# Impact of global forces and empowering situations on engineering education in 2030

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# IMPACT OF GLOBAL FORCES AND EMPOWERING SITUATIONS ON ENGINEERING EDUCATION IN 2030

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## ABSTRACT

Over the last couple of decades the world around us has changed at a dizzying pace by the globalisation and digitalisation, the horizontalisation of the socio-economic world, and the blending of technical, economical and societal cultures. The ways we communicate, work, play, travel and do business have changed dramatically, and are expected to change at an even faster pace in the future. We have entered an era where higher engineering education has to move from content coverage to content mastery. Are our programmes good enough to absorb the changes in the world 10 to 15 years from now?

This paper discusses the results of an exploration by a Think Tank of academic staff about "what future engineers should learn in higher engineering education in 2030". Key issues are the embedding of personal development in a meaningful way - the teaching of the "whole engineer", the creation of purposeful engineering profiles for society, keeping them specific enough to create in-depth learning.

## KEYWORDS

Engineering education, 2030, profile, engineering language, hub, CDIO Standards 1 (Context), 3 (Integrated Curriculum), 7 (Integrated Learning Experiences).

## INTRODUCTION

Although Moore's law of exponential growth in electronic devices is challenged today, technological innovations have not slowed down. According to Brynjolfsson and McAfee an extraordinary re-invention of our lives and economy will take place driven by digital technology. It is expected that much labour force will be supported or replaced by intelligent assistants, cognitive computing systems, who will come to know their controller through continuous interaction. These robots will complete more and more non-routine cognitive tasks and develop broad abilities in pattern recognition in big data, complex communication and other domains that used to be exclusively human (Brynjolsson & McAfee, 2014). Although the future scenario is full of uncertainty, engineers will be better off when they master the usage of multipurpose tools and methods, master common languages in engineering such as mathematics, programming, visualisation, have learnt to use their imagination and intuition, and have agile and resilient abilities. They have to be prepared for practice to learn about the kinds of practical questions that engineering scientists and professionals in their domain repeatedly face. Vivak Whadwa states we should encourage our students to develop a love for learning as they will have to reinvent themselves many times over the course of their life time. This will include technology, reading, writing and mathematics as much as the more human empathetic skills coming from non-engineering fields.

Table 1 Shifting attributes of engineering graduates (based on Kamp, 2014)

| Current MSc graduate profile | Shifting needs |
|---|---|
| Mono-disciplinary thinking | Multi- and interdisciplinary thinking |
| Reductionism | Integration |
| Convergent thinking | Creativity (divergent – convergent) |
| Independence | Collaboration |
| Techno-scientific base | Socio-economic context |
| Understanding certainty | Handling ambiguity and failure |
| Rounded expert | Employability, lifelong learning |
| Rational problem solving | Complex problem solving |

The landscape of the challenges in society, technology and engineering and the research topics in the National Scientific Agenda (NWA) of the Dutch government differs dramatically from the past because of the many deep interconnections. Solving these challenges requires innovative solutions that balance technological innovation, economic competitiveness, environmental protection and social flourishing. Today's problems are already of such complexity that they can no longer be solved in siloed engineering disciplines. Solutions ask for multi- and interdisciplinary approaches where specialised knowledge of several disciplines in engineering and humanities and social sciences are integrated into relevant solutions supported by technological advances (Kamp, 2014). But the reality is that many engineering programmes have marginally changed over the past 30 to 40 years. Whilst recruiters in engineering business emphasise that the arguments why they offer a person a job and create opportunities for successful careers is only marginally tied to knowledge, and which will even be more so in the future. More elusive factors like ambition, creativity, patience, perseverance, international orientation, organisational sensitivity and social intelligence gain importance.

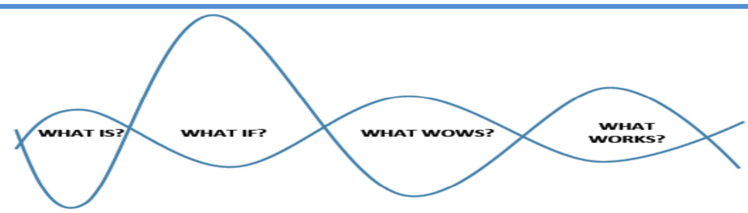
## METHOD

In spring 2015 a "Free Spirits" Think Tank has been set up as a joint initiative of the Dutch 3TU.Centre for Engineering Education and TU Delft's Directors of Education. Its aim was to look ahead to the year 2030 and revaluate what students' capacities should be, without losing their current core strengths. In five dedicated workshops with in total 12 full, associate and assistant professors, senior lecturers, programme directors, members of the valorisation centre and student bodies from all disciplines of the institution, the Think Tank challenged the following key questions:

- What type of students does TU Delft want to educate?
- What are the major changes our students will face in 2030?
- What is the added value TU Delft can deliver in terms of educational content?
- Which learning processes help to sustain preparation of the future engineer?

The Think Tank explored these questions via the method of Design Thinking, known for its effective creation of out-of-the-box solutions for new ways of working. The method is known to be effective to address complex, human centred problems with many unknowns and little objective data (Jeanne Liedtka, 2010). The Think Tank explored current trends in engineering and society, established the greatest needs in engineering capabilities, developed ideas based on possible future worlds and built concepts that addressed the "What" question. The workshops were supported by survey data on trends in science, numerous small informal workshops, ad-hoc student interviews on the campus pavements, and a "Free Spirits" Facebook page on which progress was shared with the academic community of TU Delft.

Figure 1 gives an overview of the activity flow. The steps throughout the process can be viewed in detail at https://www.youtube.com/channel/UCO3lrxZICd5ID6TmN481DFA/videos.




