	4	4	4	4	4	4
	Giving & receiving feedback	3	3	4	2,5	3,13	3	3,5	4	4	4	3,88	4
	Cooperating appropriately	3	4	4	5	4	4	3,5	4	4	5	4,13	4
Disciplined	Reflecting critically	2	3	2	3	2,5	2,5	3	4	3	4	3,5	3,5
	Developing techniques	2	2	2	2	2	2	3	3	4	3	3,25	3
	Crafting & improvising	2	3	2	2	2,25	2	5	3	4	3	3,75	3,5

Table 17: Mean and median for each participant of the AE faculty

Table 18 shows the difference between the current and desired state for IDE and AE's mean and median. Here, a minus number would indicate that the current state is higher than the desired state. However, because this is not the case in this study, all numbers are positive. The numbers indicating an increase higher than 1 are highlighted in blue. This shows that for both IDE and AE, for the attitude 'Collaborative', no major improvements are desired. We do see that for AE, higher improvements are desired for the attitude 'Disciplined' than for IDE. The opposite is true for 'Imaginative', where IDE generally wants more improvement than AE. For the attitude 'Inquisitive', a large increase is desired for both faculties.

		Diff IDE		Diff AE	
		MEAN	MEDIAN	MEAN	MEDIAN
Imaginative	Playing with possibilities	0,9	1	0,75	0,5
	Making connections	1,3	1,5	1,25	1
	Using intuition	0,7	1	0,375	0,5
Inquisitive	Wondering & Questioning	1,2	1	1,375	1
	Exploring & Investigating	1,08	1,5	0,975	0,7
	Challenging assumptions	0,8	0,5	0,875	1,25
Persistent	Tolerating uncertainty	0,4	0	0,25	0
	Sticking with difficulty	1,2	1	1,25	1
	Daring to be different	0,8	0	0,75	0,5
Collaborative	Sharing the product	0,3	0	0,25	0
	Giving & receiving feedback	0,7	1	0,75	1
	Cooperating appropriately	0,2	0	0,125	0
Disciplined	Reflecting critically	0,9	0,5	1	1
	Developing techniques	0,9	1	1,25	1
	Crafting & improvising	1,2	1	1,5	1,5

Table 18: Comparing the difference between the current and desired state for both the mean and median for IDE and AE responses.

PERSONAL INSIGHTS

Besides the wheel of creativity providing important insights, there were also general comments that were not directly related to the framework but provided particularly interesting insights. This section of the chapter will focus on the topics discussed that are worth noting for this project. For this purpose, the comments from the 13 different participants have been compiled into the following topics: The education system, the assessment method, the student's attitude and the learning process. After each insight, it is indicated if it is mentioned by an AE or IDE participant, or both.

THE EDUCATION SYSTEM

- Lack of resources: Participants feel that much is expected of them, but they are not given sufficient resources, such as time and money (both AE and IDE).
- One-size-fits-all approach: The education system is criticised for having a one-size-fits-all approach to teaching, treating every student the same and taking little account of individual differences (Both AE and IDE).
- Lack of continuity: There is a lack of continuity between courses and optional programmes, which can lead to a disjointed learning

experience (IDE).
- Ineffective way of teaching: Teachers are concerned that the current way of teaching is ineffective, as students often require repeated instruction on the same topics (IDE).
- Disconnection of student experiences: The bachelor's curriculum is not aligned with students' own experiences, which can make it less engaging and relevant to their lives (Both AE and IDE).

THE ASSESSMENT METHOD

- Too much guidance: Teachers are concerned that students are guided too much and do not have enough freedom to investigate and explore, which can hinder their creativity and autonomy (IDE).
- Difference in the interpretation of Bloom's taxonomy: Although Bloom's taxonomy is a standard framework (Figure 14), teachers have different interpretations and approaches to it, which can lead to inconsistencies in assessing creativity (Both AE and IDE).
- Limiting assessment methods: Using a rubric and point system may not be the most effective way to assess student learning, as it focuses on achieving a certain standard rather than encouraging students to go further and explore new ideas (Both AE and IDE).
- Lack of feedback application: The current assessment system prioritises getting a good grade over receiving and applying feedback, which can limit students' opportunities for growth and improvement (IDE).
- Insufficient encouragement for excellence: The credit system, where a pass ensures full credit regardless of the grade, may not provide sufficient motivation for students to strive for excellence and go beyond the minimum requirements (Both AE and IDE).

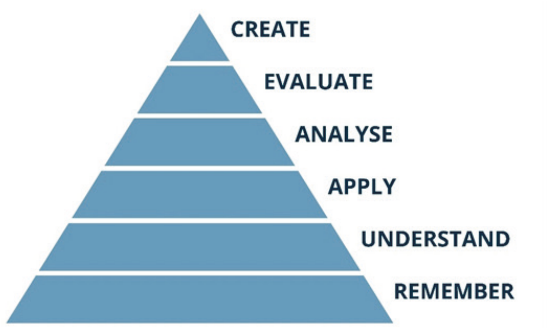


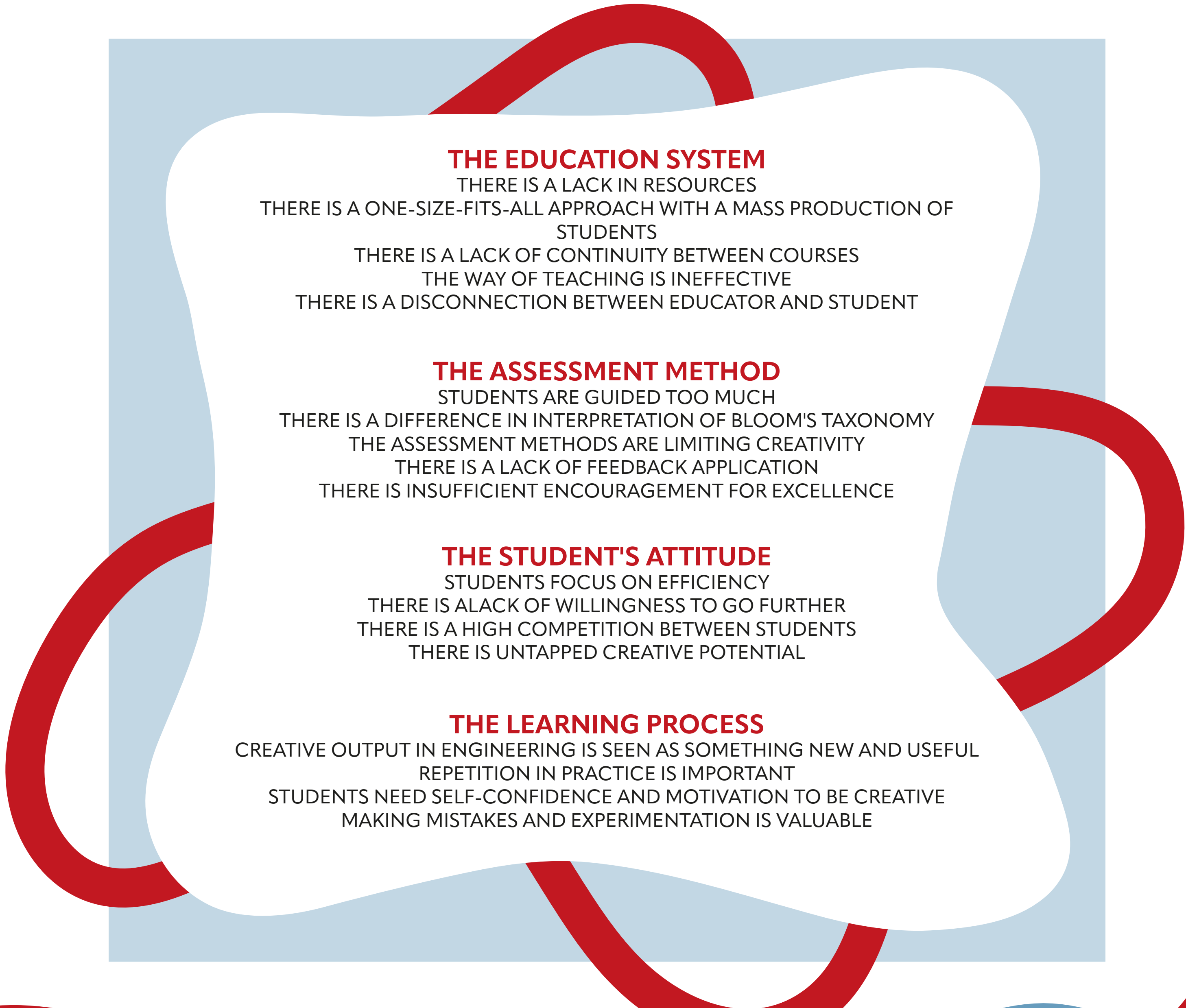
Figure 14: Bloom's taxonomy

THE STUDENT'S ATTITUDE

- Student focus on efficiency: Teachers see that students at TU Delft tend to prioritise completing assignments quickly and easily, rather than taking time to explore and deepen the subject (AE).
- Lack of willingness to go further: Students often prefer completing assignments to the minimum required level, rather than taking the initiative to go further and explore new ideas or approaches (Both AE and IDE).
- Competition among students: Students are highly competitive. Competition among AE students is powered by the programme's selective approach, which attracts high-performing students, while IDE students compete on more creative and design-oriented aspects (Both AE and IDE).
- Untapped creative potential: Teachers believe that every student has creative potential, but it is not always expressed due to different reasons, one of which is the attitude of students and their openness to creative thinking (Both AE and IDE).

THE LEARNING PROCESS

- Definition of creative output: Teachers see creative output as something both new and useful and emphasise the importance of practical application and innovation (Both AE and IDE).
- Importance of practice and experience: Teachers believe that repeated practice and experience can help students build confidence in themselves and their work, making them more comfortable with the creative process (IDE).
- Self-confidence and motivation: Teachers recognise that self-confidence and motivation are crucial for students to produce creative output, and can be developed through practical experience and interaction (IDE).
- Value of mistakes and experimentation: Teachers stress the importance of giving students space to make mistakes and learn from them, as this can help build adaptability and motivation (Both AE and IDE).
- Influence of teacher enthusiasm and passion: Teachers recognise that their passion and enthusiasm can have a significant impact on the motivation and engagement of students and that making complex theory tangible and approachable can be a powerful way to inspire students (Both AE and IDE).



DISCUSSION

The results of this education study offer a glimpse into the perspective of educators on creativity in engineering education. One of the findings is the strong desire for an increase in creativity in students, particularly in the attitudes 'Imaginative' and 'Inquisitive' . This is not entirely surprising, given the emphasis on creativity in the literature. However, what is surprising is the extent to which educators feel that the current education system hinders creativity in students. This is limited by, for example, the lack of resources, one-size-fits-all approach and ineffective teaching methods.

I expected that educators would recognise the importance of creativity in engineering education. However, the strength and magnitude of their desire for change took me by surprise. Especially from the educators of the AE faculty. The results also highlight the expressed concerns about the current assessment system. Educators address that they are focusing on achieving a certain standard, rather than encouraging students towards creativity and innovation. This is consistent with the literature, as Kazerounian and Foley (2007) address that students often report that creativity is not encouraged or assessed.

The findings also suggest that students' attitudes, such as their focus on efficiency and unwillingness to push forward, can hinder creativity. This is consistent with the literature, which suggests that students' motivations and attitudes are key in creative development (Henriksen, 2017).

Overall, the results of this study offer a nuanced and fascinating understanding of the perspective of educators on creativity in engineering education. The findings highlight the importance of addressing the limitations of the education system, assessment methods, and students' attitudes to stimulate creativity in engineering students

CONCLUSION

In conclusion, the findings of this study highlight the importance of creativity in education, with all educators indicating a desire to improve at least one of the five attitudes (imaginative, inquisitive, persistent, collaborative and disciplined). The mean and median scores for each attitude show a difference between the current and desired state, with the attitude 'Collaborate' the smallest. Based on the results from the IDE and AE participants, a comparison shows a requested improvement in the attitude 'Imaginative' by the IDE participants, while AE participants want to improve the attitude 'Disciplined'.

The education system can encourage, but also hinder creativity. Participants mention lack of resources, the one-size-fits-all approach and ineffective teaching methods as major limitations. The assessment method is also worrying, focusing on achieving a certain standard rather than encouraging creativity and innovation. Moreover, students' attitudes are hindering creativity, with their focus on efficiency and their unwillingness to push forward. However, the findings also suggest that teachers have a positive impact on creativity. Their enthusiasm and passion are inspiring, stimulating creativity in their students.

The data shows that the highest desired improvements are within the attitudes 'Disciplined' and 'Inquisitive'.

The number of participants who completed the framework (9 out of 13) and the insights gathered, provide a solid basis to build on further. Overall, the research in education highlights the need for a more personalised and flexible approach, one that encourages creativity. By encouraging creativity, teachers can help students develop the skills and confidence they need to succeed in an increasingly complex and rapidly changing world.

CONCLUSIONS

CREATIVITY IS IMPORTANT IN EDUCATION
ALL PARTICIPANTS HAVE THE DESIRE TO IMPROVE AT LEAST ONE OF THE FIVE ATTITUDES

INDUSTRIAL DESIGN ENGINEERING EDUCATORS WANT TO IMPROVE THE ATTITUDE IMAGINATIVE THE MOST

AEROSPACE ENGINEERING EDUCATORS WANT TO IMPROVE THE ATTITUDE DISCIPLINED THE MOST

THE EDUCATION SYSTEM CAN ENCOURAGE BUT ALSO HINDER CREATIVITY

THE EDUCATORS HIGHLIGHT FOUR THEMES THAT IMPACT CREATIVITY IN THEIR STUDENTS:
THE EDUCATION SYSTEM
THE ASSESSMENT METHODS
THE STUDENT'S ATTITUDE
THE LEARNING PROCESS

THERE IS A NEED FOR MORE PERSONALISED AND FLEXIBLE TEACHING APPROACHES TO ENCOURAGE CREATIVITY

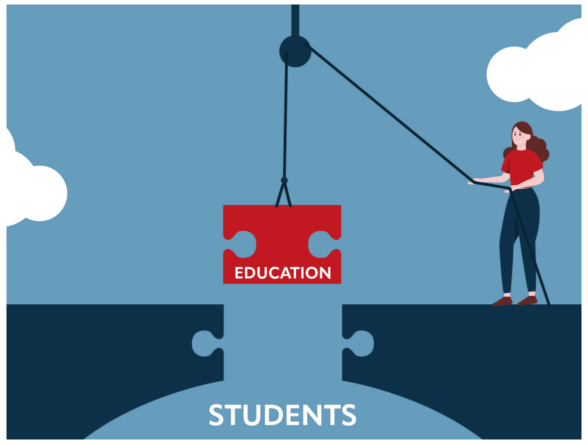
CHAPTER 5
STUDENT PERSPECTIVE

So far, I have looked at what is known in the literature, the industry and education.. Discussions with educators revealed a disconnect between the teacher and the student, indicating that the student did not always learn what was being taught. This chapter will delve into this disconnect by examining the student perspective on education and their personal experiences on the stimulation of creativity. This offers a unique perspective from both the IDE and AE students, which can give the teacher insight into the engineering bachelor students' experiences.

APPROACH

INTERVIEWS

The student's perspective is visualised as the creative habits across the different bachelor courses the student completed. This is developed for both the faculty of IDE and AE. To gain insight into the student's experiences, a total of six students were interviewed, out of which 3 students had completed the bachelor IDE and likewise 3 students had completed the bachelor AE. Prior to the interviews, each student was asked to complete a consent form. This can be found in appendix 5. The format of the interviews was an informal setting where the focus was on personal experiences. This way, the students would experience a kind of trip down memory lane.



INTERVIEW PROCESS

SIGNING THE CONSENT FORM

FILLING IN THE WHEEL OF CREATIVITY BASED ON HOW THE STUDENT PERCEIVES THEMSELF

ASKING IF ANY CLARIFICATION IS NEEDED ON THE CREATIVE HABITS OF MIND

FILLING IN THE BACHELOR TEMPLATE
MARK THE STIMULATIONS AND THE BLOCKADES

TAKING NOTES OF THE PERSONAL EXPERIENCES, MOTIVATIONS AND THOUGHTS

Since, in some cases, very personal and sensitive topics were discussed, I made sure the student was put at ease first and that I opened myself up as well. I also gave an introduction to this project here. This created an open and safe atmosphere right from the start.

Once the setting was set properly, the student was presented with the wheel of creativity, as designed by Lucas (2016). The purpose of completing this model was both to determine the current state of the creative habits in the student, as well as to walk the student through each habit in advance. This ensured that the student was familiar with the different terms, which was convenient for the remainder of the interview. While handing over the model, I also explained the meaning of the terms and the purpose of the model for my research. Accompanying this model was also an overview of all the terms with definitions. This allowed the student to check on this throughout the project for any clarification. An example of a fictional completed wheel of creativity is shown in figure 15.

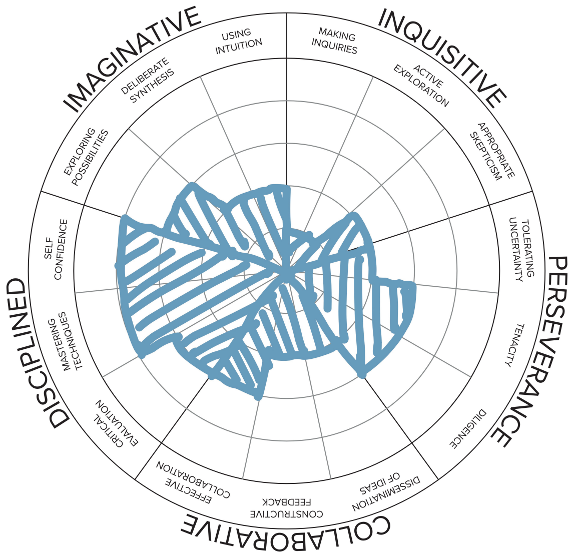


Figure 15: Fictional completed wheel of creativity

● = STIMULATION
⊗ = BLOCK

	HABIT 1	HABIT 2	HABIT 3
COURSE 1		●	⊗
COURSE 2		●	●
COURSE 3	●		

Figure 16: Fictional completed wheel of creativity

Once the wheel of creativity was completed, we explored the specific courses the student had taken. For this, I had prepared a template of the bachelor courses against all the different habits of creativity. This template can be found in Appendix 6. We went through this template together, course by course, starting with the first courses of the bachelor's. The student was asked to indicate if they had experienced a stimulation of the habits within that course. This was then indicated per habit as a dot in the template. Any blockages could also be indicated with a cross. An example representation of this can be found in figure 16.

To protect the student's perspective, students were asked to indicate only what they had personally experienced, rather than what the intention of the course was. By doing so, the answers were disconnected from the perspective of education. Students were also asked to share personal experiences, observations and memories of the courses. I noted this down on a notepad I had in front of me during the interview.

THE ANALYSIS

The data from the bachelor template provided a quantitative dataset, on which an analysis could be done. First, the three completed templates for each bachelor were superimposed, creating a heatmap. This gives a visual representation of the stimulated creative habits distributed across the bachelor. This provides an insight into the student perspective, highlighting which creative habits stand out in the bachelor, and where there are gaps.

Further, an analysis was done on the bachelor's overall creativity by comparing the total sum of creative habits between the two bachelors. This gives a representation of whether one bachelor is perceived as more creative than the other.

Next, I delved deeper into this by comparing experienced creativity for each course type. This is done by summing up the creative habits per course and then making a ranking from highest to lowest scoring courses. By indicating which courses are project courses and which are theory courses, an assessment was made of the creativity per course type.

RESULTS

All six students completed the template. On average, each session took 60 to 90 minutes. A heatmap was created by overlaying the three completed templates for each bachelor, as shown in Figures 17 & 18.

Every time a student indicated that they had experienced one of the creative habits as stimulated in a course, it was noted as a '1'. When several students had experienced the same habit as stimulated in the same course, these 1's added up to a maximum of three. The blue column on the right side of each heatmap gives the sum of the numbers from the corresponding row, and the row at the very bottom of the heatmap gives the sum of the numbers from the corresponding column.

To make a quick comparison between the bachelor AE and IDE, the total sum of all stimuli experienced per bachelor was looked at, this added up to 386 for AE and 423 for IDE. This meant that of the students surveyed, IDE students experienced 10% more stimuli than AE students. Furthermore, the mean number of stimuli a student experienced per subject was looked at. In this, the AE bachelor scored a mean of 9.19 stimuli per subject, while the IDE bachelor had a mean of 16.92 per subject, which is 84% more than the AE's. These comparisons can be seen in the tables 19 & 20.

