

Collaborate with social and economic impact

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A portrait of Prof. dr. ir. arch. Isabelle Reymen, a woman with dark, curly hair, smiling. She is wearing a dark blue top and a silver necklace. The background is blurred, showing an indoor setting with warm lighting.

Prof.dr.ir.arch. Isabelle Reymen
October 4, 2019

INAUGURAL LECTURE

Collaborate with social and economic impact

TU/e

EINDHOVEN
UNIVERSITY OF
TECHNOLOGY

DEPARTMENT OF INDUSTRIAL ENGINEERING & INNOVATION SCIENCES

INAUGURAL LECTURE PROF.DR.IR.ARCH. ISABELLE REYMEN

Collaborate with social and economic impact

Presented on October 4, 2019
at Eindhoven University of Technology

Introduction

Right now, around 10% percent of the world's population lives on less than USD 1.90 a day.¹ Each year, more than five million children die before their fifth birthday, and over 265 million children are currently out of school.² This year, we learned that our climate is changing faster than expected. Today, we consume our natural resources at a faster rate than they are being replaced, and this consumption is increasing.³ The world needs action now! The United Nations has developed 17 Sustainable Development Goals⁴ to transform our world, such as achieving zero poverty, improving children's health and education, taking action against climate change and switching to responsible production and consumption. It's interesting to note that the seventeenth Development Goal is 'partnerships for the goals', and states: *"The Global Goals can only be met if we work together. International investments and support are needed to ensure innovative technological developments, fair trade and market access, especially for developing countries. To build a better world, we need to be supportive, empathetic, inventive, passionate and, above all, cooperative."*⁵ Collaborations between many diverse partners are thus key to solving our grand challenges and, in this way, creating social and economic impact.

Universities have a key role to play in solving these challenges in our society. They are *the* source of talent and technology. A modern university develops its strategies around three missions: education, research (added in the late nineteenth century) and, for about 20 years now, what is called the "third mission" (Etzkowitz & Leydesdorff, 2000). The precise interpretation and implementation of this third mission is still being debated, but consists of the contributions of the university to industry and society. In the Netherlands, the third mission is often called 'valorization'. The third mission becomes increasingly important in a knowledge society and requires the close collaboration of the university with public and private partners. I would summarize it as creating 'social and economic impact', see Figure 1. The strategy of Eindhoven University of Technology (TU/e) for 2030 (TU/e, 2018) is also formulated on the basis of these three missions.

¹ <https://www.worldbank.org/en/topic/poverty>

² <https://www.un.org/sustainabledevelopment/>

³ <https://www.conserve-energy-future.com/causes-effects-solutions-depletion-natural-resources.php>

⁴ <https://sustainabledevelopment.un.org/post2015/transformingourworld>

⁵ idem

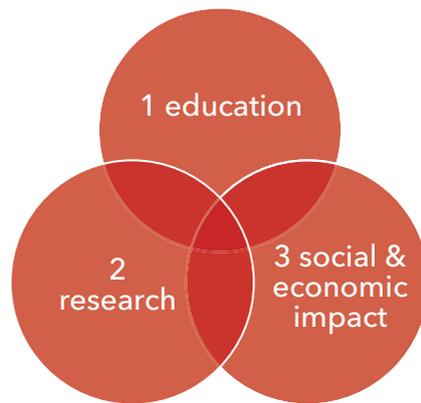


Figure 1. The three missions of a university.

TU/e performs educational and research activities and aims for social and economic impact. As an academic at this university, I perform educational and research activities, and I also explicitly aim for social and economic impact. In general, my educational activities focus on connecting education with practice and supporting students in creating impact. The topic of my research is innovation processes. More specifically, I study how we can create social and economic impact through scientific and technological results by supporting collaborations between many diverse public and private partners. For a visualization, see Figure 2.

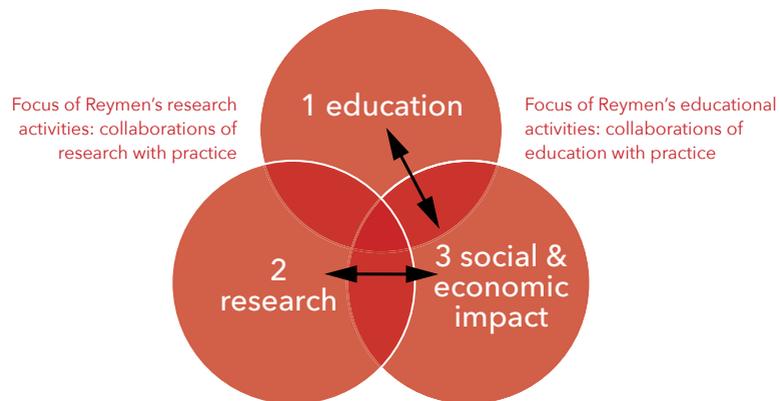


Figure 2. Focus of my educational and research activities

My *educational activities* focus on establishing collaborations between the world of education and many diverse parties in practice, including companies, governmental organizations and the public. These collaborations are needed in order to develop engineers of the future who can solve the grand challenges and create social and economic impact. TU/e is innovating its education through the implementation of a new form of learning: Challenge-Based Learning. Experiments with Challenge-Based Learning are currently taking place at TU/e innovation Space⁶, of which I have the honor of being the Scientific Director. At TU/e innovation Space, we've created an environment that encourages, stimulates and facilitates students to work hands-on and in interdisciplinary teams on societal challenges that really matter. This takes place on the basis of their intrinsic motivation. You are all invited to get to know TU/e innovation Space.

My *research activities* focus on innovation processes that support collaborations between various parties on the creation of true social and economic impact through scientific and technological results. Research into new technologies often forms the basis for innovative solutions to the grand challenges. At TU/e, we have claimed for many years to be the place "where innovation starts." We perform research that contributes to the technological development of new products, services and systems. At the Department of Industrial Engineering and Innovation Sciences, and more specifically in the Innovation, Technology Entrepreneurship and Marketing (ITEM) group, we focus on the management of innovation processes. My chair in this group is called Design of Innovation Ecosystems. To ensure that the results of my research also contribute to social and economic impacts, a design science research approach is being further developed within the research group. Through this approach, practice is studied and solutions for that practice are also designed.

