KU LEUVEN

FACULTY OF ENGINEERING TECHNOLOGY
FACULTY OF SOCIAL SCIENCES

Breaking through stereotypes: Professional roles for future engineers.

A validated competency based framework supporting professional awareness and making well informed career choices

Sofie Craps

Supervisors:
Prof. Greet Langie
Prof. Tim Smits
Heidi Knipprath
Maarten Pinxten

Dissertation presented in partial fulfilment of the requirements for the degree of
Doctor of Engineering Technology (PhD)
and for the degree of
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December 2022

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Sofie CRAPS

Supervisors:
Prof. Greet Langie
Prof. Tim Smits

Co-supervisors:
dr. Maarten Pinxten
dr. Heidi Knipprath

Members of the Examination Committee:
Prof. ir. Hilde Breesch – chair
Prof. ir. Inge Holsbeeks – assessor, secretary
Prof. ir. Mike Murphy – assessor
Mr. Rudy Goossens – assessor
Prof. Veerle Draulans
dr. Jeroen Lievens

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December 2022

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Contact: sofie.craps@kuleuven.be
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For Gus and Oskar, my sons and heroes
For Jesse, Anne-Fleur and Hanne, my godchildren

"May choices reflect your hopes, not your fears."
Nelson Mandela

Preface

Well, here we are.

What a journey it has been. As a recruitment and communication officer at KU Leuven, I have always enjoyed supporting (future) students in making a well-informed study choice and

guiding them through the many educational opportunities. I also enjoyed the world of sciences and technology that is a wonderful and inspiring work environment. This project offered the opportunity to combine my experiences and interests, offered time to dig deep, to experiment and to find answers to some of my wonderings. The question to join the project could also have been the right one to ask to someone facing a little midlife crisis when turning 37. Anyway, an exciting journey in engineering education research had begun in August 2017.

Greet Langie, thank you for asking me that question and for all the support during these years. You did a splendid job as my supervisor. Give a call, or better not, send a message or even a flower in hard times… I cannot express my gratitude for such a customized approach and for always being available, anytime.

Tim Smits, we met halfway. I am grateful that you accepted to become a supervisor of this interdisciplinary PhD. Although the road was paved already, your insights and statistical knowledge helped to move away the stumble blocks or shed light on new avenues. Your enthusiasm was more contagious than the covid virus.

Maarten Pinxten, you were my sparring partner, the one that got my focus back on track after another round of idea ping pong. Always in for a good joke, even more for food or a good beer. Thank you for giving the PhD a great kickstart and for the good talks and laughter, in and outside the office.

Heidi Knipprath, I always looked forward to our conversations. There are few people I know like you who have the gift to give such constructive, to the point feedback. Amazing how you can absorb information and start making observations or asking questions, until we get in the right direction. Thank you for guiding me that way, in real live or online.

To the assessors of the supervisory committee, prof. Inge Holsbeeks prof. Mike Murphy and Rudy Goossens, and to the additional members of the examination committee, prof. Veerle Draulans, prof. Jeroen Lievens and chair prof. Hilde Breesch: your questions challenged me to step out my comfort zone and gave this work the final tweaks it deserved. Thank you for your time and effort, and also for your kind words and encouragements.

This work would not have been possible without the support of the European Union and the Erasmus+ PREFER project. I had the opportunity to collaborate with a group of very fine colleagues. Thank you, Mariana Cruz, Gillian Saunders-Smits, Darren Carthy, Kevin Gaughan, and Brian Bowe, for sharing knowledge, giving valuable feedback and suggestions, and improving this work. Also thank you for hosting very pleasant weeks in TU Delft and TU Dublin.

Since I started the PhD, our research group ETHER (Engineering Technology Education Research) has been growing. Lynn - a phone call a day keeps the doctor away - thank you for being there and for supporting along the way. You are a warm and beautiful person. Jolan, Kurt and Wouter, you guys will nail it. Never believe otherwise! Mieke, Rani, Shan, you recently joined the team with enthusiasm and tons of new, fresh ideas. You amazed us already, so I am looking forward to collaborating in our new projects.

Presenting parts of my work and discussing the approach or results has been something I really liked to do. So many people have inspired me with their suggestions and experiences. The LESEC community offered such

opportunities. Thank you, colleagues, from the Theme Group Study Guidance. A special note to Tinne De Laet who has been a great chair of LESEC and to Wim Van Petegem for organizing the PhD Seminars and for giving me the honour to kick of the international PRACtESE Seminar Series. The European network SEFI opened new doors and a lot of interesting new contacts that truly helped me to grow as a researcher.

To let off some steam, I can always address the dear colleagues from the Dean's Office, an amazing bunch of people with the best ideas to increase team spirit and motivation. There is always hard work but also something fun, like the Big Chips Tasting Test, a book review discussion, a birthday treatment, the Christmas sweater party, the StepForestStep Challenge… Although I love you all, a special note to Sarah as she will always be my number one, Céline for the walks, Kathleen for bringing energy by a dozen, Wouter for going out tips and tricks, Julie for the talks, Anneke for the bike rides back home, Hilde for great big and small stories, Dafne for being an inspiration, Bert for playing classical music a soundbite too loud. Also, to Dirk for his data-services and Chrisje for just being you. You are both missed in Heverlee.

Thank you, Team Thirteen colleagues Geert, Bart, Steven, Marc, Bérénice, Jan, for the interest and support in the research, and for welcoming me in the Campus Group T teaching team. I tend to stay for a while if that is okay. Thank you, Wim Dewulf, for making that possible. I dedicate this work to the beloved and truly missed Birgit Van Roy, who mentored me in teaching and encouraged me to organise the case study described in Chapter 4.

A thank you also to the K building colleagues of Campus De Nayer. Apologies for the many questions about where to find something or to please make a print. Maybe we should suggest a new PhD project to solve all the administrative issues for KU Leuven staff on location!

It was great to see how my former communication colleagues helped to disseminate the PREFER results via brochures, website or ads. A special thank you to (again) Sarah – speedy Gonzales – Verryt for making that happen, to Lieze Rombauts for organising and promoting PREFER student sessions and to Yves Persoons for his interest in and appreciation for my work, for sharing his network and for putting me on the cover of ConnectING, barefoot. It is something that sticks to people's mind, and I do not need much of an introduction ever since.

My dear friends, Annelies, Katrien, Beeja, Christine, Trijs, Griet, Katrien, Francisca, Anke, Liesbeth, Sun, Tine … Thank you ladies for hearing me out, for encouraging, for organizing a drink from time to time, for asking how it is going, for enthusiastically counting off to the celebration party.

To my parents, moeke and papa, you wondered what I have doing for such a long time, in between other things. Well, this… Thank you for giving me the chance to go to university at the time. Also, for looking after the kids when I was on a conference and for just being proud. To my sisters, for discussing and supporting the value of qualitative education and appreciating my effort in contributing, and to the rest of my family (in law): thank you. It is a blessing to be part of such a warm family.

Last but certainly not least I want to thank my greatest partners in this journey. Thomas, I realize I asked a lot of your patience. You hated the night work, but never stopped supporting. I love you for that and a thousand other reasons. Although you were right: it was more than time to finish this off. Gus and Oskar were small boys when I started but it seems that I am the smallest one in the house now. Thank you, boys, for giving me this chance. I hope I have inspired you to see the unforeseen, to never stop asking questions and to persist on your way to get somewhere. To quote prof. Mike Murphy: "This is a marathon, not a sprint". Now, it is time to put on again some real running shoes.



Summary

The shortage in engineering talent has been reported for several years and it is estimated that this shortage will increase due to several global challenges in this fast-changing world, like the climate challenge. The need to increase attractiveness, diversity and retention in engineering education is bigger than ever before.

The field of engineering is broad and diverse. Although engineers can end up in a wide variety of engineering positions, the perception of engineering is often still stereotypical and seen as mainly technical. Several studies indicated that engineering students, even close to graduation, have difficulties in understanding what engineers do and in reflecting on themselves as future engineers. This lack in professional and self-awareness can hinder the education-to-work transition, with students ending up in a job that does not correspond to their expectations or students not applying to jobs that best match their capabilities. Research in this area is often focused on the so-called skills mismatch, indicating that industry reports difficulties in finding engineers with the right (level) of competencies, and tend to neglect the different roles an engineer can take on.

This doctoral thesis was set up with the aim to support students in developing a future identity as an engineer and in making well informed career choices. There were two main objectives: (1) to develop a competency based professional roles model for early career engineers, validated in education and industry to support engineering students to navigate through the broad field of engineering, and (2) to explore the role of professional awareness in making well informed career choices.

Based on a systematic literature review, three professional roles for early career engineers were defined, represented in a flexible manner (roles can overlap or change). The roles were validated in industry (survey) and in

education (focus groups and interviews). Via a series of expert panels involving engineers and HR recruiters and using a mixed method approach, essential competencies could be identified that are required to be successful in each of the roles. This resulted in the PREFER model, an innovative, competency-based and validated framework that supports students' understanding of the diversity in engineering, independent of discipline. The model presents three portraits of early career engineers in practice (engineers in a role focusing on radical innovation, on process optimisation and/or on customised solutions) and what it requires to be successful in these roles. For example, perseverance and creativity were deemed essential for engineers in an innovative role, whereas positive critical attitude and stress resistance were indicated essential for engineers focusing on optimisation. The reflective model helps students to get a grip on the myriad of job opportunities and what industry expects but also helps them to think about themselves as future engineers.

This more diverse perspective on engineering also served for deepening our understanding of how engineering students and young graduates make career choices. To date, literature on identity or career development has often framed 'an engineer' as one broad or generic concept, neglecting students might have difficulties in envisioning its meaning and, by consequence, making well informed choices. Hence, three exploratory studies were set up using the PREFER model as a research framework. First, in a survey, we explored how confident students feel to take up their preferred professional role and what predicts this professional role confidence. Second, via two case studies, we explored whether final year Master's students' choice for a job vacancy aligns with their preferences and strengths. Final we interviewed early career engineers about how they explored career opportunities and how that was related to professional and self-awareness. We asked about their education-to-job transition and investigated whether they were satisfied with their job choices.

The different studies showed the importance of a more diverse understanding and exploration of engineering roles. (Future) engineers who show good understanding of the different roles (role awareness) and professional competencies (competence awareness) also show a more active career exploration. They feel more confident that their preferred professional role is consonant with their interest (role fit confidence) and that they are able to enact this role upon graduation (competence confidence). Moreover, adding professional awareness and career exploration in a linear regression model controlling for students' characteristics, reduced the predictive value of some background variables for role fit confidence or competence confidence. For example, a technical secondary background or programme year in the engineering programme (with exception of freshmen) were no longer significant predictors for the students' confidence. Gender remained a small but significant predictor of competence confidence with female students showing less confidence in their abilities but, in contrast with earlier research, gender was no significant predictor in role fit confidence. This finding suggests that a more diverse perspective on engineering might influence the female students' confidence that an engineering role is consonant with their interest in a positive way. The results led to the following question: despite their professional confidence, what about engineering students' job choice?

The case studies and interviews showed the importance of professional awareness in making job choices that are congruent with one's interest and strengths. The findings illustrated the need to increase students' role awareness in order to choose a job that is congruent with one's role preference, an important driver to stay in the job. They also indicated a need to increase competence awareness in order to choose for a job that requires the right level of competencies. In line with earlier research, our findings call for making explicit the relevance of professional competencies in the different engineering roles so that students can make connections between the self, the learning and their future role as an engineer.

A final finding showed the importance of professional awareness in job satisfaction. Engineers with lower levels of job satisfaction in the first job regretted that they had not thought about and actively explored the roles they could take on when entering the labour market. Not being able to fulfil their expected role was an important driver for job changes, next to company culture or career trajectories with few to no perspectives. Young engineers recognized the importance of lifelong learning to develop as engineers of the future. A reflective behaviour to enhance professional and self-awareness is important in steering that future career.

The results presented in this PhD thesis offer new insights and instruments that can guide future research in identity and career development learning in engineering education and beyond. The PREFER model has been developed as an innovative, validated framework for understanding diversity in engineering. The model can also serve as a research framework for guiding research and instruction, as has been shown in the different studies, resulting in a better understanding of career choice. Future research can build upon this work, new research avenues have been drawn. The critically discussed outcomes also have led to a series of recommendations for education. For example, our results support the holistic approach of engineering competencies and call to include reflection on the future self from day one. During the PhD thesis, a series of test instruments were developed based upon the PREFER model to support the students and lecturers, as the role of the lecturer cannot be overlooked. Finally, the PhD thesis led to recommendations for industry to prepare our future engineers for the challenges of tomorrow. All stakeholders benefit from a collaborative approach in broadening the view on engineering, making expectations explicit and support our (future) engineers' personal development and lifelong learning. By breaking through the stereotypes, this work offered a common language to facilitate the conversation.

Samenvatting

Al jaren wordt gerapporteerd over een tekort aan ingenieurs, een tekort dat naar schatting de komende jaren nog zal toenemen. Verschillende globale uitdagingen, zoals de klimaatuitdaging, vragen technologische oplossingen in onze snel veranderende maatschappij. Dit maakt de nood om in te zetten op de aantrekkelijkheid van en de diversiteit en retentie in de ingenieursopleidingen groter dan ooit tevoren.

Het ingenieursveld is breed en divers. Ingenieurs komen in de meest uiteenlopende functies terecht. Toch kijken we nog vaak eng en stereotiep naar het ingenieursberoep als iets puur technisch. Uit verschillende studies blijkt dat sommige ingenieursstudenten, zelfs vlak voor hun afstuderen, moeite hebben om te vatten wat ingenieurs doen en om over zichzelf na te denken als toekomstige ingenieur. Dit gebrek aan professioneel en zelfbewustzijn kan de overgang van onderwijs naar de arbeidsmarkt hinderen. Afgestudeerden komen nog te vaak in jobs terecht die niet meteen aan hun verwachtingen voldoen of die bij hun capaciteiten passen. Onderzoek op dit gebied is vaak gericht op de zogenaamde *skills mismatch*, waarbij industrie aangeeft niet altijd ingenieurs met het juiste (niveau) van competenties te vinden. De verschillende rollen die een ingenieur kan opnemen komt in onderzoek echter amper aan bod.

Dit doctoraatsonderzoek had als doel studenten te ondersteunen bij het ontwikkelen van een toekomstige identiteit als ingenieur en bij het maken van weloverwogen loopbaankeuzes. Er waren twee hoofddoelstellingen: (1) ontwikkelen van een competentiegericht professioneel rollenmodel voor startende ingenieurs, gevalideerd in het onderwijs en in de industrie, om ingenieursstudenten te helpen hun weg te vinden in het brede ingenieursdomein, en (2) onderzoeken hoe het professioneel bewustzijn (*professional awareness*) inspeelt op het maken van weloverwogen jobkeuzes.

Op basis van een systematisch literatuuronderzoek werden drie professionele rollen voor ingenieurs aan het begin van hun loopbaan gedefinieerd en voorgesteld op een flexibele manier (rollen kunnen overlappen of veranderen). De professionele rollen werden gevalideerd in de industrie (enquête) en in het onderwijs (focusgroepen en interviews). Via een reeks expertpanels met ingenieurs en HR-recruiters konden essentiële competenties worden geïdentificeerd die nodig zijn om succesvol te zijn in elk van de rollen. Het resultaat is het PREFER-model, een innovatief, competentie-gebaseerd en gevalideerd framework dat studenten helpt om de diverse ingenieursrollen te vatten. Het model schetst drie portretten van startende ingenieurs in de praktijk (ingenieurs in een rol gericht op radicale innovatie, op procesoptimalisatie en/of op oplossingen op maat van de klant). De portretten expliciteren de professionele competenties die nodig zijn om succesvol te zijn in deze rollen. Zo zijn bijvoorbeeld doorzettingsvermogen en creativiteit essentieel voor ingenieurs in een innovatieve rol, terwijl een positief kritische houding en stressbestendigheid onmisbaar werden geacht voor ingenieurs die zich richten op optimalisatie. Het reflectiemodel helpt studenten grip te krijgen op de brede waaier aan beroepsmogelijkheden en op wat de industrie verwacht. Het model helpt hen ook over zichzelf na te denken als toekomstige ingenieurs.

Het meer diverse perspectief op ingenieurs hielp ook om diepgaander inzicht te geven in hoe ingenieursstudenten en pas afgestudeerden jobkeuzes maken. De huidige literatuur over identiteits- of loopbaanontwikkeling omschrijft 'de ingenieur' nog al te vaak als een breed of generiek concept. Er wordt geen rekening gehouden met de moeilijkheden die studenten kunnen ondervinden om zich een beeld te vormen van de betekenis en bijgevolg om goed geïnformeerde keuzes te maken. Daarom werden drie verkennende studies opgezet met het PREFER-model als onderzoekskader. Eerst onderzochten we via een enquête hoeveel vertrouwen studenten hebben dat ze hun voorkeursrol kunnen opnemen en wat deze *professional confidence* voorspelt. Vervolgens onderzochten we via twee case studies of de keuze van

laatstejaars masterstudenten voor een zelf gekozen vacature aansluit bij hun voorkeuren en sterktes. Ten slotte interviewden we ingenieurs aan de start van hun loopbaan over hoe zij job mogelijkheden verkenden en hoe dat samenhangt met professioneel en zelfbewustzijn. We vroegen hoe hun overstap naar de arbeidsmarkt verliep en onderzochten of ze tevreden waren met hun jobkeuzes.

Uit de verschillende studies bleek het belang van een meer divers begrip en van een exploratie van hun opties als ingenieur. (Toekomstige) ingenieurs die blijk geven van een goed begrip van de verschillende rollen (*role awareness*) en van de professionele competenties (*competence awareness*), vertonen ook een actievere loopbaanexploratie. Zij hebben er meer vertrouwen in dat de hun voorkeursrol aansluit bij hun interesse (*role fit confidence*) en dat zij de capaciteiten hebben om deze rol na hun afstuderen goed te vervullen (*competence confidence*). Door professioneel bewustzijn (*role* en *competence awareness*) en loopbaanexploratie toe te voegen aan een lineair regressiemodel waarin rekening gehouden werd met de achtergrondkenmerken van de studenten, verminderde de voorspellende waarde van sommige van die kenmerken voor *role fit confidence* of *competence confidence*. Zo waren bijvoorbeeld een tso-achtergrond of de programmafase waarin de student zich bevond (met uitzondering van eerstejaars) niet langer significante voorspellers voor dit vertrouwen. Geslacht bleef een kleine maar significante voorspeller van *competence confidence*, waarbij vrouwelijke studenten minder vertrouwen in hun capaciteiten vertoonden. In tegenstelling tot eerder onderzoek was geslacht geen significante voorspeller van *role fit confidence*. Dit resultaat suggereert dat bij vrouwelijke studenten een meer diverse kijk op engineering het vertrouwen dat een ingenieursrol aansluit bij hun interesse op een positieve manier zou kunnen beïnvloeden.

De casestudies en interviews toonden het belang van een meer divers begrip van ingenieurs aan bij het maken van beroepskeuzes die aansluiten bij iemands interesses en sterke kanten. De bevindingen illustreerden de

noodzaak om een goed begrip van de professionele rollen bij studenten te vergroten om een job te kunnen kiezen die aansluit bij hun interesse, een belangrijke drijfveer om in de job te blijven. Ook toonden de resultaten de noodzaak om een goed begrip van de professionele competenties te verhogen om te kunnen kiezen voor een job past bij hun sterktes. In lijn met eerder onderzoek pleiten onze bevindingen ervoor om de relevantie van professionele competenties in de verschillende ingenieursrollen meer te expliciteren, zodat studenten verbanden kunnen leggen tussen zichzelf, hun leerproces en hun toekomstige rol als ingenieur.

Een laatste bevinding toonde het belang van een meer divers begrip van ingenieursrollen aan in jobtevredenheid. Ingenieurs met een lagere jobtevredenheid in de eerste job betreurden het dat ze niet voldoende hadden nagedacht over en niet actief hadden onderzocht welke rollen als ingenieur ze konden opnemen. Een belangrijke drijfveer om van job te veranderen was het niet kunnen opnemen van een rol zoals verwacht was, naast bedrijfscultuur of loopbaantrajecten met weinig tot geen doorgroeiperspectieven. De jonge ingenieurs in ons onderzoek erkenden het belang van levenslang leren om zich verder te ontwikkelen als ingenieurs. Reflectie om het professionele en zelfbewustzijn te vergroten is belangrijk om die toekomstige loopbaan te kunnen sturen.

De resultaten uit dit doctoraatsonderzoek bieden nieuwe inzichten en instrumenten die verder richting geven aan toekomstig onderzoek naar identiteit- en loopbaanontwikkeling in het ingenieursonderwijs en daarbuiten. Het PREFER-model is ontwikkeld als een innovatief, gevalideerd kader om de diverse ingenieursrollen beter te begrijpen en biedt een framework voor onderzoek en instructie, zoals de verschillende studies in deze doctoraatsthesis aantonen, met als resultaat meer inzicht in en een beter begrip van jobkeuzes. Toekomstig onderzoek kan voortbouwen op dit werk, een aantal nieuwe onderzoekspaden werden daarvoor uitgetekend.

De kritisch besproken resultaten leidden tot een reeks aanbevelingen voor het onderwijs. Onze resultaten ondersteunen bijvoorbeeld de holistische

benadering van ingenieurscompetenties en roepen op om reflectie op het toekomstige zelf vanaf de eerste dag op te nemen. Tijdens het doctoraatsonderzoek werd, op basis van het PREFER-model, een reeks tools ontwikkeld ter ondersteuning van studenten en docenten. De rol van de docent in de ondersteuning van professionele identiteits- en loopbaanontwikkeling bij studenten is namelijk cruciaal.

Ten slotte leidden de resultaten ook tot aanbevelingen voor de industrie om onze toekomstige ingenieurs voor te bereiden op de uitdagingen van morgen. Alle stakeholders hebben baat bij een gezamenlijke aanpak om de kijk op engineering te verbreden, verwachtingen te expliciteren en de persoonlijke ontwikkeling en het levenslang leren van onze (toekomstige) ingenieurs te ondersteunen. Door het stereotiepe beeld op ingenieurs te doorbreken, biedt dit werk een gemeenschappelijke taal om het gesprek op gang te brengen.

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Introduction and context

"Students cannot aspire to that, which they have never seen."
(Tytler & Osborne, 2012, p. 618)

1. Context of Research Study

The pertinent climate issues and the COVID19 pandemic brought an already long-standing issue into an even sharper focus: technology is required to solve a broad range of worldwide challenges in our fast-changing societies. The need for highly skilled engineers is bigger than ever before (Eurostat, 2020; Michael Page, 2021). In Belgium, as in other OECD countries, a regular shortage in engineering has been reported for several years (Machin & McNally, 2007). The McKinsey Report The Future of Work estimates that, due to the COVID19 pandemic, STEM [1]-related, business and legal professional roles could even grow by more than 20 percent in the coming decade (Smit et al., 2020). This highlights the need to increase attractiveness, diversity and retention in engineering education.

1.1. Shortage in engineering

The research presented here was organised in Belgium, in the (Dutch speaking) Flanders region in particular, facing challenges that are comparable to several other countries. In Flanders, there is a shortage of STEM graduates that appear to relate mainly to technicians, engineers, computer scientists, mathematicians and physicists, as well as of teachers of certain STEM subjects (an issue that was also reported, for example, in the UK (The Royal Academy of Engineering, 2019)).

In 2012, the report *Kiezen voor STEM* [*Choosing STEM*] showed that the proportion of STEM graduates in higher education in Flanders was around the

[1] STEM is the abbreviation for Science, Technology, Engineering and Mathematics. It is also often referred to as STEAM, including Arts.

European average (14%) (Van den Berghe & De Martelaere, 2012) and has increased since then (in Flanders around 18%) (Eurostat, 2022). However, the increase in students is not enough to fill the number of job vacancies. There are various reasons. For example, female students are underrepresented in engineering programmes, although they are well represented in tracks in secondary education that prepare for engineering programmes. The shortage in engineering is not only due to the limited number of students entering the programme but also due to the number of engineering graduates that do not continue in engineering jobs. To some extent, such horizontal or field-of-study mismatch is normal due to several factors, such as the needs of different profiles in the labour market. Graduates can also have, given their competencies and interests, good job prospects in other fields. In 2015, an OECD study showed that there is a wide variation in field-of-study mismatch between fields (Montt, 2015). For example, in fields such as Humanities, Languages and Arts the mismatch was larger than in Engineering and Construction (in Flanders, resp. 76,3% vs 32,1%) due to a lower labour market demand or greater transferability of skills to other fields (Montt, 2015) whereas it was lower in fields like Health and Welfare (30,9%) or Social Sciences, Business and Law (20,8%). Studies in Flanders observed that the lowest mismatch in the fields of Health and Medicine and in Education are due to the specific nature of the study and the high demand of these graduates (De Coen et al., 2018). However, the report *Werkzoekende schoolverlaters in Vlaanderen 2020 [Job seeking school-leavers in Flanders 2020]* showed that the latter reasoning also applies for the field of Engineering. Graduates in engineering sciences and engineering technology, two types of Master's programmes in engineering (see Section 5.2.), are very popular and flow smoothly into the labour market (VDAB, 2020). Why is the mismatch in the field of engineering higher? Is it possible that there is some misunderstanding of what it is to be an engineer?