	Total stimuli experienced	Mean stimuli per student	Mean creativity per course
AE	386	128,67	9,19
IDE	423	141	16,92

Table 19: Comparison between stimuli of AE and IDE bachelor

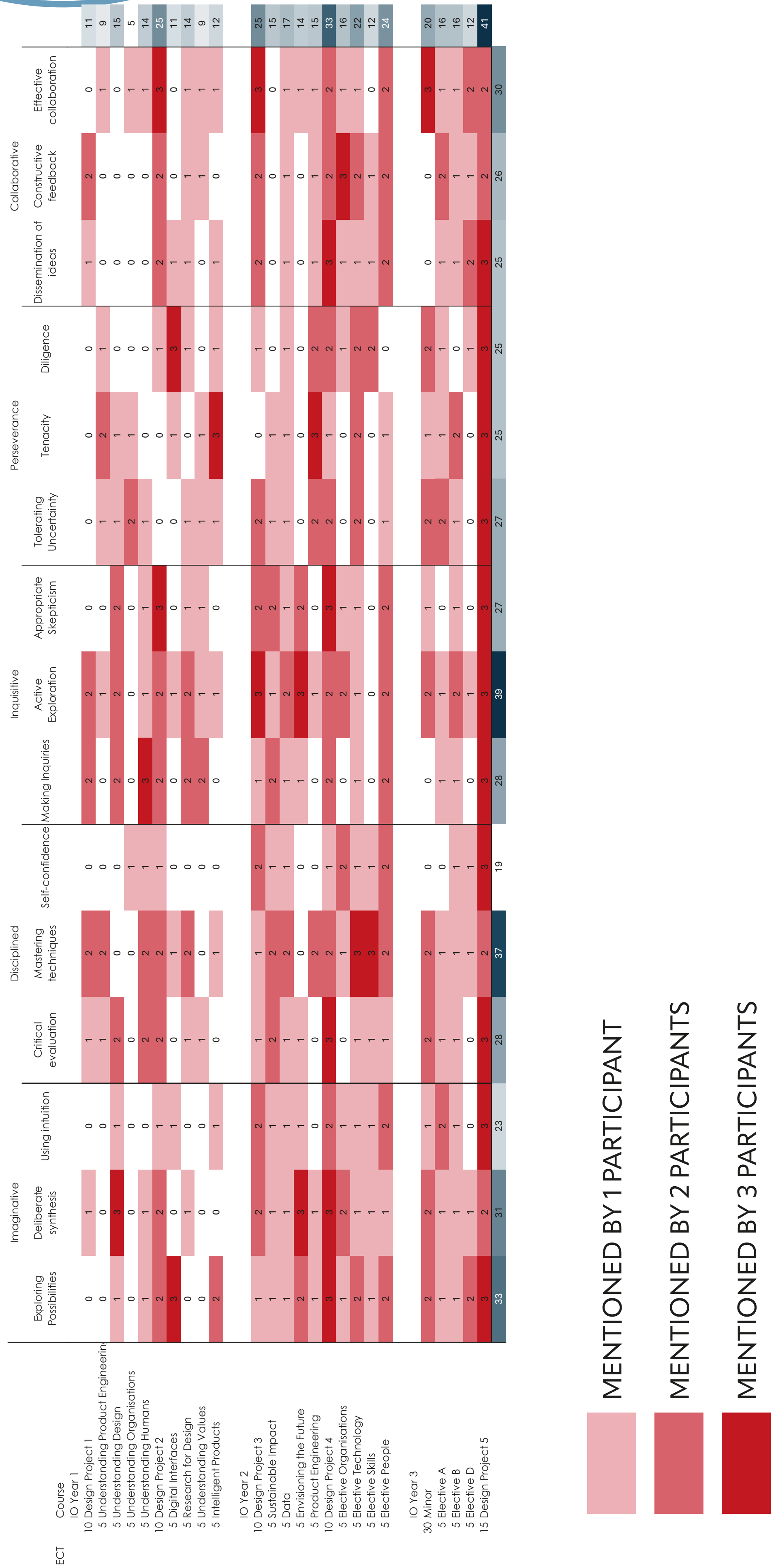


Figure 17: Heatmap IDE

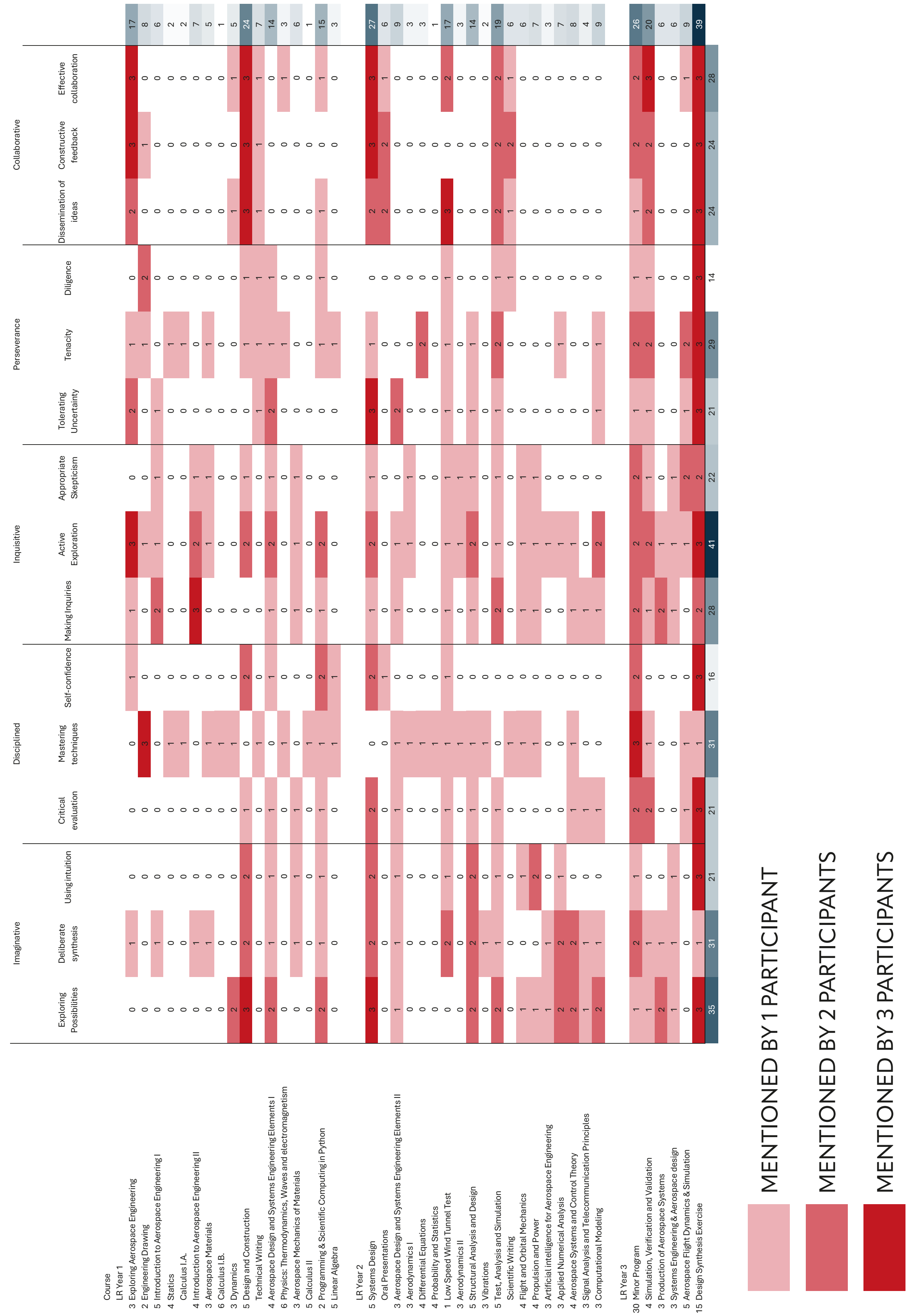


Figure 18: Heatmap AE

	Imaginative			Disciplined			Inquisitive			Perseverance			Collaborative			
	Exploring Possibilities	Deliberate synthesis	Using intuition	Critical evaluation	Mastering techniques	Self-confidence	Making Inquiries	Active Exploration	Appropriate Skepticism	Tolerating Uncertainty	Tenacity	Diligence	Dissemination of ideas	Constructive feedback	Effective collaboration	Total
AE	35	31	21	21	31	16	28	41	22	21	29	14	24	24	28	386
IDE	33	31	23	28	37	19	28	39	27	27	25	25	25	26	30	423
DIFF	2	0	2	7	6	3	0	2	5	6	4	11	1	2	2	37

Table 20: Sum of stimuli, distributed over the creative habits

Besides looking at means, it is more important to look at the concrete contents of the heatmap. For instance, in AE's heatmap, it is visible that there is a big difference in distributions per attitude. The attitude Inquisitive, as an example, is strongly distributed, but on the contrary, in Collaborative, the stimuli are strongly focused on roughly 7 single courses. In IDE's heatmap, this is less the case, and we generally see that each attitude is experienced scattered across different courses during the bachelor's.

Next, it is interesting to look at which courses stand out in terms of creativity and which ones score very low. These subjects can then be analysed based on education type (theory, project or elective) and the personal experiences the students shared in the interviews. For this analysis, the five highest-scoring and five lowest-scoring subjects from the rightmost column were selected (Tables 21 & 22).

AE COURSES	HIGH OR LOW SCORE	SCORE OUT OF 45	EDUCATION TYPE
Design Synthesis Exercise	HIGH	39	PROJECT
Systems design	HIGH	27	PROJECT
Minor program	HIGH	26	ELECTIVE
Design and construction	HIGH	24	PROJECT
Simulation, Verification and Validation	HIGH	20	PROJECT
Calculus 1&2	LOW	1	THEORY
Probability and Statistics	LOW	1	THEORY
Statics	LOW	2	THEORY
Vibrations	LOW	2	THEORY
Physics	LOW	3	THEORY

Table 21: High and low-scoring courses from the bachelor AE

IDE COURSES	HIGH OR LOW SCORE	SCORE OUT OF 45	EDUCATION TYPE
DP5	HIGH	41	PROJECT
DP4	HIGH	33	PROJECT
DP3	HIGH	25	PROJECT
DP2	HIGH	25	PROJECT
Elective People	HIGH	24	ELECTIVE
Understanding Organisations	LOW	5	THEORY + PROJECT
Understanding Product Engineering	LOW	9	THEORY + PROJECT
Understanding Values	LOW	9	THEORY
DP1	LOW	11	PROJECT
Digital Interfaces	LOW	11	THEORY

Table 22: High and low-scoring courses from the bachelor AE

In the AE bachelor's table, it is striking to see that all the high-scoring courses are project courses or electives. Also, the low-scoring courses score extremely low, with some courses having only 1 out of 3 students feeling stimulated by 1 creative habit. The low-scoring IDE courses score relatively high compared to those of AE, with the lowest score being a 5. The IDE bachelor courses also do not show such a clear division between project and theory courses, as AE does. IDE has both theory and project courses among the low-scoring courses.

PERSONAL INSIGHTS

Besides the completed template, the six students also shared many personal insights. These can be broken down into five overarching themes: freedom in courses, group work, teachers' influences, Relevance and impact and application of the content.

FREEDOM IN COURSES

In some assignments, there was significant freedom in framing the context, allowing the student to match the project to where their interests lay. This was generally perceived as very positive, with students automatically experiencing the course as more enjoyable and relevant. Students also experienced it as very positive if they were in charge of the project, and could therefore decide for themselves what was relevant to their project or not.

Students from AE also indicated that the current bachelor's program is very limited in freedom, not experiencing real freedom until the last course: Design Synthesis Exercise. This meant that the last course was also perceived as very difficult despite being a lot of fun. The students were not used to the freedom. Unlike the AE bachelor, the IDE bachelor starts with much freedom, with autonomous learning being the central focus. This is not necessarily a bad thing, but something that was experienced as very difficult by the students. This was mainly due to the mindset and habits students entered university with from high school.

In IDE, there are many courses where there is a coach to guide you. Here, students noticed a big demotivation when the coach gave too much direction to the project. Fixed templates also did not work optimally, where too little space for own initiative was experienced.

GROUPWORK

Both bachelor's had encountered projects that required them to work in groups. A notable difference between the bachelors was that at IDE, they worked in groups of around five people, while the standard group size at AE is around 10 people. The composition of the group was also considered a major influence, with a group with high commitment also resulting in a better process and final product. Every student recognised that there were differences between groups within courses, despite possibly still getting the same final grade. These differences were mainly in the difficulty of the assignment, the commitment of the group itself and the expectations within the group. Despite these differences being perceived as somewhat negative, there was also definitely a positive side. For instance, students indicated that variation between groups also gave a sense of originality and pride in their project. It was therefore perceived as very demotivating if other groups ended up with the same idea. Furthermore, the division of tasks within groups is also important, where students experienced that specialisation often took place quickly because they were often given the task they had already experienced within a group. As a result, students said they did not get the full content of all courses, purely because that was not their focus within the group.

The IDE students indicated that in addition to the group dynamics, there was often a greater sense of collaboration, even between different groups. This was described as a kind of community where there is an openness to sharing, and there can be a joint look when you run into something. This gave students a sense of not being alone in the problem. It also sparked perseverance and curiosity to help others and to move from a problem to a solution. This feeling of having a community was unknown to the AE students.

TEACHERS' INFLUENCES

A lecturer's attitude, drive and passion were considered extremely influential by all students. For instance, students saw a lecturer's enthusiasm as contagious, and so did the reverse. When a lecturer without energy conveyed a dull story, students not only felt these emotions too, but also the material did not reach them fully. The courses in which this was the case were therefore harder for the student to remember well.

AE students indicated that projects were assessed purely based on the assignment and its rubric. This specifically stated what a student had to do to earn a certain grade. Therefore, students did not feel pushed to do anything other than what was stated in the rubric, unless the teacher pushed them to do so. Further, when a course was not passed, it had to be retaken, without any change in the way of conveying material or anything like that. The AE students said they experienced this as very difficult, with the example of someone not understanding what the lecturer said in the lectures or what was written in the books, but that there was no possibility of learning the material in another way.

As with AE students, the IDE students also had a clear understanding of what needed to be done for a particular grade. However, here the problem often lies with the 'how?'. The IDE students mentioned that they sometimes lacked guidance, especially at the beginning of their bachelor's. This created student uncertainty, both in their work and in their qualities as designers. However, there were also very positive experiences between the IDE student and their lecturers. For example, one student mentioned that the personal discussions he had had with the professor had made him truly think about what he stands for as a person. In this, the teacher's openness and personal approach stimulated self-development and self-confidence. As a result, the student indicated that he now knows much better what he stands for and that the projects he does are in line with this.

RELEVANCE AND IMPACT

Something all students agreed on was that they wanted to do something relevant. When theory was linked to reality, it came across better. The students' drive to contribute something to society is deeply grounded. Thus, students experienced it very positively if a project was more than a pure theory application, where the result did not end up on a shelf somewhere under the dust. By selecting a client for a project, such as a company relevant to the topic, the projects were seen as highly relevant and also created a push for students to put in a real effort and excel from the rest.

At university, getting your credits depends on the grade you get. Here, among the AE students, it was indicated that this depends mainly on the grade you get for the exam. Although the IDE students experienced this as less extreme, they did recognise it. This strong focus on passing exams results in students learning purely to pass the exams, and not for interest or passion for a topic. The students experienced this as a flat-out learning process, with only little of it lasting.

APPLICATION OF CONTENT

Related to the need for relevance and impact is the question of applying what has been learnt. Many courses, mainly among AE students, were experienced as purely learning theory, as a dump of information. In these, theory was presented, through lectures and books, only to take an exam at the end of the period. Little application of the theory was experienced in this, even though, when it did happen, the student experienced it as much more enjoyable. Making the material tangible and personal also makes the theory stick longer, according to the students. All students indicated during the interview that they were a bit shocked at how little of everything they had learned during the bachelor's programme remained. Something they experienced as a great shame, mainly thinking back to the amount of time and energy they put into it.

Some courses work with step-by-step plans, where the student has to go through the project purely step by step to achieve it, an assignment in which little to no input is possible. Although it is applying the material, students did not experience this as a good form of application. Being in control of a project helped the students to develop self-confidence and intuition.

CONCLUSION

For this chapter, six students, three from the IDE and three from the AE faculty, were interviewed about their experiences of creativity stimulation during their bachelor's. Two heatmaps followed from this, one for each bachelor. AE students experienced fewer stimuli than IDE students. The courses at AE did stimulate a specific type of creativity, whereas at IDE it was more scattered. The courses at AE also showed a clear difference between the high and low-scoring courses for creativity stimulation. For instance, it was mainly project courses with relatively high freedom that were perceived as very high. Theoretical courses that were seen purely as information you simply had to know were rated very low. At the IDE bachelor, this difference was slightly less sharp, as there were also project courses among the low-scoring courses. However, it is noteworthy that the low-scoring project courses are courses from the beginning of the bachelor's.

Besides creating the heatmaps, the personal experiences also provided interesting insights. For instance, freedom in framing assignments and project content was perceived as very positive. Furthermore, both advantages and disadvantages of group work were mentioned, in which differences between groups create originality and pride, but also differences in difficulty level, commitment and the final learning process.

It was also found that the teacher has a crucial role in how the material comes across to the student. For instance, emotions, attitudes and passions are transferable, and teachers are needed to make students go beyond what is written in the rubric. What emerged strongly is that students want to contribute something to society, highlighting the importance of making the courses as relevant as possible.

By making sure that the student's final product in a course can have an actual impact on the context, students experience a push to go the extra mile and implement their qualities in the project. Many courses are dry theory courses, but by giving them a relevant application, the material sticks better with the student and they can make it more their own.

These insights reflect the importance of applying constructive freedom, contemporary relevance and applications with impact in the courses. In this way, lecturers can help encourage creative behaviour and motivation in students to get as much out of their bachelor's degree as possible.

CONCLUSIONS

AE STUDENTS EXPERIENCES LESS CREATIVE STIMULI DURING THEIR BACHELOR'S THAN IDE DID

CREATIVE STIMULATIONS ARE MORE FOCUSES IN AE, WHILE IN IDE THEY ARE MORE SCATTERED

THE AE PROJECT COURSES SCORE HIGH ON CREATIVITY, WHILE THE THEORETICAL COURSES SCORE EXTREMELY LOW

THE IDE COURSES AT THE BEGINNING OF THE BACHELOR'S SCORE LOWER IN CREATIVITY THAN THE COURSES AT THE END OF THE PROGRAM

THE STUDENTS HIGHLIGHTED FIVE THEMES THAT IMPACT THEIR CREATIVITY:
THE FREEDOM IN THE COURSES
THE GROUPWORK
THE TEACHERS' INFLUENCE
THE RELEVANCE AND IMPACT
THE APPLICATION OF THE CONTENT

PART 2
DEFINE

In the previous section of this report, I explored four different perspectives on creativity in engineering: The literature, industry, education and student. These perspectives provide a solid foundation for my research and help me understand the complexity of creativity in engineering. Part 2 of this thesis focuses on assessing and redesigning the wheel of creativity. I will revisit the model, making necessary adjustments and tailoring it to the engineering education at the TU Delft. The revised model serves as the basis for the rest of this report, as it provides a clear framework for identifying creativity in engineering students.

CHAPTER 6
IDENTIFYING CREATIVITY

Creativity is a complex and vague concept, making it challenging to work with. To make it more tangible, I used the wheel of creativity developed by Lucas (2016) as a framework for understanding the perspectives of industry, education, and students. However, when applying this framework, some issues arose. For example, the definitions of certain terms were unclear, leading to confusion. Upon further review of the literature, I found that the definitions provided did not offer much clarity. Also, there was no consistent format for explaining each habit. To address these challenges, I decided to reformulate the Habits of Mind and their descriptions to create a clearer and more consistent framework.

The revised model presented in this chapter provides a tailored framework for identifying creativity in engineering students, specifically suited to the engineering students at the TU Delft. This revised model addresses one of the research questions of this study: 'What are the indicators of creativity in engineering students?'. By using this model, it becomes possible to identify and recognise creativity of engineering students, which is a crucial step in understanding and stimulating creativity.

REFORMULATE

I started the reformulation of the wheel of creativity from Lucas (2016) with making an overview of the original terms and descriptions. This overview helped me to better understand the terms, but also verified the confusion for me. The cited terms and corresponding descriptions can be found in Table 23.

APPROACH

As can be seen in Table 23, each description and term varied in format and levels of depth. This caused confusion and misinterpretations when applying the framework in my interviews. Therefore, I decided to use a fixed format for describing each habit. This ensured structure and clarity. Furthermore, I also looked at the terms themselves, making sure they are more consistent and a better fit for the description.

As I took an iterative approach in the reformulation of the habits, it took me several attempts and feedback loops till I got to the final formulation. To gather feedback, I consulted with various individuals who have a connection to creativity and engineering, each bringing their unique perspective and expertise to the table (Figure 19).

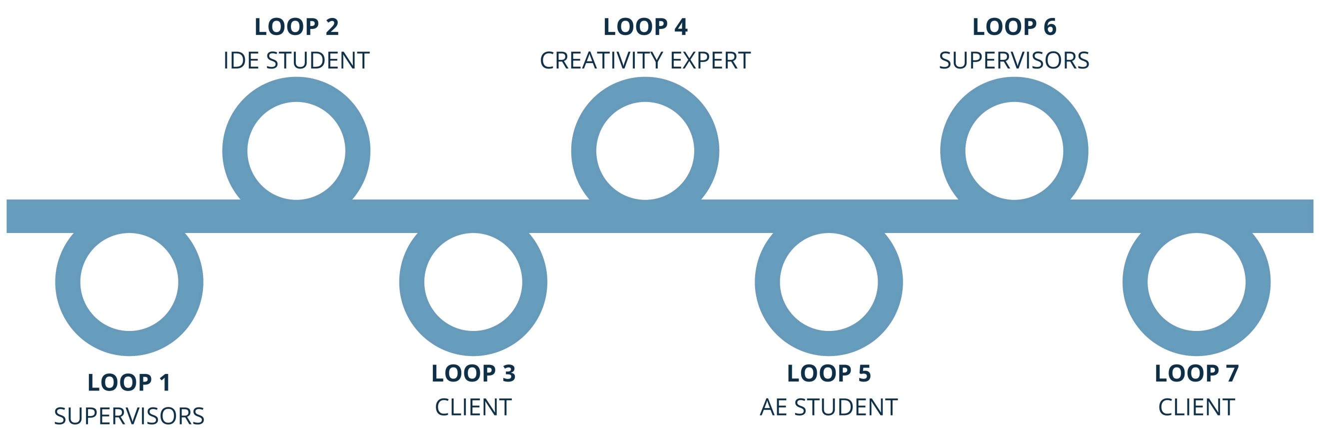


Figure 19: Feedback loops for the reformulation of the Habit of Mind

Word	Description
Imaginative	At the heart of a wide range of analyses of the creative personality is the ability to come up with imaginative solutions and possibilities.
Playing with possibilities	Developing an idea involves manipulating it, trying it out, and improving it.
Making connections	The synthesising process brings together a new amalgam of disparate
Using intuition	The use of intuition allows individuals to make new connections tacitly that would not necessarily materialise given analytical thinking alone.
Disciplined	As a counterbalance to the more intuitive side of creativity, there is a need for knowledge and craft in shaping the creative product and in developing expertise.
Developing techniques	Skills may be established or novel, but the creative individual will practice to improve.
Crafting & improving	Taking pride in work, attending to details, and correcting errors indicate people whose creative skill is of the highest order (Berger, 2003; Ericsson et al., 1993).
Reflecting critically	Once ideas have been generated, evaluation is important. Such "converging" requires decision-making skills.
Inquisitive	Creative individuals are good at uncovering and pursuing interesting and worthwhile questions in their creative domain.
Wondering & Questioning	Beyond simply being curious about things, questioning individuals pose concrete questions about things to help them think things through and develop new ideas.
Exploring & investigating	Questioning things alone does not lead to creativity. Creative individuals act out their curiosity through exploration and follow up on their questions by actively going out, seeking, and finding out more
Challenging assumptions	A degree of appropriate scepticism is important; not taking things at face value without critical examination.
Persistent	Creative individuals do not give up easily. Given the complexity and challenges inherent in much creative acts (Koestler, 1964), being able to persist in the face of difficulty is essential
Tolerating uncertainty	being able to tolerate uncertainty is important when actions or even goals are not fully set out.
Sticking with difficulty	persistence in the form of tenacity is important, enabling an individual to get beyond familiar ideas and come up with new ones.
Daring to be different	creativity demands a certain level of self-confidence as a prerequisite for sensible risk-taking.
Collaborative	In today's world complex challenges—for example, unravelling DNA, understanding climate change—require creative collaboration. Creative individuals recognize the social dimension of the creative process.
Giving & receiving feedback	the propensity of wanting to contribute to the ideas of others, and to hear how one's own ideas might be improved.
Cooperating appropriately	the creative individual co-operates appropriately with others. This means working collaboratively as needed, not necessarily all the time
Sharing the product	creative outputs matter, whether they are ideas or things and create impact beyond their creator

Table 23: Cited terms and corresponding descriptions from Lucas (2016).