In summary, I focus (on the one hand) on innovating in education by increasing the collaborations between education and many parties in practice and (on the other hand) on innovation processes that support collaborations between various parties in order to create true social and economic impacts through scientific and technological results. Both topics will be discussed in this inaugural lecture. I will start with education, as this is the primary mission of the university.

⁶ www.tueinnovationspace.nl

Education: collaborate with social and economic impact

My educational activities focus on connecting education and practice and supporting students in order to create impact. First, I will give a brief overview of global trends in (engineering) education, showing *why* education needs to change and the key position of TU/e herein. Next, I will offer insights into *how* I believe that education can be changed using examples from my own teaching. I will end with *what* we do at TU/e innovation Space when it comes to innovating education in order to create engineers of the future who are able to collaborate with social and economic impact.

WHY?

Reports⁷⁸ indicate that “profound change is imminent in the *education sector*.” They mention that global forces are impacting the university sector: “the rise of continuous learning, the changing world of work, blurring industry boundaries, evolving digital behavior and increasing international competition.”⁹ This has already been mentioned at this university in relation to the TU/expedition 2030, but for me it’s very important to make everyone working in this sector aware of this change! This is the moment for education to enter the twenty-first century. We need to step up and accelerate innovations in education.

More specifically, the *engineering education sector* is also entering a period of rapid and fundamental change.¹⁰ Graham indicates that the distinctive educational features of a new generation of engineering programs include “work-based learning, multidisciplinary programs and a dual emphasis on engineering design and student self-reflection.” In her study, she reports several trends, including “a move towards socially-relevant and outward-facing engineering curricula.”

⁷ https://assets.ey.com/content/dam/ey-sites/ey-com/en_au/topics/government-and-public-sector/ey-university-of-the-future-2030.pdf

⁸ <http://ficci.in/publication.asp?spid=23043> University of the Future: bringing Education 4.0 to life

⁹ https://assets.ey.com/content/dam/ey-sites/ey-com/en_au/topics/government-and-public-sector/ey-university-of-the-future-2030.pdf

¹⁰ http://neet.mit.edu/wp-content/uploads/2018/03/MIT_NEET_GlobalStateEngineeringEducation2018.pdf

Such curricula emphasize “student choice, multidisciplinary learning and societal impact, coupled with a breadth of student experience outside the classroom, outside traditional engineering disciplines and across the world.” Another trend is “to deliver student-centered learning to large student cohorts through a blend of off-campus personalized online learning and on-campus hands-on experiential learning.”¹¹

Our university is ranked worldwide number one when it comes to collaborating with industry on research.¹² This position is mainly the result of collaborations within the innovation ecosystem of Brainport Eindhoven.¹³ This university therefore needs to experiment with innovations in engineering education and improve collaborating with industry on education as well. Since 2012, TU/e has made an impressive educational transition, with a forward-thinking perspective on engineering education through (for example) the implementation of the Bachelor College. TU/e students are stimulated to take more responsibility for their learning, and professional skills have been given more importance within the curriculum. Profession-based education, active learning, cooperation and creativity are well-established characteristics of Design-Based Learning, the hands-on approach to education at TU/e.¹⁴ According to Ruth Graham, who evaluated the impact of the Bachelor College reform, “compared to the majority of educational changes made in engineering across the world, the Bachelor College is a genuine, curriculum-wide, systemic reform affecting every course, student and teacher. In this context, what has been achieved by the Bachelor College reform is very impressive.”¹⁵ The next big step is Challenge-Based Learning, with more of a focus on interdisciplinary education and the integration of theory and practice in order to educate engineers of the future: engineers who can combine in-depth knowledge with the skills to collaborate in diverse teams.

¹¹ http://neet.mit.edu/wp-content/uploads/2018/03/MIT_NEET_GlobalStateEngineeringEducation2018.pdf

¹² <https://www.leidenranking.com/ranking/2019/list> World’s number one university on collaboration with industry, among universities with a high publication output, measured via the number and proportion of a university’s publications that have been co-authored with one or more industrial organizations.

¹³ <https://brainporteindhoven.com/>

¹⁴ Concept Report ‘TU/e innovation Space: Design in progress’, December 2017

¹⁵ <https://www.rhgraham.org/page-2/tu-e/> Impact evaluation of the Bachelor College curriculum reform

HOW?

In my educational activities, I try to learn and innovate together with staff, students, industry and society. By combining the following guidelines, we are creating a unique position for ourselves in the engineering education sector.

a. Offer open-ended challenges from practice to all engineering students, to be worked on in interdisciplinary teams

I believe that we need to offer students challenges which they are passionate about and that encourage them to learn on the basis of intrinsic motivation. New generations of students are highly motivated by working on real-life challenges and contributing to important goals, i.e. having an impact on the outside world. Solving the grand challenges requires processes that are increasingly complex, dynamic and open-ended. The complexity of these challenges means that they must be solved in interdisciplinary teams that interact with businesses and societal organizations. As no answer can be known in advance when it comes to solving open-ended challenges, teachers learn alongside students, thereby shifting attention from teaching to learning and from directing to coaching. Students can then determine their needs for themselves (self-directed learning).

As long ago as 2007, I set up a new design course in the School of Industrial Engineering, in which students worked with companies on open-ended assignments. A project course without lectures but with peer and teacher coaching and personal and team reflection followed in 2014. In 2018, I incorporated these experiences at TU/e-level through the new Master's course Innovation Space Project, in which students from different programs work on challenges in interdisciplinary teams.

One of these challenges is agri-food, as the world's population is growing much faster than our food production. With current production methods, we might not be able to produce enough calories to feed the world's population in ten years.¹⁶ Here is an excerpt of the challenge offered last semester:

"Instead of using monocropping (fields of one type of crop), Herenboeren¹⁷ works with intercropping (strips with different crops close together so they can help to protect each other from diseases and pests) or even multicropping (different crops, completely mixed) without machines or with only light machines. Herenboeren needs different technologies (machines

and small robots that can recognize different crops and handle them differently) from the existing machines that were developed for largescale monocropping. What would be the feasible first steps for introducing such small robots? What could a roadmap be for further development alongside technology partners?"