**Critical Questioning**
**Journey Map**
**Insight questions**
**Dillema's/ SWOT**
**Survey response on scientific trends**
**Design Challenge**
**Mind Maps**

**Building World Scenarios**
**Profiles and added value**
**Pockets of knowledge**
**lego exploration**

**Profiles**
**Hubs**
**Languages**

**Pilot testing**
**Validating stakeholders**
**Policy discussions**

**What is:** Exploring present trends and innovations in engineering education, defining the problems and reframing the questions.
**What if:** Generating new concepts for on campus Engineering Education
**What Wows:** Identifying the best opportunity
**What Works/Manifests**: Define rapid prototyping options/Create a Manifest- Results of previous sessions and the way it will be disseminated

Figure 1 The Design Thinking flow with activities followed by the "Free Spirits" Think Tank

## REFRAMING THE PROBLEM

One of the first activities of the Think Tank was to make a SWOT (Strengths-Weaknesses-Opportunities-Threats) analyses. It created the boundary conditions for whatever it might be we would create as a solution to the Why and What questions, as proposed at the start of the Think Tank initiative.

### *Type of students we want to educate*

Career deliberation should start at the very beginning of higher engineering education, at admission and during the Bachelor's study programme. We, the institution, should be looking for motivated students who can deal with freedom of choice, are able to excel in key scientific areas, are focused on personal development, are able to create multiple perspectives towards subject matter, take initiatives and are self-regulatory in behaviour (engagement of students with the learning environment). Our students have a talent for realising change, having plenty analytic and creative skills. They are not afraid of getting a taste and test of success and failure to become resilient in the face of obstacles.

### *Learning path in our engineering programmes*

To facilitate the students we may need a differentiation in learning paths towards the acquisition of knowledge, skills and attitudes that intrinsically motivate students. Play, passion and purpose in education should be the key values to create education based on exciting real-life cases, wherever possible embedded in (global) societal and engineering challenges (CDIO Standards 1, 3 and 7). Authentic cases, projects and research which allow for failure and experimentation; collaborative learning and plenty of links to the outside world are leading in learning. Recent initiatives in Delft such as the building of the Holland Particle Therapy Centre in collaboration with Dutch medical centres, the Smart Industry Digital Factory Composites Fieldlab in collaboration with knowledge institutions, government and industries, the YES!Delft High-tech Incubator centre, and an Open Innovation Centre on or nearby the campus have to be stimulated. They will create the visionaries we need and allows for building up early relations with the professional market in engineering business. TU Delft has numerous of small and larger scale initiatives that create strong bridges between research, education and industry.

### *Main strengths of TU Delft*

The strong points of TU Delft are its (mono)disciplinary engineering programmes, with emphasis on application and creative workable solutions for the societal and engineering problems. Future innovations are especially expected at the fringes of mono-disciplines. If we are to stand out in the world, a stronger student preparation for innovation should make the institution more future-proof. It will be a stimulus to work with foreign partners, increase contacts with external regional partners, and create involvement and collaboration between truly diverse bodies of expertise in education. The students and specialists, educated or developed in disciplinary fields of expertise, should then be trained in multi- and interdisciplinary collaborative projects, in networks with extensive and diverse research and industrial platforms.

## THE DESIGN CHALLENGE

A design challenge is always based on what is presently needed and holds promise for the future. It is framed in a How question, yet leads to Why and What answers as intended. The design challenges, reframed from the original Think Tank questions and the SWOT analysis were:

- How to create an engineering educational programme in which personal development plays a key role, and is acceptable to accreditation bodies?
- How to create more specific profiles and programmes that will be recognised as coherent tracks?
- How to create purposeful profiles or programmes with added value to the future society?

## IDEATION

After the above framework for the design challenge was established, the Think Tank went on to explore possible future worlds, based on realistic trends in science and engineering (Figure 2), the so-called pockets of knowledge. A number of hypothetical extreme scenarios were “invented” for combinations of these future worlds (such as a world of Scarcity of Resources combined with Big Data – Smart Data, or a world of Design beyond Nature combined with Robotisation). Then backward engineering was conducted to unravel the capabilities and knowledge the future engineer in such extreme world scenarios would need to create a life and create added value to that world. The future engineers in these different hypothetical worlds could not be cast into one image and thus a number of different engineering profiles were established.

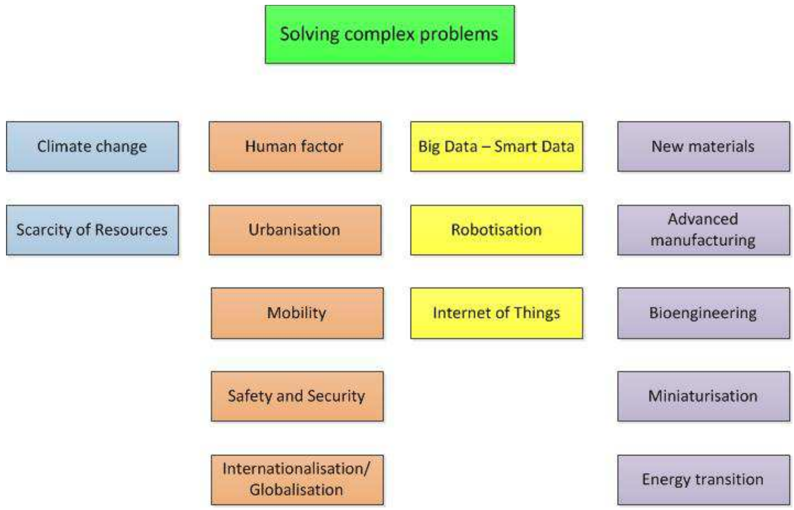



Figure 2 Megatrends in society and engineering

With these profiles the Think Tank went back to the design criteria: flexibility for personal development, keeping purposeful and specific profiles that are meaningful to the institution, society and industry. Nowadays' educational programmes are traditionally shaped in disciplinary curricula. The future requires flexible and resilient engineers, with profiles that differentiate beyond knowledge alone, and beyond engineering, science and design. Profiles that are linked to different roles one may have to play as an engineer in future society, irrespective of it being in academia, governmental organisations, industry, or as an entrepreneur. The flexibility has to enable students to become the engineering professional, i.e. operative industrial engineer, researcher, designer they want to be. Rigidly structured disciplinary curricula will no longer fit to an engineering programme. The engineering curricula will need another dimension that links the disciplinary content to the role(s) a graduate may play in his future job as an academic researcher, a professional engineer, an entrepreneurial innovator, or any other professional job. Also in future, the students in engineering programmes will remain to build a solid level of fundamental knowledge and skills in a disciplinary domain, as one cannot contribute without a broad and deep working knowledge base in one or two particular domains. Yet, within their disciplinary domain they will differentiate, learning one or more specific engineering profiles.