1.2. Narrow perceptions on engineering

Today, in most engineering curricula across countries, preparing students for the transition to an engineering career is an established learning outcome. Many universities therefore developed practice-based curricula and included learning activities, for example, company visits or guest lectures, to improve understanding of the world of work (Trede et al., 2012). However, research indicates that these efforts are not enough. Although students seem to recognize that they can end up in a wide variety of engineering positions, their perspective of career options can be strongly swayed by a single experience, such as an internship (Lichtenstein et al., 2009). Also, even close to graduation, they can hold narrow perceptions of engineering that are mainly technical (Brunhaver et al., 2018) or focus on management or leadership careers (Gerwel Proches, Chelin & Rouvrais, 2018; Kinnunen et al., 2018). These narrow conceptions about what engineering is and what engineers do lead to a gap between the graduates' expectations and their actual experiences in the real engineering practice, an observation shared by research conducted in several knowledge-driven economies (Dias, 2011; Jusoh et al., 2011; Kövesi & Kálmán, 2020; Llorens et al., 2013; Matusovich et al., 2009).

A study among five universities in Flanders (N=1948) showed that more than one in five of the engineering graduates (23%), aged 26 or younger, indicated that they changed employer with almost half of them within the first year (KU Leuven, UAntwerpen, et al., 2016). Several positive drivers for change were indicated such as working in a bigger company (16%), higher salary (29%) or more career opportunities (35%). However, for 60% of the respondents the main reason to change was job content meaning that the job did not correspond to their expectations. Regardless of whether they remain in engineering or not, for engineering graduates, this might result in feelings of frustration, uncertainty, or disappointment in their new jobs (Korte et al., 2015; Trevelyan, 2019). For companies, this leads to economic loss as they invested in recruiting and training new employees (KU Leuven, UAntwerpen, et al., 2016; Montt, 2015). The latter is a necessity for many employers as they

experience difficulties in finding graduates with the right set of competencies or the required competency level (IET 2016; Mourshed, Patel & Suder 2014), often referred to as the skills gap or skills mismatch. Several reports, such as the European report *Education to Employment* (2014) or the World Economic Forum's *Future of Jobs Report* (2020) documented a particular shortage of non-technical skills, such as communication skills, lifelong learning, teamwork skills, creativity or problem solving for different fields. Skills such as critical thinking and in self-management like active learning, resilience, stress tolerance and flexibility are even rising in prominence. A better understanding of engineering and what is required to be an engineer would be of benefit to the engineering graduates themselves, and also to the organisations that employ them.

1.3. The importance of developing an engineering identity

It is not completely surprising that engineering students encounter difficulties in grasping what it is to be an engineer given that the engineering domain is very broad and there are multiple career directions in the different disciplines. However, several theories for career development, investigating the process and content by which a professional identity and career paths, success and behaviour are formed, underline the importance of awareness of both personality (e.g., interests, strengths and weaknesses) and future career opportunities (Bridgstock, 2009; Brown & Hirschi, 2013; Eccles, 2011; Holland, 1997; Oyserman et al., 2004).

Developing a professional identity and clear future career perspectives is an important aspect in the employability debate. Several researchers have proposed identity development as a lens for understanding motivation and persistence in engineering education (Choe & Borrego, 2019; Meyers et al., 2012; Oyserman & Destin, 2010; Pierrakos et al., 2009). It has been shown that a better understanding of one's professional future and engineering identity not only has positive consequences for student learning (Bliuc et al., 2011), motivation (Frymier & Shulman, 1995; Hock et al., 2006), retention (Karataş

et al., 2016), or study and career choices (Meijers et al., 2013; Van Hattum-Janssen & Endedijk, 2020) but also increases employability and job satisfaction (De Coen et al., 2018; Gottfredson & Johnstun, 2009; Nilsson, 2010; Yorke, 2006).

Despite the societal relevance and the hot topic that professional identity has become in engineering education research, to date, there is no overarching internationally validated framework that educators can use to support students in developing their engineering identity and in reflecting on their professional future. Nor is the variety in engineering roles reflected in research regarding professional identity or career development. That is remarkable because earlier research referred to the significant limitation of one generic role for engineers, for example, since this requires the same balance of the same technical and professional competencies for all engineers (Brunhaver et al., 2013). Nevertheless, several studies have been showing that, regardless the discipline, there are different types of engineers – Nilsson (2010) suggested to use the concept of professional roles – and that the importance of professional competencies varies across job tasks and work contexts (Male, Bush & Chapman 2011; Nilsson 2010; Trevelyan & Williams 2018). For example, an engineer working in an R&D department might need other competencies than an engineer working in maintenance. This study aims to fill this gap.

2. Situating the choice for being an engineer in literature

The need to reduce the earlier described mismatches in engineering is clear and therefore the need to better prepare students for the diversity of engineering roles they can take on in the labour market. There are two streams of literature that can give us more insight in this challenge: theories in identity development and theories in career development learning, as identity and career choice are tightly linked. In this section, first, the main theories and how they evolved are described. Second, based on these insights,

a conceptual framework is designed, defining the concepts relevant for this study.

2.1. Theories of identity and career development learning

2.1.1. Professional identity development

The development of a professional identity is the fundamental aim of career guidance in education and plays a key role in understanding study and career choices (Van Hattum-Janssen & Endedijk, 2020). Professional identity reflects how people define themselves in professional work roles according to attitudes, beliefs, experiences, and motivations (Schein, 1978).

A professional identity is one of many identities. Besides an engineer, one is also a (fe)male, a student, a parent, a cyclist, a traveller etc. Two broad approaches of identity formation are identified in literature (Sets & Burke, 2000). *Identity theory* focuses on the process of identification and 'the way one categorizes himself as an occupant of a role, and incorporates the meanings and expectations associated with that role and its performance' (p. 225). *Social identity theory* emphasizes the process of self-categorisation and 'the knowledge that he or she belongs to a social category or group' (p. 225). One feels like others in the group and see things from the group's perspective. Sets and Burke (2000) argue for an integrated view on identity formation, or as put forward by Tonso (2006a, p. 275) in the context of an engineering identity: it is about '*identifying* with engineering and *being identified* as an engineer'. This is neither 'a simply individual choice, nor is it the result of belonging to the social category of an engineer' (Anderson et al., 2010, p. 156). Professional identity development is the process where students become aware of their desires, needs and goals, but also about their abilities and interests and how they correspond with one of the professional roles they can take on in the labour market (Skorikov & Vondracek, 2011; Super, 1980). This process involves students in negotiation between a professional role and its characteristics, and the desires, needs, and strengths to prepare for that role (Gee, 2000; Meijers & Lengelle, 2012; Tonso, 2006b). A sense of belonging and

attachment is instrumental in the development of a strong professional identity and is an antecedent to pursuing a specific career (Holmegaard et al., 2014; Meyers, Ohland, Pawley, et al., 2012; Pedler et al., 2021; Tonso, 2006b).

Different factors are identified that relate to engineering identity. For example, in an ethnographic study, Faulkner (2007) observed that the dominant identity among engineers is still the technical (masculine) one, neglecting the social parts of engineering, which makes it harder for women to identify with a 'real' engineer and a 'real' woman at the same time. Next to gender (Bairaktarova & Pilotte, 2020; Endedijk et al., 2017), other factors such as educational progression and future career plans (Meyers, Ohland, Pawley, et al., 2012) or institutional culture (Stevens et al., 2008) have also been identified. Murphy, Chance and Conlon (2015, p. 44) put forward the central question in exploring engineering identities: 'who is an engineer, what does an engineer do, what does performing the role of an engineer entail, and what are the responsibilities of engineers?' Indeed, being able to reflect and connect with an engineering role implies the premise that students have enough information about (a) their own competencies, preferences and personality (self-awareness) and (b) the educational, training or job requirements of the roles an engineer can take on in practice (professional awareness) (Bimrose et al. 2004).

2.1.2. Career development learning

In debating the skills and expectations mismatch, it is suggested that engineering graduates might not have chosen for a job that fits their interests, strengths and weaknesses (De Coen et al., 2018). As the economic world is rapidly changing, students need the knowledge and skills to manage their own future and access information to decide how to achieve this job fit. Career development involves developing the skills and knowledge that enable individuals to plan and make informed decisions about career choices.

Research in this area has evolved with recent theories emphasizing the learning process in making career choices. Initial *career theories* held the

perspective that a career choice is the choice for a job that matches one's personality. Holland's Vocational Model is a reference in this regard (Holland, 1997). Holland developed his theory on the idea that career choice is based on personality. People will search for environments where they can use their competencies and express their values and attitudes (Gottfredson & Johnstun, 2009). For example, an investigative type who is likely to be precise, analytical, curious, and intellectual, will more likely be happy to work in an investigative environment that matches these competencies. These theories are still relevant and have shown, for example, a positive link between job satisfaction or productivity and work contexts that have congruent characteristics with one's personality. However, these choice theories also have a narrow focus on career choice that implies a more or less stable society and they rather overlook the process of career decision (Winters, 2012).

Theories of career development look beyond the moment of career choice and help to understand choices. For example, Super (1990) links career development to a developing self-concept which he sees as the result of complex interactions between experiences and maturation in life phases. Time and experience help shape the way someone values his career and creates career goals. Self-exploration, career information seeking and gaining real life experiences are needed to obtain information about oneself and the professional world. However, it remains rather unclear how this self-concept is developed or how expectations from the environment are transferred into a self-concept.

Current *career development learning approaches* state that individuals actively shape their careers but also recognize psychological (e.g., maturation), social (e.g., background) and economical (e.g., labour market needs) influences (Savickas et al., 2009). Person-bound factors, such as interest, self-efficacy or confidence, values (i.e., personal goals or outcome expectations) are important drivers that steer the choice process (Krumboltz & Worthington, 1999; Lent & Brown, 2013). For example, students will be more likely to attempt a behaviour when they believe they have the capabilities and expect

that their effort will lead to desired consequences. Lent and colleagues (2002) see an important role for educational institutions to support students in engaging in career exploration. Activities like job shadowing or internships but also extracurricular activities enable students to clarify their interests, values and competencies in relation to a particular professional role (Bennett et al., 2017; Griffiths et al., 2021). Moreover, as beliefs and values can change, activities that create professional awareness should be offered early in education facilitating students not only to identify but also to expand their interests, beliefs and competencies (Krumboltz & Worthington, 1999).

However, in these fast-changing economies, it is not always easy to develop clear ambitions or concrete outcome expectations (the expectations that a given behaviour will lead to a particular outcome). Hence, career learning requires conscious self-directedness (also referred to as self-management, career adaptability, self-regulatory behaviours, etc. (Lent & Brown, 2013)) so that students can use their knowledge, experience and emotions in choosing a career in a context of uncertainty and change (Winters, 2012, p. 46). As described by Savickas (2012) in his Constructivist Learning Theory, career development learning is a process in which information and experiences are transformed in meaningful knowledge. In the context of engineering education, the latter is only possible when students can identify with engineering and envision themselves as future engineers, when they are ready to engage in career choice making and have life or career related experiences and stories explaining why a choice is made. When focusing on the education-to-work transition, Savickas (1999, pp. 326–327) states the students cope better with this transition if they 'have developed awareness of the choices to be made and of the information and planning that bear on these choices'.

Hence, it is important to adjust misconceptions about professional roles, as was noted by Branch (2002) in her review on career development theories. A better and more realistic understanding of engineering work is required to critically reflect on one's thoughts and prior achievements and to articulate future aspirations in the engineering profession (Yorke & Knight, 2006).

Professional awareness or knowing the world of work eases the process of career decision making and job transition. However, when the field is broad and there are various career options, it would help in making a decision if there was a more 'compact view of the world of work at a more manageable level of abstraction' (Dawis, 1996, p. 239). Such models could support students to identify their interest and the investment level that a student is prepared to make to succeed in their choices (Eccles, 2011; Gottfredson, 1985). Engineering students would benefit from a model that helps them to explore the wide variety of engineering careers, to get insight in what industry expects from the different roles and to reflect on their career interests and ambitions. However, research based professional role models for early career engineers are scarce which hampers to aid students in their professional identity and career development.

2.2. Conceptual framework

Aiming to better prepare engineering students for the labour market by enhancing professional identity development and making informed career choices, students need the knowledge and skills to manage their own futures and access information to decide how best to achieve this. Corroborating insights and perspectives from identity and career development learning theories, we draw a conceptual framework, presented in Figure 0.1, with relevant concepts to frame this doctoral study. The concepts are briefly described in the following paragraphs.

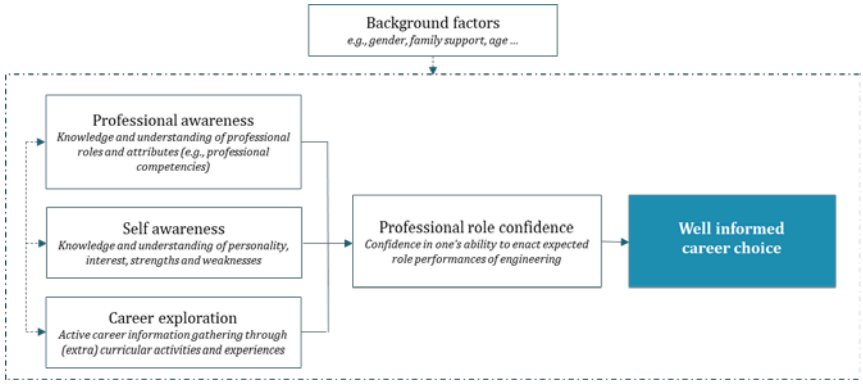


Figure 0.1. Conceptual framework.

2.2.1. Background factors

In the literature section, it was mentioned that personal and social factors have an influence on identity and career development. For example, females identify differently with engineering that is still perceived as male in the US or in Europe, and have less confidence in their abilities to fulfil an engineering role (Faulkner, 2007; Naukkarinen & Bairoh, 2021), age and maturation have an effect (Super, 1980), parental support or support from peers and supervisors enhance career exploration and the confidence of making a good career choice (Kracke, 2002), etc.

2.2.2. Professional awareness

As stated earlier, answering the question 'who am I as an engineer', requires an answer to the question 'who are engineers and what do they do?'. Students need to gain awareness of the diversity of career opportunities in engineering so that they can explore the field and develop the required professional competencies early in education (Flaherty et al., 2019). Recent studies suggest that knowledge of future professional roles does not necessarily entail knowledge of different professional competencies required in engineering (Direito, Pereira & De Oliveira Duarte, 2014; Saunders-Smits et al., 2021). In order to decrease a mismatch in expectations and skills, an understanding of both different professional roles and different essential competencies are

important. The term professional roles has been mentioned earlier, but what do we mean with this term? And what are professional competencies, a concept for which a variation of terminology is used (Knipprath & De Rick, 2013)?

- *Professional roles*

The broad and complex field of engineering with a wide variety in job titles can be quite overwhelming and it can be expected that students find it difficult to visualize and navigate (Matusovich et al., 2009). As suggested by Branch (2002) and Dawis (1996), a compact, reduced representation of different types of engineers can help students (1) to understand what engineering is beyond the dominant, stereotypical engineering identity that is marked by a mathematical and scientific (technical) knowledge (Huff et al., 2019) and (2) to navigate through the broad field of engineering, regardless disciplines. Although several terms are used in engineering education research, such as career types (Van der Heijden et al., 2009), profiles (Kubler & Forbes, 2004; Lima et al., 2017) or sub-occupations (Brunhaver et al., 2013), Nilsson (2010) suggests to use the term professional role.

The term 'role' comes from theatre; a world that has nothing to do with engineering. Actors, as 'professionals', had to be able to fill their role and suspend belief in their audience (Paulsen, 2011). Today, the term role evolved to a concept used to guide ideals and expectations of what to be and how to behave – think about gender roles, age roles, and, in this study, professional roles. The term is used in different fields, such as teaching (Lunenberg, Dengerink & Korthagen, 2014), journalism (Willnat, Weaver & Choi, 2013) and medicine (Frank, Snell & Sherbino, 2015), as described in more depth in Chapter 1 (p. 35). Building on the insights from different fields, this study defines a professional role as 'an interpretation of an (engineering) position based on expectations of the environment'. In the context of this study, the focus will be on what the work field expects from early career engineers and what is required to fulfil the position in a particular role successfully.

- *Professional competencies*

An important attribute in combatting the stereotypical thinking in engineering, is making the importance of professional competencies more explicit. Professional competencies, also referred to as transferable skills (Yorke, 2006), generic skills (Bridgstock, 2009), twenty-first century skills (Kalevi Ahonen & Kinnunen, 2014), etc., emphasize a more holistic development of non-technical competencies and the capability of adapting to change (Berdanier, 2022). Metacognition or self-regulation is an important aspect in career development learning, taking into account different situations or contexts. The OECD (2019) defines competencies as more than just knowledge and skills. 'It involves the ability to meet complex demands, by drawing on and mobilising psychosocial resources (including skills and attitudes) in a particular context. For example, the ability to communicate effectively is a competency that may draw on an individual's knowledge of language, practical IT skills and attitudes towards those with whom he or she is communicating' (Rychen & Salganik, 2005, p. 4).

In education, there has been a tendency to develop more output-oriented or competency-oriented pedagogies as a means to adapt curricula to professional activity (Lemaitre et al., 2006; Trede et al., 2012). In a systematic review of both quantitative (N=27) and qualitative (N=25) studies, Passow and Passow (2017) analysed what competencies engineering programmes should emphasize. They found that the competencies important for engineering practice differ from the learning outcomes. Also, definitions of competencies were surprisingly diverse. One reason might be that the wordings of learning outcomes of accreditation bodies, such as ABET (the US accreditation body for engineering programmes), seem rather vague and incomplete to many faculties making decisions about curricula. This makes it more difficult for programme designers to formulate expectations that correspond with those of the labour market.

Recent research in the US, Europe and Australia has been emphasizing that technical and professional competencies are intertwined in engineering

practice. In other words: competencies are context dependent and should be applied or taught in the context in which they will be used (De La Harpe et al., 2000). A portrait of engineering supports the understanding of essential competencies. Passow and Passow (2017) offer such a concise portrait of generic engineering practice. However, this portrait does not explicitly reflect that the essential competencies vary according to the different roles an engineer can take on. Lindberg & Rantatalo (2015) found that, in different professional practices, the professional competencies were indicated as characteristics of excellence and differentiate between more or less competent in different roles. Despite numerous studies identifying professional competencies in engineering, there is a gap in literature that acknowledges this differentiation in essential competencies or competency level regarding different roles.

2.2.3. Self-awareness

As indicated in the previous section, both identity and career development theories agree that self-awareness is necessary to make satisfying career decisions. Having a clear view on who one is, on one's strengths and weaknesses, interests, values and needs is important to be motivated to invest in learning, finding a career direction and judge whether an opportunity is likely to be satisfying (Verbruggen, 2020). Morin (2011) indicates that a high level of self-awareness is believed to make it easier to process information and filter relevant information in a consistent way. As such, it is an important adaptive competence. Also, it is associated with more confidence in one's ability in making a good career choice (Betz & Voyten, 1997). As described by Verbruggen (2020), self-awareness is malleable. Education can enhance students' self-awareness, for example, by offering career interventions and by triggering self-reflection, as also has been shown in research with engineering students (Bennett et al., 2017).

2.2.4. Career exploration

Career exploration, conceptualized as active career information gathering through (extra) curricular activities and experiences, including work experiences and career guidance (Kracke, 2002; Meijers et al., 2013), enables students to discover what is possible and achievable within an engineering context and to give shape to their future professional role and career path (Tomlinson & Jackson, 2019). The intensity of career exploration is perceived as the crucial prerequisite for a mature, well thought-out career choice (Bridgstock, 2009; Jackson & Wilton, 2017; Super, 1980) and for a satisfactory commitment to a career choice (Kracke, 2002; Kroger et al., 2010; Perez et al., 2014). Blustein (1992) described that young adolescents tend to explore their choices based on what they know or prefer and tend to neglect other options. Students are still in a stage of developing career interests and awareness, so their choices can change and fluctuate easily (Lichtenstein et al., 2009; Waterman, 2007). Career exploration in this stage helps to get insight in oneself (self-awareness) and to focus on how to become an engineer (in a particular role) (Lau et al., 2020). Higher career exploration would result in more realistic expectations of and fewer mismatches in the labour market.

2.2.5. Professional role confidence

Professional identity is dependent not only on professional and self-awareness, but equally important on the confidence to successfully undertake a particular professional role (Sachs, 2001). The concept of professional role confidence, introduced by Cech et al. (2011) in a US study on persistence in engineering education, refers to the students' confidence in their ability to enact expected role performances of engineering when they completed their education. Similarly to professional awareness, this concept also captures two dimensions [2]: (1) role fit confidence, or the confidence that a professional role is consonant with one's individual interest and values, and

[2] Cech et al. (2011) describe these dimensions as career fit confidence and expertise confidence. Due to consistency in terminology in this study, we will use the terms role fit confidence and competence confidence.

(2) competence confidence, or the confidence in tasks and competencies required for practice in the profession (Cech et al., 2011). As such, the concept of professional role confidence recognizes that becoming a successful engineer involves both mastery of competencies and the cultivation of confidence in, identification with and commitment to a professional role. The sub concepts relate to other concepts in career development theories. For example, competence confidence relates to the self-efficacy concept of Lent and Brown (2008) that refers to one's beliefs about their ability to perform their job. Students with higher confidence are more likely to persist in engineering. However, when their perceptions on engineering are limited or rather stereotyped, they risk entering the labour market with confidence but also with wrong expectations. The latter might have negative consequences in relating to meaningful work and job satisfaction (Buch & Andersen, 2013). Therefore, a better understanding of professional role confidence and its relationship with professional awareness is needed.

3. Objectives of the research

This study focuses on career development learning of engineering students, specifically on supporting students in making qualitative, well informed career choices. The previously described literature clearly highlights the need to increase professional and self-awareness. Therefore, we first need a better understanding of the diversity in engineering roles. There is a gap in literature, in particular regarding early career engineers, however, it is a fundamental prerequisite to better support engineering students in making well informed career decisions. Also, research in this area rarely includes perspectives from different stakeholders, which is quite remarkable in research aiming to decrease the mismatch between education and the labour market.

In addition, a more diverse perspective on engineering roles can deepen our understanding of how engineering students and young graduates make career choices. A further exploration of the career choices, taking the different roles

and expectations from industry into account, would help graduates in entering the labour market with confidence and with the right expectations and competencies, from the start. They enter the labour market more resilient to uncertainty and change, to become engineering professionals and, eventually, industry leaders. A satisfying choice at the start influences the whole career which not only benefits the engineering graduate but also companies. Embracing diversity in engineering roles is not only seen as a need to increase attractiveness and persistence in engineering, it is also recognized as a driver for innovation and productivity (Beddoes et al., 2018; Leevers, 2020).

Specifically, there are **two main objectives** in this research study:

1. To develop a competency based professional roles model for early career engineers, validated in education and industry to support engineering students to navigate through the broad field of engineering;
2. To explore the role of professional awareness in making well informed career choices

The **first objective**, to develop a competency based professional roles model, includes the following **questions**:

1.1. What roles for early career engineers can be identified and what attributes define the different roles?
1.2. What professional competencies are required to be successful in a professional role?
1.3. How do business professionals perceive the professional roles model and apply the model to positions in their company?
1.4. How do students perceive the professional roles and are they able to identify themselves with one or more roles?

The **second objective**, to explore the role of professional awareness in making well informed career choices, firstly approaches career choice from the student's point of view. Secondly, engineering graduates in different roles are invited to reflect on the choices they initially made and whether they are satisfied with their career choices so far. **Questions** that are included are:

2.1. How confident are engineering students that they can take up their preferred professional role and how well prepared do they perceive themselves in the essential competencies for that role?
2.2. Do students tend to choose for a job that is congruent with their interest (role preference), with their strenghts (competency profile) or with both?
2.3. To what extent did engineering graduates explore their career opportunities and how was this related to professional and self-awareness?
2.4. Are engineering graduates who experience a match between their role preferences and competencies and their job more satisfied with their career choice?