At the beginning of the course, the challenge owner (in this case, Herenboeren) pitched their challenge, the students gave their preference for a specific challenge (out of eight different challenges) and were matched to the available challenges in interdisciplinary teams. During the project, the students collaborated with many different parties. By the end of the semester, they had pitched their solutions to the challenge owner and general public.

An example of an extreme open-ended challenge I offer in my Master's course comes from the Netherlands Space Office. It asks for the development of "an application combining satellite data with possible other big data inputs, addressing a specific social or business problem." This challenge has twice resulted in a start-up: Callisto in 2018 and SpaceSea¹⁸ in 2019. In such a setting, students are not only challenged but also learn a lot: how to deal with many uncertainties, manage a team, deal with a diverse set of stakeholders and pitch in front of varied audiences, as well as the contribution of their discipline to a solution.

b. Combine entrepreneurial acting and design thinking

Open-ended challenges and processes require dealing with uncertainty. Designers, as well as entrepreneurs, are typically able to manage this. I am trained as a designer and have researched both design processes (Reymen et al., 2006; Peeters et al., 2008; Berends et al., 2011; Verstegen et al., 2019) and entrepreneurial decision-making (Reymen et al., 2008, 2015, 2017; Berends et al., 2014; Dolmans et al., 2014; and currently in the project with Maike Schmeitz). I have set up courses on design, coordinated campus-wide entrepreneurship education and coordinated an EU project to develop 21 teaching cases on entrepreneurship within seven countries. In 2015, I wrote a concept vision document on the future of entrepreneurship (education) at TU/e. In the course I set up two years ago, Innovation Space Project, I combine both entrepreneurial acting and design thinking. Students design a solution to one of the selected challenges and do so from the perspective of working on their own start-up. They receive coaching on both mindsets. Therefore here some basics of both.

¹⁶ <https://gro-intelligence.com/insights/articles/214-trillion-calories>

¹⁷ <https://www.herenboeren.nl/>

¹⁸ <https://www.cursor.tue.nl/en/news/2019/juni/week-1/winners-tue-contest-want-to-save-earth/>

Designers are creating a future that does not yet exist: “the activity of changing existing situations into desired ones” (Simon, 1996). This also holds true for entrepreneurs. Sarasvathy (2001) found that there are broadly two decision-making logics that describe how entrepreneurs deal with uncertainty, causation and effectuation (Sarasvathy, 2001), see Figure 3. Effectuation reduces uncertainty by emphasizing control, as opposed to causation’s emphasis on prediction. Causation focuses on selecting between given means in order to achieve a pre-determined goal. For example, if you cook a meal based on a given recipe (goal), you search for ingredients according to the recipe. Effectuation focuses on imagining possible new ends using a given set of means; in the example of cooking, you explore the ingredients in your refrigerator and the tools available to you and you cook a meal from the several options available (depending on your creativity and cultural background). Causation processes are effect-dependent; effectuation processes are actor dependent.

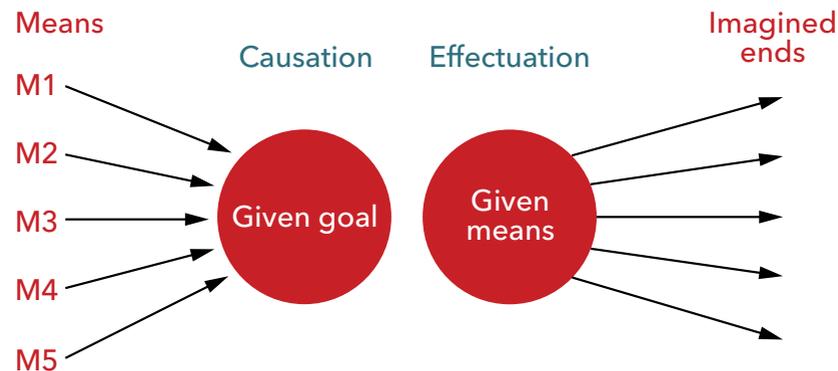


Figure 3. Two decision-making logics based on Sarasvathy, 2001

One of the innovations introduced through my educational activities is the effectual dinner. This is a hands-on, intercultural team-building experience that stimulates entrepreneurial behavior. On the first day of class, the entire group of students is split into teams and each team works on a course of the dinner. The result of each team does justice to the backgrounds and cultures of the participants.

c. Combine social sciences and engineering

The European Union¹⁹ calls for the integration of the social sciences and humanities with science and engineering. At TU/e, we have therefore developed USE learning lines which focus on the User, Society and Enterprise. I believe that these ties can become even closer.

In my educational activities, I teach students that their innovation projects need to balance the focuses on human desirability, technical feasibility and business viability, see Figure 4. This originated from IDEO in the early '00s²⁰ and states that an idea should be:

- a desirable solution, one that your customer really needs (design thinking can help with this);
- a feasible solution which is technically sound (engineering can help with this);
- a profitable solution with a sustainable business model i.e. the business side (the social sciences can help with this).

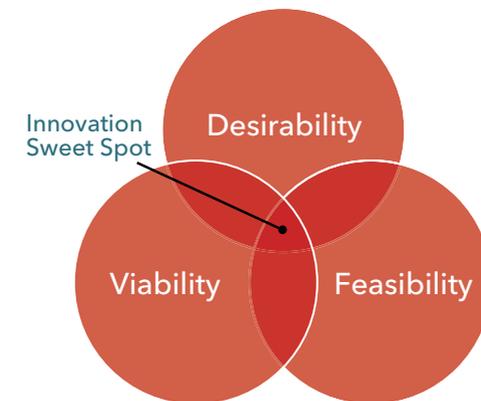


Figure 4. Balancing desirability, feasibility and viability for innovation

d. Integrate curricular and extracurricular activities

TU/e has some well-known student teams, including Solar Team²¹, the three-time winner of Australia’s World Solar Challenge using a family car, and Tech United²², which develops successful soccer and service robots. Most of the activities

¹⁹ <https://ec.europa.eu/programmes/horizon2020/en/news/report-need-integrate-social-sciences-and-humanities-science-and-engineering-horizon-2020>

²⁰ <https://www.ideo.com/blogs/inspiration/how-to-prototype-a-new-business>

²¹ <https://solarteameindhoven.nl/>

²² <http://www.techunited.nl/en/home>

performed by the students in these teams were extracurricular, with their skills and behavior serving as a fine example of taking responsibility for one's own learning. In interdisciplinary teams, students are intrinsically motivated to work on open challenges with a competitive edge, learning to think at a systems level, collaborate with companies, experiment and prototype with users in real-world settings, learn by doing and display entrepreneurial behavior. They not only develop their professional skills but also learn to apply their disciplinary skills in context and to deepen their disciplinary knowledge. The concept of Challenge-Based Learning, experimented with at TU/e innovation Space, tries to emulate this type of learning in curricular projects that are open to all students on campus; more on this later.