## THE RESULT THAT WOWS; A TRIPARTITE CONCEPT

Three idea's emerged from the Think Tank:

1. Profiles, denominating engineering roles in particular contexts that may provide opportunity for specialisation.
2. Hubs in which interdisciplinary learning takes place in an engineering or research environment that focuses on a specific pocket of knowledge.
3. Common engineering languages that are essential for communication across disciplinary boundaries and allow for problem definition, analysis, conceptualisation, visualisation (Goldberg, 2008). These ideas are elaborated upon below:

***Profiles (1)***

The Think Tank ideation about future worlds yielded four profiles: the Specialist, the System Integrator, the Front-end Innovator and the Contextual Engineer. They partly overlap the professional engineering career tracks that are implicitly identified in Figure 3.6 of the CDIO Syllabus (Crawly, Malmqvist, 2007). A complete description is available in the Appendix or digitally available from http://issuu.com/danielleceulemans2/docs/future_proof_profiles_digital.

These types of engineers tend to play a different role in projects and work environments, as they start with a different heuristic question:

- Specialist: How can we advance and optimize technology for innovations and better performance using scientific knowledge?
- System Integrator: How can we bring together disciplines, products or subsystems into a functioning whole that meets the needs of the customer?
- Front-end Innovator: How can we advance and apply knowledge and use technology to develop new products for the benefit of people?
- Contextual Engineer: How can we exploit diversity-in-thought to advance and apply knowledge and use technology in different realms to develop products and processes for the benefit of people in different cultures and context?

Each profile cannot realise a technological solution without the other and is needed to realise integrated solutions for complex problems.

*SPECIALIST - R&D for innovation in science and industry*

The role of the Specialist is advancing knowledge in fundamental science, design or engineering research fields or R&D. In industries specialists support innovation and the development of complex systems, products or services with their state-of-the-art expertise. When embarking on an academic career, most scientific staff members develop into disciplinary specialists. In the industrial environment, specialists collaborate with non-specialists with many different disciplinary backgrounds. They need a more holistic engineering mind-set to understand the impact of the interfacing levels and innovate at the fringes of their specialism. Also for a specialist, engineering is not only about mastering a fixed and known body of deep knowledge, but is about the integration of that knowledge into system and product development. The future viable profile for the specialist is therefore oriented towards a specialist with a broader orientation, a T-shaped specialist in a certain branch of engineering. The prime idea is that specialists are educated within the disciplinary department or faculty, while a broadening of their skills can be trained and practiced in multidisciplinary projects such as the Big Data or Scarcity-of-Resources type of Hubs at interfaculty level that will be discussed later.

*SYSTEM INTEGRATOR – Connector*

System Integrators are system oriented. They have a helicopter view of a wide scope of technological fields and work from the system level back to components. They collaborate in a team of T-shaped specialists, engineers and managers and are therefore socially skilled and aware of ethical aspects in engineering. To design systems or processes that can perform as components of large-scale complex enterprises, future System Integrators must have learnt to look beyond the technical system, and consider the characteristic of the enterprise in which the system will operate and the context in which the system is developed. System Integrators will transform from the architect who guides engineering projects for clients from concept toward strategic goals, to a leader who is capable of balancing his technological skills with the demands of restricted budgets, regulatory frameworks, collaboration complexity, public safety impact and public understanding. The major idea is that T-shaped System Integrators are educated within the disciplinary department or faculty, and that their disciplinary broadening and development of interdisciplinary and interpersonal skills will take place in multidisciplinary projects that will be produced in interfaculty Hubs.

*FRONT-END INNOVATOR*

Front-end Innovators are entrepreneurial design engineers with a broad education in engineering and socio-economic factors. They are customer oriented and focus on trends in engineering and the world. They have learnt to work in horizontal flat organisations and work in small teams of T-shaped Specialists, System Integrators, design engineers, business managers, customers and end-users. They are capable solving complex adaptive problems and feel comfortable to follow agile methodologies with cross-functional team work, rapid iterations, rapid prototyping, continuous user involvement.

Students who enrol in this profile are independent participants with an entrepreneurial attitude. They have a good understanding of the engineering context and an awareness of the user and client environment. They have good social and empathetic listening skills to talk with a wide variety of people, including specialists and customers or end-users. They have to be creative enough to translate market needs to technological innovation. Their education emphasises the engineering domain, and addresses the interdisciplinary context that will be available in the interfaculty Hubs. The innovation and business component may be inserted into the Hubs by involving students in humanities or social sciences.

*CONTEXTUAL ENGINEER*

The National Academy of Engineering (NAE) envisions the workplace of the near future as one of dynamic technological change that requires engineers to understand complex societal, cultural, global, and professional contexts. Multinational companies and their development teams make use of the diversity in cultures and socio-economic environments for the benefit of technological innovation, product design and engineering business. Teams of different cultures, with different perceptions of ethical responsibility and risk, collaborate for customer-centred innovations.

By 2030 multinationals from emerging countries might own enterprises with a Western origin, and vice versa. The investors, president and leaders import their beliefs, norms and values and habits into the enterprise culture and expect their employees not only to respect but also behave accordingly and exploit the differences in cultures and socio-economic environments for the benefit of technological innovation, product design and business. Strong intercultural communication and collaboration skills and attitudes will be necessary to be successful in these enterprises. Employees have to be open-minded to learn how to operate in such different realms, not only technical but also cultural. This is where the Contextual Engineer profile comes in. These engineers require much more contextual knowledge to work effectively with other cultures and get things done and influence strategic decisions.