The outcomes of the research can help students in developing a future identity as an engineer and in making satisfying career choices. The insights can inspire educators in supporting career development learning, in integrating context of engineering practice in their teaching activities and in informing policy development. Finally, the outcomes are also important for human resource as it helps to better understand the transition from education to practice.

4. Thesis outline

This chapter has been providing the context for the research to better prepare engineers to solve the challenges of the future. It stated that diversity in engineering roles should be embraced to move forward the field of identity development and career development learning. In the context of Belgium, where the need for engineers is high, an exploration of the knowledge and understanding of these different roles can provide a deeper understanding of the career choices.

The following chapters present the different studies that were set up in this research project. From a pragmatic view, we adopted a mixed method approach as the best way to investigate the two research objectives and

seeking answers to the questions (Creswell, 2009). Qualitative research was set up for exploring and understanding how engineering roles were perceived by engineering students, engineering graduates and employers. Quantitative research was conducted for generalizing findings and for examining the relationship among different variables affecting career development learning using statistical procedures. Figure 0.2 shows how the research was set up based on the conceptual framework we drew from the literature. The numbers one to five refer to the five different studies that were conducted. They also correspond with the different chapters in the manuscript.

The remainder of the manuscript is organised in two parts, one per objective. In **Part One | Towards a Professional Roles Model for Future Engineers**, *Chapter 1* presents the *literature review* which explored frameworks that categorized engineering roles for early career engineers and what attributes defined the identified professional roles. It concludes with a summary of a threefold Professional Roles Model for early career engineers (further referred to as the PREFER model) focusing on radical innovation, process optimization and/or customised solutions. In particular the work of Hofland et al. (2015), Kamp and Klaassen (2016) and Spinks et al. (2007) provided solid foundation for the framework. Although they used different methods, large similarities were found between these models.

In the literature review, the majority of studies investigated professional competencies as identifying attributes, but inconsistency in and a lack of definitions hindered the determination of the distinct professional competencies per role. However, recommendations were drawn to set up the study in developing a competency based PREFER model.

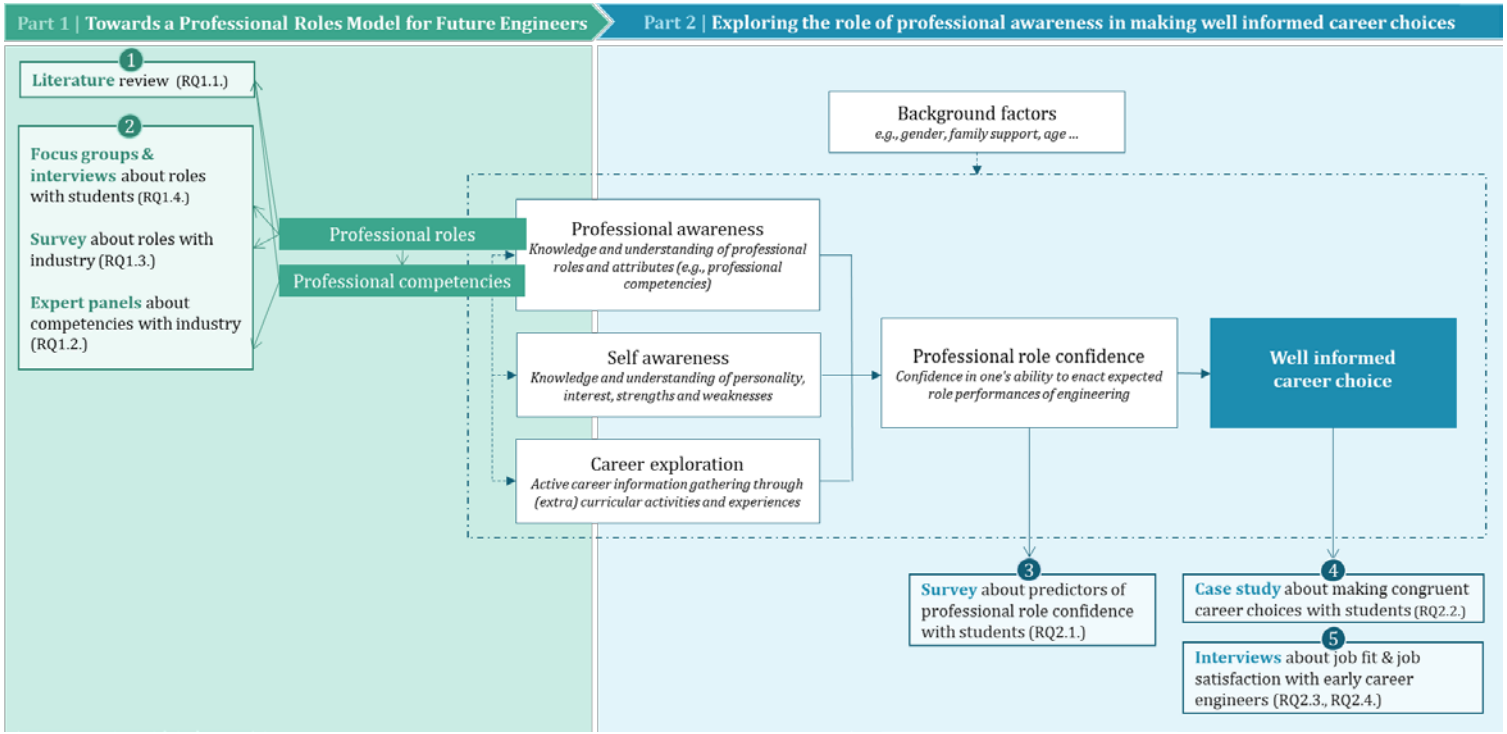


Figure 0.2. Overview of the research set up, based upon the conceptual framework.

Chapter 2 describes this *development of the competency-based model, validated by industry and higher education*. First, a study was set up to validate the PREFER model drawn from the literature review. It was decided to use the role labels (product leadership, operational excellence, customer intimacy) as suggested by Hofland et al. (2015) because of the systematic approach in their research (a vacancy analysis (N=7672), semi-structured interviews with HR managers to compare the model with another engineering categorisation (N=5), and a survey with industry to link roles to learning outcomes (N=121). Follow up research involved 197 students to identify role preferences and role perceptions (De Norre et al., 2016). Although the approach of Spinks et al. (2007) and Kamp and Klaassen (2016) were different (Spinks et al. organised 27 in-depth interviews with business leaders about the skills and attributes of the engineers of the future, Kamp and Klaassen organised a think tank of academic staff (N=15) to investigate what the future engineers should learn in the future), the outcomes of the studies were very similar. Hence, the labels were used as suggested by Hofland et al. (2015) but the role descriptions originated in the three studies and conversations with industry and academics.

To validate the PREFER model (1) a diverse sample of business professionals (through a survey) and (2) engineering students (via focus groups and interviews for a more comprehensive and nuanced understanding) were involved. It is important to note that, however not included in the reported study, academics were also consulted, for example during workshops at two SEFI conferences and regular presentations for programme committees from different engineering disciplines.

Second, a study was designed using the nominal group technique to identify the required competencies for the different roles. The different steps, involving different expert panels from industry, are outlined in Chapter 2. The result of this extensive study is a reflective instrument that serves to trigger professional awareness (the different roles an engineer can take on and what

is expected in these roles), and self-awareness (what role(s) do I prefer and what are my strengths as a future engineer).

Part two | Exploring the role of professional awareness in making well informed career choices describes three different studies to explore career choices in different ways, using the PREFER model as a research framework. *Chapter 3* explores *how professional awareness and career exploration influence professional role confidence*. Developing an engineering identity and making a career choice is not only dependent of one's knowledge of a profession, but also of the confidence in one's ability to successfully undertake a particular professional role (Sachs, 2001). Borrowing the concept and adapting measurements from Cech et al. (2011) (see also Section 2.2.5), this chapter describes the outcomes of a survey that was conducted to understand the relation between professional awareness and career exploration and professional role confidence, taking different background characteristics into account such as gender, programme year, GPA etc.

In *Chapter 4*, a case study is presented that investigated whether *final year Master students opt for a job they like or for one that they can excel in, or both*. As described earlier in the literature: when engineering graduates choose a job that is not congruent with their interest or qualities, they will more likely change the job leading to personal dissatisfaction and economic loss for industry. This study compared the congruence between the students' professional role preference, their self-perceived strengths and weaknesses and their choice for a job vacancy. The results of a group of Electronics and ICT engineering students was (1) compared with other disciplines and (2) analysed to investigate whether boosting professional awareness reduced role choice incongruency.

Selecting a job vacancy as a task in college might be different than choosing a job for real. Hence, we set up a final study, presented in *Chapter 5* to explore *engineering graduates' perception on their transition to the labour market, their job fit and their job satisfaction*, from a qualitative approach. Via semi-structured interviews we aimed to get more insight in how early career

engineers explored their career opportunities and selected their first job, and in how they perceive their job fit and job satisfaction. The PREFER model was used to guide the conversation and reflect on their current and previous job expectations and level of preparedness. The findings give insight in engineering graduates' preparation for the labour market but also in their future plans to manage their career.

All the findings of these exploratory studies are compared in *Chapter 6* which also draws implications for education and industry. This chapter concludes the thesis with a critical discussion of the main findings and new insights and recommendations for future work in this area.

This thesis is presented as a portfolio of journal articles. The work presented in Part One has been published as independent peer reviewed journal articles. The work in Part Two has been submitted and is currently accepted or under review. As a consequence, a recurrence of some paragraphs may occur, for example in the introduction of the studies. Ethical approval was obtained from KU Leuven Ethics and Privacy Committee for all studies in this doctoral research (G-2019-03-1596 and G-2021-3528). All participants included in the study have consented to be part of this research. They were informed that their participation was voluntary, and that the analysis would be conducted anonymously.

5. A Flemish study in a European project

To end this chapter, it is interesting to know that this research was not a stand-alone project. It started with the approval of the European Erasmus+ project PREFER | Professional Roles and Employability for Future EngineeRs (grant agreement 575778-EPP-1-2016-1-BE-EPPKA2-KA) which we briefly present in the next section. Although part of a European project, the research presented here focuses on Flanders and was conducted in the largest university KU Leuven. For the reader who is unfamiliar with the Flemish educational system, the KU Leuven, and/or the organisation of engineering programmes, a short description is provided.

5.1. European project PREFER

The PREFER project started in 2017 aiming to reduce the skills mismatch in the field of engineering by three objectives. This doctoral thesis was set up to fulfil the first objective: construct a Professional Roles Framework describing the different roles an engineer can take on in the beginning of their career. The results are presented in Part One of this manuscript.

The second objective was to develop a test system to increase engineering students' professional awareness and to make them reflect on their own engineering identity, their interest, strengths and weaknesses, based upon the outcomes of the Professional Roles Framework. The PREFER tests (PREFER Explore, a personal preference test to explore professional role preferences (Carthy et al., 2019), and PREFER Match, a situational judgment test to get feedback on role alignment and professional competencies (Carthy et al., 2022)) were further used in the case study (Chapter 4). For this objective, KU Leuven worked closely with TU Dublin. Although there was a profound contribution to this work, the development of the tests is not included as part of the PhD study.

Third, the project aimed to explore how innovative curriculum elements, that stimulate the development and practice of professional competencies necessary for the engineering professional roles, could be created and implemented in the engineering curriculum. For example, a game based learning activity was developed in order to trigger reflection on communication skills (Cruz, Carthy & Craps, 2019). This third objective was led by TU Delft and more results can be found in the doctoral study of Mariana Cruz (2021).

A well-balanced consortium was constructed involving three leading engineering education institutions (KU Leuven (Belgium), TU Delft (The Netherlands) and TU Dublin (Ireland)) and three multinationals with large experience in recruiting different engineering profiles (Engie, Siemens and ESB). BDO, an experienced test development partner was a member of the

team in order to develop reliable and valid test material. A large European network played an essential role in connecting higher education institutions with a large number of companies and SME's hiring engineers: three national professional engineering societies (ie-net, KIVI and Engineers Ireland), a national sector federation AGORIA (Belgium) and two European societies SEFI (European Society for Engineering Education) and FEANI (European Federation of Professional Engineers). They also helped with knowledge dissemination of the project. More information about the project can be found via www.fet.kuleuven.be/prefer.

5.2. Engineering education in Flanders and the Leuven University

STEM is well represented at different levels in higher education in Belgium. The **Flemish higher education** system is a binary system with academic programmes offered at universities and applied programmes offered at university colleges according to the principles of the European Higher Education Area.

An academic Bachelor's degree (180 ECTS) has a strong theoretical focus and prepares for Master's studies (60-120 ECTS). In Flanders, academic bachelors usually start their Master's immediately after their Bachelor's degree. To get the professional title of engineer, a Master's degree in engineering sciences, bioscience engineering or engineering technology is required. A professional (applied) Bachelor's degree combines general knowledge with practical competencies including compulsory internships. This programme prepares for the labour market in three years (180 ECTS); however, it is also possible to start some Master's programmes after a required bridging or transfer programme (45-90 ECTS). Not all Master's programmes offer transfer programmes and only specific professional Bachelor's degrees obtained in a specific discipline related to the Master's degree are eligible for the transfer programme. For example, a professional Bachelor's degree Biomedical Laboratory Technology is admitted to the transfer programme that, after

successful completion, gives access to the Masters in Chemical Engineering Technology.

The doctoral research was conducted in the **KU Leuven**, having more than 60.000 students (KU Leuven, 2020). The comprehensive university is dedicated to education and research in nearly all fields. Fifteen faculties offer education, clustered in three groups: Humanities and Social Sciences, Biomedical Sciences, and Science, Engineering and Technology (SET). The SET group organises five faculties: Faculty of Sciences, Faculty of Architecture, Faculty of Engineering Science, Faculty in Bioscience Engineering and Faculty of Engineering Technology. The latter three faculties offer engineering programmes in a lot of disciplines and specialisations, e.g., civil engineering, chemical engineering, mechanical engineering, electrical engineering, biomedical engineering etc. This study involved the Faculty of Engineering Technology, that was coordinator of the European PREFER project. With more than 6300 students, the faculty is the largest of the SET Group and the third largest of the university, following the Faculty of Medicine and the Faculty of Economics and Business.

The **Faculty of Engineering Technology** is a young faculty at KU Leuven, organised on six campuses in Flanders. Due to political reorganisation of the educational field in Flanders, the programme, that was first offered in 1922 in Mechelen, integrated in 2013 into the universities. In comparison with the programmes in Engineering Science and Bioscience Engineering who offer two-year Master's programmes (120 ECTS), the programmes in Engineering Technology include a one-year Master's programme (60 ECTS) and are characterised by a focus on making theoretical designs ready for use and thus forming a bridge between the conceptual idea and practice. So, the two engineering programmes differ in terms of their relative levels of theory and application. Every year, about 1000 master's students graduate at the Faculty of Engineering Technology in Dutch or in international programmes. The studies in the doctoral thesis involve students from the Dutch programmes.

Although there are three faculties offering engineering programmes, there is close collaboration. The **Leuven Engineering and Science Education Center (LESEC)** is a community of researchers and practitioners contributing to the advancement in education in Science, Engineering and Technology Group. Within the theme Study Career Guidance of STEAM Students, the outcomes of this study were regularly presented and discussed.

Part One | Towards a Professional Roles Model for Future Engineers

1 | Exploring professional roles for early career engineers: a systematic literature review

This study is published as : Craps S., Pinxten M., Knipprath H. & Langie G. (2020). Exploring professional roles for early career engineers: a systematic literature review, European Journal of Engineering Education, DOI: 10.1080/03043797.2020.1781062

Abstract

It is recognised that engineers end up in a wide variety of engineering positions and that the importance of professional competencies might vary accordingly. However, most studies regarding professional competencies, employability or career guidance fail to address this variety in professional roles. This systematic literature review aims to identify professional roles for early career engineers and explores the defining attributes. Twenty-four publications were selected for inclusion by screening and appraising results obtained from three databases. Three frameworks that fulfilled the analysing criteria described similar roles focusing on innovation, optimisation and customisation. The majority of studies investigated professional competencies as identifying attributes, but inconsistency in and a lack of definitions hindered the determination of the distinct professional competencies per role. Further research is recommended to identify role attributes and to investigate how a professional roles framework can support career development in engineering education, more particular in creating professional and self-awareness.

1. Introduction

Nowadays, employees have to take a more flexible and proactive approach to their working lives, involving the continuous management of their own employability, to meet the challenges of a global economy characterised by rapid change (Tomlinson, 2007). Higher education institutions increasingly acknowledge their responsibility to guide students, both in their academic growth and in their career development (Burke et al., 2017; National Academy of Engineering, 2018). Consequently, the educational field is challenged to explicitly trigger students' reflection on their professional future.

1.1. Narrow view on engineering

In engineering education, students' perceptions of their professional future are a focus that deserves due attention. Research indicates that, even close to graduation, many engineering students remain uncertain about what engineering is and what engineers do (Bennett & Male, 2017; Lichtenstein et al., 2009; Matusovich et al., 2009). Moreover, some students predominantly consider engineering education and practice as primarily technical, and hold narrow perceptions of the professional aspects of engineering (Brunhaver et al., 2018).

1.2. Mismatch

These narrow future perceptions lead to a gap between the graduates' expectations and their actual experiences (Chan et al., 2017; Watson & Meiksins, 1991) significant negative correlations to job satisfaction (Jusoh et al., 2011). Employers, regardless of the field, also refer to this mismatch, indicating that there is still a skills gap and that they experience difficulties in finding graduates with the right set of competencies or the required competency level (IET, 2016; Mourshed et al., 2014). The European report *Education to Employment* (2014) documented a particular shortage of non-technical skills, such as communication skills, lifelong learning, teamwork

skills, creativity or problem solving – further in this paper described as professional competencies. For many years now, there has been a general agreement on the importance of these competencies in engineering education (ABET, 2017a; ENAEE, 2015; Murphy et al., 2016; National Academy of Engineering, 2004), but it is also clear that the employability debate goes beyond developing competencies. It also involves identity development (Tomlinson, 2007).

1.3. Lack of reflection

Constructing a professional identity requires the ability to critically reflect on one's thoughts and prior achievement, but also the ability to articulate one's future aspirations in the engineering profession. The latter aspect presumes more awareness and a more realistic understanding of the engineering work and the competencies required (Yorke & Knight, 2006). In response, engineering education has been adapting its learning methods. Interventions to expose students to authentic engineering experiences, for example in problem-based learning, are commonly used in engineering education, but the link to the engineering practice is not always clear (Bennett & Male, 2017; Tymon, 2013). Aspects like one's beliefs and values are rarely included in engineering educational activities which makes it difficult for students to construct an engineering identity (Morelock, 2017).

Several theories for career development, investigating the process and content by which a career identity is formed, underline the importance of awareness of both personality (e.g. interests, strengths and weaknesses) and future career opportunities (Bridgstock, 2009; Brown & Hirschi, 2013; Eccles, 2011; Holland, 1997; Oyserman et al., 2004) as more congruency between personality and career leads to increased employability, greater job satisfaction and success (Gottfredson & Johnstun, 2009; Holland, 1997; Yorke & Knight, 2006). The reasoning implies the premise that students have enough information about (a) their own competencies, preferences

and personality and (b) the educational, training or job requirements (Bimrose et al., 2004).

It is recognised that there are different types of engineers – Nilsson (2010) suggests to use the concept of professional roles – and that the importance of professional competencies or the way engineers create value varies across job tasks and work contexts (Male et al., 2011; Nilsson, 2010a; Trevelyan & Williams, 2018). For example, an engineer working in an R&D department might need other competencies than an engineer working in maintenance. However, frameworks describing professional roles for engineers appear to be underexposed in the current literature.

1.4. Purpose of this study

This work contributes to the pivotal role of professional identity development in that it explores frameworks that can support career guidance of engineering students based on the needs of the professional field. Such frameworks might be valuable instruments to increase students' awareness of the engineering practice, and foster reflection of the future self. As the early career experiences are a major influence on individuals' career decisions, which affect their well-being, career development, and continuance in a profession (Korte et al., 2019), this study focuses on professional roles for early career engineers in particular. However, this article can also be a potential resource for research on career development in any stage of the engineering career.

The paper is organised as follows. First, we explore the concept of professional roles in different fields. The research methodology is concerned in the second section as well as a description of the included papers of the systematic literature review. Section three analyses the results including an in-depth analysis of the studies that fulfilled all analysis criteria. To conclude, we discuss the results and draw out recommendations for further research.

2. Professional role

The term 'role' comes from a world that has nothing to do with engineering: theatre. Actors' scripts were written on rolls of parchment in seventeenth-century France, and 'rôle' became shorthand for the set of actions and the character the actor was supposed to portray. Nobody expected actors to really be the persona of the play, but as 'professionals' they had to be able to fill their role and suspend disbelief in their audience (Paulsen, 2011).

Today, the term role evolved to a concept used to guide ideals and expectations of what to be and how to behave – think about gender-roles, age-roles and, in this study, professional roles. As such, professional roles belong to distinct professions, to groups of people who perform activities that are clearly distinguishable from other types of work. They are a cluster of more or less stringent expectations of a person in a certain position, and of what is demanded from this person by members of his or her working environment (De Jager & Mok, 1999; Lunenberg, Dengerink & Korthagen, 2014; Paulsen, 2011).

When describing six roles for teachers, Lunenberg, Dengerink and Korthagen (2014) have pointed out that the concept of professional roles mainly focuses on position and expectations from the environment whereas the concept of professional identity mainly focuses on personal views and self-images. Despite an inconsistent use of terminology and a variance in explicit and abstract definitions, the researchers could identify different roles for teachers (teacher of teachers, coach, researcher, gatekeeper etc.) and define the critical features and role behaviours.

In their international study on journalism competencies, Willnat, Weaver, and Choi (2013) argue that different views on professional roles have implications for competencies. For example, investigative reporting will be more necessary for a journalist in a critical watchdog role than in a neutral disseminator role. Of course, there will be some overlap in competencies needed to perform the different roles well. Another example in this regard

is the CanMEDS framework, an internationally recognised framework in the field of medicine, that identifies and describes the competencies required for physicians to effectively meet the health care needs of the people they serve, thematically grouped under seven professional roles (Frank, Snell & Sherbino, 2015). For example, in the role of a communicator, a physician aims to facilitate the gathering and sharing of essential information for health care. Therefore, active listening and empathy with patients and their families are crucial competencies. For physicians in a role of health advocates, who work predominantly with communities or patient populations to improve health, competencies as continuing quality improvement and responsibility in using their position and influence are very important.

In the context of engineering, literature on professional roles is scarce. Several terms such as (professional) profiles (Kubler & Forbes, 2004; Lima et al., 2017) or sub-occupations (Brunhaver et al., 2013) are also mentioned, but a clear definition of the concept is often lacking. However, like in other fields, it is generally recognised that different types of jobs are associated with different demands and that the professional role is relevant for explaining the importance of professional competencies (Male et al., 2011; Nilsson, 2010a). Brunhaver et al. (2013) refer to the significant limitation of one rather generic role for engineers since this requires the same balance of the same technical and professional competencies for all engineers. Nevertheless, most studies regarding professional competencies, employability or career guidance fail to address this variety in professional roles.

Following Lunenberg, Dengerink and Korthagen (2014, p. 6), in this review study we define the concept professional role as an interpretation of a position based on expectations from the environment. In particular, we will focus on what the work field expects from early career engineers and what attributes are required to fulfil the position in a particular role successfully. As such, a professional roles framework can be a valuable

instrument in professional identity development as it involves interaction between the expectations related to a specific professional role (from the work field) and the needs and aptitudes to prepare for that role (of the student) (Becker & Carper, 1956). To that end, we set out to address two research questions:

RQ1 'What professional roles for early career engineers can be identified?'
RQ2 'What attributes define the professional roles for early career engineers?'

3. Method

A systematic literature review was performed, as it is the best method to identify, appraise and synthesise all the relevant studies on professional roles. We followed the recommendations and methodologies from previous literature reviews in the fields of engineering education and social sciences (Borrego et al., 2014; Petticrew & Roberts, 2006). In this section, we first describe the selected databases, search terms and inclusion criteria before elaborating on the analysis criteria. Third, we will provide a description of the included papers.

3.1. Databases and search terms

A systematic literature review was performed in September 2018. An appropriate set of complementary databases was selected to get extensive and broad coverage of the literature in education research in order to increase the probability of finding highly relevant articles: Web of Science, Scopus and ERIC – the Educational Resources Information Centre. Based on the background literature and after revision and feedback of the four researchers, the search term 'engineer' was combined with one of the terms*:*

- role, profile, classification, function, value, expectation
- career, career path, career guidance, career development, career management

The search resulted in 952 potentially relevant studies.