In my own educational activities, I try to offer students the chance to further work on their ideas in extracurricular activities, such as the TU/e Contest.²³ I also support Master's students who have their own companies in doing a Master's thesis project related to their company. I believe that we can still do more to create win-win scenarios.

WHAT?

Last year, TU/e completed its strategy for 2030 and is now finishing its detailed educational vision for 2030. I truly believe that we can be a national and international role model through Challenge-Based Learning. I will now briefly describe the seeds which we have already planted in relation to interdisciplinary, hands-on Challenge-Based Learning within TU/e innovation Space.

I have led TU/e innovation Space since fall 2015, when the Executive Board of the university asked me to coordinate its set-up alongside Dr.Ir. Miguel Bruns and Dr.Ir. Rick de Lange. We were able to attract many interested lecturers to develop the initial ideas. By the end of 2016, we were able to involve a number of highly entrepreneurial students, who had experienced working in student teams. We developed the concept and were inspired by related national and international initiatives, such as Aalto Start-up Sauna and Design Factory in Helsinki and Skylab at DTU in Copenhagen. In fall 2017, we began with a subset of students on the basic course Engineering Design. In spring 2018, Miguel Bruns facilitated the interdisciplinary Bachelor End Projects and I coordinated the first pilot at Master's level (the Innovation Space Project course). We supported the new USE learning line Engineering Design and were able to attract several other courses to TU/e

²³ <https://tuecontest.nl/>

innovation Space, such as the USE learning line Sustainable Innovation in a Global Context, lead by Dr. Johanna Höffken. For one year, we piloted in the Gaslab building on campus, and we are now celebrating our first anniversary in the Matrix building. TU/e innovation Space is a next step in the Brainport region's tradition of clustering (the development of several campuses, such as High Tech Campus and Brainport Industries Campus) and bringing together of talent (of the university, industry and society).

In the remainder of this section, I will give an overview of the current situation and future developments of TU/e innovation Space.

a. Current situation

TU/e innovation Space is a community and facility that supports interdisciplinary Challenge-Based Learning. We aim to develop the engineers of the future, as demanded by industry and society. These engineers are T- or Π-shaped, have an entrepreneurial mindset, can collaborate in interdisciplinary teams and can think at a systems level.

The actual courses are given by staff from different departments to students across all TU/e programs. In TU/e innovation Space's first year in Matrix (2018-2019), we were able to support more than 1600 students across 22 courses, corresponding to more than 8000 ECTS. The courses involve (a selection of students) from the basic course Engineering Design (for all second-year TU/e students), five different USE learning lines, elective courses in the bachelor and master programs offered by the departments, and interdisciplinary Bachelor's End Projects.

As TU/e innovation Space, we have developed an educational environment that offered 43 different challenges to eight different courses last year. Because of our close connection to industry and the ecosystems around us, we were able to offer students connections and real-time exposure to industry, which helps to develop students' employability. Besides industry, we also offered challenges with artists in order to broaden students' perspectives and options.

We have also developed the concept of innoApproach, which consists of workshops tailored to all the courses that are running per quartile in TU/e innovation Space, given right when students need them. In week one of the quartile, for example, we focus on project management, and in week seven on pitching. All students on campus can attend these workshops.

For students who wish to further develop an idea following a course, Springplank offers support in an informal setting. During two networking events per quartile, POP 'n PITCH (week two) and Deep Dive (week seven), we help students launch their projects towards their next milestones.

In TU/e innovation Space, we support and host more than 27 emerging student teams and start-ups. These are working on themes such as biosensors, sustainable housing, intelligent lighting, the energy transition, agro-food and tech and artificial intelligence.

We offer flexible meeting and workspaces for students and lecturers to use during courses. In the large, flexible space, students can work in teams on their designs and prototypes. Presentations, exhibitions and other educational events can also be held there. Additionally, we offer technical facilities and support hands-on work.

Besides the educational activities, many community events are hosted in TU/e innovation Space, both for and by the community.

b. Future developments

The future plans for TU/e innovation Space are to further develop the concept of Challenge-Based Learning, together with colleagues of Eindhoven School of Education, by improving the current pilots of the interdisciplinary Bachelor's End Project and the Master's course Innovation Space Project and by stimulating, developing and supporting new pilots that will bring interdisciplinary Challenge-Based Learning to education by 2030. Together with colleagues from Education and Student Affairs, we plan to evaluate and improve all courses within TU/e innovation Space.

Furthermore, we will professionalize the set of challenges that the students work on, offering more challenges in terms of themes, like agro-food and tech and artificial intelligence. We should therefore extend our network in the relevant ecosystems and create partnerships. We can also take inspiration from the EU's mission-oriented policy, linking projects to grand challenges.²⁴ Themes can transcend courses and form the basis for a challenge-based educational program by combining preparatory (disciplinary) courses on specific topics with interdisciplinary challenges related to the theme.

²⁴ https://ec.europa.eu/info/designing-next-framework-programme/mission-oriented-policy-next-research-and-innovation-framework-programme_en

The first steps have also been taken to work together on challenges with the other technical universities (4TU) and other Dutch universities, such as Utrecht, on a food challenge for the Ministry of Defense. In line with TU/e's strategy, we will also develop challenges in which students at different levels (Bachelor's, Master's and Professional Doctorates) work together, including students from institutions for professional education in the region (e.g. Fontys and Summa). Furthermore, we will intensify our international collaborations in the Eurotech partnership.²⁵ We can also combine 'physical' challenges with online challenges and digital support tools. The idea of offering challenges to non-traditional students in order to implement lifelong learning concepts will also be explored.