Contextual Engineers are technically adept and understand the contextual constraints and consequences from discipline, policy, judicial and ethical perspective. They are a leader in realising technological innovations in political contexts. They have a helicopter view, are open minded, work in interdisciplinary settings, are agile and patient but are always focused on results. They understand how differences in disciplinary backgrounds, cultures and socio-economic environments can be an enrichment.

***Pocket of Knowledge becomes a Hub (2)***

Students will spend part of their study in a Hub, in which they collaborate in multidisciplinary teams on engineering and societal challenges together with industrial business partners and customers (CDIO Standard 7). A Hub is a physical location on campus that is flexibly organised around (families of) high-tech innovative “hot topics” like “Driverless cars”, “Developing a 5-million inhabitant city from scratch”, “Energy transition”, “Advanced manufacturing”. It is a flexible engineering research and learning space in which expertise from different disciplines (engineering, humanities, social sciences) and different stakeholders from within and outside the university is bundled, based on the pocket of knowledge to create immediate scientific and educational synergy.

A Hub may be provided by already existing initiatives like the interdisciplinary Delft Infrastructures & Mobility Initiative, the TU Delft Space Institute or the Sports Engineering Institute, or be instigated by one or more faculties around a hot topic that is relevant and of common interest, interdisciplinary and challenging for research, technology development and innovation at the intersections of disciplinary knowledge, across the faculty boundaries. For educational purposes the complex societal and research problems will have to be reframed into engineering cases for authentic interdisciplinary learning.

The specific approach in a Hub depends on the problem definition, complexity and problem solving derived from the available expertise and engineering discipline, the level of the students. In the Bachelor programme the students may explore the different profiles, orientate and discover their personal strengths in “Foundry Hubs” by adopting a profile and solving real-life problems in interdisciplinary and intercultural teams while building onto fundamental engineering knowledge they have attained in their disciplinary fields. In the Master’s the students will no longer only specialise in their field of expertise but also develop a profile of their choice. Probably the role of Specialist can still be developed at the faculties, as usual. The role of System Integrator, Frond-end Innovator and Contextual Engineer will be developed by partaking in design and research projects in Hubs.

***Languages (3)***

All students, irrespective of their engineering discipline, need to be master a set of universal engineering languages to meet the needs of the future working context. In the end it is these professional skills that make the difference of being well prepared for the job market of the future.

- Mathematics
- Digital literacy (data analytics, programming)
- Design skills
- Academic communication
- Engineering ethics.
- Collaborative and interdisciplinary teamwork

The idea is that Bachelor students have to master these languages at graduation to a basic level, so that each engineering student of whatever engineering discipline will understand another engineering student and is able to work effectively in multiple collaborative contexts, as he or she will be required to do in future professional life.

## OPTIONS FOR IMPLEMENTATION

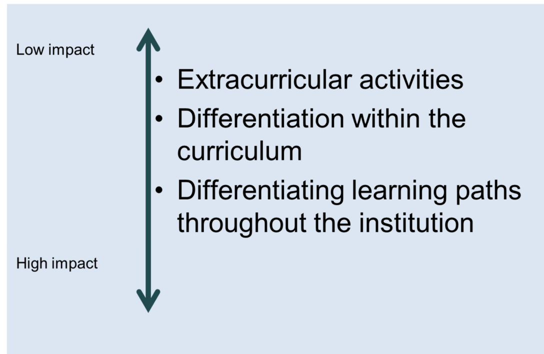



Figure 3 How to get there?

In final interview sessions we discussed options for implementation (Figure 3). Low impact options are extracurricular projects in which students work on their profiles in a Hub-type project organisation linked to already existing research institutes, living labs or other existing structures. Such option is low cost and allows for prototyping, testing and validating the conceptual philosophy. A more permanent solution would be to free up space in the Bachelor curricula for projects linked to the profiles that are complemented by obligatory courses or trainings in the "common engineering language" skills. In the Master's larger sized projects coupled to engineering or research institutes, such as the TU Delft Sports Engineering Institute, Space Institute or the research-based initiatives in health, energy, globalization and infrastructures & mobility could be aimed for, which would be complementary to the thesis in the final year of the disciplinary Master's, where the common engineering languages could be practiced and further developed.

Another possibility would be to create (for credit) verticals within a disciplinary faculty on cross-disciplinary themes. Verticals are teams of scientific professionals – full professors, associate and assistant professors, PhD students and talented Master students – working in a horizontal working relationship on particular societal and technological problems. The vertical is embedded in the curriculum for the entire study period. Students participate for credit on a theme or subject of their choice. The profiles are embedded and an interaction with industry is essential. The project may be shaped as a sort of apprenticeship with a narrow focus.

The highest impact option would be to label the courses of the study programme based on profiles and disciplines, allowing the students to develop a flexible learning path, while guided by a coach. The students would then obtain a truly personalised profile with a high level of intrinsic motivation.

## THE WAY FORWARD

The results of the Free Spirits Think Tank are a start, based on an innovation initiative for the vision of TU Delft's engineering education. The process has revealed available engineering projects and initiatives at TU Delft with structures available for experimentation with the Think Tank concepts. Some of the concepts will be prototyped and tested within existing extracurricular initiatives. Additionally the ideas and prototype outcomes will be validated amongst industrial and entrepreneurial stakeholders of multinationals in engineering like the Airbus Group, small and medium-sized enterprises (SMEs), engineering and consultancy business and young entrepreneurs. A policy working group has started to develop TU Delft's future vision on engineering education, among others on the basis of the outcome of the Think Tank, which will be followed by an implementation strategy from 2017 onwards.

## CONCLUSION

TU Delft wants to educate intrinsically motivated students, who excel in their key discipline yet go beyond their studies and their discipline and are self regulatory in behaviour, taking initiative, open to multiple perspectives, sociable and open to experimentation. The Think Tank expects that our students in 2030 will face many changes. They will be challenged during their studies to go out in the world and bring back the problems to education that need to be solved. Not while they have rounded off their education, but during their education, as integrated learning experiences.