I asked each person to carefully review the descriptions and terms, and to provide feedback on how to improve them. I wanted to know if the words and descriptions matched well, and if they would use different words themselves. By having multiple people review the framework, I was able to get a fresh perspective and make improvements. This process helped to strengthen the framework and make it more accurate.

RESULTS

First, I looked at the terms and descriptions used as the five attitudes of creativity. Based on the descriptions, it became evident to me that I needed to change the formulation of the attitude 'Persistent'. Persistent has a bit of a negative tone, which was also confirmed during the interviews with educators and the feedback loops for this process. Therefore, I decided to change it into 'Perseverance', as this formulation is a better fit to the description without giving a negative tone to it. The key differences between these two terms can be seen in table 24.

The other four terms did not need a reformulation. However, when using the framework in the interviews, it became clear that there was confusion in the definition of 'Disciplined' and 'Perseverance'. This also came forward in my conversations with my supervisors, the client and the feedback loop with the IDE student. The confusion here was mostly about the term 'Disciplined', as it can be interpreted as a form of expertise, but also as persistent. Therefore, I decided that more clarity and a better distinction was needed in the description of these two terms. For each description, I made a fixed format: 'A [attitude] person ...'. This way, each description is consistently formatted and contains the same level of abstraction and detail. The revised terms and descriptions can be found in Table 25.

Word	Key description
Persistent	Continuing, sometimes stubbornly, regardless of obstacles or feedback.
Perseverance	Enduring difficulties with determination and resilience to achieve a goal.

Table 24: Cited terms and corresponding descriptions from Lucas (2016).

Revised term	Revised description
Imaginative	An imaginative person can think creatively, generate novel solutions, and explore possibilities beyond the conventional. This trait is central to creativity, as it enables individuals to envision new ideas and approach problems with originality.
Disciplined	A disciplined individual combines creativity with knowledge, skill, and structured practice to refine their craft and develop expertise. Creativity is not just about spontaneous ideas but also about dedication, mastery, and continuous improvement.
Inquisitive	An inquisitive person is naturally curious, eager to explore, and skilled at uncovering interesting and worthwhile questions in their domain. This trait is essential for creativity, as it drives individuals to seek new ideas, challenge assumptions, and push boundaries in their field.
Perseverance	A perseverant individual persists despite difficulties, setbacks, or challenges. Creativity often involves overcoming obstacles, experimenting with new ideas, and refining work through trial and error, all of which require perseverance.
Collaborative	A collaborative individual recognises the importance of teamwork, communication, and shared creativity in solving complex problems. Creativity is often enhanced through social interaction, where diverse perspectives contribute to innovative solutions.

Table 25: Cited terms and corresponding descriptions from Lucas (2016).

Besides the five attitudes, the fifteen habits also needed a reformulation. For each habit, I again made a fixed format for the descriptions: 'The act of...'. This was done again to ensure consistency and similar levels of abstraction and detail. I rewrote each habit in an active voice, so they describe actions rather than just characteristics. This gives them a sense of dynamic energy, making them feel more practical and actionable in real-world situations. The reformulations of the habits can be seen in Table 26.

Old term	Revised term	Revised description
IMAGINATIVE		
Playing with possibilities	Exploring possibilities	The act of exploring the solution space of an idea
Making connections	Synthesising	The act of combining different ideas or things to make a whole that is new and different from the items considered separately
Using intuition	Using intuition	The act of relying on instinct or trusting one's gut feeling to make connections or decisions that may not be immediately obvious through logical analysis alone.
DISCIPLINED		
Developing techniques	Mastering techniques	The act of familiarising themselves with techniques and applying them in relevant contexts
Crafting & improving	Applying diligence	The act of persistently applying careful and steady effort to complete tasks with attention to detail and thoroughness.
Reflecting critically	Evaluating critically	The act of analysing and assessing ideas, information, or concepts in a thorough and objective manner
INQUISITIVE		
Wondering & Questioning	Inquiring	The act of seeking information by asking questions to explore and understand ideas more deeply
Exploring & investigating	Exploring actively	The act of actively following up their questions through exploration and curiosity
Challenging assumptions	Challenging assumptions	The act of questioning and critically evaluating information before accepting it as true while maintaining an open mind
PERSEVERANCE		
Tolerating uncertainty	Tolerating uncertainty	The act of accepting and navigating situations with unknown elements or outcomes
Sticking with difficulty	Persisting through challenges	The act of carrying on even when things get tough and maintaining a positive attitude even in the face of adversity.
Daring to be different	Trusting your approach	The act of having confidence in one's way of doing and working to take risks wisely
COLLABORATIVE		
Giving & receiving feedback	Exchanging constructive feedback	The act of providing and receiving input aimed at improvement while encouraging growth and positive development
Cooperating appropriately	Cooperating appropriately	The act of working together appropriately in a way that suits the context at hand
Sharing the product	Disseminating ideas	The act of spreading and sharing outputs and creating an impact beyond their creator

Table 26: Revised Creative Habits of Mind for engineering students

RESTRUCTURE

With the new formulations, the next step could be taken: reconsidering the structure. This involved looking at whether the words and descriptions were a good fit per attitude, or whether they could better be categorised under a different attitude.
Overall, I concluded that the structure was good. The words fit the attitude well and gave a full picture of what could be covered by the attitude. However, two words needed to be swapped. These were the words 'Trusting your approach' and 'Applying diligence'.
'Trusting your approach' was originally under the attitude Perseverance, however, this habit is about having confidence in yourself, something that fits better with having knowledge and expertise, than with perseverance. Hence 'Trusting your approach' was moved to the attitude Disciplined.
The Disciplined attitude also included the habit 'Applying diligence'. This habit deals with persevering with consistent and careful effort, even when faced with setbacks. Therefore, this fits better with the attitude Perseverance than with Disciplined, so the habit 'Applying diligence' moved to the attitude Perseverance. The full structure can be found in figure 20.

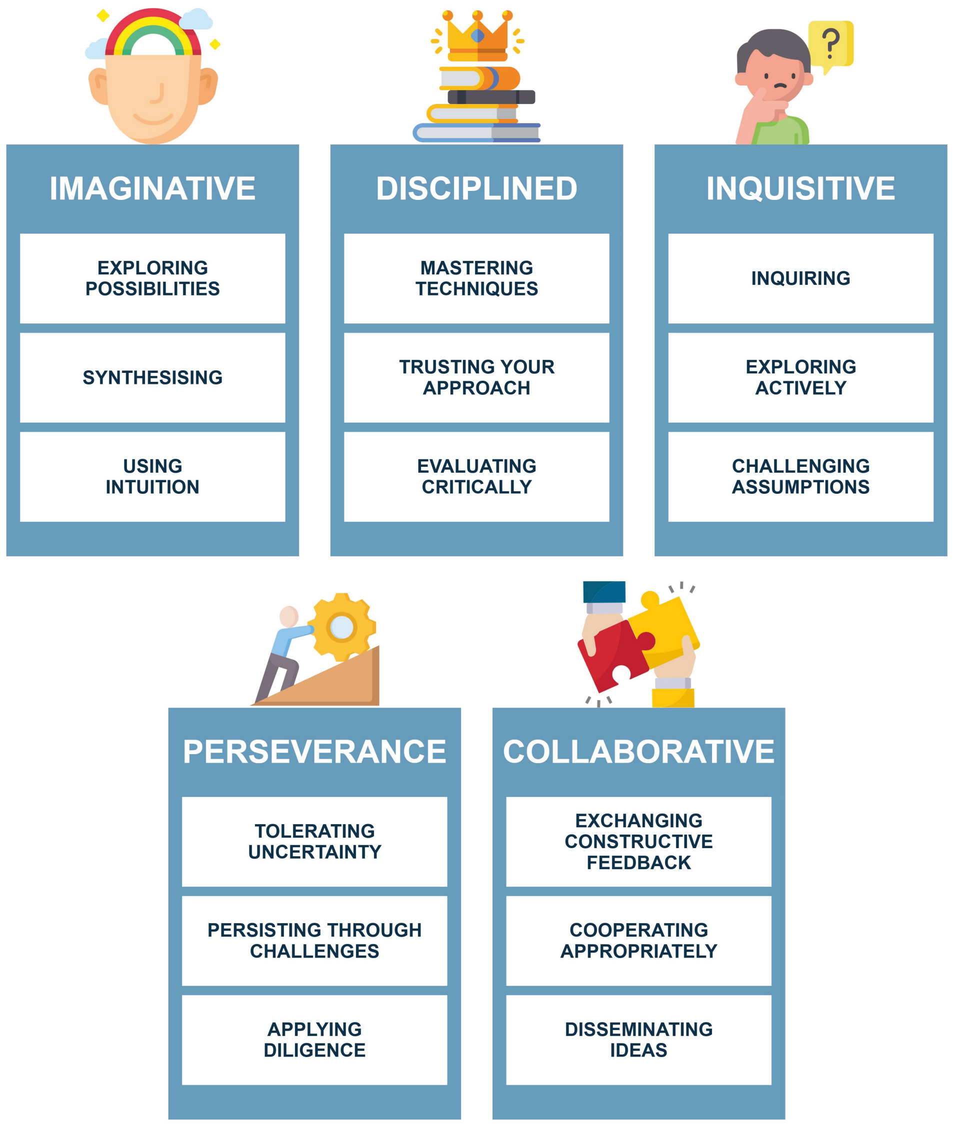


Figure 20: The 5 dimensions of creativity

REORGANISE

After presenting the revised structure to my problem owner (PO), he drew my attention to the possibility of a hierarchy within the attitudes. Since the PO mentioned that this could provide an interesting insight for him and the rest of the target group, it's certainly worth exploring. To do so, we discussed it together to determine what this hierarchy might look like and how it would apply to each attitude.

We concluded that the hierarchy we see is based on the way habits are expressed. The first level is based on a direct and observable action by the creative individual. The second level follows from this and includes cognitive habits that are routine based. The third level, which is more abstract, also occurs in the mind but requires a conscious effort from the individual, ensuring long-term impact (Figure 21).

Integrating a hierarchy into the model for creative habits provides three key benefits for engineering educators. First, it offers a clear framework, helping the educator to target their teaching based on the stages of creativity: from observable actions (level 1) to cognitive habits (level 2) and abstract thinking (level 3). Second, educators can use this hierarchy to align their course to fit the level they want to achieve during the course. Third, it helps educators to identify the creative habits, as well as help diagnose where students might be stuck. This way, they can tailor their guidance. Even though creativity is not strictly linear, the hierarchy in the model equips the educator with a tool to identify creativity and stimulate it systematically. For the remainder of this chapter, I will explain the hierarchy for each of the five creative attitudes.

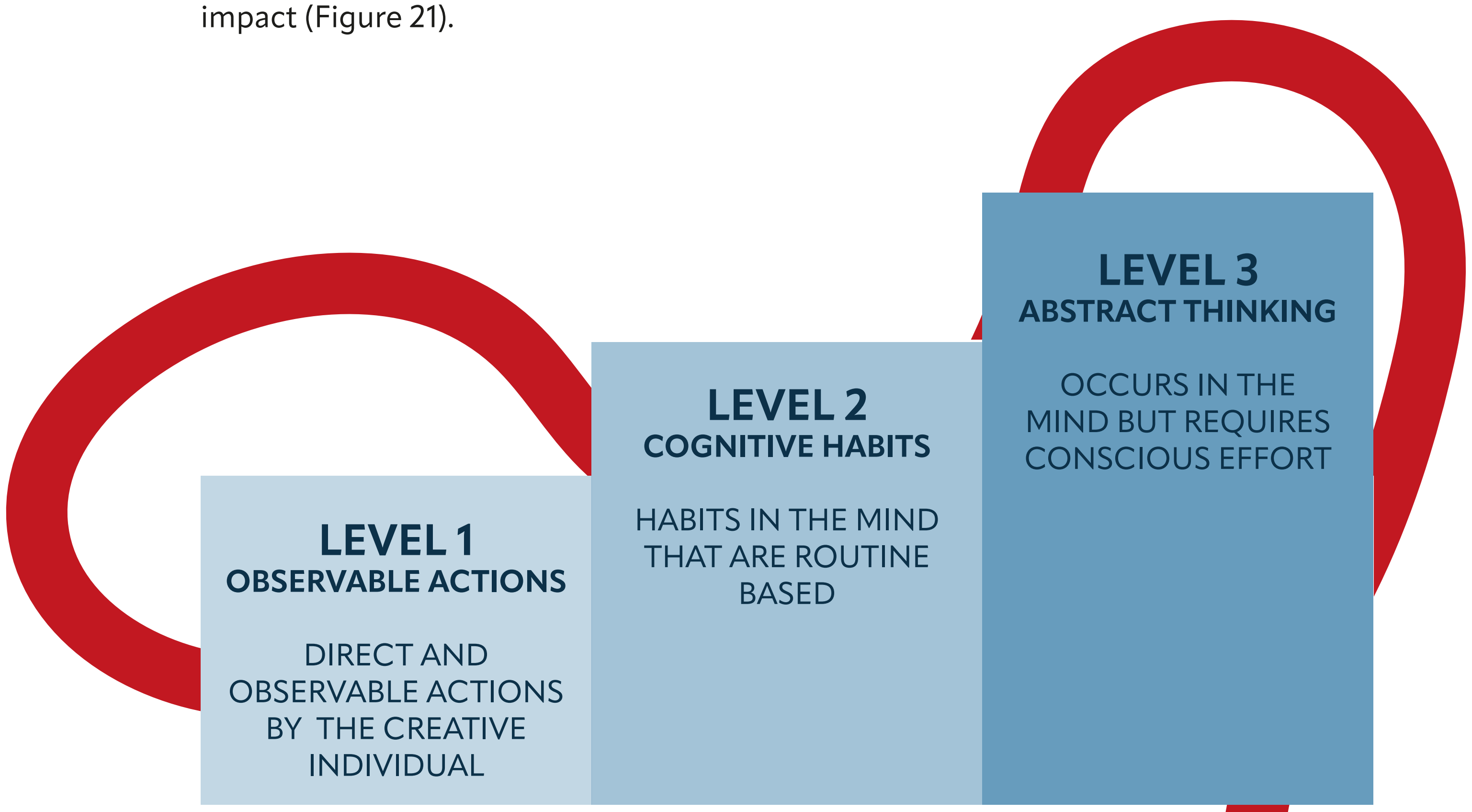


Figure 21: The levels of the creative habits for engineering students

IMAGINATIVE

Level 1: Exploring possibilities
Level 2: Using intuition
Level 3: Synthesising

When we think creatively, we start by exploring new ideas. This is the first stage, Exploring possibilities (Level 1). Here, students try out different things and see what works. As they get more comfortable, they start to trust their instincts, which is Using intuition (Level 2). The highest level is Synthesising (Level 3), where students combine different ideas to create something entirely new. This takes a lot of thought and practice..

DISCIPLINED

Level 1: Mastering Techniques
Level 2: Evaluating critically
Level 3: Trusting your approach

To achieve great things, we need to be disciplined. This starts with Mastering Techniques (Level 1), where students learn and practice new skills. Next, they need to evaluate critically (level 2), where students look at their work objectively and make informed decisions. The highest level is Trusting your approach (Level 3), where students have confidence in their methods and can see things through to the end. This takes maturity and self-confidence, but it's essential for producing high-quality work.

INQUISITIVE

Level 1: Exploring actively
Level 2: Inquiring
Level 3: Challenging assumptions

Being inquisitive means being curious and wanting to learn. It starts with Exploring actively (Level 1), where students try out new things and conduct experiments. As they get more curious, they start to ask deeper questions, which is Inquiring (Level 2). The highest level is Challenging assumptions (Level 3), where students question established ideas and think for themselves. This takes confidence and knowledge, but it's where new discoveries are made.

PERSEVERANCE

Level 1: Persisting through challenges
Level 2: Applying diligence
Level 3: Tolerating uncertainty

To succeed, we need to persevere. This starts with Persisting through challenges (Level 1), where students keep going even when things get tough. Next, they need to Apply diligence (Level 2), which means focusing their minds and paying attention to details. The highest level is Tolerating uncertainty (level 3), where students need to be and feel comfortable with not knowing everything. This takes mental toughness and resilience, but it's essential for achieving our goals.

COLLABORATIVE

Level 1: Cooperating appropriately
Level 2: Exchanging constructive feedback
Level 3: Disseminating ideas

Working together is an important part of achieving great things. It starts with Cooperating appropriately (Level 1), where students work together and share tasks. As they get more comfortable, they start to Exchange constructive feedback (Level 2), which means giving and receiving helpful comments. The highest level is Disseminating ideas (Level 3), where students share their ideas with others and make a wider impact. This takes strategic thinking and communication skills.

CONCLUSION

This chapter presents the reformulation and structuring of the model for creative habits in engineering students. The original model, based on Lucas'(2016) wheel of creativity, had limitations. To address these, I made a more clear and consistent framework. I incorporated feedback from several individuals and made changes to create a better understanding of creativity in engineering students.

The resulting model provides a structured approach to identify creativity. Each of the five creative attitudes comprises three levels: observable actions, cognitive habits, and abstract thinking. This hierarchy helps educators target their teaching and identify areas where students might need more support.
This research aimed to answer the question: What are the indicators of creativity in engineering students? The revised model provides an answer to this question. The indicators of creativity in engineering students are the 15 habits, organised into the five creative attitudes:

- Imaginative: exploring possibilities, using intuition and synthesising
- Disciplined: mastering techniques, evaluating critically and trusting your approach
- Inquisitive: exploring actively, inquiring and challenging assumptions
- Perseverance: persisting through challenges, applying diligence and tolerating uncertainty
- Collaborative: cooperating appropriately, exchanging constructive feedback and disseminating ideas

By identifying these habits, educators can recognize and stimulate creativity in engineering students. The revised model provides a practical tool for integrating creativity into teaching practices. This helps students to develop the creative abilities required for success in the engineering industry.

IMAGINATIVE
EXPLORING POSSIBILITIES
USING INTUITION
SYNTHESISING

DISCIPLINED
MASTERING TECHNIQUES
EVALUARTING CRITICALLY
TRUSTING YOUR APPROACH

INQUISITIVE
EXPLORING ACTIVELY
INQUIRING
CHALLENGING ASSUMPTION

PERSEVERANCE
PERSISTING THROUGH CHALLENGES
APPLYING DILIGENCE
TOLERATING UNCERTAINTY

COLLABORATIVE
COOPERATING APPROPRIATELY
EXCHANGING CONSTRUCTIVE FEEDBACK
DISSEMINATING IDEAS

PART 3
DEVELOP

This thesis has so far explored the different perspectives on engineering education and defined a model to identify the creative habits of engineering students. This third section will take a closer look at these perspectives and habits. It provides concrete and visual insights in the journey of a student through the IDE and AE bachelor programs. I compare the four perspectives, the literature, the industry, the education and the student, to see where they align or diverge. These findings are translated into practical advice for educators, providing them with concrete strategies to stimulate creativity in their engineering students.

CHAPTER 7
STUDENT JOURNEY

A student's journey is a complex experience that encompasses not only academic achievements, but also personal growth, creative development, and emotional struggles. As an educator, it is essential to understand the student journey to provide supportive and effective education. In this chapter, I will delve into the experiences and values of students in the bachelor's IDE and AE.

Through a series of interviews, I gathers rich and nuanced insights on the students' creative development, challenges and motivations. From this data, I designed two posters, one for each bachelor program. These posters are designed to give educators a unique perspective on their students' creative potential, motivations and moments of impact. This perspective is to inspire new approaches to teaching and learning.

CONTENT

Making the design of the posters was an iterative process, which is illustrated in Appendix 2. As an outcome of this process, I decided to include the students personality and values, the key defining moments and the bachelor program.

To create the posters, I selected key insights from the student interviews (Table 27), which are described in Chapter 5: Student Perspective. As there were many different insights from these interviews, I selected the insights that I considered to be key defining moments in the students' creative development. These moments are visually represented in the middle of the poster, accompanied by a quote based on what the students described and told me during the interviews. These quotes give a personal touch to the poster and highlight the student's perspective on their creative journey.

At the top of the poster, I included a representation of the students' personalities. This section features the Wheel of Creativity, consisting of the five creative attitudes. The values on this wheel are based on the mean scores from the creativity wheels that the students filled in during the interviews. This representation gives educators an idea of how students perceive themselves in terms of creativity. Next to the wheel, I included the title: "As an [bachelor study] student, I want to..", followed by a list of values that were considered important by the students. These values are also derived from the interviews and provide educators with insight into what matters most to their students.

Finally, at the bottom of the poster, I illustrated the bachelor's program. Here, I showcased the bachelor's program, also indicating the type of courses. This section provides educators with a clear understanding of the students' academic journey.