For now, I invite you all to get to know the innovation ecosystem of TU/e innovation Space. You can do so by:

- becoming a student at TU/e;
- choosing courses at TU/e innovation Space;
- forming a project team at TU/e innovation Space;
- becoming a lecturer or company coach at TU/e innovation Space;
- offering a challenge at TU/e innovation Space;
- defining a program for challenges;
- sponsoring TU/e innovation Space.

²⁵ <http://eurotech-universities.eu/>

Research - Collaborate with social and economic impact

My research activities focus on innovation processes that support collaborations between various parties in order to create true social and economic impacts through scientific and technological results. First, I will provide insights into *why* heterogeneous collaboration is needed to solve the grand challenges. Next, I will offer insights into *how* innovation processes can be organized. I will end with *what*, i.e. my current and future research program.

WHY?

The grand challenges of our time demand innovations in the ways that new products, services and systems are developed. New knowledge (i.e. basic and applied research, technology breakthroughs and scientific developments) often forms the basis for innovative solutions to the grand challenges. This knowledge needs to be transformed via *technology commercialization processes* (Markman et al., 2008) in order to create economic and social outputs.

There exists a gap between the resources poured into research and the resources that lead to commercialization (Markham et al., 2010). This gap is called 'the valley of death' and is illustrated in Figure 5. On the one side, it includes university research performed by faculty and students; on the other side, it features commercialization activities performed by entrepreneurs and the business community. Academia-based innovations are often prototypes which are only tested in a laboratory environment. For commercial application in the marketplace, more technological developments and testing in real-life environments are necessary, together with the upscaling of production and all related processes. The area in-between - activities which are not research but also not yet commercialization - hardly receives any resources.

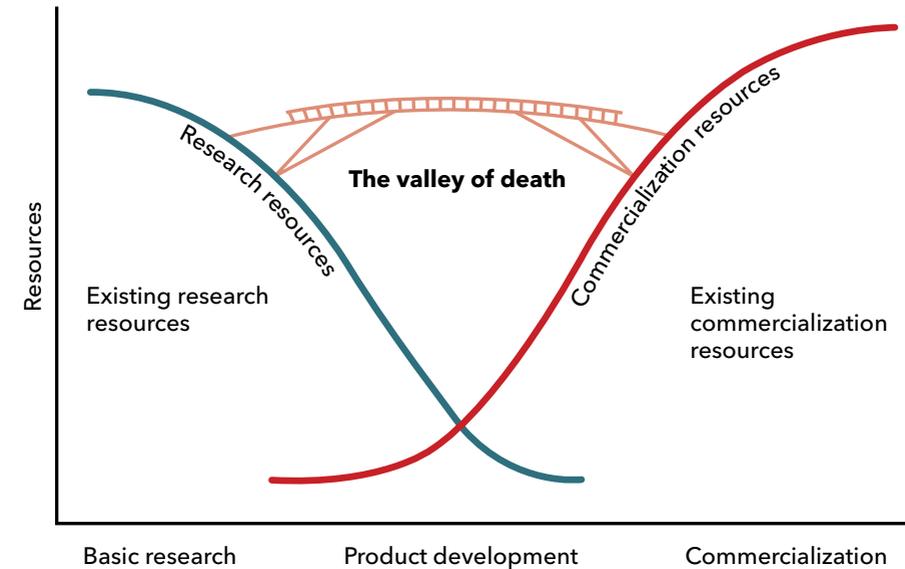


Figure 5. The valley of death

This valley of death needs to be crossed. This has been attempted via research joint ventures, strategic alliances and licensing agreements involving universities, research parks and firms, as well as the formation of start-up companies that focus on science and technology (Markman et al., 2008). People have also circulated among different organizations through visiting-scientist programs, postdocs, sabbaticals or consultant arrangements. None of this is enough.

If public research organizations like universities want their technologies to be commercialized, they need to also collaborate with the government (as a regulator, sponsor, first user or buyer of new technologies), other universities, business incubators and accelerators, science parks, venture capital firms, start-ups, small and medium-sized enterprises and original equipment manufacturers (also called "the triple helix"; Etzkowitz & Leydesdorff, 2000). Increasingly, users, citizen groups and the general public are also involved in technology commercialization processes, as value is created for customers, society or the environment, in a quadruple helix (Carayannis & Campbell, 2009), see also Figure 6. *Heterogeneous collaboration*, i.e. collaboration between diverse stakeholders, is thus key. As stated by the United Nations, these are "partnerships for the goals."

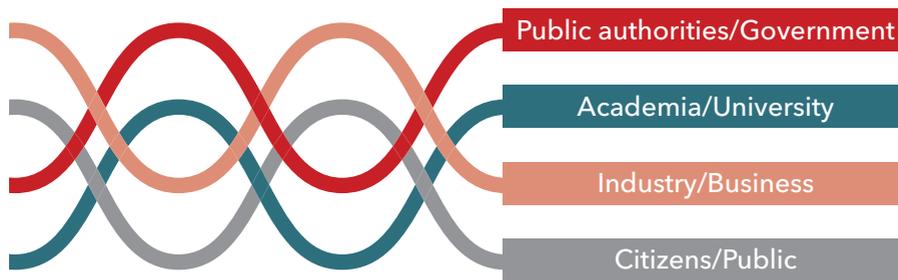


Figure 6. Collaboration in a quadruple helix

An example would be the fresh start-up SpaceSea²⁶, which developed from my course this spring and needs to collaborate with many different parties in order to grow. They develop remote monitoring of seaweed farms, thereby helping to feed the world's population in the future. They use earth observation data from satellites, which means that they collaborate with the European Space Agency and the Netherlands Space Office, who offer access to the raw data. Through talking to the farmers, they get information on the products and services they need, and can then test prototypes together. Other parties involved could be application developers, (public) research centers with knowledge of digital technologies (such as big data analytics and visualization capabilities), 'data transformation companies', satellite developers, etc.

HOW?

Heterogeneous collaborations for innovation are increasingly organized into *innovation and entrepreneurial ecosystems*. With my chair, Design of Innovation Ecosystems, I perform research on heterogeneous collaboration processes for technology commercialization in entrepreneurial innovation ecosystems. This chair is unique due to the combination of phenomena being studied and the design science research approach followed.