The added value of research universities like TU Delft remains the thorough foundation in engineering basics. More than nowadays, individual or monodisciplinary projects and courses on specialist subject matter will be complemented by flexible and diverse interdisciplinary research and engineering projects, in collaboration with third parties from industrial companies, research institutes and society. They offer a playing field for experimentation with the roles that can be played in areas at the front end of scientific advancement and innovation.

The learning process is one of passion (intrinsic motivation), peer (working collaboratively), purpose (contributing to the solution of societal challenges or on-the-edge research) and play (a culture of experimentation) to move forward the state-of-the-art knowledge as it is today towards unknown and horizons to be explored.

## ACKNOWLEDGEMENTS

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### *Biographical information*

Aldert Kamp the Director of Education for the Faculty of Aerospace Engineering at TU Delft, the Netherlands since 2007. He is deeply involved in the rethinking of engineering education at university level with a horizon of 2030, as a response to the rapidly changing world. More than 20 years of industrial experience in space systems engineering and 10 years of academic experience have given him the insight in the capabilities tomorrow's engineers need in the future world of work. Aldert has been involved in university-level education policy development, renovations of engineering curricula and audits of Dutch and international academic programmes. He is a member of the Council of the CDIO Initiative, the global innovative education framework for producing the next generation of engineers, and is TU Delft Leader of the Dutch 3TU Centre of Engineering Education (3TU.CEE) that will facilitate innovations in higher engineering educational programmes within and outside the Netherlands.

Renate Klaassen is an educational consultant, working at the TU Delft Educational Centre of expertise on Education “FOCUS”. She has been heavily involved in educational advising on the innovation of the BSc in Aerospace Engineering, and various other curriculum reforms at TU Delft. She is TU Delft Coordinator of the Dutch 3TU.CEE. Other consultancy activities include assessment (policy, quality and professionalization), internationalisation of university education and design education. Area of research interest pertain to content, language integrated learning in higher education, English language proficiency and coaching in design education.

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**APPENDIX: FUTURE-PROOF PROFILES 2030**

# Specialist

## Role in field of work

In industries the specialist supports innovation and development of complex systems, products or services with its experts knowledge. It is even more important that the specialist can collaborate in multidisciplinary teams with non-experts and people without an engineering background. The specialist visits international conferences to gain knowledge and to meet other experts from university or industry. During its professional career the specialist becomes an expert in its field.

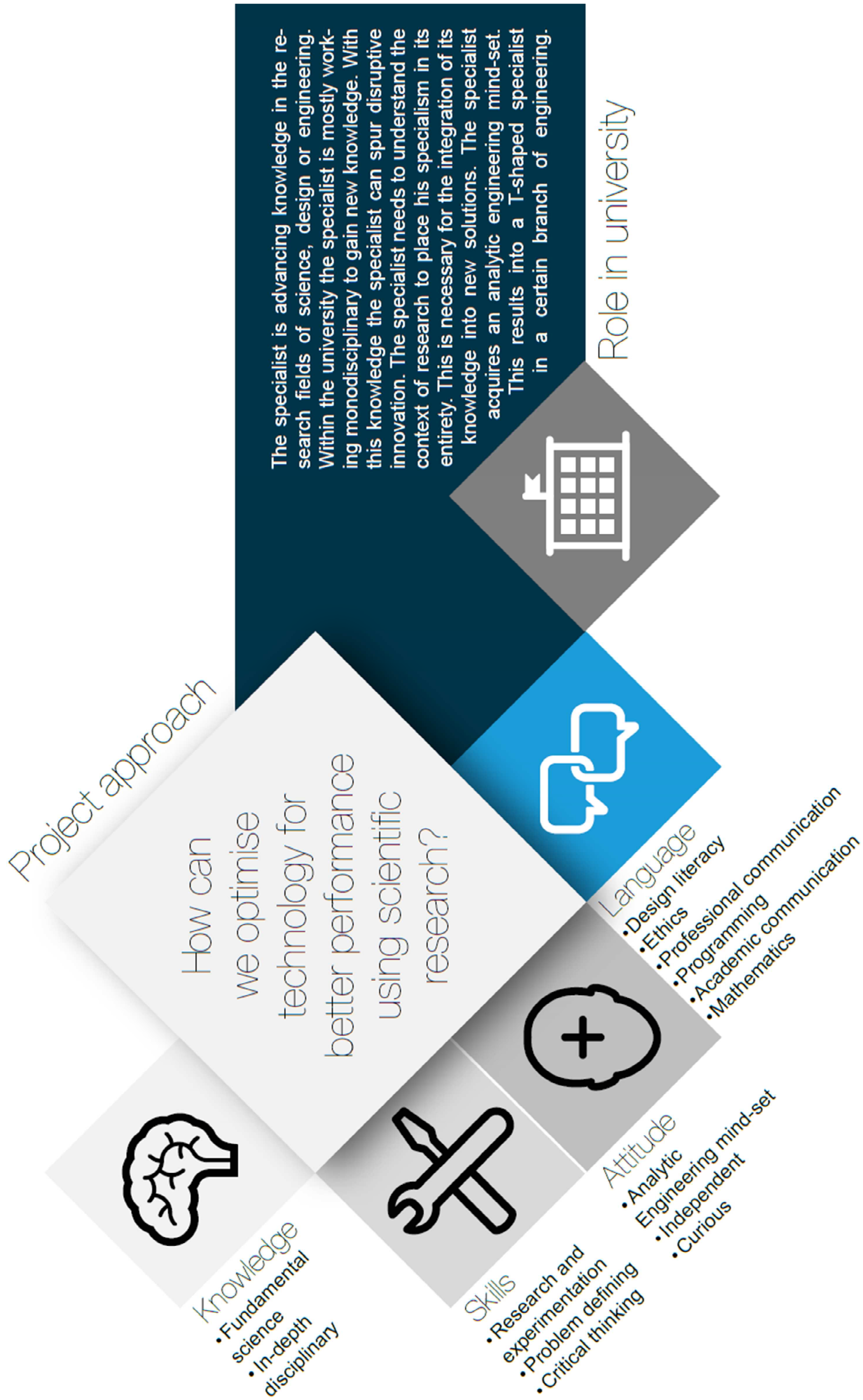
## Goals and believes

My goal is to become an expert in my field and use and share my knowledge in science and industry. I believe I can change the world with incremental innovation.