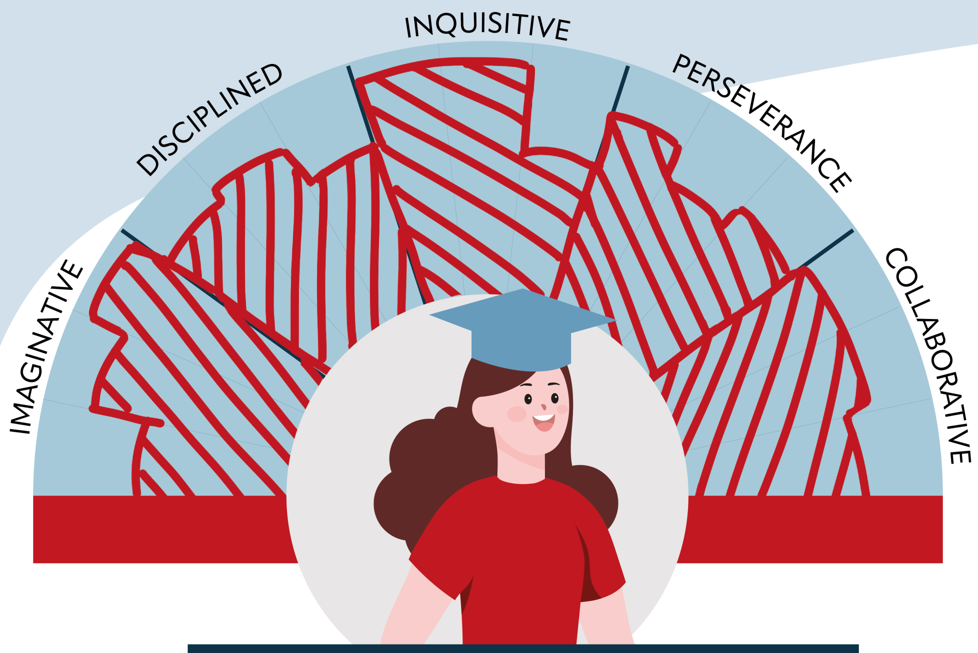
First, I wanted to put the heatmaps on the student journey posters. However, because of the size, I decided to make a separate poster for this.

By presenting this information in a visual and easy-to-understand format, I aim to give educators a comprehensive understanding on their students' experiences and values, and to provide them with valuable insight to help them better target their creative stimuli.

AEROSPACE ENGINEERING	
MENTIONED DURING THE INTERVIEWS	CONTENT ON THE POSTER
The starting courses are introduction-oriented, providing a broad understanding of the complexity of aerospace. It is exciting and opens your eyes!	"My introduction to the world of aerospace!"
It is a difficult bachelor's, having a lot of courses with a lot of theory. It sometimes felt like an infodump, and it took me a lot of time to understand it all.	"Studying is hard and a lot has to be done"
The first project course let us design our plane, which would then actually be made. Of course, it was a small-scale design, but it was so cool to see my design fly around the place!	"My own designed plane and it works"
It is quite normal to fail an exam and need to do a resit. However, the first time does feel like a big failure. But when looking at the percentages of failed students, it did give me a small spark of relieve that at least I am not the only one.	"At least I am not the only one taking a resit"
A lot of courses are exam-focused, where you just need to learn the theory and pass the exam. I did sometimes missed the implementation of the theory. And if you failed the exam, you just have to rewatch all the lectures again.	"It's just cramming theory and making the exam"
In one course, we got to work together with a PHDer, which was so inspiring. That project felt like actually achieving something big.	"Working with a PHDer is super inspiring"
The last course is the biggest and most free one. You can sign up for different topics, in which you will then be selected. Within these topics, you get to decide your own direction together with your group.	"In my last course, I get to choose the project myself"

INDUSTRIAL DESIGN ENGINEERING	
THINGS MENTIONED DURING THE INTERVIEWS	CONTENT ON THE POSTER
At the beginning of the bachelor's, there is a lot of freedom. This could feel super vague, due to what I was used to in high school. I had to find my way at IDE and doubted a lot if I should continue the study.	"IDE is a bit vague, and I am doubting if it's for me"
Having a coach was quite a personal approach in teaching. I talked a lot with my coach and they helped me through my design and pushed me to go further.	"Talking with my coach helps me to go further"
In the bachelor, you have quite some freedom within an assignment. Here, I was able to discover where I stand for as an IDE'er and as a designer.	"What do I stand for as an IDE'er?"
Sometimes, guest speakers were hosting the lectures. I found this extremely inspiring. It gave me insight in what happens in the industry and what their motivation and passion was.	"Guest speakers are super inspiring"
At IDE, you have a lot of group work. Some groups work better than others. Most times, it is just dividing the tasks and all working on our part of the project, without discussions and actual teamwork.	"Groupwork is more task division than teamwork"
With the freedom in the courses, I get to include my interests into my projects. With the many electives, I also was able to discover where my passions lay.	"I want to discover my passion in design"
Using the freedom, my interests and passion, I get to target my projects towards what I truly find interesting. This gives me energy and motivation to push through and take the extra step.	"I am focusing on topics I truly find interesting"

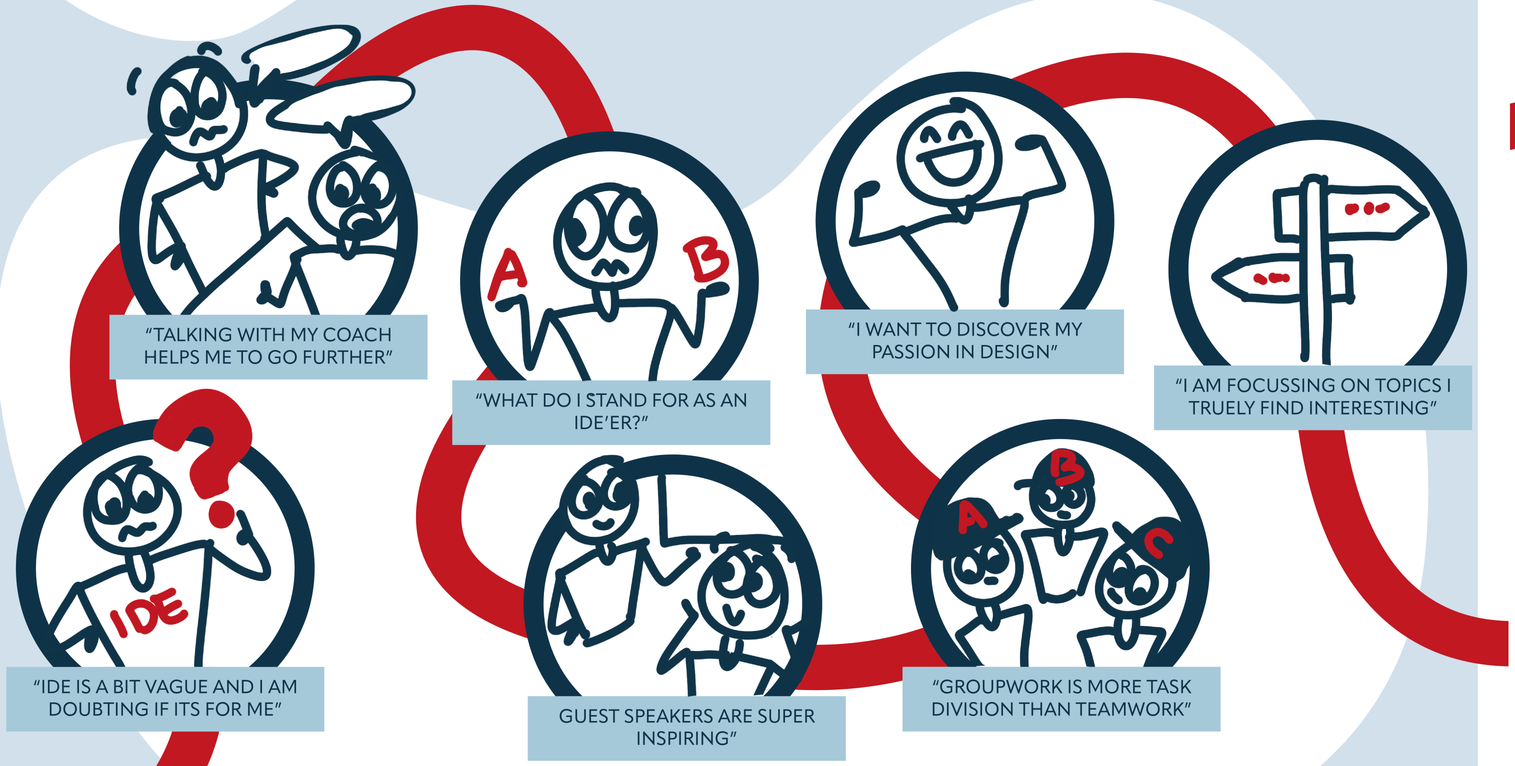
Tabl 27: Key insights from the student interviews



AS AN INDUSTRIAL DESIGN ENGINEERING STUDENT, I WANT TO...

DO THINGS THAT I FIND VALUABLE
KNOW MY STRENGHTS
DISCOVER MY WAY OF DESIGNING
IMPLEMENT MY INTERESTS
HAVE A REAL IMPACT

INDUSTRIAL DESIGN ENGINEERING STUDENT



"TALKING WITH MY COACH HELPS ME TO GO FURTHER"

"WHAT DO I STAND FOR AS AN IDE'ER?"

"I WANT TO DISCOVER MY PASSION IN DESIGN"

"I AM FOCUSSING ON TOPICS I TRUELY FIND INTERESTING"

"IDE IS A BIT VAGUE AND I AM DOUBTING IF ITS FOR ME"

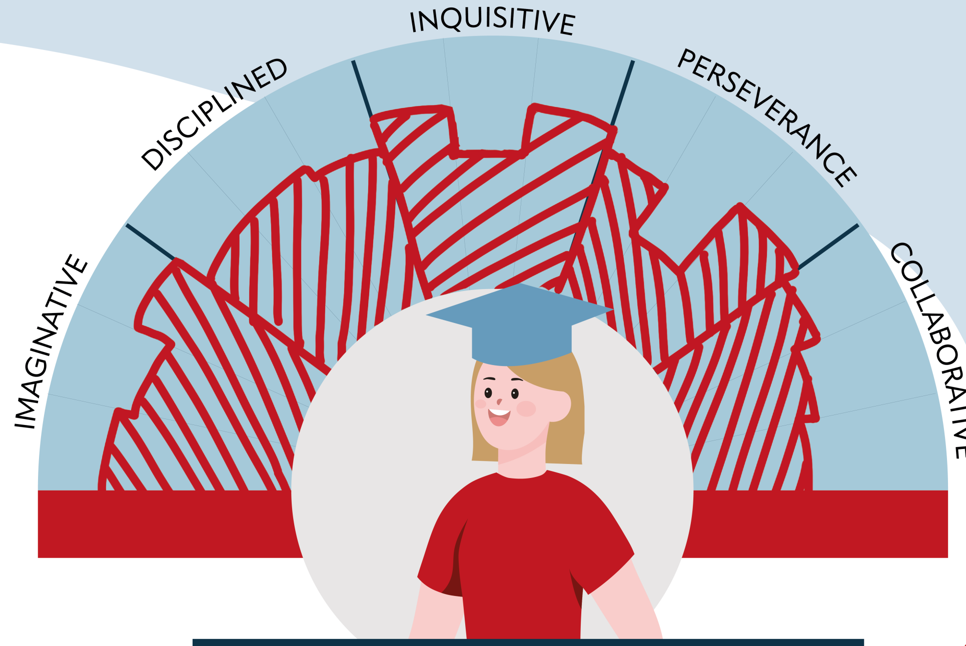
GUEST SPEAKERS ARE SUPER INSPIRING"

"GROUPWORK IS MORE TASK DIVISION THAN TEAMWORK"

BACHELOR PROGRAM INDUSTRIAL DESIGN ENGINEERING

FIRST YEAR	DESIGN PROJECT 1		DESIGN PROJECT 2	
	UNDERSTANDING PRODUCT ENGINEERING	UNDERSTANDING ORGANISATIONS	DIGITAL INTERFACES	UNDERSTANDING VALUES
	UNDERSTANDING DESIGN	UNDERSTANDING HUMANS	RESEARCH FOR DESIGN	INTELLIGENT PRODUCTS
SECOND YEAR	DESIGN PROJECT 3		DESIGN PROJECT 4	
	SUSTAINABLE IMPACT	ENVISIONING THE FUTURE	ELECTIVE ORGANISATIONS	ELECTIVE SKILLS
	DATA	PRODUCT ENGINEERING	ELECTIVE TECHNOLOGY	ELECTIVE PEOPLE
THIRD YEAR	MINOR PROGRAMME		ELECTIVE SLOT A ELECTIVE SLOT B ELECTIVE SLOT D	DESIGN PROJECT 5 BACHELOR FINAL PROJECT

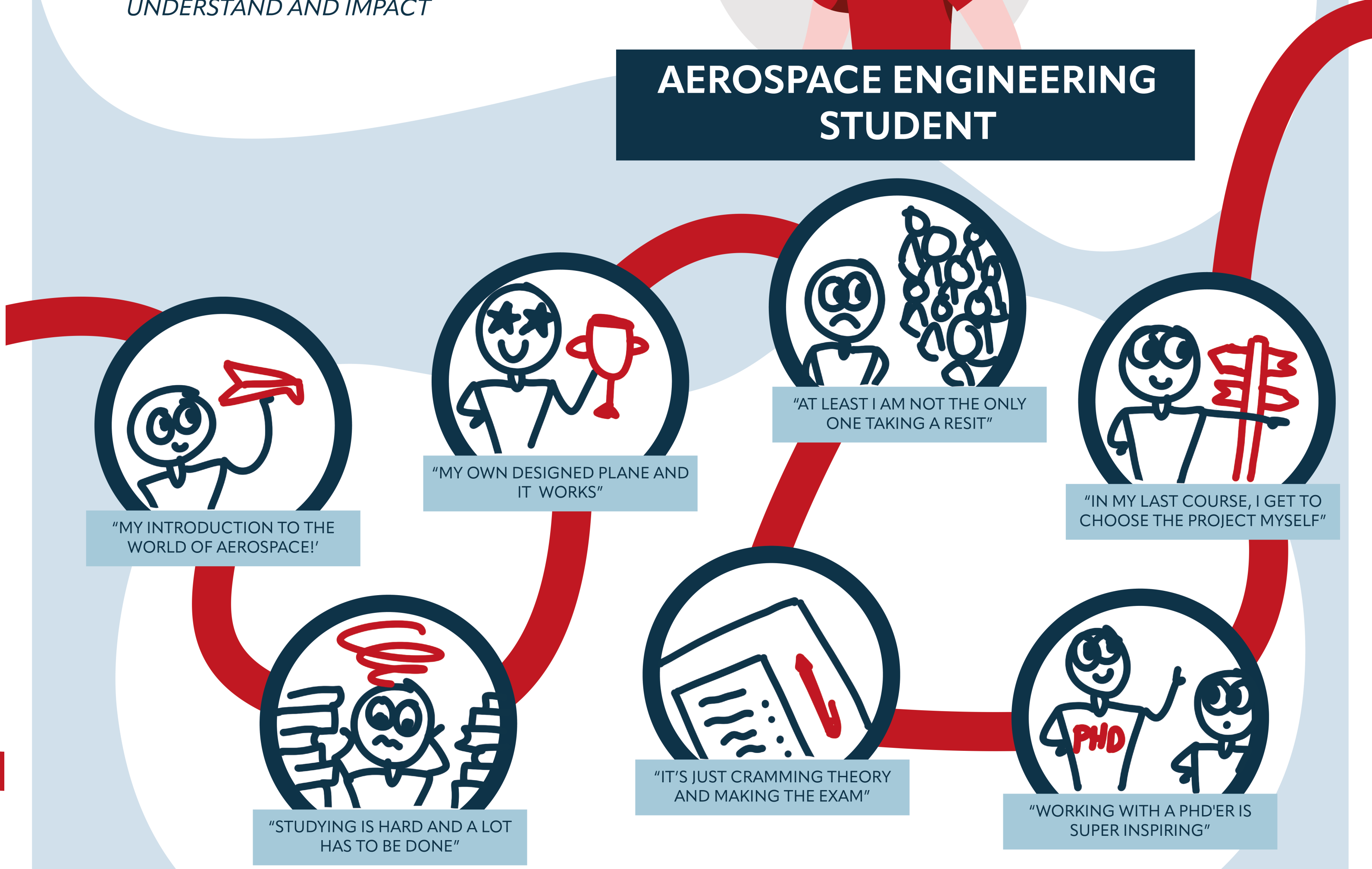
DESIGN PROJECT · ELECTIVES · GENERAL · ORGANISATION · PEOPLE · TECHNOLOGY



AS AN AEROSPACE ENGINEERING STUDENT, I WANT TO...

USE MY KNOWLEDGE
MAKE A DIFFERENCE
DISCOVER MY INTERESTS
SEE RELEVANT RESULTS
UNDERSTAND AND IMPACT

AEROSPACE ENGINEERING STUDENT



"MY INTRODUCTION TO THE WORLD OF AEROSPACE!'

"MY OWN DESIGNED PLANE AND IT WORKS"

"AT LEAST I AM NOT THE ONLY ONE TAKING A RESIT"

"IN MY LAST COURSE, I GET TO CHOOSE THE PROJECT MYSELF"

"STUDYING IS HARD AND A LOT HAS TO BE DONE"

"IT'S JUST CRAMMING THEORY AND MAKING THE EXAM"

"WORKING WITH A PHD'ER IS SUPER INSPIRING"

BACHELOR PROGRAM AEROSPACE ENGINEERING

FIRST YEAR	EXPLORING AEROSPACE ENGINEERING		DESIGN AND CONSTRUCTION	
	ENGINEERING DRAWING		TECHNICAL WRITING	
	INTRODUCTION TO AE 1	INTRODUCTION TO AE 2	AEROSPACE DESIGN AND SYSTEMS ENGINEERING ELEMENTS (ADSEE) 1	
	STATICS	AEROSPACE MATERIALS	AEROSPACE MECHANICS OF MATERIALS	PYTHON
	CALCULUS I.A	CALCULUS I.B	CALCULUS II	LINEAR ALGEBRA
		DYNAMICS	PHYSICS: THERMODYNAMICS, WAVES AND ELECTROMAGNETISM	
SECOND YEAR	SYSTEMS DESIGN		TEST, ANALYSIS AND SIMULATION	
	ORAL PRESENTATIONS		SCIENTIFIC WRITING	
	ADSEE II	LOW SPEED WIND TUNNEL TEST	FLIGHT AND ORBITAL MECHANICS	AEROSPACE SYSTEMS AND CONTROL THEORY
	AERODYNAMICS I	AERODYNAMICS II	PROPULSION AND POWER	SIGNAL ANALYSIS AND TELECOMMUNICATION
	DIFFERENTIAL EQUATIONS	STRUCTUAL ANALYSIS AND DESIGN	AI FOR AE	COMPUTATIONAL MODELING
	PROBABILITY AND STATISTICS	VIBRATIONS	APPLIED NUMERICAL ANALYSIS	
THIRD YEAR	MINOR PROGRAMME		INTRODUCTION TO AE 2 AEROSPACE MATERIALS CALCULUS I.B DYNAMICS	DESIGN SYNTHESIS EXERCISE

AEROSPACE DESIGN PROJECTS · AEROSPACE ENGINEERING AND TECHNOLOGY · ACADEMIC DEVELOPMENT · BASIC ENGINEERING SCIENCES

CHAPTER 8

ADDRESSING THE CONFLICTS

So far, this thesis has provided insights into the perspectives of the literature, the market, education and the student. All these perspectives have their own opinions, challenges and visions of the future. This chapter will put these perspectives side by side to highlight the agreements and conflicts on creativity in engineering students. This chapter aims to synthesise the information found so far into a valuable and applicable conclusion, addressed to the educators of the TU Delft. For this purpose, the last part of this chapter will provide concrete approaches that educators can take to improve the stimulation of creativity in their engineering students.

AGREEMENTS

Throughout the different perspectives of this report, several common themes can be highlighted. These show the importance of stimulating creativity in engineering students. Four key similarities stood out to me: the importance of creativity in engineering education, the role of educators in stimulating it, the impact of motivation and the fear of failure.

Firstly, the importance of creativity in engineering education. The literature showcased creativity as important and essential to make innovative solutions (Spencer & Lucas, 2025; De Vere, 2009; Zhou, 2012). This is in line with the industry, which indicated that they are in need of engineers who can think and act creatively. The education perspective agreed, as they recognised that it helps students to come up with new and innovative ideas. Students see creativity as an important competence to develop during their bachelor's, as it helps them to retain the theory and apply it to further context. Therefore, it can be concluded that every perspective from this research sees and understands the importance of creativity in engineering education.

Secondly, the role of de educator in stimulating creativity in their students. The literature suggests that the teacher has a great influence on the students' experiences and learning process (SOURCE). The students confirm this in the interviews, as they mention the positive influence of an educator's enthusiasm, passion and openness. Furthermore, the students highlight the importance of educators in inspiring and guiding students, with guest speakers, live demonstrations and coaches being particularly effective in stimulating and motivating students. This is also reflected in the education perspective, where they see themselves as crucial in stimulating creativity in students.

Thirdly, the impact on motivation and its importance for creativity. The student perspective shows the positive impact on their motivation by discovering their passions and interests and implementing them in their projects. This positive impact is also reflected in the literature perspective. Here, motivation is seen as a crucial factor in student engagement and creativity (van Straten, 2024). This is also mentioned in the interviews with the educators, where they felt a lack in students' willingness to persevere. This lack is causing below-average results and low engagement in courses.

Lastly, the fear of failure is a common concern among students, particularly with the AE students. Many AE students were often among the best in their high school classes, now facing difficulties in adapting to the high competition and standards of their bachelor's program. The students, both IDE and AE, mentioned in the interviews their fear of failing exams, as they felt the pressure to maintain their academic standards and live up to their expectations, having a lasting impact on their confidence. This is reflected in the industry, where mistakes can have serious consequences on both the project and your salary. Especially in industries with high precision and accuracy, errors can have catastrophic impacts. As a result, the industry demands a high level of perfectionism, leaving little room for mistakes. This takes away the opportunity to learn and grow from your mistakes.

CONFLICTS

There are several conflicts that arise from the different perspectives on engineering education. These conflicts highlight the challenges and tensions that exist between students, educators, and the industry.