My chair is situated in the ITEM group in the Department of Industrial Engineering and Innovation Sciences. Research in the ITEM group, one of the four groups in the School of Industrial Engineering, focuses on "understanding and improving new business development and new product development processes within and across firms, organizations and institutions operating in a high-tech context" (Romme,

²⁶ <https://www.cursor.tue.nl/en/news/2019/juni/week-1/winners-tue-contest-want-to-save-earth/>

2019). Research in this group is mainly published in journals within the Business and Management categories of the Social Sciences Citation Index (SSCI) and the Operation Research and Management Science category of Web of Science (SCIE).

a. Technology commercialization in innovation and entrepreneurial ecosystems

To advance the development of new technologies, the business community – inspired by Chesbrough (2003) – has developed the open innovation concept, through which they can combine internal and external ideas as well as internal and external paths to the market. Firms following open innovation seek to co-create and co-commercialize research and technology regardless of whether the technology originated inside or outside of their boundaries (Markman et al., 2008). This interdependence between organizations means that companies cannot successfully innovate entirely by themselves. Unless they manage not just their own innovation processes but also their entire *innovation ecosystem*, they are unlikely to succeed (Adner, 2012). An innovation ecosystem involves a network of interconnected and interdependent actors (the focal firm, customers, suppliers, complementary innovators and other agents and regulators) which facilitates value creation (de Vasconcelos Gomes et al., 2018). The innovation ecosystem construct has emerged as a promising approach in the literature on strategy, innovation and entrepreneurship (de Vasconcelos Gomes et al., 2018). However, the use of the term 'innovation ecosystem' is not without critique (Oh et al., 2016).

A nice piece of work has recently been written by Dattée, Alexy and Autio (2018) on the *creation of innovation ecosystems*. It combines process research with qualitative data, applies systems thinking and links ecosystem design to dealing with uncertainty and the creation of possible futures. It is published in one of the best journals in the field (Academy of Management Journal). They demonstrate how a firm can (1) steer a collective process to discover and implement a complex value proposition via an innovation ecosystem and (2) ensure that they will benefit from the fruits of this collective effort. "Ecosystem creation is a systemic process driven by coupled feedback loops which organizations must try to control dynamically." We will apply these concepts to the enabling technology of integrated photonics in order to study and support its ecosystem.²⁷ Romme (2017) has already published content on the creation of the innovation ecosystem High Tech Campus Eindhoven, and this was also the topic of the Master's thesis of Jolan Hulscher (2017).

²⁷ <https://www.photondelta.eu>

Entrepreneurial ecosystems is a concept used to indicate ecosystems that specifically support entrepreneurship. These ecosystems typically involve a set of agents, institutions, activities or processes and a surrounding culture (Feldman et al., 2019). Key elements, outputs and outcomes of entrepreneurial ecosystems have been defined in Stam (2015) and Spigel (2017), while guidelines for creating entrepreneurial ecosystems have been defined in an OECD report.²⁸ *University-based entrepreneurial ecosystems* are treated separately in literature. Based on a large empirical study, Graham²⁹ has identified components critical to the establishment of a successful entrepreneurial university. Universities play an increasingly important role in regional innovation ecosystems.³⁰ This is the context for the *fourth generation university* of Maarten Steinbuch³¹ and Pawłowski (2009), based on Wissema (2009). Building an environment conducive to student entrepreneurship is part of creating an entrepreneurial university (Etzkowitz, 2003). Student entrepreneurship also requires the creation of entrepreneurial ecosystems, which in turn require the involvement of a variety of actors (Wright et al., 2017).

Technology commercialization processes have been studied by numerous innovation and entrepreneurship scholars (Rothaermel et al., 2007; Markman et al., 2008). Within the PhD projects of Elco van Burg, Sharon Dolmans and Frek Meulman, we've contributed to research into technology commercialization by focusing on the individual level: the formation of fairness perceptions in the cooperation between entrepreneurs and universities (van Burg et al., 2013), the evaluation of university inventions (Dolmans et al., 2016) and the preference of technology licensing officers for specific inventors (Shane et al., 2015). At the organizational level, we've developed guidelines for creating university spinoffs (van Burg et al., 2008) and for corporate venture transition processes within established technology firms (van Burg et al., 2012). Additionally, Master's thesis students who I supervised have dived into the topic of supporting student entrepreneurship (Velasco Montañez, 2017; Selten, 2018). At the ecosystem level, we've studied intermediaries in technology transfer (Meulman et al., 2018b).

b. Heterogeneous collaboration processes

As mentioned before, my research focuses on heterogeneous collaborations for technology commercialization within entrepreneurial innovation ecosystems. I use the term *heterogeneous* to indicate collaborations between diverse stakeholders,

²⁸ <https://www.oecd.org/cfe/leed/Entrepreneurial-ecosystems.pdf>

²⁹ <https://www.rhgraham.org/resources/MIT:Skoltech-entrepreneurial-ecosystems-report-2014-.pdf>

³⁰ <https://eua.eu/resources/publications/819:the-role-of-universities-in-regional-innovation-ecosystems.html>

³¹ <https://steinbuch.wordpress.com/2016/07/23/towards-the-4th-generation-university/>

such as interdisciplinary, cross-sectoral and hybrid collaborations. Cross-sectoral collaboration, for example, is studied together with the European Space Agency (ESA) and the Netherlands Space Office (NSO). We look at cross-sectoral collaborations between Space and Energy (Kerstens et al., 2017, 2019) and Space and Security (Antoni et al., 2019).

Heterogeneous collaboration processes in entrepreneurial innovation ecosystems are processes that are dynamic, open-ended and driven by coupled feedback loops (iteration) (Dattée et al., 2018). Since decisions have to be made under conditions of uncertainty, principles of effectuation (Sarasvathy, 2001) can be followed: the basis for taking action is the means available; dealing with risks should be done according to the affordable loss principle; the attitude towards outsiders should focus on stakeholder commitments and partnerships; and unexpected contingencies are dealt with via leveraging. Expert entrepreneurs often follow an effectual process. They prefer to do the following, also known as the effectual cycle (Sarasvathy & Dew, 2005) and illustrated in Figure 7:

- Begin with who you are, what you know and whom you know and begin DOING the doable with as little resources invested as possible;
- Begin interacting with a wide variety of potential stakeholders and negotiating actual commitments;
- Let the actual commitments reshape the specific goals of the venture;
- Repeat the process until the chain of stakeholders and commitments converges into a viable new venture.