## Pain and frustration

I think it is difficult when there is a language gap with non-experts. I have less experience in business or entrepreneurship and I think it is hard to make compromises with the system integrators or other specialists of different disciplines.

TUDelft



The specialist is advancing knowledge in the research fields of science, design or engineering. Within the university the specialist is mostly working monodisciplinary to gain new knowledge. With this knowledge the specialist can spur disruptive innovation. The specialist needs to understand the context of research to place his specialism in its entirety. This is necessary for the integration of its knowledge into new solutions. The specialist acquires an analytic engineering mind-set. This results into a T-shaped specialist in a certain branch of engineering.
Role in university
Project approach
How can we optimise technology for better performance using scientific research?
Language
•Design literacy
•Ethics
•Professional communication
•Programming
•Academic communication
•Mathematics
Attitude
•Analytic Engineering mind-set
•Independent
•Curious
Skills
•Research and experimentation
•Problem defining
•Critical thinking
Knowledge
•Fundamental science
•In-depth disciplinary

# System integrator

## Role in field of work

The system integrator collaborates in interdisciplinary teams with different departments, clients and stakeholders. For solid communication the system integrator needs to understand the management team and the specialists. System integrators develop end-to-end solutions from technical to business level. They also focus on schedule constrains, cost savings and risk reduction. The system integrator is employed at a company that works on close to the market products or services. They coordinate test runs to make sure the integrated system works perfectly prior to implementation.

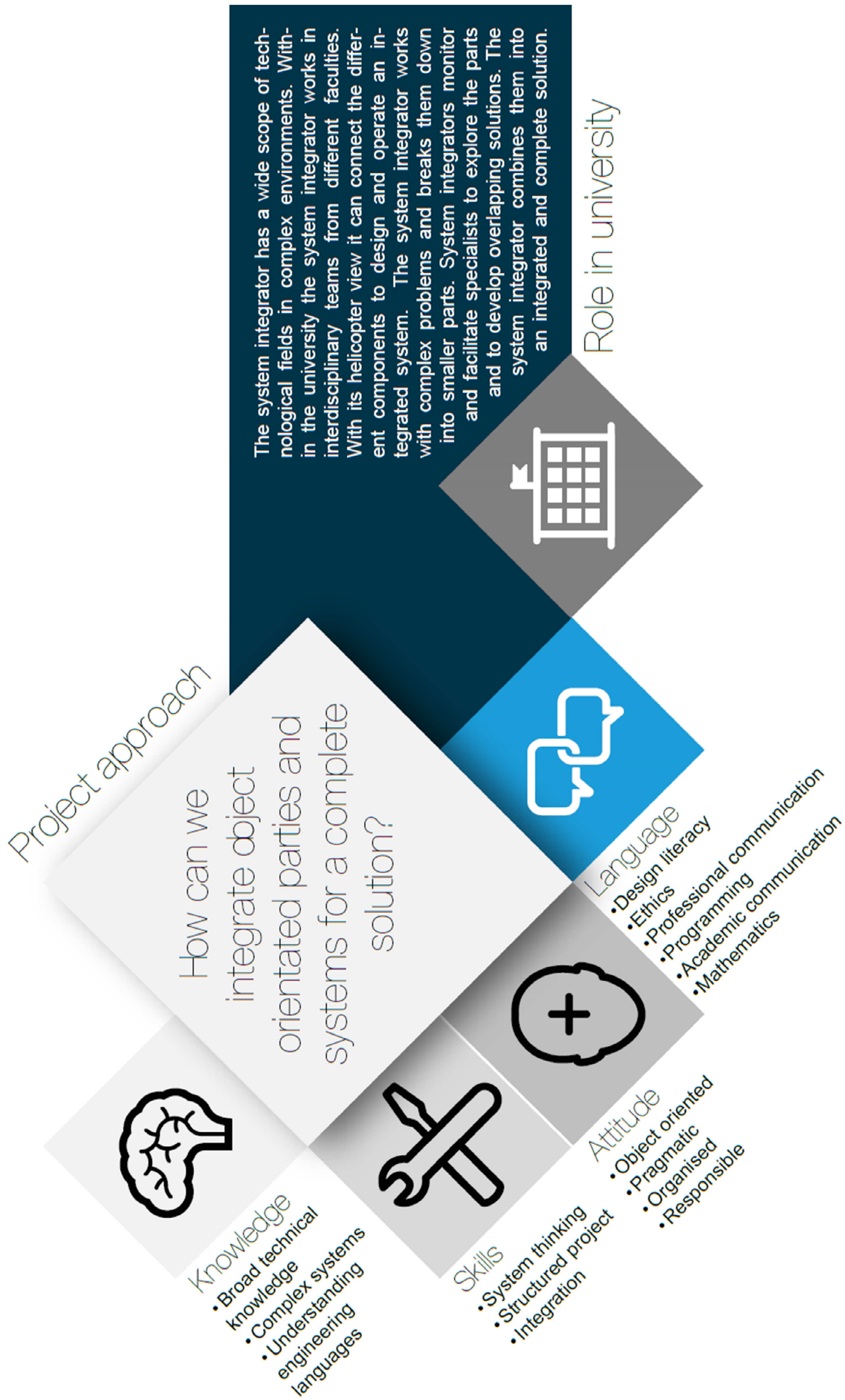
## Goals and believes

My goal is to develop complete and integrated solutions that meet the needs of the customer. I like to work efficient and with fewer errors for a proper implementation.