One of the main conflicts is the tension between freedom and structure. Students want to have the freedom to implement their passions and interests in their projects, but educators are constrained by the need to provide structure and guidance to ensure fair assessment. Furthermore, the mass production of education makes it difficult for educators to provide freedom while still maintaining a fair and efficient assessment. This conflict is aggravated by the limited time educators have for teaching and assessing, making it challenging to balance the need for structure with the desire for freedom.

Another conflict is the balance between theory and practice. Students often experience education as an "infodump," where they are required to memorize theory without being given the opportunity to apply it in practice. Both students and educators recognize that some aspects of engineering education are purely about "knowing," rather than directly implementing. But the lack of time and resources can make it difficult to provide a balance between theory and practice. The industry also reflects this need for practical experience. They often find that new engineers lack the hands-on skills and experience needed to apply theoretical knowledge in real-world settings. Students want to work on relevant projects that make an impact, rather than just producing reports that will never be read, but the constraints of the education system can make it difficult to provide these opportunities.

A third conflict arises from the lack of true teamwork. Both students and the industry highlight the fact that students have courses with groupwork, but that there is no real experience in actual teamwork. Students describe groupwork as a task division, where individuals work alone in a group, rather than collaborating to make the project better. The industry also faces challenges in teamwork, as the use of non-disclosure agreements (NDAs) can limit the ability of engineers to discuss and work together on projects. This is seen as a shame, as both students and the industry recognize the value of teamwork in producing high-quality projects.

Finally, there is a conflict around assessment. Educators use Bloom's taxonomy as a basis for their learning objectives and assessment. However, there is an inner conflict around how to interpret and apply this taxonomy. Additionally, creativity is often mentioned in course rubrics, but it is not always clear what this means in practice, leading to differences in assessment and interpretation. The assessment of courses is also a source of conflict, especially in Aerospace Engineering. Here, most courses are assessed based on a single exam. Students are frustrated that their process and sub-assignments are not always taken into account, and that the focus is purely on exam theory. This can lead to a narrow focus on memorisation, rather than deeper learning and understanding.

APPROACHES & STRATEGIES

The agreements and conflicts give educators an opportunity to make a positive impact on the creativity of their students. By understanding the agreements and conflicts that exist between the four perspectives, educators can develop strategies to address these challenges. In this section, I explore some concrete approaches that educators can take to address the conflicts and promote creativity, motivation and deep learning in their students.

TENSION BETWEEN FREEDOM AND STRUCTURE

The use of scaffolding techniques can help to address the tension between freedom and structure in engineering education. Gradually reducing the level of guidance and support over a project helps the educator to balance the need for structure and guidance with the desire for freedom. In combination with establishing clear and concrete requirements and expectations, educators can steer projects. This approach can help to ensure fair and consistent assessment across all project groups. This way, it can help to mitigate the concern of freedom leading to increased complexity in assessment. The incorporation of scaffolding techniques and clear expectations provides students with the freedom to explore and learn, while still maintaining a structured and fair assessment process.

Another approach is the implementation of 'sandbox' assignments in the course program. These assignments should be mandatory, but should not have an impact on the students' grades. They provide students with a safe and supportive environment in which they can experiment and learn from their mistakes. By giving students the freedom to try out new ideas and approaches without fear of failure, the educator can encourage them to take risks and be creative.

Finally, the educator can frame required course elements in a way that allows students to take ownership of the topic. For example, by providing the students with a range of topics to choose from, or allowing them to propose their project ideas. This will give students the freedom to pursue their interests and passions, while still meeting the learning objectives of the course.

BALANCE BETWEEN THEORY AND PRACTICE

To create a better balance between theory and practice, educators can take several concrete steps. First, they can reassess the required course material and identify where hands-on experience can replace traditional lectures. By doing so, educators can provide students with more opportunities to apply theoretical knowledge to real-world problems, making the learning experience more engaging and relevant. One way to achieve this is by incorporating more project-based learning experiences, where students can work on practical assignments that require them to apply theoretical concepts to solve real-world problems.

Additionally, educators can use interactive tools such as simulations, live demonstrations, and hands-on activities to bring theoretical concepts to life. For example, educators can use live demonstrations to show students how theoretical concepts are applied to real-world engineering scenarios, such as building a bridge or explaining rotational forces.

Furthermore, educators can invite industry professionals to share their experiences and provide insights into the practical applications of theoretical concepts. This gives students a deeper understanding of how theory is used in real-world settings. By taking these steps, educators can help address the lack of practical experience, and provide students with a more well-rounded education that prepares them for the challenges of the real world.

LACK OF TRUE TEAMWORK

To foster true teamwork among students, educators can take a few different approaches. First, they can provide training and workshops on effective teamwork and project management. For the AE bachelor, this can be included in the academic development courses. The IDE bachelor can have a similar approach as the synergy week they designed within the master program (IDE MSC Synergy, n.d.). These moments will teach students the skills they need to work collaboratively and manage projects successfully. This can include lessons on communication, conflict resolution, and problem-solving, as well as strategies for dividing tasks and setting goals.

Moreover, educators can treat project groups as real teams, giving them the autonomy to make decisions and take ownership of their projects. This can involve providing students with the freedom to choose their own project topics, set their own sub-deadlines, and develop their own work plans. Educators can also encourage students to take on different roles within their teams, such as leader, designer, or communicator, to help them develop a range of skills and perspectives. Furthermore, educators can use team-based assessments and evaluations, rather than individual assessments, to encourage students to work together and rely on each other's strengths.

ASSESSMENT ON CREATIVITY

To address the conflict on assessment, educators can rethink their approach to assessment and focus on creating a more holistic and student-centred process. One way to do this is to use a variety of assessment methods, such as project-based assessments, peer review, and self-assessment, to get a more complete picture of student learning.

Additionally, educators can adopt a different approach towards Bloom's taxonomy. By moving away from the traditional hierarchical model and instead embracing a more integrated and interconnected approach. Rather than seeing the taxonomy as a staircase, where students must master one level before moving on to the next, educators can view it as a pie. Here, each slice represents a different aspect of learning, such as remembering, analysing, and creating. By recognizing that each slice is essential to the whole, educators can redesign their assessments. In doing so, recognising that in each of these slices, a student can express creatively.

By implementing a portfolio-based approach on the bachelor, educators can also help students to see their progress and development over time. In this approach, the student is obligated to build a portfolio during their bachelor's, showcasing all the projects and achievements over the years. This allows for feedback to be carried over the different courses of the bachelor program. This can be particularly powerful when combined with regular feedback and guidance. This can help students stay on track and make adjustments as needed. Ultimately, the goal of assessment should be to support student learning and help them grow as a engineer, rather than simply to evaluate it. Implementing a portfolio-program in the bachelor's program is a great way to push the students to reflect and be proud of their achievements. By taking this approach to assessment, educators can help to create a more positive and long-term oriented learning journey. This will help the students to build on their interests and prepare them for the future.

EXAMPLE APPROACHES TO STIMULATE CREATIVITY IN ENGINEERING STUDENTS

TENSION BETWEEN FREEDOM AND STRUCTURE

USE SCAFFOLDING TECHNIQUES
ESTABLISH CLEAR AND CONCRETE EXPECTATIONS AND REQUIREMENTS
INCLUDE SANDBOX ASSIGNMENT
LET STUDENTS TAKE OWNERSHIP

BALANCE BETWEEN THEORY AND PRACTICE

REASSESS THE COURSE MATERIAL TO MAKE ROOM FOR PROJECT-BASED LEARNING
USE INTERACTIVE TOOLS
INVITE INDUSTRY PROFESSIONALS

LACK OF TRUE TEAMWORK

PROVIDE TRAINING AND WORKSHOPS IN EFFECTIVE TEAMWORK AND PROJECT MANAGEMENT
TREAT PROJECT GROUPS AS REAL TEAMS

ASSESSMENT ON CREATIVITY

TAKE A INTEGRATED AND CONNECTED APPROACH TO BLOOM'S TAXONOMY
PORTFOLIO-BASED BACHELOR APPROACH

PART 4

DELIVER

Now that I've explored the concept of creativity in engineering education and developed a framework for identifying and stimulating creativity in students, it is time to take a step back and critically evaluate my research and outcomes. In this final part of my thesis, I will be using the Theory of Change Analysis to examine the relations and impacts between the different components of my research. I identify the assumptions and external influences that could affect the success of my outcomes. I will also comp[are my research to similar studies from England and Germany. Thich provides a useful benchmark for evaluating the relevance of my findings. This critical evaluation provides the basis for the conclusion of my thesis. Here, I will reflect on the key takeaways from my research and identify potential areas for future study. I demonstrate the value and relevance of my thesis and show its' contribution to the ongoing conversation about the importance of creativity in engineering education.

CHAPTER 9
EVALUATION AND DISCUSSION

A Theory of Change Analysis (ToCA) is a framework that helps to explain, monitor and evaluate interventions, programs and plans (Mayne, 2017). It identifies the underlying assumptions and relationships between factors contributing to a specific outcome, revealing how change is expected to occur.

In my research, I will apply the ToCA framework based on Mayne's work (2017). It creates a structured approach to understanding the complex relations between factors that influence creativity in engineers. By using this framework, I aim to create a detailed overview of the various relations and impacts involved, and to identify the key drivers for improving creativity in engineers. The ToCA framework is a valuable tool. It helps me identify potential risks and opportunities that may impact the success of my research.

In this chapter, I introduce the ToCA framework and its different components, apply this framework to my research and conclude with a discussion on the results and implications of this analysis.

THEORY OF CHANGE ANALYSIS

The Theory of Change Analysis (ToCA) framework, as outlined by Mayne (2017), consists of six phases that are interconnected and build on each other to achieve a desired outcome. These phases are: Goods & Services/Activities, Reach & Response, Capacity Change, Behavioural Change, Direct Benefits, and Wellbeing Change. In the context of my research, I will explore how these phases contribute to the development of creativity in engineering students.

The first phase, Goods & Services/ Activities, is all about the specific interventions or programs that are put in place to achieve the desired outcome. For my thesis, this means implementing new teaching approaches and strategies that are designed to foster creativity in engineering students. This could include things like project-based learning, flat structure of the Bloom's Taxonomy, and industry partnerships.

The next phase, Reach & Response, is about understanding how the students, educators, and industry partners respond to these new teaching approaches and strategies. This is a crucial stage, as it helps me to understand whether the interventions are having the desired impact, and whether there are any potential barriers or challenges that need to be addressed.

The third phase, Capacity Change, is focused on the development of new skills, knowledge, and abilities among the stakeholders. This means that educators and students will learn new skills and gain new knowledge as a result of the new teaching approaches and strategies. For example, educators may learn how to facilitate scaffolding-based learning, while students may develop skills in time management and critical thinking.

The fourth phase, Behavioural Change, is all about the changes in behaviour that result from the capacity change. In my research, this means that engineering students will develop their creative attitudes and habits as a result of the new teaching approaches and strategies. This could include habits like using intuition and disseminating ideas. The fifth phase, Direct Benefits, refers to the immediate and tangible benefits that result from the behavioural change. In my context, this means that engineering students will experience direct benefits such as increased motivation and engagement as a result of the new teaching approaches and strategies.

Finally, the sixth phase, Wellbeing change, is about the long-term and overall impact of the interventions. In my research, this means that the new teaching approaches and strategies will have a positive impact on the creativity of engineering students, and will help them to develop into creative engineers.

ASSUMPTIONS & EXTERNAL INFLUENCES

As I developed my research and designed new teaching approaches and strategies to stimulate creativity in engineering students, I made several assumptions that are worth considering.

One of the main assumptions is that these new approaches and strategies will be effective in stimulating creativity in engineering students. While I based my designs on the insights I gained from the four perspectives, I did not have the opportunity to test them out in practice. This means that there is a risk that they might not be as effective, scalable, or sustainable as I expected. Additionally, I do not want to limit educators to only the approaches and strategies I've outlined. I encourage them to be creative and explore other options that might work better for them and their students.

Another assumption I made is that educators and the industry will be willing and able to adapt to the new teaching approaches and strategies. My research shows that the people I interviewed recognize the importance of creativity, but that does not necessarily mean they are open to changing their teaching practices. There is a risk that they might resist the changes, and this could be due to a variety of factors, including a lack of resources. In fact, some of the educators and students I interviewed mentioned that they felt limited by the resources available to them, and this is something that I tried to take into account when designing my approaches and strategies. However, I'm aware that there might be other, unanticipated limitations that could arise.

Finally, I need to consider the social and cultural influences that might impact the effectiveness of my research. Because my project was focused on the bachelor's programs in Aerospace Engineering and Industrial Design Engineering at the University of Delft, using my own network, my sample of students was limited to those with Dutch nationality. This means that there might be differences in the student journey and conflicts that I identified if I had worked with a more culturally and socially diverse group of students. Additionally, education and student life can vary significantly from one country or city to another, so it is possible that the conflicts and insights I highlighted in my research might not be applicable in other contexts. By recognizing these limitations, I hope to encourage further research and adaptation of my approaches and strategies to suit different contexts and populations.

THEORY OF CHANGE ANALYSIS

INPUT

Educators' development and implementation of new teaching approaches and strategies to address the four conflicts in engineering education

REACH AND REACTION

The awareness and initial response of students, educators, and industry professionals to the new teaching approaches and strategies

CAPACITY CHANGES

The development of new skills, knowledge, and attitudes among educators and students, as a result of the new teaching approaches and strategies

BEHAVIOURAL CHANGES

Students improving their creative habits
Educators adopting more student-centered and flexible teaching approaches

DIRECT BENEFITS

Improved student engagement and motivation
Improved collaboration between industry, education and student

WELLBEING CHANGES

Students developing into creative engineers who are well-prepared for the challenges of the 21st century

CHAPTER 10
COMPARING TO A BROADER CONTEXT

As I reflect on my findings on creativity in engineering education in the Netherlands, I am curious to see how my conclusions compare to similar studies in other countries. To do so, I am comparing my research to two other studies: one by Spencer & Lucas (2025) on creativity in engineering education in England, and another by Deckert & Mohya (2022) on the same topic but in Germany.

In these studies, I look at how they identify and stimulate creativity in their engineering students and the recommendations they made to educators. This comparison is not just about highlighting the similarities and differences between our findings, but also about demonstrating the importance of my research in a broader context.

This analysis will help to validate my insights and recommendations and show the significance of my conclusions to engineering education.

Dutch	English	German
How to identify creativity in engineering students?		
Creativity is recognised in five creative attitudes, each consisting of three corresponding habits.	Engineering Habits of Mind: Systems thinking, Adapting, Problem-finding, Creative Problem Solving, Visualising and Improving	functional creativity, which focuses on solving technical problems with practical, functional outcomes
What conflicts on stimulating creativity exist?		
• Tension between freedom and structure • Balance between theory and practice • Lack of true teamwork • Assessment of creativity	• Prioritisation of core subjects • Relevance to engineering • Lack of resources • The standardised testing and performance metrics • Lack of confidence with experts being teachers	• Creativity is not being prioritised in education for engineers • Creativity is barely mentioned in the engineering curriculum • Students only know generative techniques
What can educators do to stimulate creativity in their engineering students?		
• Use scaffolding techniques and 'sandbox' assignments • Establish clear requirements and expectations, and frame the areas of freedom • Reassess required course material • Use interactive tools • Invite industry professionals • Push for realistic team roles • Adopt an integrated and connected approach to Bloom's Taxonomy • Implement portfolio-based approach	• Incorporate creative thinking, collaborative problem-solving and communication. • Use methods that allow for flexibility and creativity in teaching and assessment. • Create a learning environment where students feel safe to take risks, make mistakes, and learn from them. • Incorporate hands-on learning experiences.	• teaching different creativity techniques and reflecting on their advantages and disadvantages • Use teaching and examination methods (case studies, group discussions, role-play, and projects) • Create a creativity-enhancing work environment

CHAPTER 11
CONCLUSION

This research has focused on the creative person, highlighting the importance of recognizing and stimulating creativity in engineering students. Creativity in engineering is a useful area of study, as it has the potential to improve the way we approach engineering education and prepare students for the complex problems faced in the engineering industry.

Through a comprehensive literature review and several interviews, this research has established four different perspectives on creativity in engineering education: the literature, the industry, the education and the student. By analysing these perspectives, I have developed a deeper understanding of the complex factors that influence creativity in engineering education.

One of the key outcomes of this research is the development of a model for identifying creativity in engineering education. Based on the Habits of Mind by Lucas (2016), I have made a model that highlights the different creative attitudes and habits of an engineering student. This model is tailored to the education on the TU Delft, based on the case study on the bachelor Aerospace Engineering (AE) and Industrial Design Engineering (IDE). It provides a framework for educators to identify creativity in their students, therefore answering the first research question of my thesis: "What are the indicators of creativity in engineering students?"

In addition to the model of creative habits in engineering students, I also created two student journeys. These visualise the perspective of the AE and IDE students, highlighting their values and key defining moments from their bachelor's. This gives educators with a unique insight into the perspective of an AE and IDE bachelor student, allowing them to better understand their students' needs and tailor their teaching approaches accordingly.

A comparison of the four perspectives revealed several areas of agreement and conflict. The four conflicts identified are: tension between freedom and structure, balance between theory and practice, the lack of true teamwork, and the assessment of creativity. For each of these conflicts, I have made recommendations for educators to resolve them. These recommendations are concrete approaches and strategies that educators can apply to stimulate the creativity in their students. They are meant to inspire educators to experiment and be creative in their teaching approaches and strategies.

A comparison with two similar studies, one in the English context and one in a German context, shows that the conflicts identified in this research are not unique to the Dutch context. These studies pose alternative approaches to tackling the conflicts, indicating that my research is relevant and in line with similar studies done by experts. By combining this comparison with the conflicts and recommendations of my research, it provides and answer to the second research question of this thesis: "How to stimulate creativity in engineering students?"

Future research can build on this study by exploring a broader context, implementing more disciplines, and using bigger sample groups with a more diverse social and cultural context. This could involve investigating creativity in different engineering studies, exploring differences between creativity in bachelor and master students and discovering the impact of creativity on student engagement and motivation.

In conclusion, this research made a contribution to the understanding of creativity in engineering education. By identifying and stimulating creativity, educators can help students develop the competence needed to succeed in an increasingly complex and rapidly changing world. It is essential to prioritise creativity more in engineering education. In doing so, providing students with the freedom to experiment, the support to take risks, and the guidance to develop unique outcomes. Therefore, educators can unlock the full potential of engineering students, empowering them to creative solutions that shape the future. The future of engineering education depends on the ability to stimulate creativity, and it's up to all of us, educators, industry professionals, and researchers, to work together to make this vision a reality. By doing so, we can create a brighter, more innovative future for generations to come.

CHAPTER 12

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APPENDICES

1. Problem-finding creative process
2. Student Journey creative process
3. Consent form Education
4. Wheel of Creativity Template
5. Consent form Student
6. Bachelor AE and IDE Templates
7. Project Brief
8. Personal Learning Objectives
9. Personal Reflection

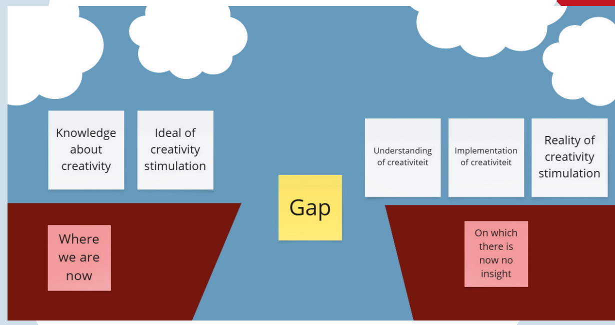
APPENDIX 1

PROBLEM FINDING CREATIVE PROCESS

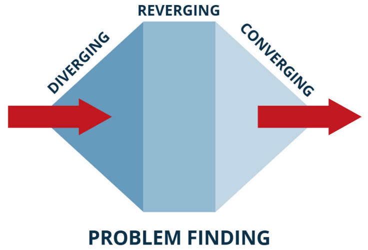
From the first meeting with my client, I received the problem as given:

How can we close the gap between the understanding and the implementation of creativity in the program of engineering studies?

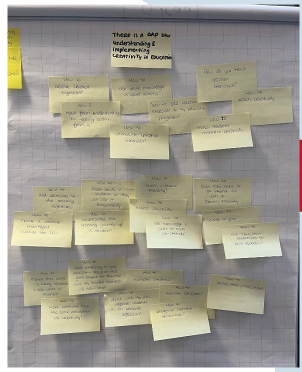
I made a visualisation to make sense of the different components of the problem at hand.



I decided I wanted to do a problem exploring creative diamond, using methods from Heijne and van der Meer (2019).



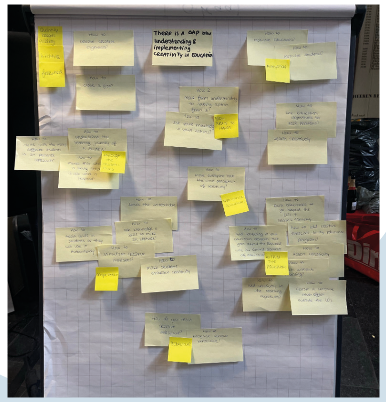
My first phase of the creative process was the DIVEREGING stage. The purpose was to broaden my view and discover underlying questions



I used the method "H2's", which resulted in 26 different questions, all related to the PaG.

With these 26 options, I went into the REVERGING stage. Here, the goal was to take a step back and create an overview of the options.

In this stage, I used the method "Spontaneous Clustering". This resulted in a total of 9 different clusters.



In the CONVERGING stage, I narrowed my focus, determining the direction of my research.

From the nine clusters, I picked the ones that had a direct connection to both the educators and the PaG.

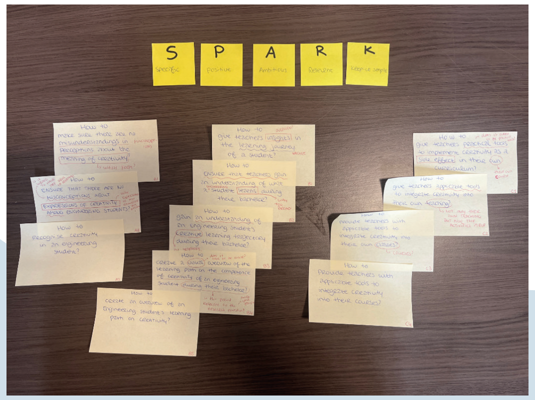
From this selection, three main topics stood out:

Misunderstandings about creativity

Student experiences

The difficulty of implementation.