3.2. Inclusion criteria

The aim of this research is to look for frameworks that can support career guidance of engineering students based on actual and future needs of the professional field. Therefore, recent studies are of particular interest. We noticed an increasing number of studies since 2008. Moreover, almost 68% of the studies were published in the last decade, so we decided to focus the review on the period between 2008 and 2018 resulting in 645 studies (Figure 1.1).

The titles and abstracts of peer reviewed articles and book chapters written in English were screened. As the topic is underexposed in literature, peer reviewed conference proceedings were included also. Further screening discarded studies on gender roles, on the attractiveness or on persistence in STEM programs in middle or high schools, as well as studies focused on career shifts unless they explicitly described the starting point of this path addressing young graduates at the beginning of a career.

The quality of the papers was appraised and assessed after which papers were excluded that seemed not methodologically sound (reliability, validity). Additionally, a snowball approach was used to identify other relevant studies that had not shown up in the systematic literature search. This added 7 more papers to the collection. We ultimately identified 24 unique studies for further analysis. The search track of exclusion/inclusion is tabulated in Figure 1.1.

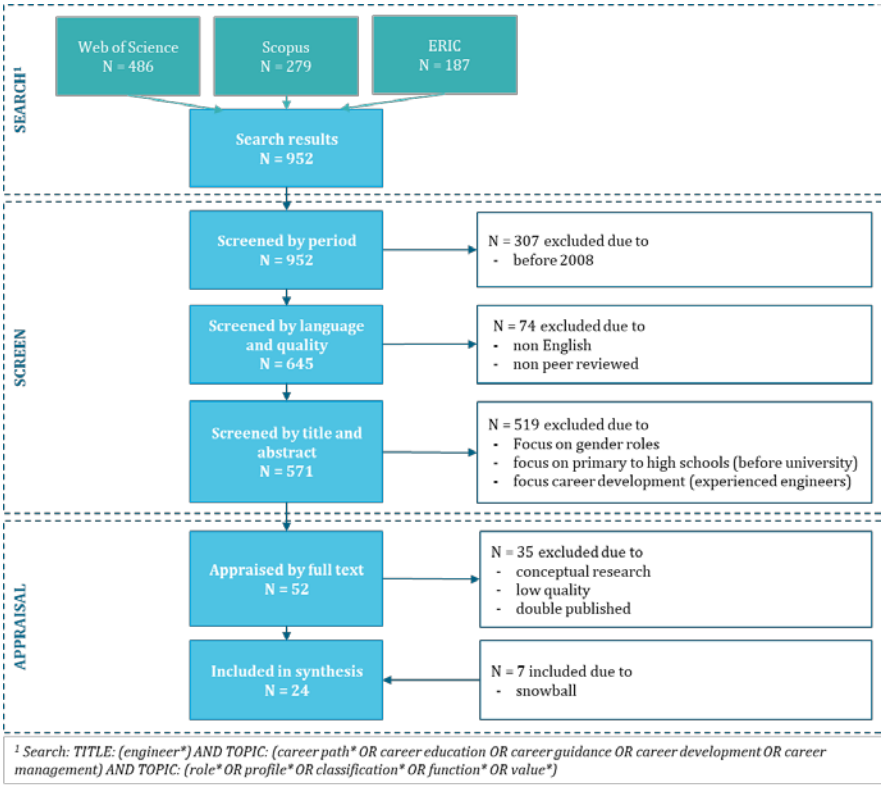


Figure 1.1. Flowchart of filtering process and results.

3.3. Analysis criteria

The previous section emphasised the importance of creating awareness of both personality and future career opportunities when addressing the skills and expectations gaps. For example, engineering students should be aware of the fact that different (early career) jobs require different professional competencies, but also be aware of their strengths and weaknesses regarding these competencies.

The reasoning above was converted into three analysis criteria, in particular, whether the studies were:

(a) applicable to engineering graduates, entering the labour market (expectation management)

(b) applicable to different disciplines or fields (to expand the

traditionally narrow focus beyond learning technical and scientific knowledge)

(c) involve different stakeholders from the professional field and higher education (bridging the gaps)

3.4. Description of the included publications

In order to describe the 24 publications, the studies are first classified by terminology related to the concept of professional role. Second, we describe whether developing a framework was a research objective. The descriptive items are included in Table 1.1.

3.4.1. Terminology related to the professional role concept

Eleven different terms were found for concepts that could categorise engineers in the work field (Table 1.1, column 4). 'Roles' (roles or job roles) was used most often ($N = 9$), followed by 'career paths' or 'career trajectories' ($N = 5$), 'profiles' ($N = 2$) and 'job or career preferences' ($N = 2$). Other terms appeared in only one study each, such as 'career types', 'sub-occupations', 'positions', 'professions', 'job functions' or 'work identities'.

Only six studies described the concept they used as overarching classifications, addressing professional competencies (Hofland et al., 2015; Kamp & Klaassen, 2016; Spinks et al., 2007) or motives and preferences (Bignon & Szajnfarber, 2015; Itani & Srour, 2016). Wilcox (2015, p. 1) was the only author that explicitly defined the role concept in her study, namely: 'Roles do not necessarily represent formal titles, but identity-related roles that can signify the motives with which [people] engage [in their work]'. This definition is more related to what Lunenberg, Dengerink, and Korthagen (2014) describes as professional identity and less to the expectations of the environment.

3.4.2. Research objective and methodologies

In most studies (N = 16) engineering categorisations were predominantly used as a framework to elaborate on a specific topic like career preferences. For 10 out of 16 studies, developing a framework or categorisation was an explicit objective (Table 1.1, column 5). The latter frameworks were developed mostly based on mixed research methods. Interviews were used as a grounded theory method to construct the categories and paired with a subsequent survey of engineers or company representatives (e.g., Brunhaver et al., 2013; Hofland et al., 2015; Spinks, Silburn & Birchall, 2007). In other studies, interviews were used to refine a framework based on vacancy analyses (Lauwers, Bonte, & Vanmaercke, 2013) or role play (Smith, McClelland & Smith, 2017). Two frameworks were based on a literature study (Trevelyan & Williams, 2018; Wilcox, 2015). Trevelyan and Williams performed a content analysis of data from earlier studies. Finally, one study conducted a design thinking method where a panel discussed what engineering students' competencies should be in 2030 (Kamp & Klaassen, 2016).

Although the studies aiming to develop a framework applicable to different engineering disciplines are of particular interest in our research, the other studies will be included in the analysis, as they can provide interesting insights into the study. By consequence, some studies will be discussed more in depth than others.

Table 1.1. Results of the systematic literature review by different criteria.

Studies	Roles		Terminology	Framework as research objective	Focus on early career	Domain		Stake-holders		Key elements			
	Roles (N)	Categories				Specific	Generic	Industry	Education	Competencies	Value creation	Expectations	Preferences
Gemme and Gingras (2012)	2	academic, non-academic	Career preference			●			●				●
Sinche et al. (2017)		research-intensive, non-research-intensive	Career trajectory			●		●		●			
Betz (2014)		technical specialist, (project) management	Profile				●	●		●			
Hodgson, Paton and Cicmil (2011)			Role				●	●				●	
Saunders-Smits and De Graaff (2012)			Career path			●		●		●			

Brunhaver et al. (2013)	3	engineering practitioners, consultants, managers	Sub-occupations	•	•		•	•		•			
De Norre, Pinxten, and Langie (2016)		operational excellence, product leadership, customer intimacy	Role		•		•		•				•
Hofland et al. (2015)			Role	•	•		•	•		•			
Gerwel Proches, Chelin and Rouvrais (2018)		technical, entrepreneurial, management	Professional path		•		•		•			•	
Spinks, Silburn, and Birchall (2007)		specialist, change agent, integrators	Role	•	•		•	•		•			
Wilcox (2015)		inventor, consultant, entrepreneur	Role	•		•							
Bignon and Szajnfarber (2015)	4	enablers, bridgers, researchers and intrapreneurs	Work identities	•		•		•					•

Kamp and Klaassen (2016)		specialist, front-end innovator, integrator, contextual engineer	Role	•	•		•		•	•			
Van der Heijden, Brinkman, and During (2009)		personal firm or lifestyle entrepreneur path, professional entrepreneur path, managerial growth path, entrepreneurial growth path	Career Type	•	•	•		•		•			
Choudhary and Jesiek (2015)	5	faculty job with focus on research, faculty job with focus on teaching, industry job with focus on research, government job with focus on research, job as an entrepreneur	Career path		•	•			•				•
Fernandez-Sanz (2010)		programmer, analyst, system technician, consultant, CIO or similar management positions	Positions			•			•	•			

Kinoshita, Young, and Knight (2015)		technical, supervisory , consultant, non-technical, other (e.g., academics)	Job function		•		•	•		•			
Srour et al. (2013)		Project Controls Manager, Project Management Track Position, Entry Level Technical Position, Medium Level Technical Position, Senior Level Technical Position	Career path		•		•	•					
Itani and Srour (2016)	6	technical engineer, technical and administrative engineer, general or nontechnical consultant, consultant in the technical field, opportunity involving management or supervisory training, job rotation program (position will be determined at a later stage)	Job preference		•		•		•	•			•

Lauwers, Bonte, and Vanmaercke (2013)	8	product, process and automation engineer; maintenance engineer; quality -, prevention-, environment- and safety engineer; project engineer; R&D engineer; planning and work preparation engineer, method engineer; commercial engineer	Profile	•	•	•		•		•			
Medina et al. (2018)		Project Management (PM); Production, Distribution and Logistics (PDL); Manufacturing and Process Engineering (M&PE); Supply Chain Management (SCM); Ergonomics and Human Factors (EHF); Strategic Planning (SP) and Financial Engineering (FE)	Role		•	•		•					

Kinunnen et al. (2018)	9	Software designer, project manager, entrepreneur, programmer, administrator, solving societal problems, researcher, teacher or educator, something else	Professions / Job duties			•			•			•	
Trevelyan and Williams (2018)	14	No roles defined, 14 ways of value creation in enterprises	Role	•			•	•			•		
Smith, McClelland, and Smith (2017)	15	No roles defined, but 15 responsibilities on Corporate Social Responsibility	Role	•		•			•		•		

4. Results

An in-depth exploration of the 24 studies would go beyond the scope of this study. An overview of the details of the different studies is presented in Table 1.1. In the following paragraphs, we will elaborate on the most promising models according to the analysis criteria. We first examined the different roles in the studies; more specifically how many roles were included and how were they described (RQ1). The three analysis criteria (focus on young engineering graduates, independent of discipline and involving different stakeholders) were the guiding principle. Second, we examined which attributes identified the different roles (RQ2).

4.1. What professional roles for early career engineers can be identified? (RQ1)

The studies used a wide range of frameworks consisting of two to fifteen roles or ways to categorise different types of engineers. More than half of the studies described frameworks including two roles (N = 5), three roles (N = 6), or four roles (N = 3). Although different labels were used, we will systematically use the term 'roles' when referring to the different types of engineers in the work field.

4.1.1. Focus on early career engineers

Thirteen of the included studies specifically focused on early career engineers (Table 1.1, column 6). Other studies included frameworks that might also be applicable to young graduates as they do not explicitly refer to work experience (e.g., Bignon & Szajnfarber, 2015; Fernandez-Sanz, 2010; Kinnunen et al., 2018; Wilcox, 2015). These studies agree that a more elaborate categorisation is needed for better engineering education or career development. When investigating career paths or tracks in career development, it can be noticed that there is only a differentiation in roles when progressing in the careers. For example, engineers can develop into a

technical expert role or a managerial role (Betz, 2014; Hodgson, Paton & Cicmil, 2011; Saunders-Smits & De Graaff, 2012). However, these studies identified different professional competencies for the future professional roles that affect the professional success.

4.1.2. Independent of disciplines

Half of the studies focused on a specific engineering domain (N = 12), the other half focused on the broad field of engineering (N = 12) (Table 1.1, column 7 and 8).

A *specific engineering domain* could be a specific engineering discipline, for example, aerospace (G. Saunders-Smits & De Graaff, 2012), ICT (Fernandez-Sanz, 2010; Kinnunen et al., 2018), electromechanical or industrial engineering (Lauwers, Bonte & Vanmaercke., 2013; Medina et al., 2018). It could also be a particular area, such as research and academia (Choudhary & Jesiek, 2015; Gemme & Gingras, 2012; Sinche et al., 2017; Wilcox, 2015), entrepreneurship (Van der Heijden, Brinkman & During, 2009) or corporate social responsibility (Smith, McClelland & Smith, 2017) (Table 1.1, column 3 and 7). Some of these studies, like Saunders-Smits and De Graaff (2012) or Wilcox (2015) described professional roles that were not bound to the discipline and the categories reoccurred in more generic studies. However, often the specific focus was reflected in the professional roles, which hindered transferring the roles to other domains. For example, Fernandez-Sanz (2010) identified six roles for IT engineers, like programmer, analyst, system technician, etc. In their research on potential career paths of doctoral students, Choudhary and Jesiek (2015) distinguished three focuses: research (in faculty, industry or government job), teaching (in faculty) or entrepreneurship. Although the latter construct is not necessarily bound by one specific discipline, the framework for doctoral engineers does not cover all engineering professions.

Studies identifying *professional roles independent of discipline* seemed to address quite similar models but varied in how detailed the roles were

conceived (Table 1.1, column 3 and 8). For example, Brunhaver et al. (2013) categorised engineers in practitioners, managers and consultants, whereas Gerwel Proches, Chelin & Rouvrais (2018) identified technical, management and entrepreneurial roles. Itani and Srour (2016) referred to the entrepreneurial role more precisely as general non-technical consultants and consultants in the technical field. Kinoshita, Young & Knight (2015) also included a category other (e.g., academics). Although the authors did not give clear definitions for each role, it can be argued that these roles can be applied to different engineering domains or disciplines.

An in-depth comparison of the frameworks was bounded by the fact that only three 'generic' frameworks applicable to early career engineers included well-described definitions of the identified roles (De Norre, Pinxten & Langie, 2016; Hofland et al., 2015; Kamp & Klaassen, 2016; Spinks, Silburn & Birchall, 2007) (see Table 1.2 for full definitions). The three frameworks defined the roles by describing the different expectations related to operating in the work environment. Although they were categorised and labelled differently, three similar roles occurred: one role focusing on advancing and optimising technology which requires technical expertise (operational excellence, specialist), the second role focusing on innovation and developing new products (product leadership, change agent, specialist, front-end innovator), a third role focusing on the needs of the customer in different environments (customer intimacy, integrator, system integrator).

Table 1.2. Overarching models with well-defined professional roles.

Study	Role 1	Role 2	Role 3	Role 4
Hofland et al. (2015)	**Operational Excellence** organises and optimises processes	**Product Leadership** develops new products/ technologies	**Customer Intimacy** provides solutions according to the needs of the customer	
De Norre, Pinxten, and Langie (2016)	focus on process efficiency and finding ways to achieving the best total cost	focus on new ideas and developing the best product	focus on the best total solution for customers	
Spinks, Silburn, and Birchall (2007)	**Specialist** recognises the continued need for engineers who are technical experts of world-class standing	**Change agent** provides the creativity, innovation and leadership to shape the industry in an uncertain future.	**Integrator** operates and manages across boundaries, be they technical or organisational in a complex business environment	
Kamp and Klaassen (2016)	**Specialist** advances and optimises technology for innovations and better performance using scientific knowledge	**Front-end Innovator** advances and applies knowledge and uses technology to develop new products for the benefit of people	**System Integrator** brings together disciplines, products or subsystems into a functioning whole that meets the needs of the customer	**Contextual Engineer** exploits diversity-in-thought to advance and apply knowledge and uses technology in different realms to develop products and processes for the benefit of people in different cultures and context

Kamp and Klaassen (2016) included a fourth role: the contextual engineer who understands complex societal, cultural, global, and professional contexts. They defined the role after a Think Tank discussion questioning what kind of engineers we need to educate to meet future challenges. Where Hofland et al. (2015) developed roles based on what industry needs today, Spinks, Silburn, and Birchall (2007) integrated both today's and future challenges, such as globalisation, complexity in technology or sustainability within the role concepts itself.

Unlike Brunhaver et al. (2013) or Gerwel Proches, Chelin, and Rouvrais (2018), none of these three frameworks included a managerial role. In the survey of Spinks, Silburn, and Birchall (2007), company representatives indicated that only 5% employ graduates (max. 2 years after graduation) in management roles, although graduates were likely to find themselves involved in project management. It seemed likely that there will be some managerial responsibility in all of the roles. This was also observed in the study of Hodgson, Paton, and Cicmil (2011) investigating the role of project manager. Kamp and Klaassen (2016) highlighted the collaboration between the different roles because 'each role cannot realize a technological solution without the other and [each role] is needed to realize integrated solutions for complex problems' (p. 6). The model of Spinks, Silburn, and Birchall (2007) and Hofland et al. (2015) approached their framework differently. They both stated that engineers will more than likely focus on one of the roles but may be equally able to operate in two or more and they might change roles in the course of their career.

4.1.3. Stakeholder involvement

Table 1.1 (column 9 and 10) shows that the work field or higher education are the stakeholders involved when examining engineering roles or engineering attributes. The work field is mostly represented by engineers in the field and alumni (N = 14). Three of these studies also involved company representatives and engineering recruitment agencies (Hofland et

al., 2015; Lauwers, Bonte & Vanmaercke, 2013; Spinks, Silburn & Birchall, 2007). When higher education is involved (N = 9), faculty staff (researchers and staff) were mostly questioned (N = 7). Three studies engaged also students (De Norre, Pinxten & Langie, 2016; Gerwel Proches, Chelin & Rouvrais, 2018; Kamp & Klaassen, 2016). De Norre, Pinxten, and Langie (2016) included both students' and staff's perspectives in a follow-up study of Hofland et al. (2015) who involved the work field. That means that only one framework was validated by both work field and education.

In sum, when excluding engineering roles that are only applicable in specific disciplines or contexts, there seems to be similar categorisations of engineers varying in detail (e.g., consultant vs different types of consultants). However, most of these studies failed to give clear definitions of the roles and used a typology for other research purposes than developing a framework. A managerial role was often included whereas other studies infer that managerial tasks are essential in all the roles. A convergence occurred between the frameworks of Hofland et al. (2015), Kamp and Klaassen (2016) and Spinks et al. (2007) as the categorisations reflect similar expectations of the work field related to innovation, optimisation and customer needs. Only the first framework was validated by both the educational and work field. As these frameworks were developed to better prepare students for an engineering career, we need to know what the work field expects. At the same time, the frameworks should also be recognised by students and staff as it will be implemented in education.

4.2. What attributes define the professional roles for early career engineers? (RQ2)

Twelve studies indicated that different roles required different professional competencies. Ten studies did not focus on competencies but on preferences (N = 5), expectations (N = 3) and value creation (N = 2) (Table 1.1, column 11-14). They will be discussed in the following paragraph, after which we examine the results regarding the identifying competencies.

4.2.1. Preferences (N = 5), expectations (N = 3) and value creation (N = 2)

Eight studies approached the roles by analysing preferences and expectations of engineering students. For example, when comparing job preferences and learning outcomes (De Norre, Pinxten & Langie, 2016); when studying the evolution of students' preferences over time (Gemme & Gingras, 2012) or the motivational dimensions of preferences (Bignon & Szajnfarber, 2015); or when investigating students' expectations from an engineering career (Gerwel Proches, Chelin, & Rouvrais, 2018; Hodgson, Paton & Cicmil, 2011; Kinnunen et al., 2018). These results confirm that preferences might be malleable over time and that developing a range of professional competencies in education is important. They also indicate that students should be equipped with the ability of self-management to make professional choices that are congruent with their personality.

Two studies focused on *value creation*. Smith, McClelland, and Smith (2017) emphasised on a specific area, namely corporate social responsibility that implies the ethical challenges of an engineer's future work. A more generic approach was the research of Trevelyan and Williams (2018) who determined value creation as a key element to deepen their understanding of engineering practice in different contexts. They identified 14 ways in which engineers create value in the enterprise: from innovation and design, from engineering analysis, from due diligence, from technical collaboration, etc. These findings could support students to understand that all engineering jobs create value to the enterprise and society, also engineers working in roles with few, if any, opportunities for innovation.

4.2.2. Professional competencies (N = 12)

Twelve studies indicated that different roles require a different set of competencies, or at least different importance of the same set of competencies (Table 1.1, column 11). In an attempt to identify the distinct competencies, we were bounded by the variety of research methods, even

when only focusing on the frameworks that described generic roles for early career engineers (*N* = 6). On the one hand, competency lists were drawn from existing literature or other sources (Brunhaver et al., 2013; Hofland et al., 2015; Itani & Srour, 2016; Kinoshita, Young & Knight, 2015). Unfortunately, every study administered a particular list. For example, Brunhaver et al. (2013) used a list of 20 competencies based on competencies from ABET and Engineer2020 whereas Hofland et al. (2015) based their research on the 13 learning outcomes of the engineering curriculum of their university. On the other hand, important competencies were retrieved from interviews and discussions with industry (Kamp & Klaassen, 2016; Spinks, Silburn & Birchall, 2007). This method resulted in specific engineering competencies that might be a role requirement, like customer awareness, but were not included in for example competency lists based on learning outcomes.

Although these latter studies could provide us with examples of competencies that seemed to vary in importance when applied in different professional roles (Table A1, see Appendix), it should be highlighted that the studies rarely define the competencies in the study and different interpretations of a similar concept might have occurred. By consequence, the lack of definitions hindered further analysis of, for example, the inconsistent results regarding communication skills and teamwork. For example, where communication skills (a very broad concept) were highlighted to vary according to roles, Kamp and Klaassen (2016) and Spinks, Silburn, and Birchall (2007) indicated that communication skills are core competencies for every engineer. Hofland et al. (2015) found the same reasoning regarding teamwork.

In sum, the results confirmed earlier findings that the work field expects early career engineers to have specific (level of) professional competencies in order to be successful in a particular professional role. Due to a variation of competency lists and a lack of definitions, the outcomes of the studies were

difficult to compare and only an overview of competencies that might be more important in some roles could be provided (Table A1, see Appendix).

5. Discussion, limitations and further research

This study aimed to contribute to the conversation of professional identity development of engineering students by exploring frameworks that categorise professional roles for early career engineers. Such frameworks might be valuable in engineering education to create awareness of the future career as a driving compass for reflection on the future self. To this end, we systematically reviewed literature from 2008 to 2018 and identified 24 relevant papers. In the following discussion, we will expand on the results and suggest future directions for research in career development in engineering education.

5.1. Professional role concept

The results in this systematic literature review confirm that literature on professional roles in engineering is scarce and is characterised by an inconsistent use of terms. Very few studies defined the concept but there seems to be an agreement that professional roles are more than just jobs or function titles and reflect the expectations of the work field. Different characteristics such as cross-disciplinary or the importance of non-technical competencies seem to support the definition of professional roles we used in this study (Section 2). Hence, in the context of engineering graduates entering the labour market, we may suggest endorsing the concept of professional roles for future research.

5.2. Professional roles for early career engineers

In our search for professional roles focused on early career engineers and applicable to multiple engineering disciplines, there seems to be a high degree of convergence between the models of Hofland et al. (2015), De Norre, Pinxten, and Langie (2016), Kamp and Klaassen (2016), and Spinks,

Silburn, and Birchall (2007). The models are simple and clearly describing three to four roles for early career engineers (Table 1.2). These descriptions indicate that the work field seems to be looking for early career engineers who focus on (1) innovation, (2) optimisation, or (3) customisation. While Kamp and Klaassen identified a separate fourth role to emphasise the diversity and different cultures or contexts, Spinks et al. incorporated future oriented aspects due to globalisation and rapid change within all roles. This high degree of convergence allows us to propose a model with only three professional roles embedded in a broader global or intercultural context (Figure 1.2).

Furthermore, Spinks et al. and Hofland et al. and De Norre et al. both stress the flexibility of their framework in similar venn diagram visualisations, allowing to operate in two or more roles or to change roles in the career. This is in line with role models from other fields than engineering that also recognise that in practice several roles are often combined (Frank, Snell & Sherbino, 2015; Lunenberg, Dengerink & Korthagen, 2014; Willnat, Weaver & Choi, 2013). Since there is a general need for a flexible interpretation of the professional roles, the venn diagram, allowing role overlap, is suggested to visualise the proposed threefold model (Figure 1.2).

The framework of Hofland et al. and De Norre et al. was the only framework validated in a triangulation way by engineers and company representatives, faculty staff and students. A surprising result when addressing the skills and expectations gap.