## Pain and frustration

I think it is very frustrating if the specialists in my team cannot think systematically and not see their project in its entirety. If they cannot look beyond their horizon it is hard to create a solid and reliable integrated system.

TUDelft



Project approach
How can we integrate object orientated parties and systems for a complete solution?
The system integrator has a wide scope of technological fields in complex environments. Within the university the system integrator works in interdisciplinary teams from different faculties. With its helicopter view it can connect the different components to design and operate an integrated system. The system integrator works with complex problems and breaks them down into smaller parts. System integrators monitor and facilitate specialists to explore the parts and to develop overlapping solutions. The system integrator combines them into an integrated and complete solution.
Role in university
Knowledge
•Broad technical knowledge
•Complex systems
•Understanding engineering languages
Skills
•System thinking
•Structured project
•Integration
Attitude
•Object oriented
•Pragmatic
•Organised
•Responsible
Language
•Design literacy
•Ethics
•Professional communication
•Programming
•Academic communication
•Mathematics

# Front-end innovator

## Role in field of work

The front end innovator works in different industries because their methods can be implemented in various complex problems. They focus on trends in engineering, society and industry to meet the market needs and even create new markets. The front end innovator develops concepts within transdisciplinary teams using user insights or co-creation to increase the chance of acceptance. Companies employ front end innovators as designers and entrepreneurs in open-innovation labs or start-ups to generate more innovations for the company.

## Goals and believes

My goal is to develop new solutions that meet the demands of the complex changing world. I believe that user-insights, rapid prototyping and open labs can help make the innovations become successful in performance and time.

## Pain and frustration

Intellectual property rights slow down my innovation process. On the contrary, without intellectual properties I think it is hard to make fast choices due to the rapid innovation of competitors.

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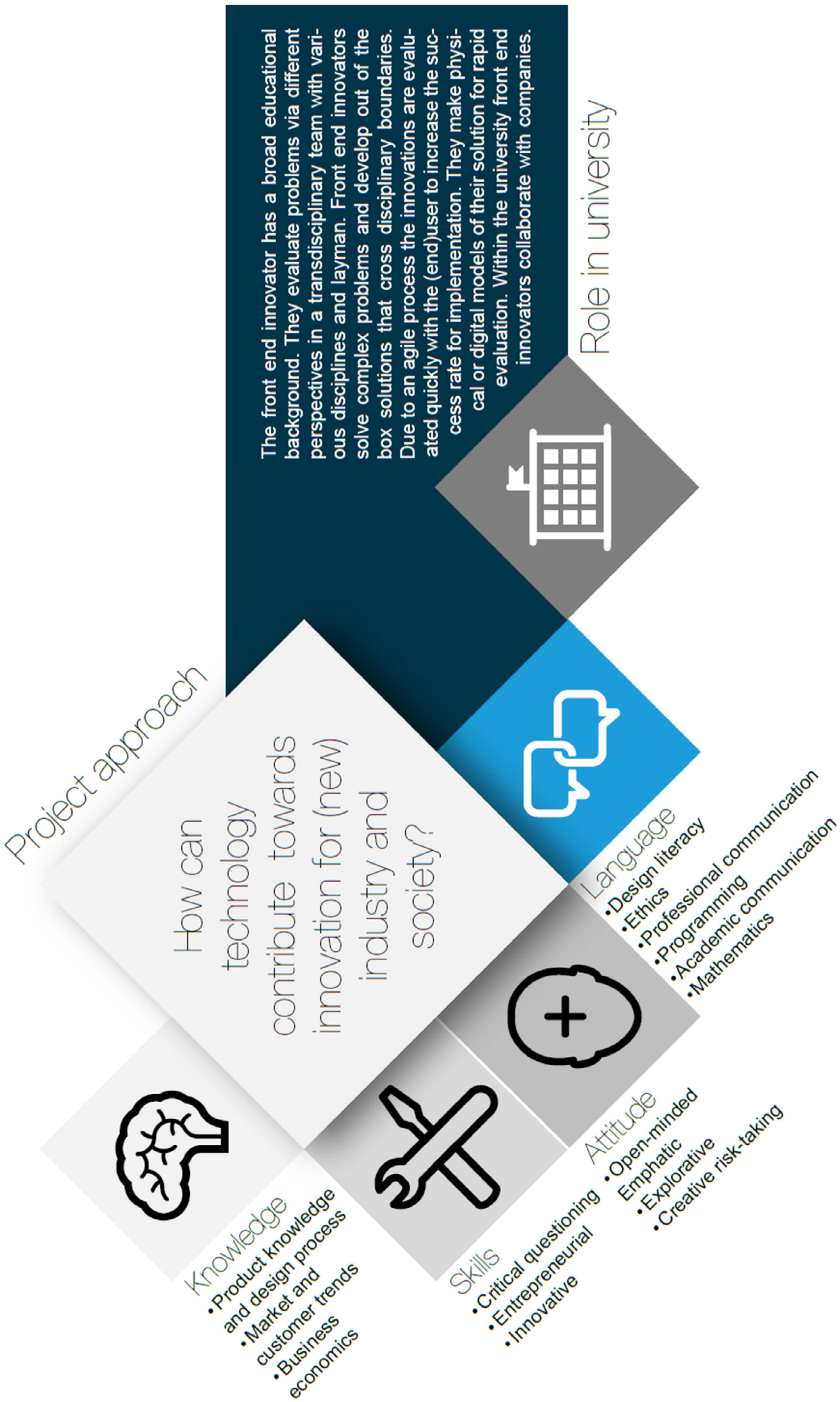
Role in university
The front end innovator has a broad educational background. They evaluate problems via different perspectives in a transdisciplinary team with various disciplines and layman. Front end innovators solve complex problems and develop out of the box solutions that cross disciplinary boundaries. Due to an agile process the innovations are evaluated quickly with the (end)user to increase the success rate for implementation. They make physical or digital models of their solution for rapid evaluation. Within the university front end innovators collaborate with companies.
Project approach
How can technology contribute towards innovation for (new) industry and society?
Language
•Design literacy
•Ethics
•Professional communication
•Programming
•Academic communication
•Mathematics
Attitude
•Open-minded
Emphatic
•Explorative
•Creative risk-taking
Skills
•Critical questioning
•Entrepreneurial
•Innovative
Knowledge
•Product knowledge and design process
•Market and customer trends
•Business economics