I used the method "Restating the Problem" to translate these three topics into manageable, comprehensive and clear problem statements.



Misunderstandings about creativity translated to:
What are the indicators of creativity in engineering students?

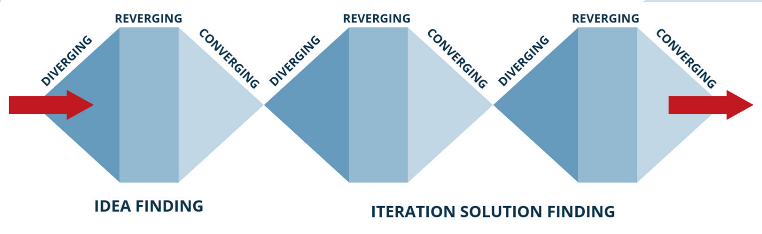
Student experiences and difficulty in implementation were combined into:
How to stimulate creativity in engineering students?

With these two research questions, I was ready to start my research!

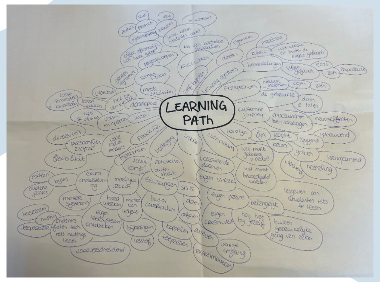
APPENDIX 2
STUDENT JOURNEY CREATIVE PROCESS

To translate the student perspective from the insights of the interviews, I wanted to do a creative design process.

I decided to do a three-diamond process. One on Idea finding and two on solution finding.



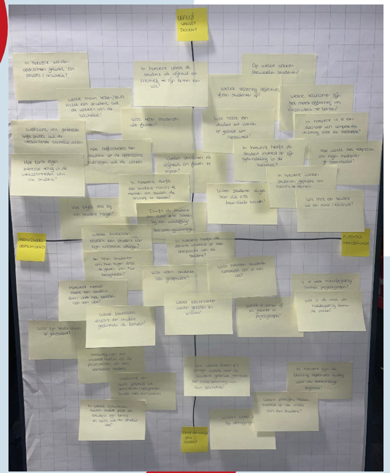
The methods and techniques used are from the book by Heijne and van der Meer (2019).

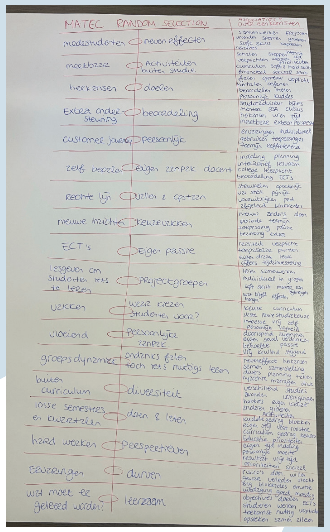


For the DIVERGING stage of the first diamond, I started with the method “Flower Association”. I came up with 99 different associations.

I found difficulty in making a connection between the randomness of the options. Therefore, I decided to do an extra diverging method called “MATEC”. I selected 36 random words from the Flower Association, making 18 different pairs.

For the REVERGING stage, I applied the method “Sequencing”. This method helped me to look holistically at my options and identify any blind spots. As axes, I choose “Influence of Educator” and “Individual Dependency”. With these, I could make a clear distinction between ideas on which the educator could act directly and to what extent the ideas would vary between students.

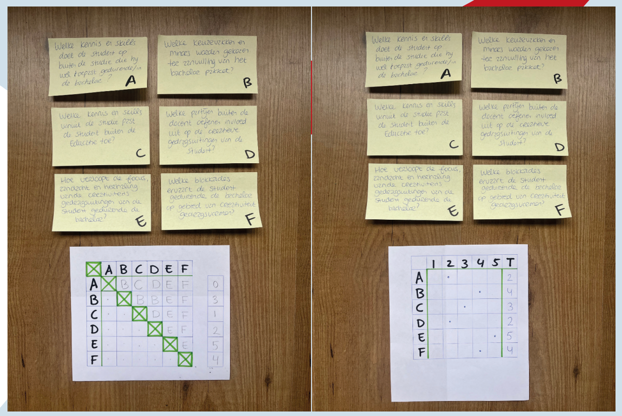




I altered the method a bit by adding an extra step: I noted down the associations and similarities I found between the pairs. This made it easier for me to make a meaningful combination. This method resulted in a total of 41 ideas.

In the CONVERGING stage, I started by making a selection from the sequencing method. I selected 12 different ideas, based on my perceived potential towards the problem, and how much I liked them personally.

On this selection, I made a combination. This resulted in a total of 6 ideas, on which I applied the “Paired Comparison” method. I assessed each idea based on how it individually solved the problem, and in comparison on how well I expected it to perform in solving the problem.



Based on these assessments, the following ideas stood out:

IDEA 1	IDEA 2	IDEA 3
What blockages does the student experience during the bachelor in terms of creative habits?	How does the focus, attention and repetition of students' creativity habits progress over the bachelor?	What electives and minors are chosen to complement the bachelor's curriculum?

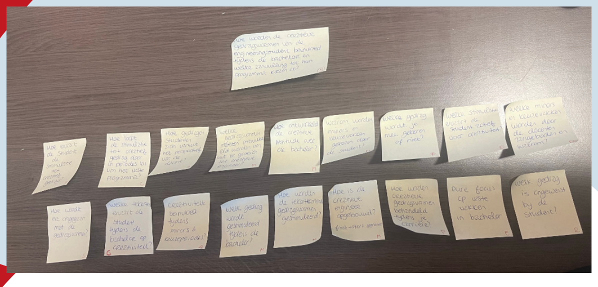
These three ideas each have very interesting parts. To make it easier for the next cycle to continue, I have merged the three ideas into one question statement:

‘How are engineering students’ creative behaviours influenced during their bachelor's and what electives do they choose?

With this new problem statement, I entered the next creative diamond.

The second diamond started with a DIVERGING stage, in which I used the "SCAMPER" method. This method helped me to look beyond the obvious and explore new directions.

S	C	A	M	P	E	R
SUBSTITUDE	COMBINE	ADAPT	MODIFY	PUT TO OTHER USE	ELIMINATE	REVERSE



Even though it was quite challenging to apply this method correctly, I was able to create a diverse set of 18 different ideas.

With the set of ideas, I entered the REVERGING stage. To be sure I paid similar attention to each of these ideas, I used the method "Idea Gallery".

By looking at the uniqueness, advantages and limitations of each idea, I selected three ideas:

IDEA 1	IDEA 2	IDEA 3
What blockages does the student experience during the bachelor in terms of creative habits?	How does the focus, attention and repetition of students' creativity habits progress over the bachelor?	What electives and minors are chosen to complement the bachelor's curriculum?

Entering the CONVERGING stage, I selected five ideas, based on their link to the educator and to solving the problem. On these five ideas, I applied the "UALo" method. Here, all options are evaluated and substantiated, focusing on the pros and cons of each option and protecting novelty.

UALo

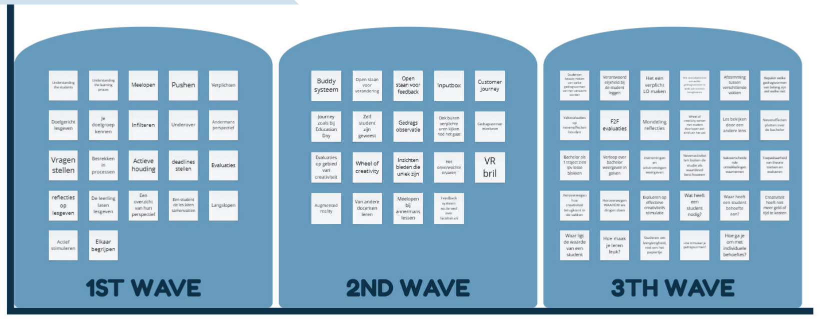
- THE IDEA
- WHAT MAKES THIS IDEA UNIQUE?
- WHAT ARE THE ADVANTAGES?
- WHAT ARE THE LIMTATIONS?
- HOW CAN YOU OVERCOME THESE LIMITATIONS?

These three ideas, I merged into one concept:

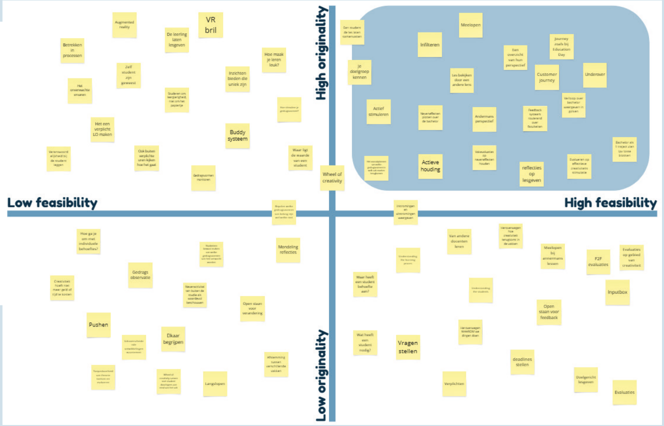
A BSc student journey on stimulation and blockages on creative behaviour and inflows of developments and insights from moments outside the regular BSc program.

Due to the parallel nature of my research, the problem framing changed a bit over time. Therefore, at this point, I decided to do an extra solution-finding diamond. This ensured that the final concept was a great match to the reframed problem.

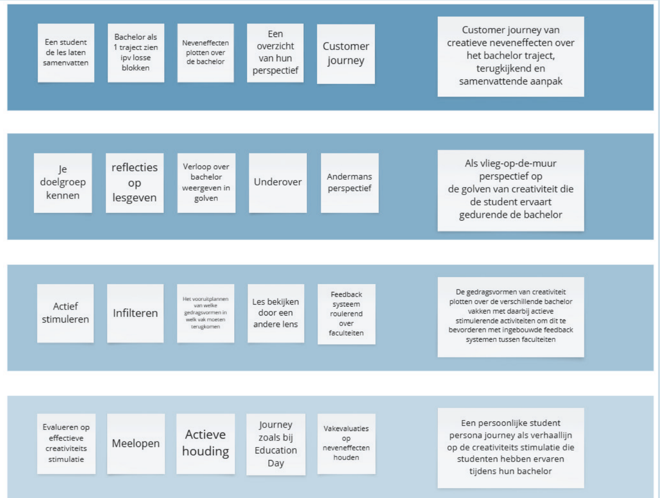
The third diamond started again with a DIVERGING stage, this time using the method "Brainwriting". I worked in three waves: the first addressing the obvious ideas, the second going already a bit deeper and the third encouraging real creative outputs. I came up with a total of 60 different ideas.



With these 60 ideas, I entered the REVERGING stage. I used the "Sequencing" method again, this time using the axes "feasibility" and "originality".



I started the CONVERGING stage by selecting the 20 ideas from the quadrant with high feasibility and high originality. I applied a self-made method on these 20 ideas, dividing the ideas into four random groups. Each of these groups had to result in 1 concept by applying every idea within the group. This resulted in four different concepts.



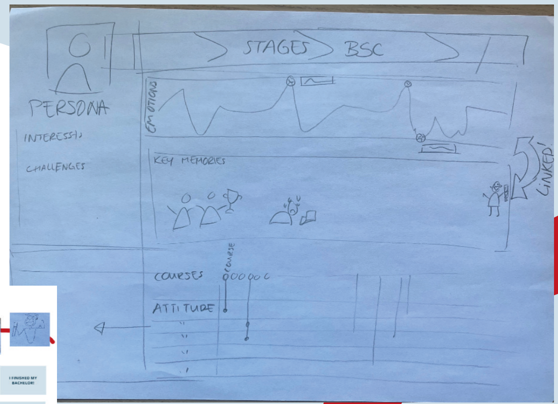
From each concept, there were elements I really liked. Therefore, I combined them into one final concept:

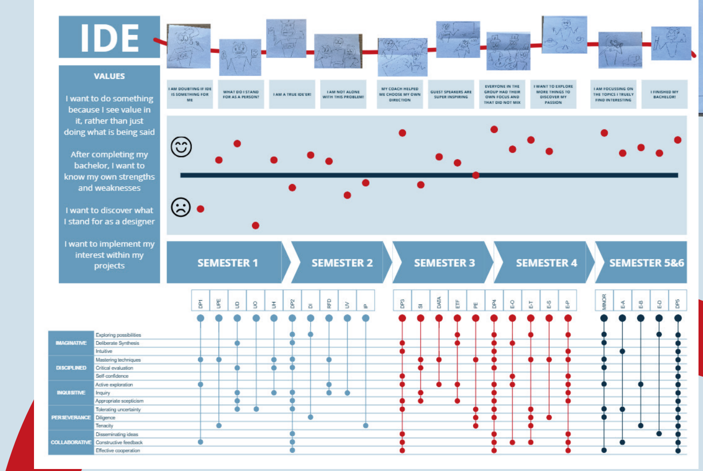
CONCEPT

Persona reflecting the values of the engineering students	Student journey over the bachelor program, showing key personal experiences and creativity boosts & blokkages the students had experienced

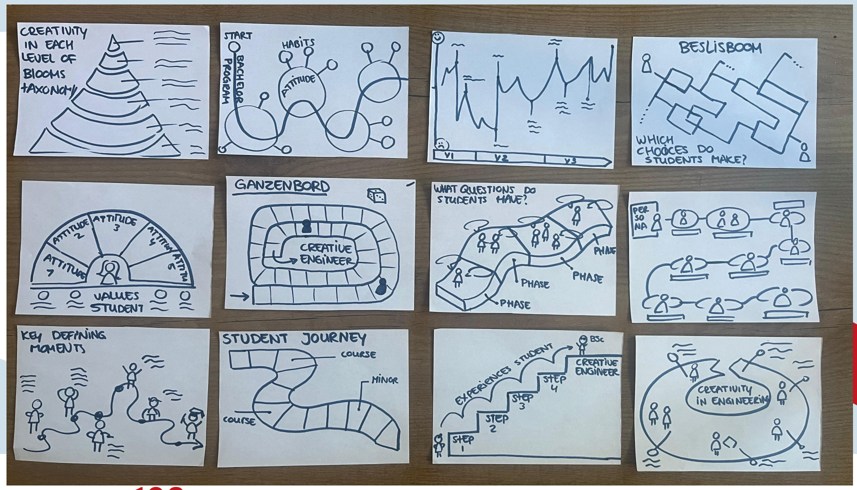
This concept had to be designed. I started by looking at different examples on the internet, searching with the terms “Student journey”, “ Customer journey” and “Student life visualisation / poster”.

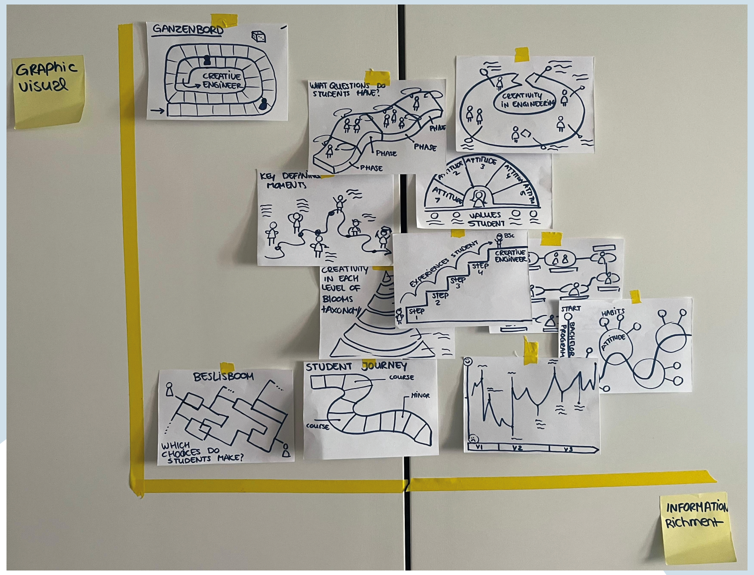
I picked different elements from these examples, resulting in a hand drawn concept. I digitally visualised this concept and presented it to my supervisors and client for feedback.





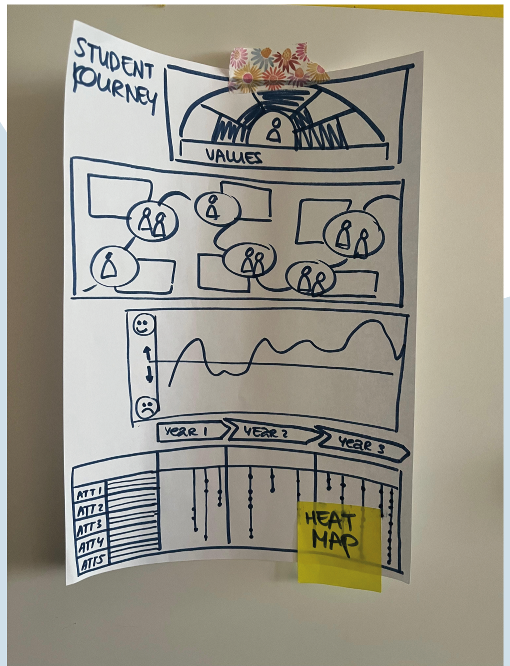
I was not fully satisfied with the concept. Therefore, I took a step back and drew different visualisation ideas of a student journey.





These ideas I put on a graph, with the axes “Graphic visual” and “Information richness”. I picked these two axes, as I wanted to make a visually pleasing journey, while still conveying enough relevant information.

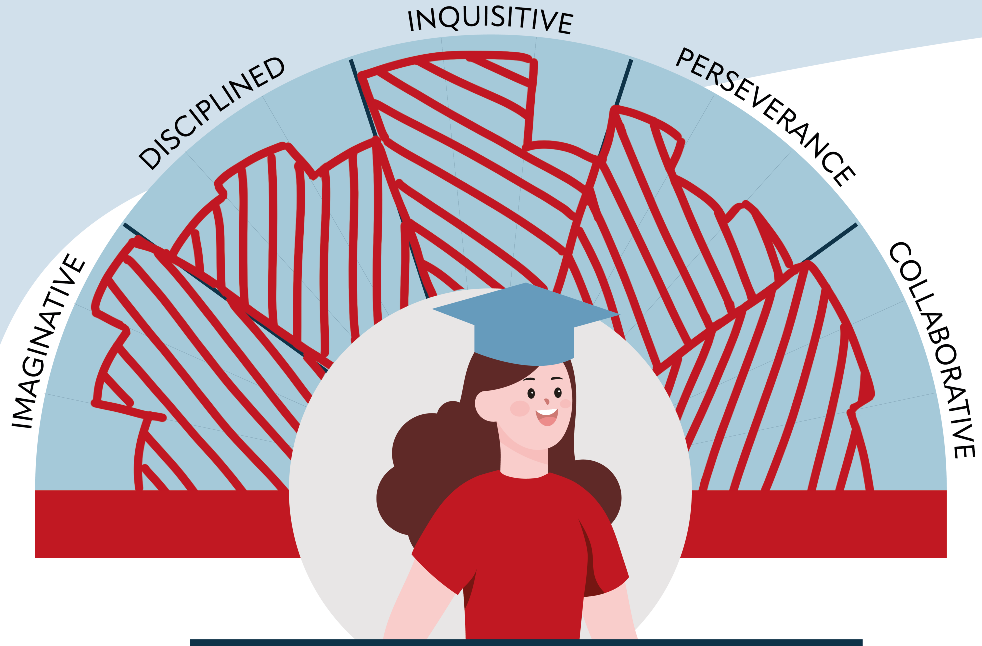
From this graph, I picked different elements that I found interesting and fun to use. This resulted into a new hand drawn concept.



I started implementing this analogue concept into a digital design. However, due to the differences in amount of courses, I had difficulty with implementing the heatmap in a visually pleasing way. Therefore, I decided to leave the heatmaps out of the student journey and make a separate poster of it.

I replaced the heatmaps with a visual of the bachelor program, indicating the different types of courses.

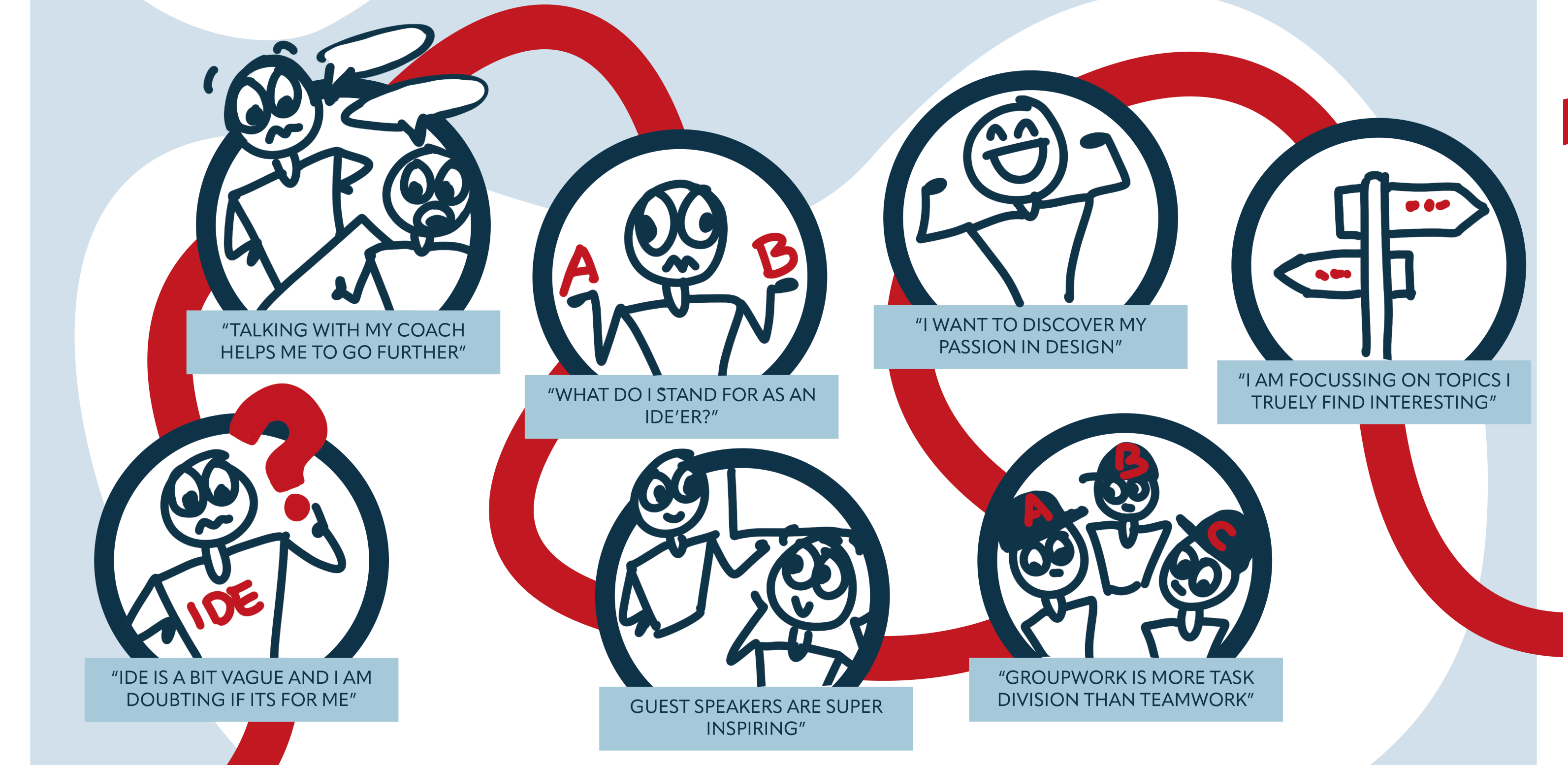
Using the information from the student perspective research, I was able to make two posters who are visually pleasing, while still rich in information!