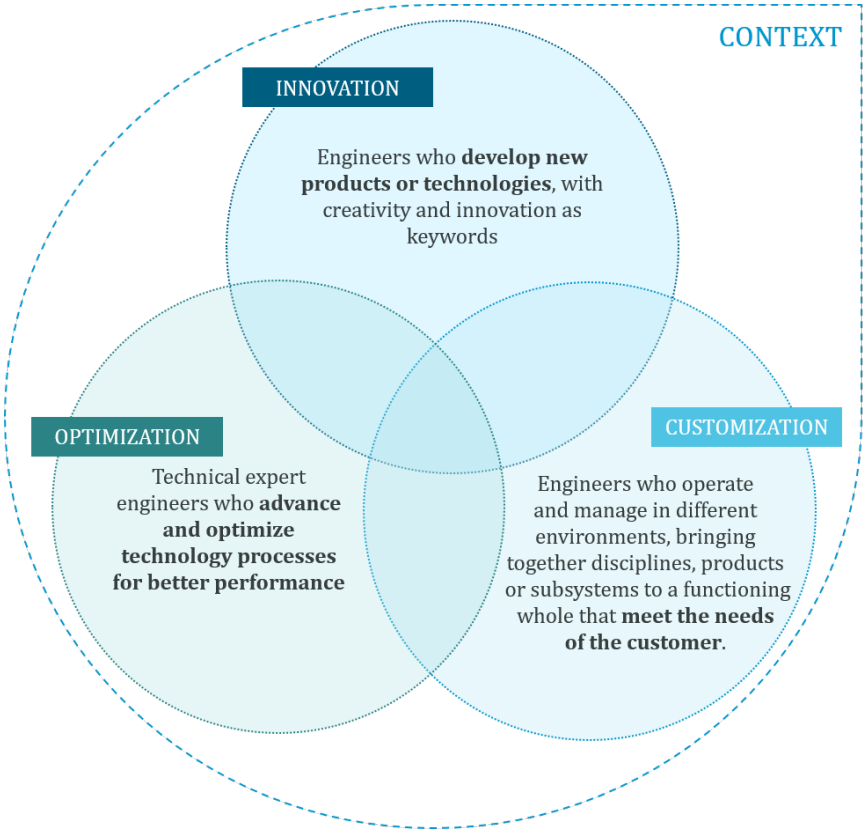


Figure 1.2. A flexible professional framework defining three professional roles for engineering graduates.

Further research investigating to what extent the model might evolve or expand can be valuable in the area of career development. The studies included in this review seem to suggest a manager role as a career ladder opportunity (Betz, 2014; Hodgson, Paton & Cicmil, 2011; Saunders-Smits & De Graaff, 2012) whereas engineering graduates will have some managerial responsibility in all roles (Spinks, Silburn & Birchall, 2007). It can be remarked that the studies which included a separate managerial role for early career engineers did not aim to develop categorisation but used predefined categories for other research purposes (Brunhaver et al., 2013; Gerwel Proches, Chelin & Rouvrais, 2018; Itani & Srour, 2016; Kinoshita, Young & Knight, 2015; Srour et al., 2013).

Although innovation is a crucial competence in the rapidly evolving world of technology, Trevelyan and Williams (2018) pointed out that most engineers work in roles with few opportunities for innovation. It would be interesting to further investigate how the three roles relate to each other in the work field and whether that might vary in different fields, or in large or small enterprises. Also, the model might be a potential framework for research on the attractiveness of engineering, as the roles make explicit that engineering is not just creating artefacts, processes or systems, but is also involving customer needs. By emphasising this, we might, for example, be able to attract more female students (Bairaktarova & Pilotte, 2020). A study on role preference and gender or engineering discipline might contribute to this work.

A limitation of this study is the focus on expectations from the work field. The work field in the included studies were companies or alumni. This excluded non-engineering career possibilities from the beginning, or they were excluded due to low sample sizes (Kinnunen et al., 2018; Kinoshita, Young & Knight, 2015). The framework should be interpreted within these boundaries.

5.3. Role attributes

Only two studies investigated value creation in engineering. This is in line with previous findings indicating that value creation seldom intrudes on engineering education discourse (Alaksan, 2018). Further research on how professional roles can be defined more specifically by creating value in different ways might contribute to enhancing engineering students' reflection on the kind of engineer they want to be.

The majority of the reviewed studies defined roles referring to professional competencies. That might not be surprising as higher education is competency based. The results of this review confirm that different roles require different (levels) of professional competencies, but none of them

developed competency profiles that can help educators to devise more precisely activities for students.

In an attempt to identify what competencies might be more required in different roles, we were hindered by the inconsistency of methods and measurements. Many of the reviewed papers failed to address the validity of the measures, which impeded the comparison of outcomes. Different pre-defined competency lists were used to investigate which competencies might be more important. Although some competencies are rather common in engineering education, other competencies are usually not present in the repository of educational resources (e.g. customer orientation, results orientation) (Fernandez-Sanz, 2010). In addition, very few studies defined the listed competencies. As research on career development or on professional competencies for engineers has gained a lot of interest in recent years, we might expect accurate definitions of concepts or variables to really move forward to a broader understanding in the field. There is substantial literature on competencies in a work place environment and on the personality dimensions related to specific competency domains, such as The Great Eight Competencies (Bartram, 2005). Bartram showed that openness is, for instance, one of the determinants of creating and conceptualising. These studies can offer a solid ground for concepts and definitions that are well known in the repository of career development.

Finally, several studies emphasise the need for differentiation in learning paths towards the acquisition of competencies that motivate the students (Kamp & Klaassen, 2016; Male, Bush & Chapman, 2011; Spinks, Silburn & Birchall, 2007). Curriculum designers should be aware of the differences in professional roles and maintain flexibility so that graduates know how to choose from a variety of career options. Also, the impact of co-curricular activities on professional competencies should be recognised (Kinoshita, Young & Knight, 2015). Further research is recommended to refine the model and identify the role attributes so that the conceptual framework can evolve into a practical model in engineering education for curriculum

designers, tutors, career counsellors, and even student recruiters. As such, the model can be a useful instrument to create professional and self-awareness, so that students can be adequately supported in minding the gap.

2 | Different roles, different demands. A competency-based professional roles model for early career engineers, validated in industry and higher education

This study is published as : Craps S., Pinxten M., Knipprath H. & G. Langie (2021): Different roles, different demands. A competency-based professional roles model for early career engineers, validated in industry and higher education, European Journal of Engineering Education, DOI: 10.1080/03043797.2021.1889468

Abstract

This study contributes to the current research in career and professional identity development in that it developed a validated competency- based framework to enhance professional and self-awareness of future engineers. Through a mixed-method design, key competencies were identified for three professional roles for early career engineers. Ninety- six engineers and HR experts from different fields were involved. This resulted in three portraits of early career engineers in practice (engineers in a role focusing on radical innovation, on process optimisation and/or on customised solutions) and what it requires to be successful in these roles. For example, perseverance and creativity were deemed essential for engineers in an innovative role, whereas positive critical attitude and stress resistance were indicated essential for engineers focusing on optimisation. The competency profiles with an aspiration to career perspectives can be a valuable instrument in creating more diversity in engineering. Implications for education, industry, and future research are discussed.

1. Introduction

Excellent communication skills, great team player, problem solver, flexible and creative … This is just a selection of professional competencies mentioned in vacancies addressed to young engineers. Unless they are super(wo)man, it seems impossible for students to acquire a mastery level in all professional skills upon graduation (World Economic Forum, 2014). Therefore, employers are encouraged to ensure clear and efficient recruitment strategies to attract the right talent. Education providers are encouraged to put on the agenda high-quality career guidance that helps inform educational and career choices, in order to create awareness and understanding of the labour market and job demands. 'Employers, education providers and youth live in parallel universes' states the European Report 'Education to employment: designing a system that works' (Mourshed et al., 2013, p. 18). Employers and education providers should communicate and collaborate more to increase mutual understanding and youth should be better informed to understand professions. This to the benefit of all: employers will better find graduates with the right set of competencies or the required competency level and graduates' expectations will be better aligned with their experiences with positive consequences for job satisfaction (Chan et al., 2017; Jusoh et al., 2011; Mourshed et al., 2014).

1.1. Understanding the engineering profession

In response, engineering education has been adapting its learning methods offering for example authentic learning experiences, like project-based learning, involving industry. Research shows, however, that the need to increase students' understanding of the engineering profession is still high because many engineers, even close to graduation, have no clear image of what engineering is and what engineers do (Bennett & Male, 2017; Lichtenstein et al., 2009; Matusovich et al., 2009). Moreover, some students hold narrow and naive perceptions of the professional aspects of engineering and consider engineering as primarily technical (Brunhaver et al., 2018;

Karataş, Bodner & Unal, 2016). However, it has been recognised for many years now that engineers need more than only technical expertise. Accreditation bodies like ABET (2017), the European Network for Accreditation ENAEE (2015), or the Accreditation of Higher Education Programmes AHEP set by the UK Engineering Council (2014) have included non-technical or professional competencies, such as communication skills, teamwork, or lifelong learning. However, these professional competencies are described as broadly applicable to all engineers. The broadly-defined nature allows for variation between programmes on the one hand but, on the other hand, risks to assume that these competencies are the same for all jobs (Male et al., 2011). The latter might limit understanding of the variation of engineering professions or of industry's expectations of an engineering graduate undertaking a specific first role.

1.2. Understanding the different roles in engineering

Research shows that there are different types of engineers and that the importance of professional competencies or the way engineers create value varies across job tasks and work contexts (Brunhaver et al., 2013; Male et al., 2011; Trevelyan & Williams, 2019; Walther & Radcliffe, 2007). Nilsson (2010) suggests that the professional role is relevant for explaining the importance of competencies. For example, an engineer working in maintenance might need different professional competencies than an engineer working in research and development. In this study, a professional role is defined as 'the interpretation of a position based on expectations of the environment, in particular what the work field expects' (Craps et al., 2020).

Although recognised that there is not one generic engineering role, Craps et al. (2020) found that there are only relatively few studies available that aim to investigate the different roles an engineer can take on, let alone what competencies are required in the different roles. It seems that this variety in professional roles, regardless of disciplines, is not addressed in engineering

education. However, it could provide students with a guide to navigate through and explore the myriad of career opportunities.

1.3. Understanding the future self

The importance of providing students opportunities to explore both themselves and the variety of engineering roles and make connections between them has been highlighted in several studies (Bennett & Male, 2017; Lichtenstein et al., 2009; Oyserman et al., 2006; Trevelyan & Williams, 2018). It is assumed that when students can align with the attributes thought essential for success in a professional role, they will experience feelings of role congruence and increase their perception of role fit (Cardador, 2017; Cech et al., 2011; Eagly & Karau, 2002). It will make them more specialised in a professional role (Nilsson, 2010a) and increase their motivation (Oyserman, Bybee & Terry, 2006), learning (Bliuc et al., 2011), employability (Yorke, 2006), and job satisfaction (Weiss & Merlo, 2015). However, this implies that students have enough information about their own preferences and competencies, and about the educational, training, or job requirements (Bimrose et al., 2004). Hence, a professional roles model describing what essential competencies are required in the different roles could offer an even richer insight of engineers in practice and enhance professional and self-awareness.

1.4. Purpose of this study

The aim of this study is to develop a competency-based professional role model for future engineers, validated by different stakeholders in industry and education. Such model has the potential to trigger reflection on the future career, raise awareness of the desirable professional competencies for specific career pathways and by consequence inform choices and plans for personal development.

The remainder of the paper is as follows. In the next section (Section 2), the PREFER model, a professional Roles Model for Future Engineers, is introduced

as the theoretical framework of this study. The framework, identifying three roles focusing on radical innovation, process optimisation, and customised solutions, was built upon the outcomes of a systematic literature review (Craps et al., 2020) and was validated with both industry and education stakeholders. This study was set up to identify the essential competencies for each role. The concept of professional competencies and the competency framework that is used in this study is described in the third section. Section four addresses the mixed-method approach in identifying the key competencies of the different professional roles, which includes the involvement of 12 industry expert panels and one meta panel to consolidate the results. In section five, we present the findings of the different panels and summarise them in three portraits of professional roles in engineering practice. Finally, we discuss implications for stakeholders in education and industry, and suggest areas for future research.

2. Professional Roles Model for Future Engineers

A systematic literature review (N = 24) prior to this study, indicated that research of professional roles for early career engineers is scarce (Craps et al. 2020). High convergence was found between the models of Spinks, Silburn, and Birchall (2007) (UK), and of Hofland et al. (2015) (Belgium). The descriptions of the roles were very similar indicating that the work field seems to be looking for early career engineers who focus on radical innovation, process optimisation, and/or customised solutions (Craps et al., 2020). Both models had their strengths. The model of Spinks, Silburn, and Birchall (2007) was built upon an investigation of UK undergraduate engineering education requirements in terms of current and future needs of the engineering industry based on industry's perspective. Hofland et al. (2015) 're-engineered' the business model of Treacy and Wiersema (1993), questioned the recognisability of their model with industry representatives from different fields, and conducted a mapping exercise with job vacancies and with the learning outcomes of their home faculty at a Belgian university.

Also, it seemed that student's preferences for particular roles could be identified (De Norre, Pinxten & Langie, 2016). As such, it was the only model that involved both industry and education.

The authors decided to build upon this work but refined the definitions based on the insights of the literature review and several conversations with professors, engineers, and HR managers. The flexibility of the model, allowing combining roles, was represented in a Venn diagram visualisation (Figure 2.1). Since the aim is to develop a professional role model to prepare future engineers, the model was also named this way: Professional Roles Model for Future Engineers (PREFER model).

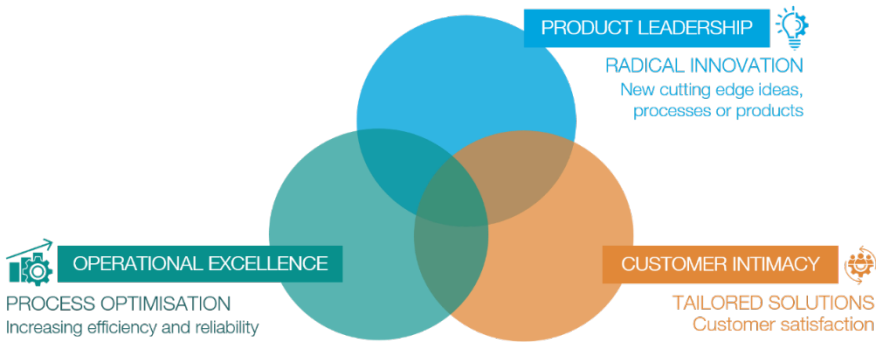


Figure 2.1. Professional Roles Model for Future Engineers.

2.1. Three professional roles

The three roles were defined as follows:

- *Product Leadership:* In this role, the emphasis is on innovation and creativity through research and development. These engineers explore new paradigms and identify radical alternative solutions. They translate theoretical ideas into marketable applications that provide added value to (yet) unidentified end users.
- *Operational Excellence:* This role focuses on the smooth design and implementation of operational processes. The engineer locates opportunities to create efficiency gains, fixes flaws, and overseas

operations, either in psychical production facilities or in the digital domain.

- *Customer Intimacy:* This role entails close collaboration with clients in complex business environments. These engineers develop a (commercial) relationship with clients, help them express their needs, and provide a technical tailored solution to these needs.

2.2. Validation by industry and education

In a validation research study, Craps, Pinxten and Langie (2019) examined first the external validity of the PREFER model with a diverse sample of business professionals [3]. A survey was distributed in 2018 at job fairs of six different campuses of the Leuven University in Belgium (N=188). About 2/3rd of the respondents (very) easily recognised the model to classify functions for young engineering graduates and about 60% agreed they could (very) easily apply the model in their respective company. No statistical differences were observed between recognisability and the respondents' professional background or the company size. The majority (55%) indicated that most engineering positions require a combination of two roles. No statistical differences were observed based on company size.

Second, focus groups were organised with Bachelors' and Masters' students in Engineering Technology (N = 69, 2018) followed up by 16 semi-structured interviews with Masters' students in order to investigate (1) how students perceive the professional roles for early career engineers and (2) whether they are able to identify themselves with one or more professional roles (Craps, et al., 2019) [4]. The findings indicate that both Bachelors' and Masters' students found the PREFER model rather intuitive and they could easily link the roles with previous experiences. Most students could easily align with one or more roles. They appealed most strongly to the roles of

[3] The article on industry validation is available via the SEFI 2019 Conference proceedings pp. 1519-1530 or via https://lirias.kuleuven.be/retrieve/549127

[4] The article on student validation is available via the Proceedings of the 2019 University-Business Interaction Conference pp. 188-202 or via https://lirias.kuleuven.be/retrieve/541702

operational excellence (optimisation) and product leadership (innovation) as they recognised these roles the most from the curriculum. Although they were least familiar with the role of customer intimacy, almost 40% indicated they prefer to work in this role (single of combination with another role). Some of them even mentioned it was a relief to discover this professional role as 'real engineering'. The students made a clear call to concretise the theoretical model. Role definitions do not fully grasp what companies expect from the different roles or what it requires to be successful in a particular role. Reflection of the future self goes beyond reflection of interest and motivation but also requires a critical thought of the strengths and weaknesses allowing students to deepen or broaden their competencies. Hence, this study aims to further develop the PREFER model to provide students a richer and more nuanced portrait of engineers in practice and foster understanding and reflection on professional competencies. To that end, we set out the following research question:

> RQ 'Which professional competencies do early career engineers need to possess in order to be successful in one of the professional roles?'

In the next section, we define the concept of professional competencies in this study and face two barriers in engineering education research to move forward the field of competency research. Consequently, we opted for a mixed-method design as described in Section 4.

3. Competencies required for engineering work

For more than a decade, there has been a tendency in education to develop more output-oriented or competency oriented pedagogies as a means to adapt curricula to professional activity (Lemaitre et al., 2006). Professional competencies are suggested as a key in improving graduate employability (Teijeiro & Jesús Freire, 2013). However, a variation of concepts and terminology is used to refer to the non-technical competencies (Knipprath & De Rick, 2013). In this section, we first define the concept of professional competencies. Second, we point out two problems that emerged when

reviewing research aiming to identify competencies. Finally, we describe the Great Eight Competencies as the competency framework in this study.

3.1. Defining professional competencies

In the 1980s, transferable or generic skills were often used referring to skills learned in one context that could be transferred to another (Yorke, 2006) where later concepts such as employability skills (Markes, 2006), twenty-first century skills (Kalevi Ahonen & Kinnunen, 2014), transversal competencies (Care & Luo, 2016) or professional skills (Shuman, Besterfield-Sacre & McGourty., 2005) are often used interchangeably emphasising a more holistic development and the capability of adapting to change. Metacognition or self-regulation has become an important aspect taking into account different situations or contexts.

In this study, the authors opt for the concept 'professional competencies' for two reasons. First *competencies* is a more comprehensive concept than skills. Kurz and Bartram (2002) highlight that competencies relate to the behaviours underpinning successful performance. It relates to what it is people do in order to meet their objectives and what enables their competent performance. The OECD definition describes competencies as follows (Rychen and Salganik, 2005, p. 4):

> A competency is more than just knowledge and skills. It involves the ability to meet complex demands, by drawing on and mobilising psychosocial resources (including skills and attitudes) in a particular context. For example, the ability to communicate effectively is a competency that may draw on an individual's knowledge of language, practical IT skills and attitudes towards those with whom he or she is communicating.

Second, *professional* refers to the professional engineering context as competencies are dependent on the learning context, whether in engineering education or on the job training (De La Harpe, Radloff & Wyber, 2000). Shuman, Besterfield-Sacre, and McGourty (2005, p. 43) point out that 'success as an engineer requires technical expertise, but also competencies such as

communication and persuasion […] or the ability to work effectively and an understanding of the non-technical forces that affect engineering decisions'. An engineer needs technical expertise to respond to the immediate needs and the sector's tendencies and professional competencies that are more related with personal and relational attributes. These competencies are less prone to be affected by technological changes (Direito, Pereira & De Oliveira Duarte, 2014), however, they cannot be applied or taught in isolation of the technical context in which they will be used (Passow & Passow, 2017). Although Lindberg and Rantatalo (2015) found that, in different professional practices, the professional competencies were indicated as characteristics of excellence and differentiate between more or less competent in different roles. Endorsing the holistic perspective on competencies, this study aims to identify what professional competencies are more desirable in engineering practice according to the professional role an engineer can take on.

3.2. Two barriers in identifying professional competencies

In engineering education, the growing emphasis on employability, professional identity, and career development, has triggered research on professional competencies. However, two problems were observed to really move forward the field. First, there is a lack of consensus on the definition of the different professional competencies between the different engineering education communities, government bodies, and employers, and by what behaviours would exhibit mastery (Shuman, Besterfield-Sacre & McGourty., 2005). Often studies even fail to give any definition of the competencies which hinders future research to build upon the results (Craps et al., 2020; Cruz, Saunders-Smits & Groen., 2019).

Second, the difficulty in measuring competencies and the variety of approaches generates diverging results (Teijeiro, Rungo & Jesús Freire, 2013). Suleman (2018) points out that one of the problems is that there is no well-defined competency catalogue to build upon. In the literature review previous to this study, Craps et al. (2020) similarly found that there is no

single rule in identifying or assessing competencies: some researchers assess just one competence or use a short/long competency list. Other researchers use methods allowing stakeholders to freely enumerate required competencies resulting in competencies that are rather common in engineering education, like communication, and in others that are usually not present in the repository of educational resources, like customer orientation (Fernandez-Sanz, 2010). Passow and Passow (2017) conducted an extensive systematic review integrating a quantitative synthesis inspired by meta-analytic techniques and a qualitative analysis and identified the relative importance of 16 professional competencies in engineering practice, independent of engineering discipline or work contexts. For example, they found that communicating effectively or taking initiative differentiates between ordinary and outstanding engineering performance.

This study aims to refine their concise portrait of engineering practice by taking it one step further and investigate what competencies are deemed more important according to the role an engineer takes on. For example, do all engineers need to be outstanding in taking initiative or might the expectations vary depending on the professional role?

3.3. The Great Eight Competency Framework

In order to identify the essential competencies per role, the authors followed Suleman's (2018) recommendation to use a well-defined competency catalogue with well-defined competencies and, as described in the Method section (Section 4), the option to add possible missing competencies. As there is no common standard of competency catalogues in engineering education, the authors decided to work with a catalogue based upon the well-known Great Eight Competencies of Bartram (2005). Bartram relates competencies to how knowledge and skills are used in performance and applied in the context of some particular set of job requirements. These eight competency domains include leading and deciding, supporting and co-operating, interacting and presenting, analysing and interpreting, creating and

conceptualising, organising and executing, adapting and coping, enterprising and performing. It has also been shown that personality dimensions are related to specific competency domains (Kurz & Bartram, 2002). For example, openness is one of the determinants of creating and conceptualising. As such, this framework allows to clearly describe the relationship between competencies as constructs on the one hand, and psychological constructs such as motives and personality traits on the other hand (Klendauer et al., 2012). It offers opportunities to develop competency profiles for the different professional roles that enhance students' awareness on their future roles, competencies, and preferences.

4. Method

From a pragmatic qualitative approach, a mixed-method design was set up in a sequential transformative way to give voice to diverse perspectives from the work field on the essential competencies of the different professional roles (Creswell, 2009). More specifically, it comprised the nominal group technique as a way to gather general agreement on topics that do not yet have empirical evidence (Waggoner, Carline & Durning, 2016). This technique is a consensus method that allows a group of experts to develop ideas or solutions in a structured manner (Savin-Baden & Major, 2012): each expert panel comprised an initial quantitative individual assessment, followed by a qualitative group discussion. Twelve expert panels and a meta panel were organised in different engineering fields to maximise the diversity of participants sampled. The following paragraphs describe the participants and how they were recruited. Then we elaborate on the nominal group technique and the panel structure, after which the different quantitative and qualitative phases are presented in more detail.

4.1. Participants of the panels

Experts participating in the panels were identified as engineers and HR managers or recruiters with expertise in hiring engineers as they are

supposed to make a good estimate of the required competencies of a certain professional role.

4.1.1. Expert panels

The expert panels were, except for one mixed panel, organised in companies from different sectors such as construction, nuclear & energy, telecommunication, automotive, additive manufacturing and biomedical technology, automation, (micro) electronics & IT, chemical, pharmaceutical, and food industry. The number of expert panels was not clearly defined at the start. We aimed for input from a wide range of sectors but also observed a point of data saturation after 12 panels.

In a preliminary meeting, the research project was presented to a liaison in the company after which the liaison selected the experts within his or her company according to the following criteria:

- 6–8 engineers from different professional roles, preferably of different age and tenure;
- 1 or 2 recruiters or HR managers with expertise in hiring engineers;
- male and female experts.