# Contextual engineer

## Role in field of work

The contextual engineer easily communicates and solves contextual problems with foreign and diverse colleagues. They develop solutions that are acceptable within the different realms of culture and environment. The contextual engineer is prepared to travel and explore international opportunities for the company. Being aware of the cultural, ethical and political elements they assure a successful implementation. They are also able to translate and adapt the company's current solutions for other environments and cultures that have similar problems.

## Goals and believes

It is my goal to make borders disappear and come to a whole solution that is in line with the context. I believe that the durability of innovations can be extended when the contextual constrains are taken into account.

## Pain and frustration

International differences in values, norms, beliefs and regulations limits extending the international success of the solution. This requires a lot of perseverance and maneuvering from me.

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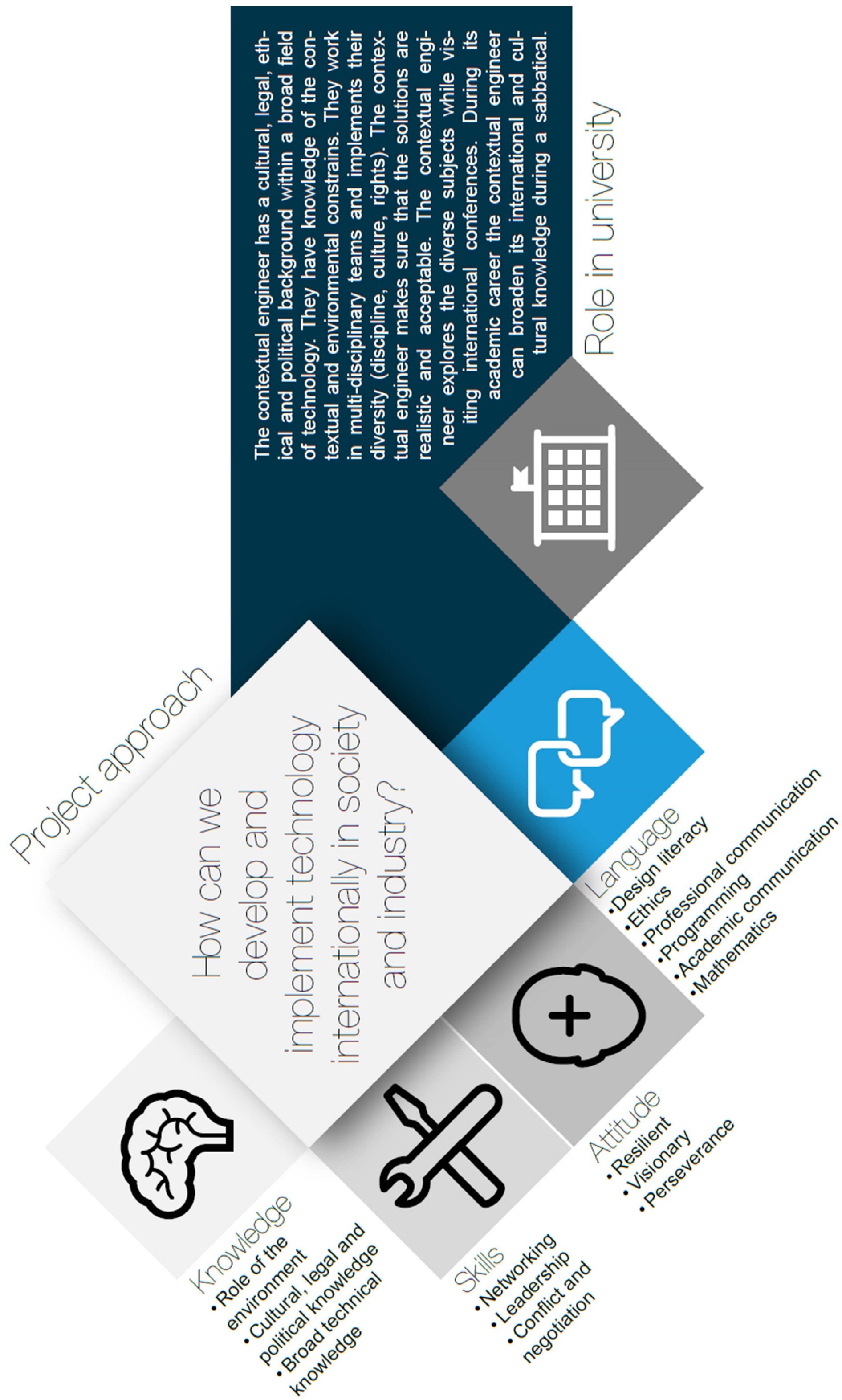
Role in university
The contextual engineer has a cultural, legal, ethical and political background within a broad field of technology. They have knowledge of the contextual and environmental constrains. They work in multi-disciplinary teams and implements their diversity (discipline, culture, rights). The contextual engineer makes sure that the solutions are realistic and acceptable. The contextual engineer explores the diverse subjects while visiting international conferences. During its academic career the contextual engineer can broaden its international and cultural knowledge during a sabbatical.
Project approach
How can we develop and implement technology internationally in society and industry?
Language
• Design literacy
• Ethics
• Professional communication
• Programming
• Academic communication
• Mathematics
Attitude
• Resilient
• Visionary
• Perseverance
Skills
• Networking
• Leadership
• Conflict and negotiation
Knowledge
• Role of the environment
• Cultural, legal and political knowledge
• Broad technical knowledge