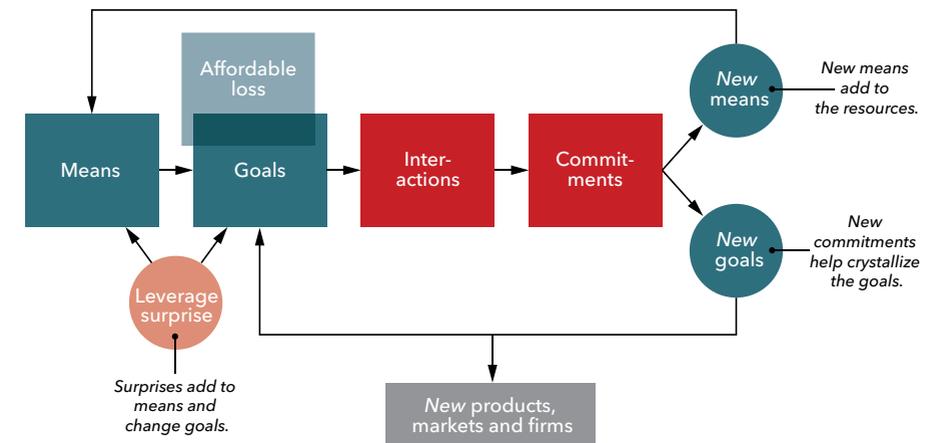


Figure 7. Effectual process (based on Sarasvathy and Dew, 2005)

These processes require activities such as experimenting and prototyping in real-world settings, learning and reflecting. No outcomes can be stated beforehand. Only process choices can be made, such as which partners to involve when and how, i.e. what type of interaction, and how to organize individual and joint value creation and capturing, see Figure 8.

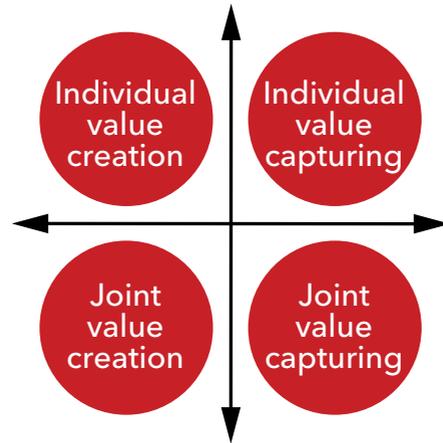


Figure 8. Individual and joint value creation and capturing

Studying *which partners to involve* in open innovation settings has resulted in a great publication (Meulman et al., 2018b) and tool (Meulman et al., 2018a). *When to involve which partners* has been studied by Kerstens et al. (2018), building on literature on boundary spanning. Colleagues in the ITEM group, Talmar et al. (2018), have also developed a nice pie chart for stakeholder mapping in innovation ecosystems. Studying *how to collaborate* has resulted in a nice publication by Verstegen et al. (2019) on collective digital technology usage for organizing digital innovation.

WHAT? CURRENT AND FUTURE RESEARCH

a. Research approach

Within my research, I aim to develop *theoretical understanding* and *instrumental knowledge* related to heterogeneous collaboration processes for technology commercialization. To understand these processes, I mainly utilize *process studies* (Langley, 1999) with qualitative data collection methods, suitable for exploring new phenomena and developing new theories (as opposed to testing theories).

To improve these innovation processes, I apply and further develop *design science methodology*. This ensures that the results of my research also have a social and economic impact. Through this approach, not only is practice studied but solutions are also designed for this practice. Design orientation can increase the relevance and usefulness of research in practice. Designing solutions for practice seems logical to an engineer and engineering researcher, but in the social sciences, especially in business and management research, a design approach to research is still very uncommon. Our work has resulted, for example, in a change to the IP policy for the grant proposals of STW in 2013 and the organization of two workshops within the EU parliament (Kerstens et al., 2019).

Within the ITEM group, we contribute to the worldwide development of a design science approach to the field of management, innovation and entrepreneurship (Romme & Reymen, 2018). A publication on how to create design principles (van Burg et al., 2008) is still often used in our educational activities.

b. Current and future research

Through my research, I aim to study and improve collaboration processes for technology commercialization within innovation ecosystems, studying barriers and enablers and developing guidelines to improve these processes. I therefore focus on the questions of who (which partners) to involve and when, and how to collaborate. Table 1 gives a chronological overview of the PhD projects which have papers in the pipeline related to collaboration processes between diverse parties, as indicated in the first column. The different topics which I study and aim to study within these processes are summarized below.

| Heterogeneous collaboration processes | Theme | Scientific topics | Project | Main researcher |
|--|--------------------------------------|---|--|------------------|
| SMEs and corporates | Sustainable energy | Role of intermediaries | KIC InnoEnergy | Meulman |
| Design and production | Dynamic and complex design practices | Organizing digital innovation | Cre8tive | Verstegen |
| Cross-sectoral | Space and Energy | Boundary spanning | ESA and NSO | Kerstens |
| Education and practice; curricular and extracurricular | Entrepreneurial university | Student-driven technology commercialization | TU/e innovation Space | Velasco Montanez |
| Combined technical and entrepreneurial development; interdisciplinary teams | Personalized Healthcare | Search process in innovation contests | Sensus | Unteregger |
| Cross-sectoral | Space and Security | Strategic decision-making | ESA and NSO | Antoni |
| Heterogeneous team composition | International entrepreneurship | Decision-making in entrepreneurial teams | Interreg | Schmeitz |
| Citizens and public and private parties | Co-creation practices | Empowerment for stakeholders in co-creation | Scalings | Tsui |
| International project teams | International innovation networks | Boundary objects | The Hague University of Applied Sciences | Zehtabchi |

Table 1. Overview of recent PhD research projects

1. Decision-making under uncertainty

Within many different projects, I've studied *decision-making under uncertainty* (Reymen et al., 2008, 2015, 2017; Berends et al., 2014; Dolmans et al., 2014; and currently within the project with Maïke Schmeitz on decision-making in entrepreneurial teams). I will continue this research on a three-level structure: the individual and team level, the organizational level and the ecosystem level. One of the key principles of effectuation focuses on *stakeholder interactions* and stakeholder commitments, which help with an understanding of collaboration processes. Together with Ntorina Antoni, we are developing a blueprint for stakeholder commitments under conditions of uncertainty (Antoni et al., 2019).