AS AN INDUSTRIAL DESIGN ENGINEERING STUDENT, I WANT TO...

DO THINGS THAT I FIND VALUABLE
KNOW MY STRENGHTS
DISCOVER MY WAY OF DESIGNING
IMPLEMENT MY INTERESTS
HAVE A REAL IMPACT

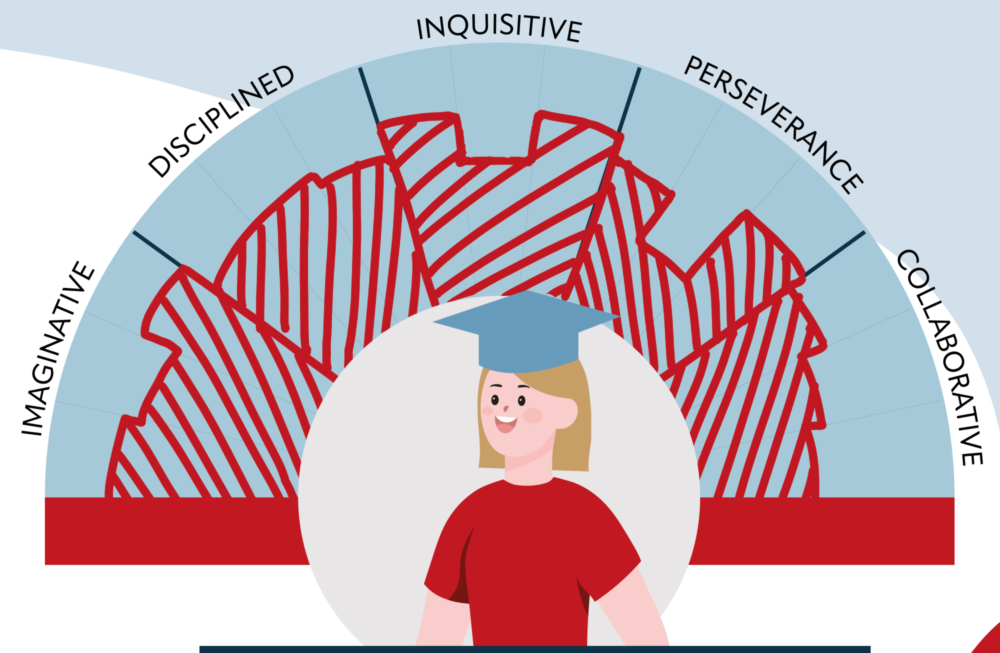
INDUSTRIAL DESIGN ENGINEERING STUDENT



BACHELOR PROGRAM INDUSTRIAL DESIGN ENGINEERING

FIRST YEAR	DESIGN PROJECT 1		DESIGN PROJECT 2	
	UNDERSTANDING PRODUCT ENGINEERING	UNDERSTANDING ORGANISATIONS	DIGITAL INTERFACES	UNDERSTANDING VALUES
	UNDERSTANDING DESIGN	UNDERSTANDING HUMANS	RESEARCH FOR DESIGN	INTELLIGENT PRODUCTS
SECOND YEAR	DESIGN PROJECT 3		DESIGN PROJECT 4	
	SUSTAINABLE IMPACT	ENVISIONING THE FUTURE	ELECTIVE ORGANISATIONS	ELECTIVE SKILLS
	DATA	PRODUCT ENGINEERING	ELECTIVE TECHNOLOGY	ELECTIVE PEOPLE
THIRD YEAR	MINOR PROGRAMME		ELECTIVE SLOT A	DESIGN PROJECT 5 BACHELOR FINAL PROJECT
			ELECTIVE SLOT B	
			ELECTIVE SLOT D	

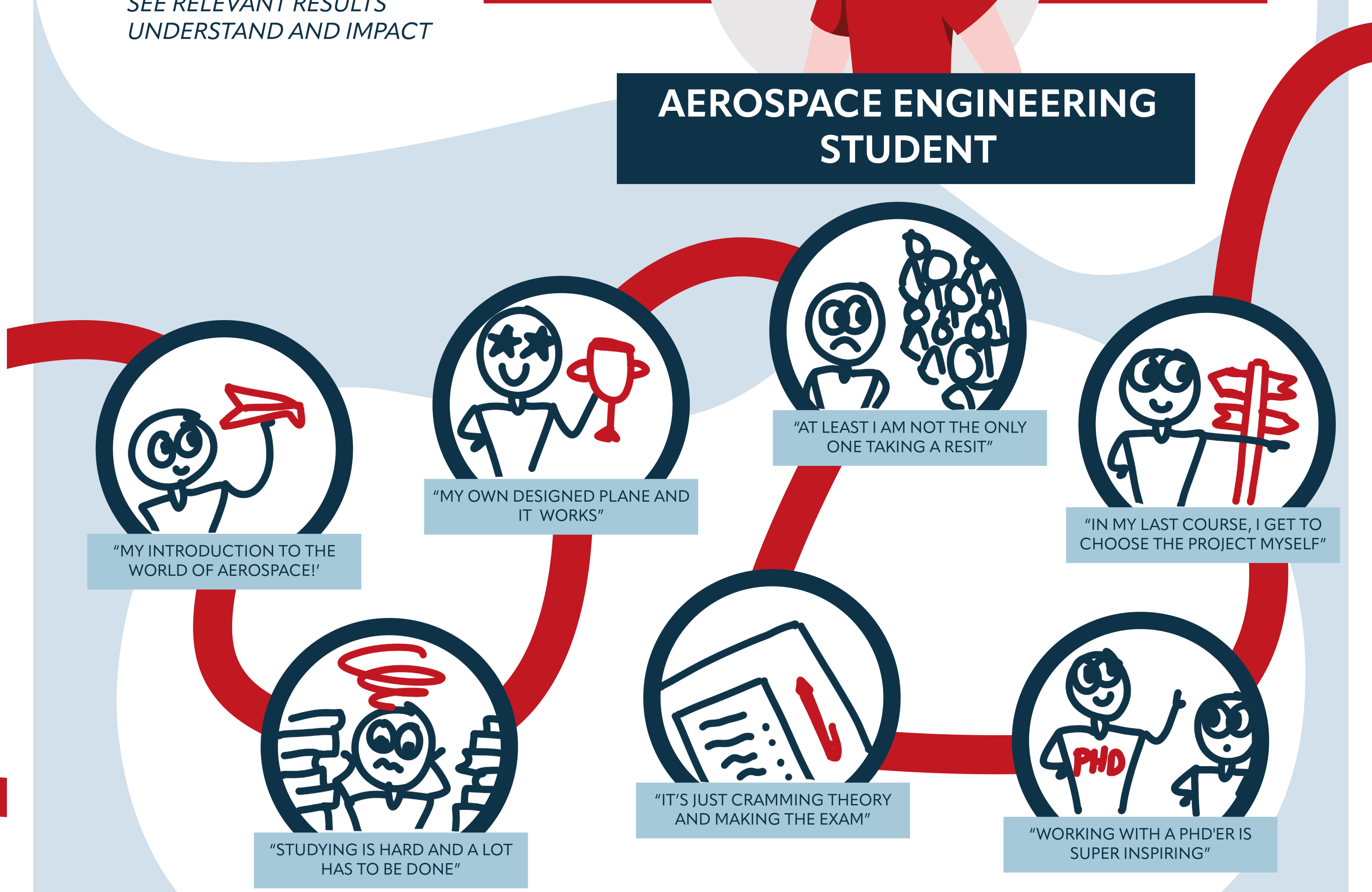
DESIGN PROJECT | ELECTIVES | GENERAL | ORGANISATION | PEOPLE | TECHNOLOGY



AS AN AEROSPACE ENGINEERING STUDENT, I WANT TO...

USE MY KNOWLEDGE
MAKE A DIFFERENCE
DISCOVER MY INTERESTS
SEE RELEVANT RESULTS
UNDERSTAND AND IMPACT

AEROSPACE ENGINEERING STUDENT



BACHELOR PROGRAM AEROSPACE ENGINEERING

FIRST YEAR	EXPLORING AEROSPACE ENGINEERING		DESIGN AND CONSTRUCTION	
	ENGINEERING DRAWING		TECHNICAL WRITING	
	INTRODUCTION TO AE 1	INTRODUCTION TO AE 2	AEROSPACE DESIGN AND SYSTEMS ENGINEERING ELEMENTS (ADSEE) 1	
	STATICS	AEROSPACE MATERIALS	AEROSPACE MECHANICS OF MATERIALS	PYTHON
	CALCULUS I.A	CALCULUS I.B	CALCULUS II	LINEAR ALGEBRA
		DYNAMICS	PHYSICS: THERMODYNAMICS, WAVES AND ELECTROMAGNETISM	
SECOND YEAR	SYSTEMS DESIGN		TEST, ANALYSIS AND SIMULATION	
	ORAL PRESENTATIONS		SCIENTIFIC WRITING	
	ADSEE II	LOW SPEED WIND TUNNEL TEST	FLIGHT AND ORBITAL MECHANICS	AEROSPACE SYSTEMS AND CONTROL THEORY
	AERODYNAMICS I	AERODYNAMICS II	PROPULSION AND POWER	SIGNAL ANALYSIS AND TELECOMMUNICATION
	DIFFERENTIAL EQUATIONS	STRUCTUAL ANALYSIS AND DESIGN	AI FOR AE	COMPUTATIONAL MODELING
	PROBABILITY AND STATISTICS	VIBRATIONS	APPLIED NUMERICAL ANALYSIS	
THIRD YEAR	MINOR PROGRAMME		INTRODUCTION TO AE 2	DESIGN SYNTHESIS EXERCISE
			AEROSPACE MATERIALS	
			CALCULUS I.B	
			DYNAMICS	

AEROSPACE DESIGN PROJECTS | AEROSPACE ENGINEERING AND TECHNOLOGY | ACADEMIC DEVELOPMENT | BASIC ENGINEERING SCIENCES

APPENDIX 3
CONSTENT FORM EDUCATION

AEROSPACE ENGINEERING

Course	Imaginative: Exploring possibilities	Imaginative: Using intuition	Imaginative: Synthesising	Disciplined: Mastering techniques	Disciplined: Evaluating critically	Disciplined: Trusting your approach	Inquisitive: Exploring actively	Inquisitive: Inquiring	Inquisitive: Challenging assumptions	Perseverance: Persisting through challenges	Perseverance: Applying diligence	Perseverance: Tolerating uncertainty	Collaborative: Cooperating appropriately	Collaborative: Exchanging constructive feedback	Collaborative: Disseminating ideas
Exploring Aerospace Engineering							●					●	●	●	●
Engineering Drawing				●							●				
Introduction to Aerospace Engineering I								●							
Statics															
Calculus I.A.															
Introduction to Aerospace Engineering II							●	●							
Aerospace Materials															
Calculus I.B.															
Dynamics	●														
Design and Construction	●	●	●			●	●						●	●	●
Technical Writing															
Aerospace Design and Systems Engineering Elements I	●						●					●			
Physics: Thermodynamics, Waves and electromagnetism															
Aerospace Mechanics of Materials															
Calculus II															
Programming & Scientific Computing in Python	●					●	●								
Linear Algebra															
Systems Design	●	●	●		●	●	●					●	●	●	●
Oral Presentations														●	●
Aerospace Design and Systems Engineering Elements II												●			
Aerodynamics I															
Differential Equations										●					
Probability and Statistics															
Low Speed Wind Tunnel Test			●										●		●
Aerodynamics II															
Structural Analysis and Design	●	●	●				●								
Vibrations															
Test, Analysis and Simulation	●							●		●			●	●	●
Scientific Writing														●	
Flight and Orbital Mechanics															
Propulsion and Power		●													
Artificial intelligence for Aerospace Engineering															
Applied Numerical Analysis	●		●												
Aerospace Systems and Control Theory	●		●												
Signal Analysis and Telecommunication Principles															
Computational Modeling	●						●								
Minor Program			●	●	●	●	●	●	●	●			●	●	
Simulation, Verification and Validation					●		●			●			●	●	●
Production of Aerospace Systems	●							●							
Systems Engineering & Aerospace design															
Aerospace Flight Dynamics & Simulation									●	●					
Design Synthesis Exercise	●	●			●	●	●	●	●	●	●	●	●	●	●

INDUSTRIAL DESIGN ENGINEERING

Course	Imaginative: Exploring possibilities	Imaginative: Using intuition	Imaginative: Synthesising	Disciplined: Mastering techniques	Disciplined: Evaluating critically	Disciplined: Trusting your approach	Inquisitive: Exploring actively	Inquisitive: Inquiring	Inquisitive: Challenging assumptions	Perseverance: Persisting through challenges	Perseverance: Applying diligence	Perseverance: Tolerating uncertainty	Collaborative: Cooperating appropriately	Collaborative: Exchanging constructive feedback	Collaborative: Disseminating ideas
Design Project 1				●			●	●						●	
Understanding Product Engineering				●						●					
Understanding Design			●		●			●	●						
Understanding Organisations												●			
Understanding Humans				●	●			●							
Design Project 2	●		●	●	●		●	●	●				●	●	●
Digital Interfaces	●										●				
Research for Design				●			●	●							
Understanding Values								●							
Intelligent Products	●									●					
Design Project 3		●	●			●	●		●			●	●	●	●
Sustainable Impact				●	●			●	●						
Data				●			●								
Envisioning the Future	●		●				●		●						
Product Engineering				●						●	●	●			
Design Project 4	●	●	●	●	●		●	●	●		●	●	●	●	●
Elective Organisations			●			●	●							●	
Elective Technology	●			●						●	●	●		●	
Elective Skills				●							●				
Elective People	●	●		●		●	●	●	●				●	●	●
Minor	●		●	●	●		●				●	●	●		
Elective A		●										●		●	
Elective B							●			●					
Elective D	●												●		●
Design Project 5	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

Delft University of Technology
HUMAN RESEARCH ETHICS
INFORMED CONSENT FORM

Introduction
You are being invited to participate in a research study titled Exploring creativity in engineering: why it matters and how it shapes the future. This study is being done by Mandy Vermeijs from the TU Delft. The purpose of this research study is to get a better overview on the perception around creativity in engineering context and how it is stimulated through the education programs, and will take you approximately 30 minutes to complete. The data will be used for to design a learning line of creativity developments over the education programs of the TU Delft. We will be asking you to share your opinions, your approaches and your current and future vision on creativity in an engineering context. As with any research activity the risk of a breach is always possible. To the best of our ability your answers in this study will remain confidential. We will minimize any risks by only sharing data with my personal supervisors if needed, and deleting all data after processing. Also I will keep the interview completely anonymous, as I will not use your name or any other personal data. Your participation in this study is entirely voluntary and you can withdraw at any time. You are free to omit any questions. Mandy Vermeijs Eva Kalmar

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION		
1. I have read and understood the study information dated [/ /], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
3. I understand that taking part in the study involves: an audio-recorded discussion. These will be processed by the researcher and deleted afterwards.	☐	☐
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)		
4. I understand that taking part in the study also involves collecting your perspective within the research (educator, student or market) with the potential risk of my identity being revealed.	☐	☐
5. I understand that the following steps will be taken to minimise the threat of a data breach, and protect my identity in the event of such a breach: anonymous data collection, data storage with limited access and deletion of the data after processing	☐	☐
6. I understand that personal information collected about me that can identify me, such as my name, email address and my job description will not be shared beyond the study team.	☐	☐
7. I understand that the (identifiable) personal data I provide will be destroyed after processing	☐	☐

C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		
8. I understand that after the research study the de-identified information I provide will be used for the master thesis.	☐	☐
9. I agree that my responses, views or other input can be quoted anonymously in research outputs	☐	☐

Signatures

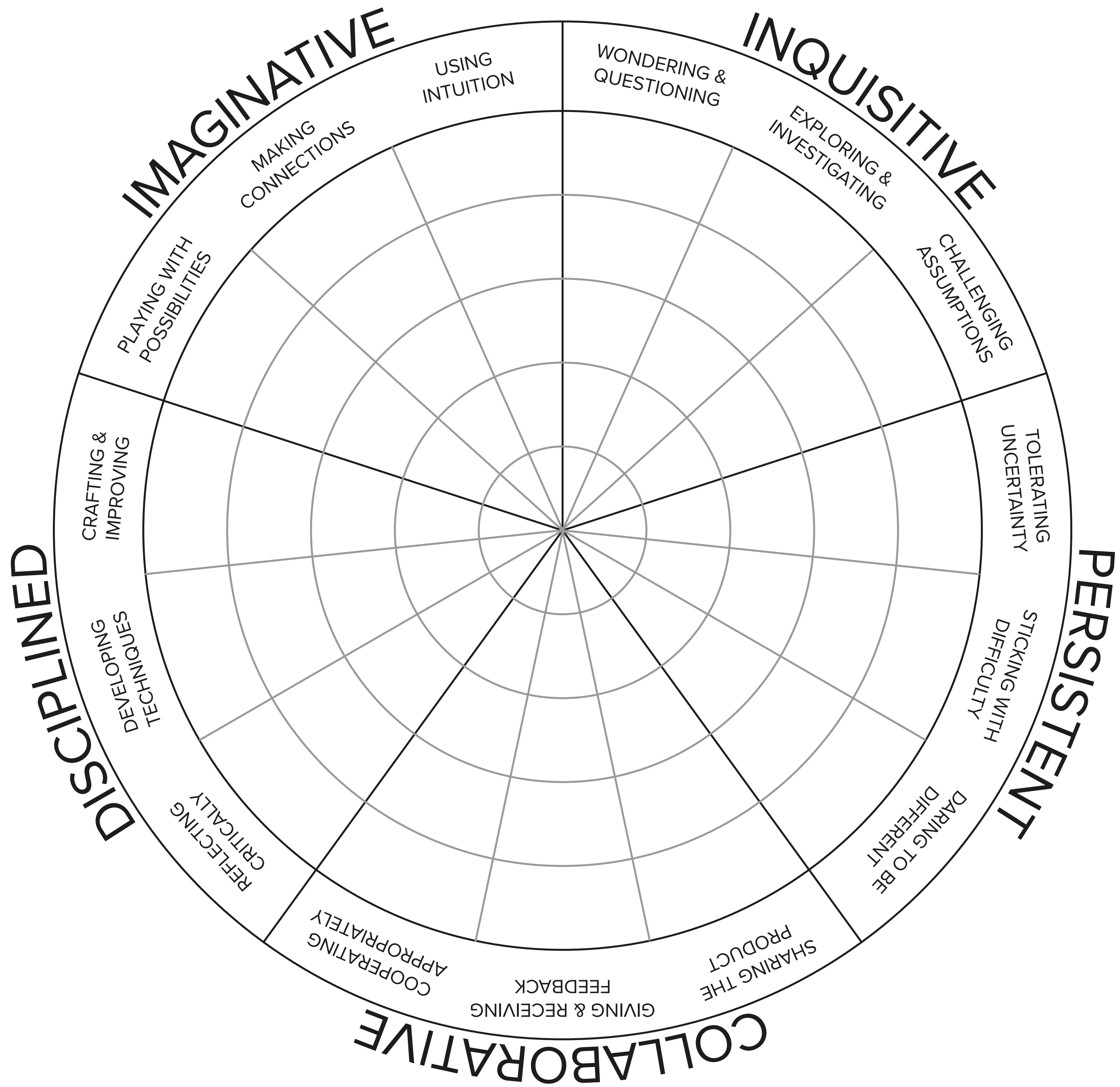
________________ ________________ ________
Name of participant Signature Date

I, as researcher, have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Mandy Vermeijs ________________ ________
Researcher name Signature Date

Study contact details for further information:
Mandy Vermeijs

APPENDIX 4
WHEEL OF CREATIVITY TEMPLATE



APPENDIX 5
CONSENT FORM STUDENTS

Delft University of Technology
HUMAN RESEARCH ETHICS
INFORMED CONSENT FORM

Introduction
You are invited to participate in a research project for the master's thesis: Promoting creative competence in engineering students: Embedding Stimuli for Creative Behaviour into Educational Practices. This thesis is being conducted by Mandy Vermeijs from TU Delft. The purpose of this research is to get an overview of the student's perspective on creativity habits within the bachelor. This survey will take approximately one hour. The data from this study will be used to create a heatmap across the bachelor's that reflects students' experiences and opinions about the different bachelor's courses. Personal insights will also be used to argue design choices. We therefore ask you to share your own personal opinions and experiences about your bachelor during the study. As with almost all studies, there is a risk of data breach. To best prevent this, no personal information, such as name, student number or contact details, will be stored or shared. Your participation in this survey is entirely voluntary and you have the option to withdraw from the study at any time. You can also ask questions at any time. Mandy Vermeijs Eva Kalmar