As such, we aimed to organise a heterogeneous panel with around eight participants (min. 5, max. 10), which is considered a good panel size to provide enough input for discussion and encourage a good group conversation (Savin-Baden & Major, 2012; Waggoner, Carline & Durning, 2016).

4.1.2. Meta panel

The experts of the meta panel were carefully selected from companies of different sizes and active in different sectors locally and internationally. The researchers contacted the experts following the same criteria (engineers, HR, (fe)male). None of the meta panel experts participated in one of the previous 12 expert panels. As such, we aimed to maximise panel heterogeneity in order to mitigate the possible influence of company culture and company size to the panel consensus.

In total, 87 experts participated in the regular expert panels and nine in the meta panel. Table 2.1 gives an overview of participants' profiles.

Table 2.1. Participant profiles of the expert and meta panels.

Experts (N = 96)		**N**
Age	20–29 years	21
	30–39 years	24
	40–49 years	17
	50–59 years	8
	60+ years	2
	(blank)	24
Gender	M	75
	F	21
Background	Engineer	72
	Engineer-HR	6
	HR	18
Work experience	<5 years	17
	5–10 years	11
	10–20 years	26
	20–30 years	13
	>30 years	5
	(blank)	24
Number of jobs before current	<1	10
	2-3	38
	4-5	10
	>5	12
	(blank)	26
Participating companies (N=24)		**N**
Size	Large (>250)	15
	Medium (50–250)	6
	Small (10-50)	2
	Micro/start up	1

Note: The participant profiles of the first two panels were not recorded.

4.2. The nominal group technique

The nominal group technique is a more structured approach of focus groups and was used as a means to prioritise the most essential professional competencies per role. The technique is used as a ranking exercise with the aim of obtaining consensus between experts in the field (Savin-Baden & Major, 2012). This mixed method includes (1) a quantitative part in which competencies are ranked individually resulting in an overall group score and (2) a qualitative group discussion to obtain the consensus. The technique is closely linked to the Delphi methodology that is widely used across numerous disciplines as a method to seek expert opinion in an iterative structured manner (Van de Ven & Delbecq, 1974). Where the Delphi method guarantees anonymity between experts, iteration, and controlled feedback, the nominal group technique allows face-to-face group discussion. Although the latter technique includes an individual round to encourage more passive members to participate.

This technique addresses some critiques given to other methods that are used in competency research. Interviews, for example, have been criticised for the variation (and confusion) in definition used by the respondents and therefore non-comparable different employers' needs (Bennett, 2002) whereas surveys that work with lists of competencies, have the risk of missing information as the respondents only rate those skills in the survey (Suleman, 2018).

The technique was applied in 12 expert panels and one meta panel following a well-defined structure with different stages (Figure 2.2) (Savin-Baden & Major, 2012; Van Teijlingen et al., 2006). Each expert panel consisted of three phases and took two hours. The meta panel was organised similarly but with an additional step to triangulate the findings of the expert panels (O'Cathain, Murphy & Nicholl, 2010). Figure 2.3 shows how the methods were mixed in the different phases of the study.

The expert panels were organised by the researcher-observer and a moderator. The moderator, an expert in talent management and HR screening

tools, led the actual expert panel without bias (Figure 2.2, phase 2 and 3). The next paragraphs describe the different phases of the panel in detail.

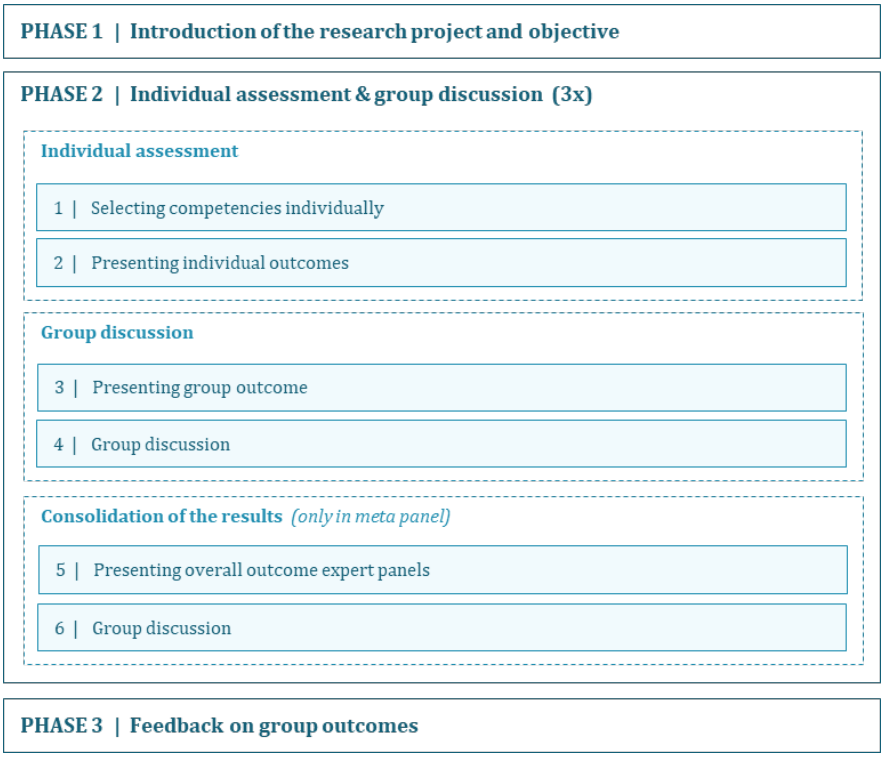


Figure 2.2. Different phases of an expert panel.

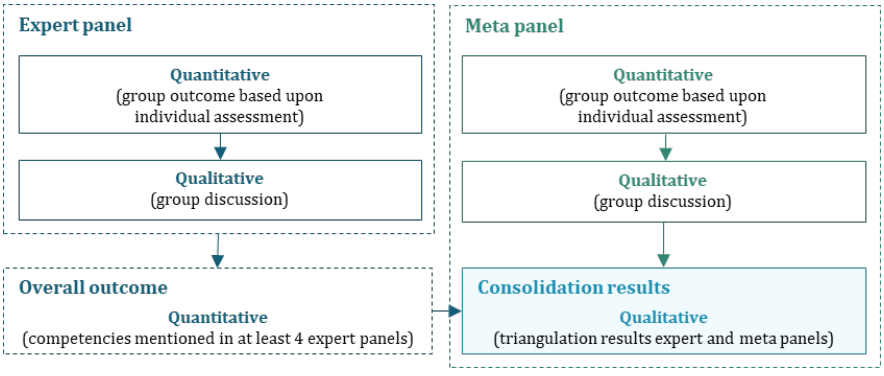


Figure 2.3. Mixed method design.

4.3. Phase 1: Introduction of the research project and objective

The researcher presented the Professional Roles Model for Future Engineers to the experts in a consistent way, without mentioning competencies. The participants were allowed to give feedback on the model or ask questions to clarify the roles after which the objective of the panel was described.

4.4. Phase 2: Individual assessment and group discussion

The moderator explained the principles and guidelines to the experts:

- One exercise consists of two rounds: (1) individual assessment and (2) group discussion;
- The exercise is finalised when the experts reach consensus about the competency profile or decide that no consensus can be reached;
- Consensus is reached when the experts agree on 6–10 competencies that an early career engineer needs to possess in order to be successful in one of the professional roles;
- The exercise will be repeated for each of the three roles, with a final feedback moment at the end (phase 3)

4.4.1. Selecting competencies individually

The participants received an extensive lists of 64 competencies with a clear definition. BDO Human Capital, internationally active and recognised for its expertise in workforce strategy and intelligence, HR screening tools and talent management, allowed us to use their competency catalogue that was built upon the Big Eight Competencies of Bartram (2005) (due to its length, the catalogue is not included but available on request).

The participants selected individually seven key competencies for each particular role. This forced the participants to focus on essential competencies and make well thought choices without the risk of picking one competence in each category or selecting a broad range of engineering competencies. It was allowed to add competencies if the expert considered that they were missing

in the competency catalogue. After selecting the seven most important competencies for one role, the participants were asked to rank them from most to least important.

4.4.2. Presenting individual outcomes

The experts presented the top four of the individually selected competencies in order of importance and the top four of each participant was tabulated and scored simultaneously in a dedicated excel file. The highest ranked scored seven points, the second ranked scored six points, etc. No discussion was allowed to avoid that participants would feel limited to express their opinion.

4.4.3. Presenting group outcomes

When all the experts had presented their top four competencies, a sum score was calculated for each competence. These sum scores were then ranked in decreasing order in real-time on the screen. The moderator pointed out certain particularities, e.g., a clearly defined top three or a less distinctive top five. The top five (or more in the case of equally scored competencies) was highlighted and presented as the key competencies that are required to be successful in the professional role.

4.4.4. Group discussion

Based on this quantitative result, a group discussion was initiated. Experts could discuss the result, add key competencies or decide a 'top' competence was ranked too highly. They also had the opportunity to add competencies that were not mentioned in the individual outcomes. The group score fed the discussion. The scores will not be discussed for further analyses as the ranking changed throughout the group discussion. The discussion was ended when consensus was reached on 6– 10 competencies.

4.4.5. Consolidation of the results

Participants of the meta panel were assigned to run through the same steps as described above. Competencies that were never selected in the previous

panels were left out of the meta panel competency catalogue to gain some time and to reduce the participants' efforts in the quiet intensive panel sessions. An additional step was introduced in which the overall outcomes of the 12 expert panels (an overview of the competencies that were mentioned in at least a third of the panels) were presented and compared to the outcome of the meta panel. The result was consolidated through a group discussion.

4.5. Phase 3: Feedback on group outcomes

When the previous phase was repeated three times (one per role), an overview of the competency profiles was presented to the panel. The experts had the opportunity to confirm the consensus or to make adjustments after comparing the three competency profiles.

5. Results

This section describes the results in three ways. First, we present the findings based upon qualitative observations in obtaining consensus through group discussions. Second, we outline the outcomes (competencies identified) of the 12 expert panels in a quantitative way and describe how the meta panel consolidated this overall outcome. Third, the final result per role is described in more detail.

5.1. Obtaining consensus through group discussions

All the panels reached consensus on the competency profiles. As the panels were organised in-company, the company culture and strategy might have facilitated the consent between the experts. However, the mixed expert panel and the mixed meta panel also reached consensus although they had to argue more profoundly and illustrate with more examples why they considered a competence essential. Though, it was observed that these discussions were reasonably fast followed by a common decision that was equally supported by all participants.

The competency profile of the customer intimacy role (client focus) reached most easily consensus where the competency profile of the operational excellence role (focus on optimisation) seemed the most difficult to construct. This was reflected in the top scores that were less distinct (see 5.2.) and in the discussions that were more intense. Nonetheless, the experts recognised the importance of this role and did not express the need to develop a fourth role. The more extensive outcome is likely typical for the role of operational excellence, which can include various functions, tasks, and responsibilities.

The competency profiles comprised on average eight competencies per role. One panel managed to describe each role by five key competencies, the other panels pictured the roles by 6–10 competencies. We noticed a point of data saturation in the 12th panel: no new elements were brought up in the group discussion that were not mentioned in one of the previous panels. This was confirmed in the meta panel. No remarkable differences were observed between the different companies from different sectors.

Although the competency catalogue provided a brief and comprehensive definition per competence, the experts identified similar competencies (competencies labelled differently but with a comparable meaning): networking and relation building, stress tolerance and stress resistance. We combined these competencies in the overall outcome and in the catalogue of the meta panel.

5.2. Identifying competencies

5.2.1. Overall outcome of the 12 expert panels

Table 2.2 shows the overall findings of the 12 expert panels by presenting the professional competencies that were mentioned in at least a third of the panels (N≥4).

Table 2.2. Overall result of the 12 expert panels.

Product leadership		**Operational excellence**		**Customer intimacy**	
Competence	N	Competence	N	Competence	N
Creativity	12	Positive critical attitude	10	Client focus	12
Innovation	12	Solution-oriented	10	Networking & building relations	11
Client focus	7	Focus on results	6	Clear communication	10
Initiative	7	Planning	6	Negotiation	9
Out of the box thinking	7	Clear communication	5	Capacity for empathy	8
Persuasiveness	6	Initiative	5	Focus on results	8
Vision	6	Creativity	4	Solution-oriented	7
Conceptualisation	5	Networking & building relations	4	Stress resistance	5
Perseverance	5				

Note: N = number of panels that identified the competence.

A few competencies overlapped in two roles. For example, initiative appeared to be very important for engineers in the role of operational excellence and product leadership. However, in the group discussions, it became clear that the experts nuanced some overlapping competencies. For example, client focus in the role of product leadership indicated that engineers must be aware of prospect client markets for new innovative technologies, while in the role of customer intimacy it is expected that engineers are able to attune their actions to the needs and wishes of a particular client.

5.2.2. Consolidation of the meta panel

The outcome of the meta panel was in line with the overall outcome of the 12 expert panels, but also showed some differences. As in the expert panels, the roles focusing on radical innovation and customised solutions were easily constructed and the role of operational excellence generated more discussion. The discussion did benefit from the panel heterogeneity as more insights allowed developing a more nuanced and distinct competency profile. For

example, competencies like helicopter quality or work management, which were discussed in the expert panels as well but not always selected in the final outcome, were included by the meta panel in favour of overlapping competencies such as networking or clear communication. The latter seemed to be important when working in teams or managing work. The competence focus on results was incorporated in solution orientation reasoning that engineers in the operational excellence role should strive to obtain a result, but an overemphasis on the result also risks ending the drive to optimise. In line with similar discussions in the expert panels, the meta panel decided that including these competencies better reflects the competency profile of the operational excellence role.

In the meta panel, we intentionally focused on the nuances of the definitions in overlapping competencies. This resulted in combining two more similar competencies: influence and persuasiveness, and creativity and out of the box thinking.

Based upon this additional discussion and a comparison of the three competency profiles in phase 3, the meta panel reached a final consensus for each role. Figure 2.4 shows these outcomes presenting the most essential professional competencies in each professional role. In line with the overall outcome, the union of the three roles is empty. This was perceived as the core for all engineers and by consequence not essential to be successful in a particular role. The following section describes for each role why the experts consider the selected competencies to be very important. The full definitions of the competencies are included in the Appendix Table A2.

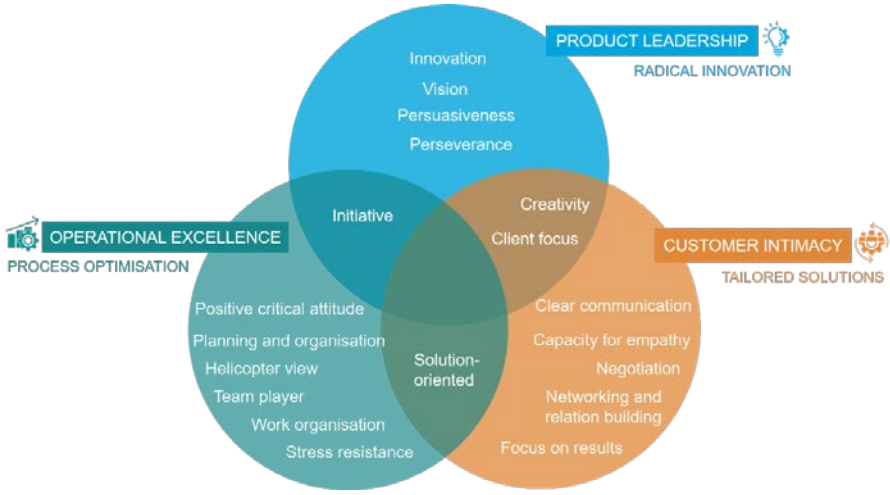


Figure 2.4. Professional competencies required to be successful in a professional role.

5.3. Detailed results per role

5.3.1. Product leadership

Early career engineers in the role of product leadership, focusing on radical innovation and state of the art technologies, are expected to focus on future *innovations* in strategy, products, services, and markets with an inquiring and inquisitive mind. They approach problems in an out-of-the-box *creative* manner, from different angles breaking through established thinking patterns. They should be able to conceptualise a clear *vision* for a product with a long-term perspective of the field or speciality. They are supposed to undertake actions and make proposals on their own *initiative*. They can obtain buy-in for ideas and proposals by making the right arguments in an appropriate manner and *persuade* others about new ideas. This is not always easy for an early career engineer and not always successful from the first time. Therefore, also *perseverance* was perceived an essential competence, even when confronted with boring and repetitive tasks.

5.3.2. Operational excellence

In the role of operational excellence, a *positive critical attitude* was considered as indispensable: being able to question methods, techniques, and strategies in a positive manner. Engineers in this role are supposed to take *initiative* where they think they spot opportunities to optimise and to increase efficiency and reliability. Therefore, they think in terms of *best solutions* to a given problem for which they need a *helicopter view*: in taking decisions, they are expected to adequately evaluate the consequences of different alternative actions and keep an overall overview on the process, even if they are responsible for just one part. They need *planning* ability to plan activities in accordance with a specific timeline and *work organisation skills* to confer with colleagues on how to distribute tasks. They can *perform effectively under work or time pressure*, despite setbacks, resistance, disappointment, or criticism. These engineers often engage in *teamwork* wherein they supervise operators and/or collaborate with other divisions. In collaborating with other people, personal conflict resolution is seen as an important competence.

5.3.3. Customer intimacy

In a customer intimacy role, engineers are expected to be *client-focused*. In attuning their actions to the feelings, needs, and wishes of clients, it is key to find the right balance between responding to the client's needs and the company's interest. It is imperative to be able to take the perspective of other stakeholders in general and of clients in particular. This *capacity for empathy* does not mean, however, that one's own or organisation's perspective should be discarded. *Clear communication* is an important competence when bringing a message in a clear and concise manner. It requires the ability to tailor the communication to a (nontechnical skilled) audience or person. It requires *creative thinking* outside the box to find the right, safe and pragmatic *solution for a particular clients' problem*. Therefore, it is also key to understand the *negotiation* dynamics well and to keep in mind that the goal is to serve the interests of both parties involved. *Delivering results*, even in situations in

which confronted with unexpected setbacks, is what the customer expects. Finally, engineers in the customer intimacy role need to have *networking skills*, which entails a good understanding of what it takes to build fruitful commercial relationships.

6. Discussion

This study contributes to the current research in career and professional identity development by developing a validated competency-based framework to enhance professional and self-awareness of future engineers. The PREFER model describes professional roles in the early stage of the career as these early career experiences are a major influence on career decision which affect well-being, career development, and continuance in a profession (Korte, Brunhaver & Zehr, 2019). The roles create value in different ways by focusing on radical innovation, process optimisation, and/or on customised solutions and were validated by stakeholders from both industry and education.

This study confirms research indicating that different engineers require different (levels) of competencies (Brunhaver et al., 2018; Male et al., 2011; Nilsson, 2010). Through a mixed- method study design involving 96 experts with a background in engineering and HR, competency profiles per professional role were developed. These profiles are not prescriptive in detail but reflect only the essential professional competencies that the labour market expects from an early career engineer to be successful in the role, regardless of the engineering discipline. The importance of the included competencies is perceived higher in the particular role than those which were not included. This does not entail that the latter are perceived as irrelevant. As such, the PREFER model must be interpreted as a reflective instrument and not as a matching instrument aiming at a one-on-one fit. In the following paragraphs, we describe implications for education, research, and industry.

6.1. Implications for education

In line with Male, Bush and Chapman (2011), we recommend that engineering educators design their programmes with an understanding that diverse programmes and diverse graduates are desirable. Such programmes can help students to develop a realistic understanding of engineering work and the different competencies required by different engineering roles. They should maintain flexibility so that engineering students know how to choose from a variety of career options (Basart, Farrús & Serra, 2015; Nilsson, 2010; Spinks, Silburn & Birchall, 2007) or to select their desired individual competencies and apply them purposefully in the professional context (Walther & Radcliffe, 2007).

The PREFER model can be a reference in this regard. The competency profiles with an aspiration to career perspectives can be easily implemented both extracurricular, for example in activities including career guidance, and in existing curricula, for example, when reframing activities with industry, in project work, or elective courses on specific competencies. They can help to provide contextualisation to the professional competencies in the engineering curriculum and avoid a rather superficial 'tick box' approach (Bridgstock, 2009; Tomlinson & Holmes, 2017). As indicated by Passow and Passow (2017, p. 492) 'learning outcomes without a portrait [of engineering] lose the most important concept, which is that in engineering practice, competencies are intertwined and coordinated'. It has been shown that establishing relevance enables students to make vital connections between self, learning, and their intended field of work with positive consequences for student success and job satisfaction (Bennett & Male, 2017; Bliuc et al., 2011). The PREFER framework offers a more diverse image of engineering which facilitates to trigger awareness of important competencies, also of those that are less easily trained and assessed in education such as vision or helicopter view.

The PREFER framework can be a supportive instrument to enhance accreditation. Accreditation bodies such as ABET (ABET, 2017b) endorse the design of customisable curricula or the development of competencies from a

holistic perspective or of dynamic hands-on training with an immediate link to practice. An illustration of how the PREFER model could support curriculum redesign has been presented by (Langie & Craps, 2020). They describe how the professional roles have been introduced in an engineering curriculum in the Leuven University in Belgium in a gradual way through different learning activities: from introduction with the roles in the first year, through creating awareness and reflection on preferences, to specific skills training in the final year. Two tests that have been developed based upon the PREFER model facilitate this process. A personal preference test was developed to help engineering students evaluate which professional role they would most like to fulfil (Carthy et al., 2019). A situational judgement test (SJT) was developed in close collaboration with industry to provide students insight on their role alignment based on their judgment of situations in practice. The test allows giving feedback on role alignment and professional competencies [(Carthy et al., 2022)].

6.2. Limitations and implications for research

The PREFER model was validated by both industry and education stakeholders mainly in Belgium. Experts from locally and internationally oriented companies participated in the panels and two expert panels were organised in Ireland and the Netherlands. The outcomes of these latter panels did not seem to deviate; however, the model would benefit from larger samples in more countries. To reduce the risk of bias, the meta panel was set up in a diverse and heterogeneous way to triangulate the results. This resulted in a final tweaking of the overall outcomes of the 12 panels. The decisions were made consciously and well argued in order to identify the essential competencies and to create more refined portraits of early career engineers in practice. The study design with clearly defined steps and criteria was set up to avoid that the meta panel would overrule the overall outcome of the 12 panels. Two additional researchers monitored the collaboration between the participants and the way consensus was reached to ensure the quality of the final outcome (Waggoner, Carline & Durning, 2016). The authors

believe that a different composition of the meta panel would have led to similar outcomes. However, the study should be interpreted within these boundaries.

Because there is no standard work on competency research in engineering education, a competency catalogue based on the work of Bartram was selected allowing working with comprehensive competencies that were clearly defined. This might be perceived as yet another list. However, a comparison with alternative frameworks, such as the OECD DeSeCo framework (Definition and Selection of Competencies) (Rychen & Salganik, 2005) which works with three broad categories (acting autonomously, using tools interactively, and interacting in socially heterogeneous groups) did not suggest to expand the competencies or definitions. Participants received the opportunity to indicate if particular competencies were missing, but no missing competencies were identified. Future research on competencies would benefit from standards, clear definitions of concepts, and methods to move forward in this field.

Career development is a development process. A study by Carthy et al. (2020) suggests that first-year engineering students in Belgium and Ireland had, by large, similar preferences for each of the three professional roles in favour of the innovative role of product leadership. However, in reality, only a small proportion of engineers are directly involved in technological innovation (Trevelyan & Williams, 2019). The study also suggests differences in preference between male and female (Carthy et al., 2020; Craps, Van de Kerkhof, et al., 2019). A longitudinal study would be interesting to investigate to what extent role preference changes over time and to what extent male and female students' role preference differentiate.

The PREFER model might also have potential in attracting undecided students to engineering by encouraging greater understanding of the value of engineering and the contributions it makes to society (National Academy of Engineering, 2004). As stated by Faulkner (2007, p. 351) 'promoting heterogeneous images of engineering will create space for a more diverse

range of people to become engineers'. We suggest further research in this direction.

6.3. Implications for industry

Although professional roles and competency profiles were validated by industry, the interpretation of the roles and (level of) competencies might slightly vary according to the company's culture. For example, one of the experts active in a nuclear facility said '*In our R&D department, we need engineers in an innovative role. However, if you are the next Steve Jobs, then you will probably not be happy in a much-regulated nuclear plant*.' Companies are recommended to make explicit what they expect in their specific context and facilitate graduates to identify the different interpretations or expectations when applying for jobs with similar function titles.