2. The university as a strategic partner in ecosystems

The central role of knowledge creation in post-industrial economies and societies has given universities the role of orchestrating multi-actor innovation networks.³²

³² <https://eua.eu/resources/publications/819:the-role-of-universities-in-regional-innovation-ecosystems.html>

Universities are an increasingly important player in innovation and entrepreneurial ecosystems. What are the guidelines for performing this central role in practice? How do we structure university/industry/government and user/citizen group/general public/student collaborations for technology commercialization, as well as for combining learning and working (e.g. learning communities)?

In order to realize strategic partnerships with external parties, the university also has to perform internal systematic institutional transformations.³³ How can we combine the traditional roles of educating students and developing research while also exploring new roles, education models and business models? To do so, we can learn from concepts within innovation management - such as ambidextrous development - but also from the implementation of organizational changes.

3. Design and governance of entrepreneurial innovation ecosystems

By focusing on the design and governance of entrepreneurial innovation ecosystems under high uncertainty, we can build on the work of Dattée et al. (2018) and the effectual process model (Sarasvathy & Dew, 2005). How, for example, can we support the dynamic control of innovation ecosystem creation? How do we combine individual and shared value creation and value appropriation? I have already contributed to some publications on innovative business models for value creation and appropriation (Berends et al., 2016; Reymen et al., 2017). We aim to study these questions in relation to different application areas, such as integrated photonics, agro-food and tech, smart cities, artificial intelligence and crossovers with space technology.

4. TU/e innovation Space

We have already performed some research at TU/e innovation Space: Bachelor's (Klos, 2018) and Master's thesis reports (Velasco Montañez, 2017; Selten, 2018; Teeuwen, 2019), one PhD student studying TU/e innovation Space (Marisol Velasco Montanez) and one postdoctoral researcher on the assessment of interdisciplinary, hands-on challenge-based projects (Ana Valencia Cardona). The first steps towards designing the concepts were even taken by students in my courses Design Science Methodology and Design Project.

In the future, I would like to create insights into the ecosystems related to TU/e innovation Space (the university's entrepreneurial ecosystem and ecosystems related to different themes) and how they can strengthen one other. What is the role of TU/e innovation Space in these ecosystems? What are the best approaches

³³ <https://eua.eu/resources/publications/819:the-role-of-universities-in-regional-innovation-ecosystems.html>

for supporting entrepreneurial students in order to optimize their impact? What is the role of TU/e innovation Space in innovating the university as a scalable edge³⁴ (Hulscher, 2017)?

Furthermore, I would like to set up research related to learning within TU/e innovation Space. We need to further develop the Challenge-Based Learning concept and publish on it. We can experiment with upscaling the concept, improve the implementation of reflection e.g. on the role of discipline and ethical aspects (reflection was also the topic of my PhD; Reymen, 2001), learn how to set up hybrid collaborations with companies for challenges and find a balance when it comes to performing a challenge for challenge owners (keeping the owners happy) that leaves room for students to reframe the problem (more freedom for students).

In general, I aim to understand and improve collaboration processes for technology commercialization in innovation ecosystems. This is an approach to crossing the valley of death in order to create solutions for the grand challenges of our time. I hereby invite academics from the university, as well as companies and governments, to collaborate on strengthening the innovation ecosystems they work in - not on the technical side of things, but in regard to knowledge on innovation and collaboration processes.

³⁴ <https://www.forbes.com/sites/peterhigh/2016/07/25/john-hagel-scalable-learning-is-the-key-differentiator-for-enterprises-of-the-future/#1cd111aa1a15>

Conclusion

An overview has been given of my educational and research activities and my related plans for the future. To illustrate how all of my activities are intertwined, I am also providing an example from Sensus, the international student competition on biosensors for health.³⁵ This competition is organized by a student team from TU/e, which is one of the key project teams in TU/e innovation Space. With PhD student René Unteregger and his supervisors Dr. Annelies Bobelyn and Dr. Johanna Höffken, I have studied this innovation competition. Annelies and I also offered entrepreneurship coaching and training to all of the international teams participating in the competition. Sensus itself is developing an ecosystem for accelerating the development and innovation of biosensors.

To summarize, my educational activities focus on increasing collaboration between education and diverse parties in practice by encouraging, stimulating and facilitating students to work hands-on in interdisciplinary teams on societal challenges that really matter. We do so via educational innovation experiments within TU/e innovation Space, and thereby also develop and implement the new Challenge-Based Learning concept at TU/e. You are all invited to get to know TU/e innovation Space.

My research activities focus on innovation processes that support collaborations between various parties in order to create true social and economic impact through scientific and technological results. I aim to study and improve collaboration processes for technology commercialization within entrepreneurial innovation ecosystems. I hope that by collaborating, we can collectively solve the grand challenges of today and tomorrow. We therefore need to continue innovating, investing and transforming.

In essence, I focus on innovation processes and collaborations between different people because they are the ones who make the difference in the end: it is all about people.

³⁵ <https://www.sensus.org/>

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Three people at this university were especially crucial to my career here. First is George Romme, who appointed me to the ITEM group and was my mentor up to now. His focus on the personal development of employees has been extremely valuable. I learned a lot from him and hope to apply similar principles with the colleagues I work with. The second person I would like to thank is Hans Berends, who was my buddy for all activities which I had to learn as an assistant professor. We taught the same courses, supervised Master's thesis students together, wrote several papers together, worked on research projects we obtained together and even both became members of the ITEM board. The third person who was crucial to me over the last four years is Lex Lemmens. He stimulated me to lead the development of TU/e innovation Space and is still our main champion. Thanks for the trust in me and the opportunities you gave us!

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Curriculum Vitae

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