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION		
1. I have read and understood the study information dated [/ /], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)		
4. I understand that taking part in the study also involves collecting your perspective within the research (educator, student or market) with the potential risk of my identity being revealed.	☐	☐
5. I understand that the following steps will be taken to minimise the threat of a data breach, and protect my identity in the event of such a breach: anonymous data collection, data storage with limited access and deletion of the data after processing	☐	☐
6. I understand that personal information collected about me that can identify me, such as my name, telephone number, email address and my study will not be shared beyond the study team.	☐	☐
7. I understand that the (identifiable) personal data I provide will be destroyed after processing	☐	☐

C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		
8. I understand that after the research study the de-identified information I provide will be used for the master thesis.	☐	☐
9. I agree that my responses, views or other input can be quoted anonymously in research outputs	☐	☐

Signatures

____________________ ____________________ ________

Name of participant Signature Date

I, as researcher, have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Mandy Vermeijs ________________ ________

Researcher name Signature Date

Study contact details for further information:

Mandy Vermeijs

APPENDIX 6
BACHELOR TEMPLATE IDE & AE

		Inquisitive			Persistent			Imaginative			Collaborative			Disciplined		
ECT	Course	Wondering & Questioning	Exploring & investigating	Challenging assumption	Tolerating Uncertainty	Sticking with difficulty	Daring to be different	Playing with possibilities	Making connections	Using intuition	Sharing the product	Giving & receiving feedback	Cooperating appropriately	Reflecting critically	Developing techniques	Crafting & Improving
	S-IO-1															
	IO Year 1															
10	Design Project 1															
5	Understanding Product Engineering															
5	Understanding Design															
5	Understanding Organisations															
5	Understanding Humans															
10	Design Project 2															
5	Digital Interfaces															
5	Research for Design															
5	Understanding Values															
5	Intelligent Products															
	IO Year 2															
10	Design Project 3															
5	Sustainable Impact															
5	Data															
5	Envisioning the Future															
5	Product Engineering															
10	Design Project 4															
5	Elective Organisations															
5	Elective Technology															
5	Elective Skills															
5	Elective People															
	IO Year 3															
30	Minor															
5	Elective A															
5	Elective B															
5	Elective D															
15	Design Project 5															

		Inquisitive			Persistent			Imaginative			Collaborative			Disciplined		
ECT	Course	Wondering & Questioning	Exploring & investigating	Challenging assumption	Tolerating Uncertainty	Sticking with difficulty	Daring to be different	Playing with possibilities	Making connections	Using intuition	Sharing the product	Giving & receiving feedback	Cooperating appropriately	Reflecting critically	Developing techniques	Crafting & Improving
	S-AE-3															
	LR Year 1															
3	Exploring Aerospace Engineering															
2	Engineering Drawing															
5	Introduction to Aerospace Engineering I															
4	Statics															
	Calculus I A.															
4	Introduction to Aerospace Engineering II															
3	Aerospace Materials															
6	Calculus I B.															
3	Dynamics															
5	Design and Construction															
	Technical Writing															
4	Aerospace Design and Systems Engineering Elements I															
6	Physics: Thermodynamics, Waves and electromagnetism															
3	Aerospace Mechanics of Materials															
5	Calculus II															
2	Programming & Scientific Computing in Python															
5	Linear Algebra															
	LR Year 2															
5	Systems Design															
	Oral Presentations															
3	Aerospace Design and Systems Engineering Elements II															
3	Aerodynamics I															
4	Differential Equations															
4	Probability and Statistics															
1	Low Speed Wind Tunnel Test															
3	Aerodynamics II															
5	Structural Analysis and Design															
3	Vibrations															
5	Test, Analysis and Simulation															
	Scientific Writing															
4	Flight and Orbital Mechanics															
4	Propulsion and Power															
3	Artificial intelligence for Aerospace Engineering															
3	Applied Numerical Analysis															
4	Aerospace Systems and Control Theory															
3	Signal Analysis and Telecommunication Principles															
3	Computational Modeling															
	LR Year 3															
30	Minor Program															
4	Simulation, Verification and Validation															
3	Production of Aerospace Systems															
3	Systems Engineering & Aerospace design															
5	Aerospace Flight Dynamics & Simulation															
15	Design Synthesis Exercise															

APPENDIX 7
PROJECT BRIEF

DESIGN FOR our future

7461

TU Delft

IDE Master Graduation Project

Project team, procedural checks and Personal Project Brief

In this document the agreements made between student and supervisory team about the student's IDE Master Graduation Project are set out. This document may also include involvement of an external client, however does not cover any legal matters student and client (might) agree upon. Next to that, this document facilitates the required procedural checks:

- Student defines the team, what the student is going to do/deliver and how that will come about
- Chair of the supervisory team signs, to formally approve the project's setup / Project brief
- SSC E&SA (Shared Service Centre, Education & Student Affairs) report on the student's registration and study progress
- IDE's Board of Examiners confirms the proposed supervisory team on their eligibility, and whether the student is allowed to start the Graduation Project

STUDENT DATA & MASTER PROGRAMME

Complete all fields and indicate which master(s) you are in

Family name	Vermeijs	IDE master(s)	IPD ☐ Dfl ☐ SPD ✔
Initials	M.A.	2nd non-IDE master	
Given name	Mandy	Individual programme *(date of approval)*	
Student number	4850408	Medisign	☐
		HPM	☐

SUPERVISORY TEAM

Fill in he required information of supervisory team members. If applicable, company mentor is added as 2nd mentor

Chair	Éva Kalmár	dept./section	DOS / Creative processes
mentor	Katrina Heijne	dept./section	DOS / Creative processes
2nd mentor			
client:	Steven Flipse		
city:	Delft	country:	The Netherlands

optional comments: I have chosen two supervisors from the same section, because they add the expertise that I need i my project: educating creativity and education innovation and transdisciplinarity. Besides, Eva and Katrina did not do any graduation projects together yet.

! Ensure a heterogeneous team. In case you wish to include team members from the same section, explain why.

! Chair should request the IDE Board of Examiners for approval when a non-IDE mentor is proposed. Include CV and motivation letter.

! 2nd mentor only applies when a client is involved.

APPROVAL OF CHAIR on PROJECT PROPOSAL / PROJECT BRIEF -> to be filled in by the Chair of the supervisory team

Sign for approval (Chair)

Name Eva Kalmar Date 29 Oct 2024 Signature

CHECK ON STUDY PROGRESS

To be filled in by SSC E&SA (Shared Service Centre, Education & Student Affairs), after approval of the project brief by the chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total ______ EC

Of which, taking conditional requirements into account, can be part of the exam programme ______ EC

X	YES	all 1st year master courses passed
	NO	missing 1st year courses

Comments:

Sign for approval (SSC E&SA)

Name Robin den Braber   Date 13-11-2024   Signature RdB

APPROVAL OF BOARD OF EXAMINERS IDE on SUPERVISORY TEAM -> to be checked and filled in by IDE's Board of Examiners

Does the composition of the Supervisory Team comply with regulations?

YES	V	Supervisory Team approved
NO		Supervisory Team not approved

Comments:

Based on study progress, students is ...

V	ALLOWED to start the graduation project
	NOT allowed to start the graduation project

Comments:

Sign for approval (BoEx)

Name Monique von Morgen   Date 13/11/2024   Signature

DESIGN FOR our future

TU Delft

Personal Project Brief – IDE Master Graduation Project

Name student Mandy Vermeijs   Student number 4,850,408

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT

Complete all fields, keep information clear, specific and concise

Project title Exploring creativity in engineering: why it matters and how it shapes the future

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

Creativity is a concept that evokes different associations for everyone. But what does it mean to be creative as an engineer? There are voices shouting that we need creative engineers if we are to solve the most complex problems of the future (Felder, 1987). Demand is high, and universities are blasting one innovative creation after another from the rooftops. Yet there is a dissatisfaction with how creativity is woven into the programs. This project investigates the stimulation and incorporation of creativity in the engineering education program of the TU Delft.

This project will be transdisciplinary, looking at the education system, educators, students and the market. This will allow us to explore the concept of creativity from different perspectives. Perceptions and assumptions are collected, programs are examined and compared and knowledge and application gaps are identified. This all comes together in a learning line, a demonstration of the undergraduate student's learning process.

This line of learning is of great interest to both the client and the university as a whole, as it closes a knowledge gap they are currently facing. There is knowledge about creativity, and there is an understanding of the importance. However, there is no knowledge about the HOW question. This project will provide insight into this question, providing an underlay that will become applicable in the broader research field on engineers' soft skills.

Felder, R. M. (1987). ON CREATING CREATIVE ENGINEERS. *Engineering Education*, *77*(4). http://www4.ncsu.edu/unity/lockers/users/f/felder/public/Papers/Creative_Engineers.pdf

→ *space available for images / figures on next page*

introduction (continued): space for images

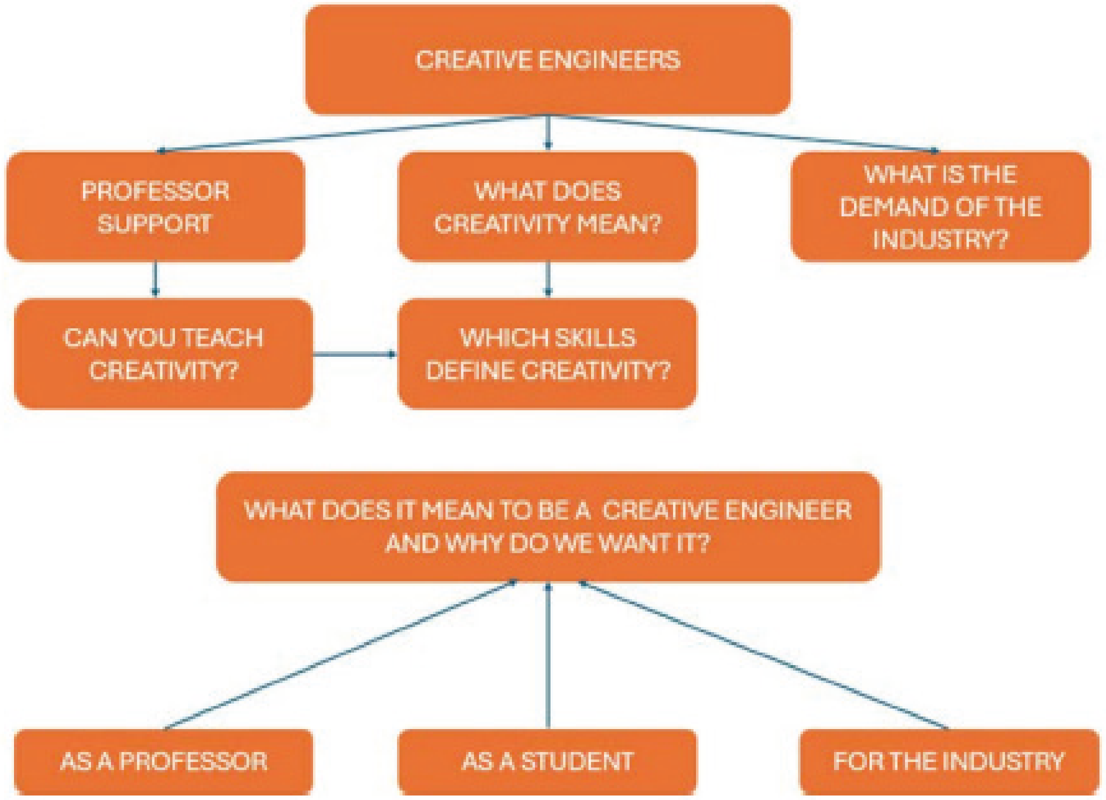


image / figure 1

image / figure 2

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

The problem this project aims to address is the lack of knowledge on the implementation and stimulation of creativity in the program of engineering studies. Currently, the client is expressing a great dissatisfaction with the level of creativity within the education programs. This dissatisfaction is supported and confirmed by other parties at the university. A challenge we foresee is the measurability and assessability of creativity, as there is a knowledge gap on how it should be measured.

To close the knowledge gap, a vision is needed that showcases the elements of creativity that belong in the engineering context. This vision can then be translated into a learningline that demonstrates the applicability of creativity throughout the education period of the engineer. This outcome will give the client the tools to encourage the implementation of creativity. It can also serve as a starting point for driving better applicability of other hard-to-measure but extremely important skills that should come with an engineer's education.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence) As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

Design a concept to improve the incorporation of creativity for course coordinators at TUDelft.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

In order to create a vision on the elements of creativity that belong in the engineering context, a transdisciplinary approach is needed. By doing research (literature, quantitative and qualitative) on the perception of creativity with educators, students and the engineering market, a skillset will be identified that embodies the definition of a creative engineer. However, just a skillset is not enough. A kind of implementation plan is needed to answer the question on HOW creativity can be incorporated into an engineering program. In order to understand the possibilities, this project will dive deep into the bachelor programs of the IDE and AE faculty. As these two faculties show quite the contrast, even though their markets show great interest in creative engineers.

This research will conclude into a learningline showing the implementation and incorporation of the skillset needed to create a creative engineer at the end of a bachelor's degree at the TUDelft.

Project planning and key moments

To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a ***kick-off meeting*****,** ***mid-term evaluation meeting*****,** ***green light meeting*** *and* ***graduation ceremony****. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	24 okt 2024
Mid-term evaluation	19 dec 2024
Green light meeting	6 mrt 2025
Graduation ceremony	3 apr 2025

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

My strong passion for creativity - its understanding, stimulation and implementation - is the main driver for this project. Throughout my education at the TUDelft, my bachelor's and master's as well as my extra-curricular activities, I have been concerned with the concept of creativity. To end my learning career with a cherry on top, I would like to leave a mark and act as a stepping stone to change and thereby make an impact.

I am very curious about the timeline of this project, as well as the organizational side of it. I am leading this project and that brings challenges that you would normally have a course coordinator or teacher for. I need and want to make quick yet strong informed choices, have good and clear communication and work effectively. I also work with many different groups in this project, due to the transdisciplinary approach.

APPENDIX 8
PERSONAL LEARNING OBJECTIVES

LEARNING OBJECTIVE 1
Na het voltooien van mijn afstudeerproject heb ik relevante connecties gelegd tussen literatuur en realiteit.

LEARNING OBJECTIVE 2
Na het voltooien van mijn afstudeerproject ben ik meerdere malen uit mijn comfortzone gestapt, waarbij ik verdwaald ben en in de chaos mijn eigen weg heb gevonden, en hierop gereflecteerd om zelfontwikkeling te stimuleren.

LEARNING OBJECTIVE 3
Na mijn afstuderen kan ik effectief communiceren en discussiëren, door actief te luisteren, door te vragen en connecties te leggen.

LEARNING OBJECTIVE 4
Na het voltooien van mijn afstudeerproject ben ik in staat om verschillende methodes en technieken toe te passen om een divers en iteratief proces te garanderen.

LEARNING OBJECTIVE 5
Na het voltooien van mijn afstudeerproject ben ik trots op zowel mijn proces als het eindproduct.

LEARNING OBJECTIVE 6
Na mijn afstuderen kan ik effectief projectleiderschap vertonen, door middel van parallel en toekomstgericht plannen, het betrekken van relevante informatie en personen, en het doorvoeren van een lopende en iteratieve documentatieaanpak.

LEARNING OBJECTIVE 7
Na het voltooien van mijn afstudeerproject ben ik in staat om verschillende methodes en technieken toe te passen om een divers en iteratief proces te garanderen.

LEARNING OBJECTIVE 8
Na mijn afstuderen ben ik in staat om complexe relaties, concepten en theorieën visueel toe te lichten

APPENDIX 9

PERSONAL REFLECTION

Wat een enorm en gigantisch gaaf project heb ik achter de rug. En nu ben ik ineens al op het einde. Zowel van dit project, als mijn eigen student journey. Wat een enorm raar gevoel.

Graag wil ik afsluiten met een persoonlijke reflectie. Aan het begin van mijn afstudeerproject heb ik zeven learning objectives (LO's) opgesteld. Als reflectie zal ik deze LO's één voor één afgaan.

LO1: Na het voltooien van mijn afstudeerproject heb ik relevante connecties gelegd tussen literatuur en realiteit.

Hierop durf ik met zekerheid heel hard ja op te zeggen. Ik heb in het begin van mijn project een redelijk uitbundige literatuur onderzoek gedaan. De ondervindingen daaruit heb ik naast alle drie de andere perspectieven weten te leggen. Ook heb ik hier nog een hoofdstuk aan gewijd. Ik moet zeggen dat ik dit als enorm lastig heb ervaren. Er was een hele hoop literatuur waar je eigenlijk eindeloos in door kan blijven gaan. Ik vond het erg lastig om op een gegeven moment te zeggen van Ho nu is het genoeg. Wat nou als ik nog een super relevante paper mis? Dit bleef gedurende het hele project flink aan mij knagen. Uiteindelijk was het de tijdsdruk die mij de knoop liet doorhakken om te stoppen met het duiken in de literatuur.

LO2: Na het voltooien van mijn afstudeerproject ben ik meerdere malen uit mijn comfortzone gestapt, waarbij ik verdwaald ben en in de chaos mijn eigen weg heb gevonden, en hierop gereflecteerd om zelfontwikkeling te stimuleren.

Die chaos was er zeker. Ik ben van mezelf een enorm gestructureerd persoon. Als ik geen overzicht meer heb, raak ik al snel verdwaald of overspoeld. Dit heb ik dan zeker ook ervaren in zowel de literatuur als de vele gesprekken en daaruit volgende inzichten. Er was zo enorm veel verschillende data. Ik heb hier voor mezelf een eigen weg in proberen te maken door middel van grote Excel bestanden en een enorm MIRO bord. Ik ben erg trots op hoe ik de literatuur heb aangepakt in dit project. Ik had hiervoor een groot word document opgesteld met een vast format. Hierdoor had ik alle inzichten voor mezelf bij elkaar. Door deze inzichten vervolgens te clusteren in MIRO vind ik dat ik een erg goede verhaallijn heb weten te maken. Zelfs ondanks dat dit project mij toch wel weer bewezen heb wat voor een hekel ik eigenlijk heb aan literatuur reviews schrijven..

LO3: Na mijn afstuderen kan ik effectief communiceren en discussiëren, door actief te luisteren, door te vragen en connecties te leggen.

Ik heb gefocust op actief luisteren door alle interviews met de educatoren op te nemen. Dit was enorm fijn tijdens de gesprekken, omdat ik echt vol kon focussen op wat er gezegd werd. Dat dit vervolgens een grote hel zou worden om daarna uit te werken, had ik wel even over het hoofd gezien. Wat betreft communicatie en discussies, heb ik mij actief opgesteld tijdens de supervisor meetings. Ik zorgde ervoor dat ik altijd van tevoren klaar had staan wat ik wilde vertellen, om zo tijdens het gesprek de diepte in te kunnen duiken. Ik vond dit zelf enorm fijn en hoop zeker ook dat mijn supervisors dit ook zo ervaren hebben.

LO4: Na het voltooien van mijn afstudeerproject ben ik in staat om verschillende methodes en technieken toe te passen om een divers en iteratief proces te garanderen.

Voorafgaand aan dit project had ik al redelijk wat ervaring met verschillende methodes en technieken. Hierdoor was deze LO een gemakkelijke voor mij. Toch heb ik mezelf gepusht om soms net wat andere methodes te gebruiken dan dat ik misschien in eerste instantie gedaan zou hebben. Dit pakte soms goed en soms wat minder goed uit. Ook heb ik soms een eigen draai gegeven aan methodes of zelfs zelf iets bedacht. Ik vond het belangrijk om bij mezelf te blijven

LO5: Na het voltooien van mijn afstudeerproject ben ik trots op zowel mijn proces als het eindproduct.

Trots ben ik zeker. Gedurende het project had ik zeker een aantal keren dat de moed me in de schoenen zakte. Gelukkig had ik in die gevallen mijn supervisors, familie en vrienden die mij er altijd weer bovenop kregen. Ik heb op het einde veel tijd gestoken in het report en de visuals, om ervoor te zorgen dat ze echt in lijn staan met hoe ik ben. Ik vind het er echt enorm vet uit zien uiteindelijk, zeker iets wat ik vol trots op de kast wil zetten. Ook vind ik het onderzoek die ik gedaan heb enorm vet. Het was enorm inspirerend om alle enthousiasme en passie te zien vanuit zowel de educatoren als de studenten. Ik heb echt het idee dat wat ik gedaan heb relevant is en impact kan maken.

LO6: Na mijn afstuderen kan ik effectief projectleiderschap vertonen, door middel van parallel en toekomstgericht plannen, het betrekken van relevante informatie en personen, en het doorvoeren van een lopende en iteratieve documentatieaanpak.

Op al deze punten durf ik van te zeggen dat ik zeker erin gegroeid ben dit project. Ik hanteerde strenge planningen voor mezelf, had allerlei interne deadlines gesteld en hield in detail een Gantt chart en planning bij. Ik probeerde zo effectief mogelijk mijn begeleiders en client te gebruiken. Dit was ook zeker nodig met de drukke agenda's. Ik had ook voor mezelf een gestructureerde aanpak opgezet wat betreft documenten. Ik had drie verschillende word documenten: één waarin ik de eerste versie van mijn thesis typte, één waarin mijn green light uitwerking staat en dan nog een laatste waar de final tekst in staat van mijn report.

LO7: Na mijn afstuderen ben ik in staat om complexe relaties, concepten en theorieën visueel toe te lichten

In de visualisaties van mijn report heb ik geprobeerd om zo direct en concreet mogelijk de conclusies weer te geven. Op deze manier probeerde ik direct duidelijk te maken wat de verschillende conclusies waren. Ook heb ik veel tijd besteed aan de hiërarchie van mijn posters. Ik wilde een visuele uitstraling die mij past, maar ook nog voldoende informatie weergeven. Dit was zeker een uitdaging. Ik heb zeker stappen gemaakt hierin tijdens dit project, al denk ik wel dat het zeker nog beter zou kunnen. Maar goed er moet altijd ruimte blijven voor verbetering.