A nice side effect of the expert panels was that the participants were triggered to reflect on the company's recruitment policy. Almost all companies asked to receive the outcomes. One company decided after the panel to revise their vacancies and make them more specific according to the competency profiles. These companies are no longer looking for super(wo)man. They prefer an engineer that fits the job.

Acknowledgements

The authors would like to thank Elies Hendrickx, Michael Tack and their colleagues from BDO Human Capital for their valuable feedback and for moderating the expert panels. We are also grateful for the collaboration of all the companies that allowed their employees to empty the agenda and to participate in an intensive two-hour expert panel.

Part Two | Exploring the role of professional awareness in making well informed career choices

3 | The importance of professional awareness and career exploration in increasing professional role confidence of future engineers.

This study is submitted as : Craps S., Smits T., Knipprath H., Pinxten M. & G. Langie (2022): The importance of professional awareness and career exploration in increasing professional role confidence of future engineers. (In Journal of Engineering Education)

Abstract

Background: Engineering students often have difficulties in identifying engineering roles or have rather stereotypical, mainly technical perspectives. Consequently, they may lack the confidence in their ability to successfully fulfil future engineering roles (professional role confidence) when graduating, which hampers their persistence in engineering.

Purpose/Hypothesis: To better prepare engineering students in the transition to work, a better understanding of professional role confidence and its relationship with professional awareness is needed. This study explored which students' characteristics and components of professional awareness and career exploration predict professional role confidence.

Method/Design: A questionnaire was distributed in May 2019 and 2020 (n=898) among Belgian engineering students. Multiple regression analysis was used to identify which student characteristics, components of professional awareness and career exploration predict professional role confidence. Group differences were explored using t-tests and ANOVA.

Results: The results showed that most of the variance in professional role confidence was explained by career exploration and additionally by role

awareness (understanding of different engineering roles) and competence awareness (understanding of importance of different professional competencies). Gender was a small but significant predictor showing lower competence confidence for female students. Program year was a significant predictor with first year bachelor students being highly confident in their future role.

Conclusion: The findings provide empirical evidence for using more refined concepts of engineering roles and of professional awareness in studies on engineering students' identity or career development. This study lay groundwork for future research and interventions to increase professional role confidence, which is important in persistence in engineering and in making well informed career decisions.

1. Introduction

The pertinent climate issues and the COVID19 pandemic brought an already long-standing issue into an even sharper focus: technology is required to solve a broad range of worldwide challenges in our fast-changing societies. The need for highly skilled engineers is bigger than ever before. The McKinsey Report *The Future of Work* estimates that, due to the COVID19 pandemic, STEM-related, business and legal professional roles could grow by more than 20 percent in the coming decade (Smit et al., 2020). This highlights the need to increase attractiveness, diversity and retention in engineering education.

Developing an engineering role identity and clear future career perspectives is an important aspect in the employability debate. Several researchers have proposed identity development as a lens for understanding motivation and persistence in engineering education (Choe & Borrego, 2019; Meyers et al., 2012; Oyserman & Destin, 2010; Pierrakos et al., 2009). Students with stronger engineering identification are more likely to persist. Meijers et al. (2013) observed that Dutch vocational high school pupils who had difficulties

in developing a clear career wish made rather random educational choices and had higher chance of drop out. In a US study, Godwin et al. (2016) found that undergraduate first year students are more likely to pursue an engineering major if they could identify with math and science. Interest, a component of identity, was a significant positive predictor of persistence in engineering programmes. Similar findings were observed for graduate students (Choe & Borrego, 2019). Whereas interest of undergraduates seemed to be mainly captured in learning engineering and positive attitude toward engineering, interest of graduate students additionally captured interest in engineering work.

However, previous research showed that engineering students encounter difficulties in grasping what it is to be an engineer or what engineers do (D. Bennett & Male, 2017; Craps, Van de Kerkhof, et al., 2019; H. Matusovich et al., 2009). Although students seem to recognize that they can end up in a wide variety of engineering positions, their perspective of career options can be strongly swayed by a single experience, such as an internship (Lichtenstein et al., 2009). Also, even close to graduation, they can hold narrow perceptions of engineering that are mainly technical (Brunhaver et al., 2018) or focus on management or leadership careers (Gerwel Proches, Chelin & Rouvrais, 2018; Kinnunen et al., 2018). However, several theories for career development, investigating the process and content by which a professional identity is formed, underline the importance of awareness of future career opportunities (further referred to as professional awareness) (Bridgstock, 2009; Brown & Hirschi, 2013; Heijke et al., 2003). More congruency between the personality, such as interest or strengths and weaknesses, and the future career leads to increased employability, and greater job satisfaction and success (G. D. Gottfredson & Johnstun, 2009; Holland, 1997; Yorke, 2006).

Through their education, 'students are expected to develop views of themselves as competent, skilled, successful future professionals and to become committed to and enthusiastic about their future careers' (Cech et al., 2011, p. 659). Introducing the concept of professional role confidence in a

study on gendered persistence in engineering, Cech and colleagues (2011) found that persistence was higher for engineering students who had the confidence in their ability to successfully fulfil the roles, competencies and identity features of an engineering profession already early in education. However, if students have difficulties in identifying engineering roles or have rather stereotypical, mainly technical perspectives, they risk entering the labour market with confidence but also with wrong expectations. The latter might have negative consequences in relating to meaningful work and job satisfaction (Buch & Andersen, 2013). A Belgian study among 467 engineers indicated that 23% of the respondents, aged less than 26, were no longer working with their first employer after one year and that almost half of them left because the job did not meet their expectations (KU Leuven et al., 2016). This has consequences for the young engineer: early career experiences are a major influence on individuals' career decisions, which affect their well-being, career development, and continuance in a profession (Korte et al., 2019; Tomlinson & Jackson, 2019). It also leads to economic losses for companies that are in high need of engineers.

This study explores the relation between the professional role confidence concept, which is perceived important for persistence, and its relation with professional awareness and career exploration, which influence expectations and making well informed career choices. A survey was organized among 898 engineering students using the recently developed PREFER model (Professional Roles for Future Engineers) as methodological framework (Craps et al., 2021). The latter model captures the diversity in early careers of engineers through three engineering roles and associated professional competencies, regardless discipline. The framework allows investigation of whether students' awareness of both professional roles and professional competencies in engineering predicts students' confidence in these aspects. The approach gives insight into, on the one hand, students' awareness of what engineers do in the field and of what it requires to be an engineer, and, on the other hand, into their respective confidence. Differences in confidence levels

are explored between gender and between the different phases of the engineering programme.

2. Conceptual framework

We seek to explain professional role confidence as a result of career exploration and professional awareness. In Figure 3.1, a schematic for the conceptual framework in this study is represented. The two dimensions of professional awareness (role awareness and competence awareness) and professional role confidence (role fit confidence and competence confidence) are included and will be explained further.

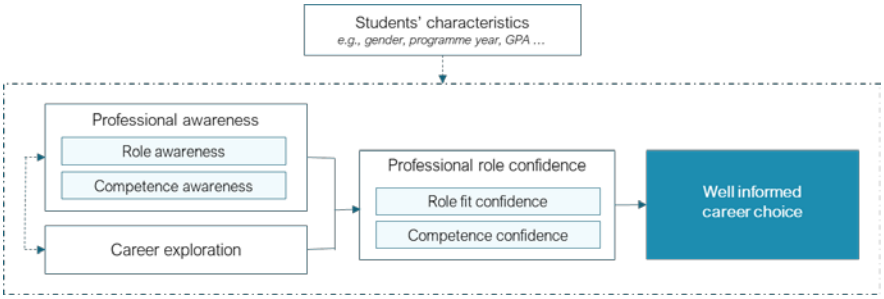


Figure 3.1. Schematic of conceptual framework and expected relationships between professional awareness, career exploration and professional role confidence.

2.1. Career exploration

Career exploration was conceptualized as active career information gathering through (extra) curricular activities and experiences, including work experiences and career guidance to give shape to one's own career path (Kracke, 2002; Meijers et al., 2013). In his career development theory, Super (1980) states that the intensity of career exploration is perceived as the crucial prerequisite for a mature career choice. He asserted that exploration of both the various career opportunities as well as the internal search regarding one's abilities, interests, goals and goal-achieving strategies, is essential in making a choice which matches both one's abilities and interest as well as the demands of the job or labour market. Super considers the concept as a dynamic process for all career development stages (Makki et al., 2015).

Also identity theory considers exploration as paramount for a satisfactory commitment to a choice – a career choice in the context of professional identity (Kracke, 2002; Kroger et al., 2010; Perez et al., 2014). Waterman (2007) noted that among younger adolescents commitments evoke little motivation for change. They are still at the stage of developing career interests and awareness, so their choices constantly change and fluctuate. Career exploration in this stage helps to increase self-awareness and focus on career planning and making career choices (Lau et al., 2020).

Most engineering degree programmes are offered as a tight sequence of courses and students need to choose quite quickly for their major and professional degree. Due to the shortage, the degree often leads to a career immediately after graduation, so little exploration is required (Huff et al., 2019). However, Werbel (2000) showed in an investigation of college graduates in a sociology course and in a business course that students who engaged in career exploration were more active in job searching and experienced more success. This active job search behaviours and the students' confidence in performing tasks that are important to the job search process are demonstrated to be positively correlated with employment outcome (Saks and Ashforth, 1999). Higher career exploration would result in more realistic expectations of and fewer mismatches in the labour market.

2.2. Professional awareness

Becoming aware of a possible future occupation and preparing for the transition from school to work, like career exploration, is regarded as a major developmental task in the transitional period of adolescence (Erikson, 1971). Engineers can end up in a myriad of career opportunity. On the one hand, this is appealing but, on the other hand, this makes it also quite vague to understand what engineering is or how to navigate through the wide variety in engineering careers (Craps, Van de Kerkhof, et al., 2019). However, students need to gain awareness of the diversity of career opportunities in engineering so that they can explore the field and develop the required professional

competencies early in education (Flaherty et al., 2019). In a Portuguese study, Direito and colleagues (2014) observed that engineering students tend to recognize the importance of professional (non-technical) competencies for their future professional roles, but presented a less differentiated vision about these competencies than companies. This might suggest that knowledge of future professional roles does not necessarily entail knowledge of different professional competencies required in engineering. Indeed, a study of Saunders-Smits et al. (2021) comparing professional role preferences in Belgium, the Netherlands, and Ireland showed the need to increase awareness in both roles and competencies. First, they noticed that first-year engineers across the three countries had no clear image of engineering but, on average, they had a main preference for a job in an innovative role. However, Trevelyan and Williams (2019) indicated that the least number of engineering jobs in the labour market are offered in this role. Second, Saunders-Smits and colleagues observed that first year students tend to overestimate their level of preparedness in these roles. This may lead to a dangerous form of students overestimating themselves and therefore denying themselves the acquisition of required competencies.

This study introduces two dimensions of professional awareness: (1) role awareness, or the knowledge and understanding of the different roles an early career engineer can take on, and (2) competence awareness, or knowledge and understanding of the professional competencies required in engineering.

Although it is recognized that there are different roles and that different roles require different competencies, Craps et al. (2020) observed in a systematic literature review that research regarding the diverse roles that early career engineers can end up was scarce. Based on these insights and earlier work of Spinks et al. (2007) and Hofland et al. (2015), a validated competency-based Professional Roles Model for Future Engineers (PREFER model) was developed, offering students very concrete opportunities to grasp aspects of the complex and varying careers that an engineer can pursue (Craps et al., 2021; Craps, Pinxten, & Langie, 2019; Craps, Van de Kerkhof, et al., 2019). The

PREFER model describes three roles for early career engineers, each having specific focus, independent of discipline: Product Leadership (focus on radical innovation and research & development), Operational Excellence (focus on process or product optimization and increasing efficiency), and Customer Intimacy (focus on tailored solutions for individual clients). The roles are flexible in use since several roles can be combined in one job and essential professional competencies have been identified for each role (Craps et al., 2021). For example, persuasiveness and perseverance are essential in a Product Leadership role, whereas networking and capacity for empathy are crucial in Customer Intimacy. Engineers working in the role of Operational Excellence need, amongst others, a positive critical attitude and must excel in work management.

As such, the PREFER model presents students a more diverse perspective on engineering and an insight in what industry expects of the different roles regarding the professional competencies. Choe and Borrego (2019) highlighted the importance of professional competencies for both undergraduate and graduate students in predicting engineering identity. Students perceived for example communication skills as important for success as an engineer. The PREFER model triggers reflection on the personal preferences (interest in engineering work) and strengths as future engineers (that go beyond communication, as recommended by Choe and Borrego).

In the present study, the model was perceived as a useful instrument to further investigate professional awareness by the two sub constructs of role awareness and competence awareness. Taking both role and competence awareness, and career exploration into account, as done in this study, might contribute to effective career guidance in helping students to make the transition to the labour market with more accurate expectations.

These more refined sub concepts also allow for a more refined investigation of students' awareness and its association with professional role confidence which includes role fit confidence and competence confidence, as described in the next section.

2.3. Professional role confidence

According to Bandura (1977), belief and confidence in different possibilities to get employed is a prerequisite to get employed. In his career construction theory, Savickas (2013) put forward career adaptability for successful career construction (or development of the self within the career domain and context). Career adaptability is understood as the readiness to cope with real world constraints on career goals and consists of planning, making choices, confidence and exploration. Where exploration represents a less focused dimension, more focused efforts are perceived in planning, making choices and confidence as they indicate a professional identity commitment. Stringer et al. (2011) demonstrated that career planning and making career choices can be perceived as exploration in depth (focused exploration of a chosen option) which precede confidence to carry out the chosen plans.

This study builds upon the concept of professional role confidence as presented by Cech et al. (2011) in a US study on persistence in engineering education. The concept refers to the students' confidence in their ability to enact expected role performances of engineering when they completed their education (Cech et al., 2011, p. 646):

> 'the confidence in wielding practical competencies of day-to-day professional work and identifying with the professional role and believing that one will enjoy this role, with all complexity, uncertainty, and responsibility that accompany its fulfilment.'

The conceptualisation of professional role confidence captures two dimensions [5]: (1) role fit confidence, or the confidence that a professional role is consonant with one's individual interest and values, and (2) competence confidence, or the confidence in tasks and competencies required of practice in the profession (Cech et al., 2011). As such, the concept of professional role confidence recognizes that becoming a successful engineer involves both

[5] Cech et al. (2011) describe this dimension as career fit confidence and expertise confidence. Due to consistency in terminology in this study, we will use the terms role fit confidence and competence confidence.

mastery of competencies and the cultivation of confidence in, identification with and commitment to a professional role.

In a longitudinal set up, Cech and colleagues found that role fit confidence was strongly and positively related to future career plans where competence confidence was more related to persistence in an engineering major, a rather short-term decision. Consequently, we can expect that career exploration will positively relate with role fit confidence, more than with competence confidence.

Cech discovered that professional role confidence of male students was higher than of female students (2011). In a recently published study on gender differences in professional identity and competency development among early career engineers in Finland, Naukkarinen and Bairoh (2021) observed that early career male and female engineers perceived the importance of competencies differently which might affect both the competence and role fit confidence of female graduates and their intended career paths. Our study will contribute to this research by further exploring professional role confidence among male and female engineering students in Belgium.

2.4. Research questions

Based on the background literature, following research questions are addressed:

1. Are there significant differences in professional role confidence between gender groups?
2. Are there significant differences in professional role confidence between students enrolled in different programme years?
3. Which students' characteristics, components of professional awareness, and career exploration predict professional role confidence?

3. Method

3.1. Sample and data collection

Survey data was collected from engineering students of the Faculty of Engineering Technology at the Leuven University (Belgium). Students, from freshmen to master's, were invited by email in May 2019 or 2020 and received one reminder after a week. Respondents were entered into a raffle for one of four €25 gift cards. With a response rate of 40%, 1041 students from different engineering disciplines filled in the survey. Incomplete surveys were deleted (N=143) after which 898 participants were included in the study. Sophomore students were slightly overrepresented (23,3% compared to 19,8% in the campus' student population) and Master's students were slightly underrepresented (resp. 15,5 and 21,1%) (Table 3.1.). No significant differences for students' characteristics were found between the complete and incomplete surveys.

Data was collected cross-sectionally via a 10-minute electronic survey in Dutch using Qualtrics. The students' characteristics were retrieved from the university's Data Management system according privacy regulations. Ethical approval was sought and obtained for this study from the university's Ethics and Privacy Committee (G-2019-03-1596 and G-2021-3528) and participants have consented to be part of this research. They were informed that their participation was voluntary, and that the analysis would be conducted anonymously.

3.2. Survey development

The survey consisted of four parts. The first part included the informed consent and questioned whether one of the parents is an engineer. In the second part, a visual of the PREFER model was presented and the three professional roles were described as defined by Craps et al. (2021, p. 4) [See Chapter 2, 2.1., pp. 77-78] after which students' role preference and the constructs of role awareness and role fit confidence were measured.

Table 3.1. Students' characteristics including descriptive statistics of the sample of participants (N=898).

Name	Description	Scale	Percentage sample (Scale = 1)	Percentage student population (Scale = 1)
Female	Gender of the student	0 = Male / 1 = Female*	15.00	15.74
Parent engineer	At least one of the parents is an engineer	0 = No / 1 = Yes*	29.05	not available
Technical secondary education	Secondary educational background	0 = General secondary education 1 = Technical secondary education*	20.30	21.56
Programme year				
Bachelor 1	Freshmen	0 = No / 1 = Yes	31.00	29.75
Bachelor 2	Sophomore	0 = No / 1 = Yes	23.30	19.79
Bachelor 3	Third (final) year Bachelor	0 = No / 1 = Yes	23.80	22.65
Transfer	Transfer or bridge programme	0 = No / 1 = Yes	6.30	6.70
Master	Master year	0 = No / 1 = Yes*	15.50	21.11
Engineering discipline				
Common programme		0 = No / 1 = Yes	32.27	28.53

In the third part, the PREFER model describing the competencies required in each role was presented visually (Craps et al., 2021, p. 12) [See Chapter 2, 5.3., p. 94] after which students were asked where they would position themselves in the framework based on the competencies and the constructs of competence awareness and competence confidence were measured. The fourth part concluded with questions measuring career exploration.

The authors borrowed, adapted and generated items to measure professional awareness, career exploration and professional role confidence (see next paragraphs). Four expert reviewers, experienced in engineering research education, provided feedback on the items to evaluate whether these were appropriate descriptors of the concepts defined, and to provide alternative suggestions were needed. The questionnaire was also distributed on paper to five individual student reviewers (2 freshmen and 3 master students), who provided feedback on the formulation and comprehensibility of the different items. The interviews with these students confirmed that the survey items were properly worded and communicated the meaning of the survey items as intended.

Twenty-seven items were developed to measure the different constructs on which exploratory factor analyses (EFA) using maximum likelihood with oblique rotation (Promax) was conducted. The Kaiser-Meyer-Olin measure verified the sampling adequacy, KMO = .83 and Bartlett's Test of Sphericity reached statistical significance supporting factorability of the correlation matrix (Field, 2013). The initial set of 27 items was reduced to 22 items after the item factoring and elimination process. The EFA results indicated that the subconstructs of professional role confidence, professional awareness and career exploration itemed as expected. Cronbach's alphas were calculated per subconstruct ranging from relatively low/moderate to high (from .53 to .82) (Table 3.2). Low reliability reduces statistical power and may result in an underestimation of the effects of the different measurements (Bacon, 2004). After consideration of the low number of items in the subconstructs (Ponterotto & Ruckdeschel, 2007) and after another inspection of the item's

content, the authors decided that the reliability scores fall within an acceptable range of internal consistency because of the exploratory nature and the early development of the survey.

The next sections describe how the dependent and independent variables were measured. Table 3.2 shows the operationalization of all variables.

3.3. Dependent variables

We tested two constructs of professional role confidence: role fit confidence and competence confidence based upon the survey of Cech et al. (2011) who captured professional role confidence with measures that ask about students' confidence as a result of their initial exposure to engineering and learning experiences in education. The questions were slightly adjusted in the sense that a general reference to 'a career' or 'engineering' was more specified as the students' preferred professional role. The questions making up the professional role confidence scale measures (resp. role fit confidence and competence confidence measures) began with 'The following statements are about your preferred role(s). Indicate the level of agreement in the context of your engineering experiences' prompting students to respond in the context of their experiences (1 = strongly disagree to 4 = strongly agree). Because the questions were translated in Dutch, a few questions were added with alternative formulation (three for role fit confidence, two for competence confidence). After reliability analysis, one item was deleted for role fit confidence and two for competence confidence obtaining respectively good (Cronbach's alpha = .74) and acceptable (Cronbach's alpha = .54) construct reliability (see Table 3.2). The latter was lower than found in the study of Cech et al. (2011). The items were used to create factor scores of the confidence constructs used in the current study.

Table 3.2. Operationalization and measurement of study variables.

Key Independent Variables	Key Dependent Variables
Professional awareness: role awareness (α = .53)	*Professional role confidence: role fit confidence (α = .74)*
(1 = strongly disagree to 4 = strongly agree)	As a result of my engineering courses (1 = strongly disagree to 4 = strongly agree)
I understand the description of the different professional roles.	This professional role is the right role for me.
I can relate the roles to learning experiences from the courses.	A job in this professional role will give me great job satisfaction.
I can relate the roles to types of engineers in the field.	I am trying my best to succeed in this role.
	I am confident that I chose the role that suits me best.
Professional awareness: competence awareness (α = .59)	I know for a long time that this is the role I want to fulfil.
(1 = strongly disagree to 4 = strongly agree)	
I recognize most of the competencies in this model.	
I am not sure what to make of these competencies.*	*Professional role confidence: competence confidence (α = .54)*
I think all these competencies are important for an engineer.	As a result of my engineering courses (1 = strongly disagree to 4 = strongly agree)
I doubt that an engineer can be successful in so many competencies.*	I possess the required non-technical competencies to develop my preferred engineering role.
Career exploration (α = . 82)	I have sufficient insight in my talents and competencies to succeed in my preferred role.
(0 = never to 4 = frequently)	Compared to my peers I am good in non-technical competencies.
I explore possible careers through reading, videos or by talking to engineers.	
I keep in touch with engineers and/or companies that might be relevant in the future.	
I look for engineering job offers.	
I attend job fairs or company events.	
I talk to my parents, friends, teachers or professionals about my opportunities on the labour market.	
I try to explore and develop my strengths and weaknesses so I can find a job that suits me.	
I have relevant work experience.	

** Coding reversed*

3.4. Independent variables

- *Professional awareness*

To measure professional role awareness, two constructs were set up. The role awareness measure (Cronbach's alpha = .53) combines Likert-scale responses where students were asked about their agreement with statements regarding their understanding and knowledge of the professional roles for early career engineers (1 = strongly disagree to 4 = strongly agree). The competence awareness measure (Cronbach's alpha = .59) prompted statements regarding their understanding and knowledge of professional competencies required in engineering (see Table 3.2).

These new constructed measures first included four questions for role awareness and five questions for competence awareness, but reliability analyses reduced the constructs to resp. three and four questions resulting in Cronbach's alpha's showing acceptable reliability (.53 and .59). These were used to create factor scores of the professional awareness constructs used in the current study.

- *Career exploration*

Students were asked to rate the frequency of participation in a range of career exploration activities (0 = never to 4 = frequently). The seven questions (see Table 3.2) showed good construct reliability (Cronbach's alpha = .82) and were used to create a factor score for the career exploration construct.

- *Students' characteristics*

As shown in Table 3.1, different background variables were included: gender, whether one of the parents is an engineer, secondary education (students from a general secondary education (a broad theoretical education that prepares pupils for higher education) but also from specific technical (vocational) secondary education can enrol in the engineering programme), GPA score obtained at the end of the academic year, and year in the

programme (first year bachelor to master). In Belgium, a bachelor's programme consists of three years. Most students enrol immediately in the one-year master's programme after bachelor graduation. Students who succeeded in particular vocational programmes in higher education are also admitted in the master's programme after successful completion of a bridging or transfer programme (Van Den Broeck et al., 2017).

3.5. Data analysis

Analyses were performed in SPSS. Multiple linear regression models were run to understand the predictive value of students' characteristics, professional awareness and career exploration for professional role confidence in engineering students. Model 1 includes the students' characteristics (gender, parents engineer, secondary education, programme year and GPA). Model 2 comprised professional awareness (role awareness and competence awareness), and career exploration. The hierarchical regression Model 3 adds all variables of Model 1 and 2. Separate analyses were conducted for the two confidence sub constructs (role fit confidence and competence confidence).

Preliminary analyses tested several assumptions, such as normality, linearity, homoscedasticity via scatter plots and it was ensured that there were no multicollinearity issues in the regression models via the variance inflation factors (VIF < 2.8) (Pallant, 2020) (see also Table A3). All background variables were dummy coded. The reference group (indicated with * in Table 3.1) does not appear in the regression table. Table A3 in the Appendix presents correlations among the variables included in the study. Differences in gender and programme year were explored using t-tests and one-way between-groups ANOVA.

4. Results

The two components of professional role confidence are positively and significantly correlated ($r = .29$, $p < .001$), indicating that students who have more confidence that their preferred professional role will fit their interest

and values (role fit confidence) also have more confidence that they will have the required competencies to fulfil this role (competence confidence) (Table A3). In the following paragraphs, we first analyse the differences in the different variables between gender groups and between programme years. Second, the significant predictors are described.

4.1. Differences between gender groups

Female students had significant lower competence confidence scores (t_{890} = 2.23, p < .05) than male students. However, the magnitude of the differences in the factor scores (mean difference = .09, 95% CI [.00, .17]) was very small (eta squared = .004). No statistical differences between male and female students were found for role fit confidence, nor for role awareness, competence awareness or career exploration (p > .05).

4.2. Differences between programme years

As expected, the results per programme year (Figure 3.2) show that career exploration increased significantly when progressing the engineering programme (see also Table A3). ANOVA analyses confirmed significant differences in career exploration with large effect size (eta square = .16) between all years, except between Bachelor 1 and Bachelor 2. Differences in competence awareness were only significant between Bachelor 1 and Master and in competence confidence between Bachelor 1 and 2, and Master with medium effect size (eta square = .02).

No significant differences were found in role awareness. It was noted that role fit confidence level decreased in Bachelor 2 after which the level increased further throughout the programme, However the differences were not significant (p > .05).

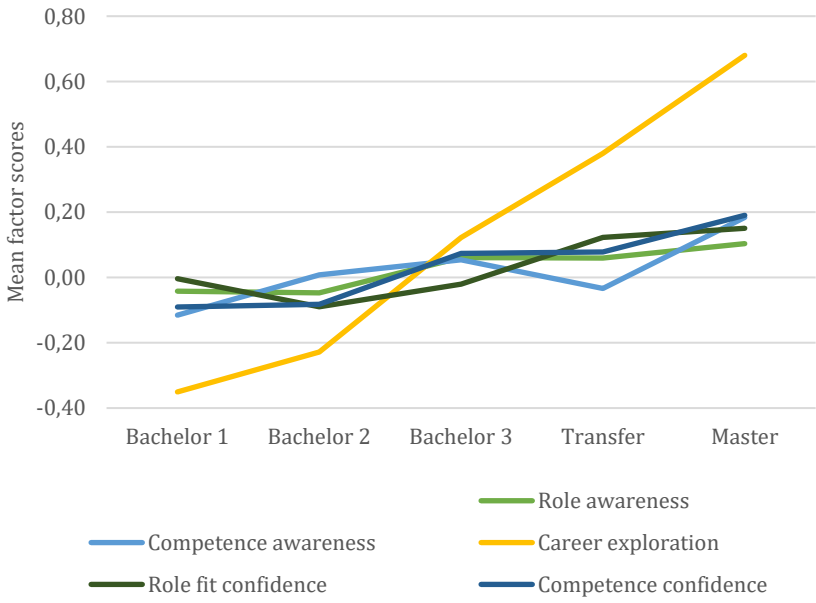


Figure 3.2. Mean factor scores per programme year for the different variables included in the analyses.

4.3. Predictors of role fit confidence and competence confidence

Table 3.3. presents the three regression models to predict professional role confidence. Model 1 showed that students' characteristics explained only 2% and 2,8% of the variance in resp. role fit confidence and competence confidence. Model 2 included only the two components of professional awareness and career exploration explaining 15,7% of the variance in role fit confidence and 14,4% of the variance in competence confidence. In Model 3, when controlling the students' characteristics, these components explained 15,4% and 12,5% of the variance in resp. role fit confidence and competence confidence. Model 3 as a whole predicting role fit confidence explained a total variance of 17,4%, $F(11, 835) = 15.96$, $p < .001$. The total variance explained of Model 3 predicting competence confidence was 15,4%, $F(11, 835) = 13.77$, $p < .001$.

Table 3.3. Beta coefficients from multiple regression models predicting role fit confidence and competence confidence.

	Model 1		**Model 2**		**Model 3**	
	Role fit confidence	Competence confidence	Role fit confidence	Competence confidence	Role fit confidence	Competence confidence
Students' characteristics						
Female	-.058	-.083*			-.058	-.082*
Parent engineer	-.020	-.005			-.017	-.004
Technical secondary education	.087**	-.030			.060	-.053
Bachelor 1	-.065	.-185***			.115*	-.005
Bachelor 2	-.120*	-.161***			.025	-.020
Bachelor 3	-.073	-.072			.007	.011
Transfer	-.041	-.051			-.003	-.014
GPA	.025	-.004			.018	-.015
Professional awareness						
Role awareness			.222***	.090**	.221***	.090**
Competence awareness			.109***	.178***	.117***	.175***
Career exploration			.242***	.270***	.267***	.275***
R^2	.020	.028	.157	.144	.174	.154
ΔR^2					.154	.125
Δ F test					51.788***	41.183***

* p < .05; ** p < .01; *** p < ,001

The reference group for the categorical variable Gender were male students, for Secondary background education were students with a general secondary education, and for Programme year were Master's students

Differences in R^2 and F test in Model 3 are compared to Model 1.

4.4. Components of professional awareness and career exploration

In both predicting role fit confidence and competence confidence, the two components of **professional awareness** were positive significant predictors in Model 2 and Model 3. It can be noted that role fit confidence was more affected by role awareness (β = 0.221, p < .001) than by competence awareness (β = 0.117, p <.001) whereas competence confidence was more affected by competence awareness (β = 0.175, p < .001) than by role awareness (β = 0.090, p < .01).

Career exploration seemed the strongest significant predictor in predicting role fit confidence (β = 0.267, p < .001) and competence confidence (β = 0.275, p < .001). While expected that career exploration had a stronger relation with role fit confidence than with competence confidence, we found that active information gathering about future careers has an important unique contribution in both role fit confidence and competence confidence.

4.5. Students' characteristics

Different students' characteristics predicted role fit confidence and competence confidence, although the explanatory factor was small (R^2 = 0.02 and 0.03) as is shown in Table 3.3.

- *Secondary education*

When investigating *role fit confidence*, we noted that in Model 1 secondary education was a significant predictor of role fit confidence (β = 0.087, p = .01). The significant coefficient explains that students with a technical secondary background have more confidence that their preferred professional role is appropriate for them and will lead to a fulfilling career than students with a general secondary education background. However, the secondary education variable was no longer a significant predictor when including professional awareness and career exploration.

- *Programme year*

In Model 1, programme year seemed to affect professional role confidence. Compared to master's students, second year bachelor's students seem to have less *role fit confidence* (β = -0.120, p < .05), however the Bachelor 2 variable is no significant predictor in the final model. Remarkably, when including professional awareness and career exploration, freshmen seem to have significant more role fit confidence compared to master's students (β = 0.115, p < .05).

Bachelor 1 and Bachelor 2 were significant negative predictors for *competence confidence* in Model 1 indicating that freshmen and sophomore students have less confidence in their skills than master's students. However, no significant contribution was found when the professional awareness and career exploration measures were included.

- *Gender*

Gender was a significant predictor for *competence confidence* in Model 1 (β = -0.083, p < .05), and Model 3 (β = -0.058, p < .05), meaning that male students have more confidence in their ability to fulfil their preferred role successfully.

5. Discussion

People rather approach what they are confident in and deny what they lack confidence in (Reddan, 2015). This study demonstrates that professional awareness and career exploration are important factors in explaining professional role confidence. By introducing a more refined concept of professional awareness acknowledging both the knowledge and understanding of different professional roles in engineering (role awareness) and the knowledge and understanding of the required professional competencies in different engineering roles (competence awareness), a broader understanding of professional role confidence was provided allowing to better prepare confident engineering graduates with more accurate

expectations. In the following paragraphs, we discuss the most important findings and draw recommendations for education and future research.

5.1. Professional awareness and career exploration

Blustein (1992) described that young adolescents tend to explore their choices based on what they know or prefer and tend to neglect other options. Also, when they are faced with numerous options, they restrict their choices relying on rather stereotypical options instead of accurate information. In engineering education, students are at high risk to fall for this strategy as the lack of accurate information about career opportunities and the rather stereotypical image of engineers is echoed in multiple research. Our findings emphasize the importance of professional awareness and career exploration in engineering education. Most of the variance of the professional role confidence constructs was explained by career exploration and additionally by one of the professional awareness dimensions. Role awareness has stronger predictive validity in explaining role fit confidence and competence awareness has stronger predictive validity in explaining competence confidence.

The positive significant contribution of both role awareness and competence awareness is in line with the more recent stream in research stating that employability debate goes beyond the skills approach (Tomlinson & Holmes, 2017). Competency based education might overemphasize a broad range of skills that are important for engineers which can be overwhelming and lead to ruminative exploration. Luyckx et al. (2010) indicated when one is unable to close the exploration process and keeps on worrying where his life would lead him, the risk for anxiety is higher than for confidence. In developing a professional identity and becoming confident in their future role as an engineer, students benefit from an increased awareness of the different roles and realisation that different roles have different demands. For example, Cech et al. (2011) proposes an approach to offer a directed internship seminar on real-world engineering problems in which students collaborate with

engineers in the field. Meijers et al. (2013) emphasize the importance of career dialogue interventions, in particular dialogues about the personal meaning of real-life experiences with work. The PREFER model, a reflective, rather simple model, can be an instrument for teachers and career counsellors to increase professional awareness and guide career exploration in engineering students as was shown in a case study with master's students in electronics and ICT engineering [Chapter 4]. Picard et al. (2021) argue in favour of bigger, longer and more complex projects than from smaller in-course projects and emphasize the need for explicit teaching and regular formative and summative feedback. Either way how these opportunities are offered (problem based learning, seminars with industry, elective courses, career counsellor sessions …), a prerequisite is that the relevance should be established because this enables students to make vital connections between self, learning and their intended field of work (Bennett & Male, 2017). The implication is that academics or course coordinators should realise and recognize that students may need guidance and examples in order to understand the relevance of learning.

5.2. Secondary education

In the first model, secondary education was a significant predictor for role fit confidence. Students with a technical secondary educational background are a minority that enrol in the KU Leuven bachelor's programme but quite a large group that applies for the transfer programme that certifies them to enrol in a master's programme. The authors hypothesize that the technical background makes them more confident that their future role as an engineer will be consonant with their interests and values. However, the predictive value of secondary educational background was no longer significant when including professional awareness and career exploration. These findings support the importance to increase professional awareness and career exploration in all educational stages and to offer career exploration activities tailored to the needs of the individual students (Scott & Willison, 2021).

5.3. Gender

Earlier research showed that engineering is still stereotyped as male which makes it more difficult for female students to identify with an engineering career resulting in male students having more confidence and are more likely to persist their education (Faulkner, 2007; Kolmos et al., 2013; Meyers, Ohland, & Silliman, 2012). In contrast with the findings of Cech et al. (2011), gender was not significant in predicting role fit confidence. A possible explanation might be that the survey instrument presented the diverse roles of the PREFER model that go beyond the stereotypical image of an engineer. This reasoning could not be applied when predicting competence confidence. The competencies presented in this study were professional (non-technical) competencies that are perceived more 'people oriented' and are considered important for female students to identify with engineering (Bairaktarova & Pilotte, 2020; Naukkarinen & Bairoh, 2021). However, our results showed that female students feel less confident that they will possess the professional competencies required for that role, although the differences are small. Earlier research showed that female students tend to underestimate their ability beliefs, such as in mathematics (Perez-Felkner et al., 2017) which might impact emerging aspirations and early career-relevant decisions (Correll, 2001), or in other fields such as economics (Jakobsson, 2011).

5.4. Programme year

Students early in education will more easily give away their commitments to new rounds of exploration as they encounter increasing new experiences in their education. Identity commitments will become more stable during education (Kroger et al., 2010; Waterman, 2007). This process is linked to adequate preparation for transition to the world of work 'involving activities such as clarification of personal aims and abilities, understanding the requirements of the labour market and the ability to actively engage in the career building process' (Bridgstock, 2009, p. 35). Our findings are in line with this reasoning. The further in education, the more aware engineering students

were of and the more actively they explored career opportunities and what it requires to be an engineer. Students' role fit confidence increased, and they became more confident in their abilities as future engineers. However, when controlling for students' characteristics in the final model, programme year was only a significant predictor in role fit confidence with freshmen showing high role fit confidence compared to master's students.

The findings emphasize the importance of increasing professional awareness already early in education. It has been shown that students early in education tend to have a poorly formed idea of the world of work and do not autonomously engage in active thinking about their future careers (Bridgstock, 2009; Perrone & Vickers, 2003). However, this lack of awareness can be addressed in education with low effort but great impact. For example, Langie and Craps (2020) described the development of a new curriculum in KU Leuven which included a focus on increasing professional and self-awareness already in the first year of engineering education. For illustration, first year students will have to job shadow a professional engineer for one day, reflect on the tasks and competencies they have observed and discuss this with their peers who have followed other engineers. By doing this, they would like to make students aware of the fact that industry needs different types of engineers. Another example is that of sophomores who will have to assign the appropriate roles to professionals in action during company visits and guest lectures.

5.5. Limitations

As all research, this study has its limitations. In this study, two dimensions of professional awareness (role awareness and competence awareness) were introduced. Reliability was considered acceptable due to the exploratory set up of the study. However, Cronbach's alpha values did not reach values as high as for validated constructs reported throughout literature. In future research, new items need to be developed that represent the constructs resulting in higher construct validity.

We approached professional awareness as a broad construct integrating a degree of self-awareness via questions regarding the extent to which students explore and develop their competencies. However, it is agreed that self-awareness is highly important for people's career development. At the same time, high self-awareness may lead to self-doubt and distress when one struggles to accept one's strengths and weaknesses (Verbruggen, 2020). The broader approach in our study might not fully attribute the effects found to self-awareness. Further research is recommended to study the effects of professional and self-awareness separately.

The results were based on a sample in one university in Belgium and should be interpreted within this context. For example, the higher educational system with open admission policy could have influenced the results. This might explain the importance of secondary education background or the findings regarding gender that were slightly different than earlier studies. Future work might consider other background variables, such as migration background or first-generation students. In KU Leuven, these groups of students have higher risk to drop out, which might be related to lower professional role confidence. In the US, for example, ethnicity was observed important in the research of Cech and colleagues (2011).

Data was collected in a single measurement and a cohort analyses was performed to compare the confidence outcomes of students in different stages of their engineering programme. A longitudinal approach might give more insight in the students' professional role confidence development during education and their persistence to become an engineer.

6. Conclusion

This study contributes to the understanding of career and identity development in engineering education by exploring different predictors of professional role confidence. It described a framework containing role awareness, competence awareness and career exploration. These factors were positive and significant predictors of role fit confidence and competence

confidence. Also, programme year played a small but significant role in predicting role fit confidence underlining the importance of engaging engineering students in professional awareness and career exploration already early in education. Female students showed lower competence confidence than male students, but no significant differences were found for role fit confidence. This study lays the groundwork for future research and interventions to increase professional role confidence, which is important in persistence in engineering and in making career decisions.

Acknowledgment

The authors would like to thank the students for their participation in the survey, colleagues Tom Bekers and Dirk Van Landeghem for their assistance in background data and Lynn Van den Broeck for her support and wise advice in statistical analyses.

4 | Choosing a job that you like, one that you excel in, or both? Role choice congruence among Belgian engineering students in Electronics and ICT.

This study is accepted with minor revisions as : Craps S., Smits T., Knipprath H., Pinxten M. & G. Langie (2022): Choosing a Job that you like, one that you excel in, or both? Role Choice Congruence among Belgian Engineering Students in Electronics and ICT. IEEE Transactions on Education.

Abstract

Contribution: Career guidance in Electronics and Information and Communication Technology (ICT) engineering education can be improved thanks to the provided insights in career choice.

Background: Industry still reports difficulties in finding engineers with the right (level of) competencies while graduates indicate a mismatch between their expectations and engineering practice. This leads to economic loss and personal job dissatisfaction. To address this mismatch, this study explores role choice congruency (similarity between professional role preferences, self-perceived professional competency level and choice for a particular job vacancy).

Research Questions: 1) How aligned are engineering students' professional role preferences with their self-perceived professional competency levels? 2) How do Unaligned students differ from Aligned with respect to their job vacancy choice? 3) Does the degree of role choice incongruency decrease when engineering students are acquainted with professional roles? 4) Is the degree of role choice incongruence discipline specific?

Methodology: Two case studies using mixed method design were set up.

Students were categorized from Aligned to Unaligned (comparing preferences and competency level) and from Congruent to Incongruent (comparing the (Un)Alignment and the job vacancy choice).

Findings: About half of the students were unaligned. They chose a job vacancy that they prefer, rather than one they can excel in. Professional roles acquaintance did not significantly affect role choice congruency. However, students indicated a broader preference and showed some differences in the competency profiles and job vacancy choice. Engineering disciplines seem to influence role choice congruency, however, there are similar battles to tackle when aiming to increase the quality of choice.

1. Introduction

Research has demonstrated that a student's better understanding of his or her professional identity not only has positive consequences for student learning and study choices (Bliuc et al., 2011; Draaisma, Meijers & Kuijpers, 2018; Godwin & Kirn, 2020) but also increases employability and job satisfaction (Eliot & Turns, 2011; Gottfredson & Johnstun, 2009; Nilsson, 2010; Yorke, 2006). The development of such professional identity involves an iterative process matching the expectations related to a specific professional role with the needs and aptitudes of the student preparing for that role (Becker & Carper, 1956). However, this argument presumes that students have enough information about (a) their own competencies, preferences and personality and (b) the professional roles and role requirements (Bimrose et al., 2004; Yorke & Knight, 2006).

Earlier research showed that engineering students often lack this information resulting in a misalignment between engineering education and practice which has been debated for several decades (Trevelyan, 2019). Industry often refers to this misalignment as the skills mismatch, indicating that they experience difficulties in finding graduates with the right set of competencies or competency level (Mourshed, Patel & Suder, 2014). Similarly, engineering graduates indicate that they experience engineering practice to be different

from what they expected (Chan, Zhao & Luk, 2017; Korte, Brunhaver & Sheppard, 2015; Watson & Meiksins, 1991) due to misconceptions of what engineering is and what engineers do (Bennett & Male, 2017; Brunhaver et al., 2018; Lichtenstein et al., 2009). Although interventions to expose students to authentic engineering experiences are commonly used in engineering education, the link to the engineering practice is not always clear (Bennett & Male, 2017; Tymon, 2013). Aspects like one's beliefs and values are rarely included in engineering educational activities which makes it difficult for students to construct a professional engineering identity (Morelock, 2017).

This study contributes to this contemporary debate on the pivotal role of engineering identity by exploring to what extent students' better understanding of the professional roles for engineers contributes to an improved quality of professional role choice. In this study, the quality of role choice will be operationalised by role choice congruence. More specifically, we will examine (1) to what extent students' professional role preferences align with their self-perceived professional competency level and (2) whether they would make congruent career choices. A cohort comparison will be made between a group of Master's students in Electronics and ICT Engineering Technology who participated in an intervention to boost professional role awareness and a group that did not participate. Second, a comparison will be made between a group of Master's students in Electronics and ICT Engineering Technology and a group of Master's students in other engineering disciplines.

2. Background

2.1. Role congruence

According to Holland's Theory of Vocational Choice, people will search for work environments where they can optimally use their competencies and express their values and attitudes (Holland, 1997). For example, an investigative type who is likely to be precise, analytical, curious, and

intellectual, will search for an investigative environment that matches these competencies. More congruency between one's personality and career typically leads to greater job satisfaction and success (Gottfredson & Johnstun, 2009). This implies that engineering students must be aware of both their personality (e.g., interests, strengths and weaknesses) and the job type (e.g., professional role, wage, job autonomy) they choose to apply for.

Thornton and Nardi (1975) describe four stages in the process of professional role identification, which ranges from idealised perceptions of the professional role to making the role more congruent with one's own values and goals (Thornton & Nardi, 1975). The final stage – the personal stage in which one internalises a professional role – is often not reached by the time students graduate. One essential reason is that they lack experiences in the professional role, but they may also lack 'sense making' opportunities in their education in which students learn to connect information about professional roles with their skills and knowledge and with their needs and ambitions (Eliot & Turns, 2011; Thornton & Nardi, 1975).

Several studies have also observed a difference between students', academics' and industry's perceptions regarding professional competencies in the field of ICT or computer engineering (Direito, Pereira & De Oliveira Duarte, 2014; Kinnunen et al., 2018; Llorens et al., 2013) or in other fields such as chemical engineering (Alford & Thomas, 2017). The different perceptions can hinder students in grasping and understanding what engineering work looks like or what is required (Brunhaver et al., 2018; Gerwel Proches, Chelin & Rouvrais, 2018; Itani & Srour, 2016). However, earlier research has reported that when students are able to align their competencies with those essential in a professional role, they will experience feelings of role congruence and increase their perception of role fit which will make them more confident in a professional role (Cardador, 2017; Cech et al., 2011; Eagly & Karau, 2002). In a study on gendered persistence in engineering, Cech et al. (2011) examined two dimensions of professional role confidence: expertise confidence referring to the confidence in the competencies required in the job, and

career-fit confidence referring to the confidence that a career path is consonant with one's interests and values (Cech et al., 2011). In a study with Dutch vocational high school students, Meijers, Kuijpers and Gundy (2013) found that career dialogue (conversations with students about their strengths, motives and future career) contributed to the development of a professional identity and the quality of choices of study and work placement.

2.2. Professional Roles Model for Future Engineers

The Professional Roles Model for Future Engineers (PREFER-model) was recently developed as an instrument to support engineering students in understanding engineering practice in the early career stage and to reflect on oneself as a future engineer (Craps et al., 2021) [Chapter 2]. A professional role was defined as 'the interpretation of a position based on expectations of the environment, in particular what the work field expects' (Craps et al., 2020) [Chapter 1, p. 46]. The PREFER-model represents three professional roles for early career engineers independent of discipline: Product leadership (focus on radical innovation & research and development); Operational excellence (focus on process optimization & increasing efficiency); Customer intimacy (focus on tailored solutions for specific clients). As shown in Figure 4.1, the roles are flexible in use since several roles can be combined in one job.

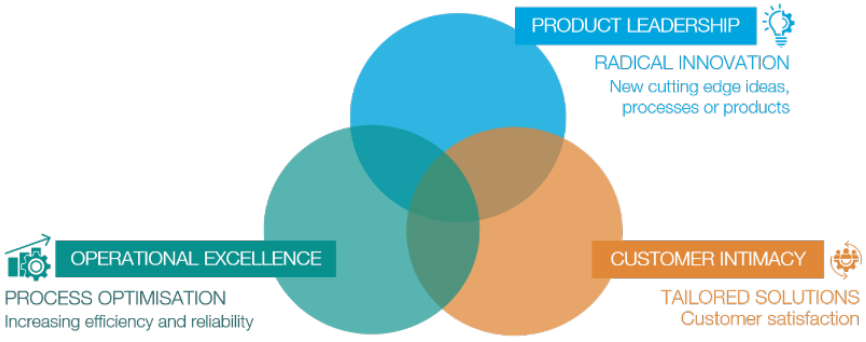


Figure 4.1. Professional Roles Model for Future Engineers (PREFER-model) (Craps et al., 2021).

As different jobs have different requirements, the PREFER-model describes competency profiles per role reflecting the professional competencies engineering graduates need to possess in order to be successful in one of the professional roles (Craps et al., 2021) [Chapter 2]. For example, persuasiveness and perseverance are essential in a product leadership role, whereas networking and capacity for empathy are crucial in customer intimacy. Engineers working in the role of operational excellence need, amongst others, a positive critical attitude and must excel in work management. The PREFER model must be interpreted as a reflective instrument that not only allows engineering students to navigate through the broad range of engineering jobs and discover what industry might expect, but also triggers reflection on the personal preferences and strengths as a future engineer.

The PREFER model, that was thoroughly validated with both industry stakeholders (engineers, HR) and engineering students (bachelors and masters) (Craps et al., 2021; Craps, Pinxten, & Langie, 2019; Craps, Van de Kerkhof, et al., 2019) [Chapter 2], offers a framework to investigate to what extent the students' professional role preferences and personal strengths are congruent with their job vacancy choices. The framework allows comparison of the student's role choice congruence in the specific context of engineering which can contribute to a better understanding of career choices of future engineers. The PREFER model and two tests derived from the model (see Method 3.2.) were also used as an educational tool to boost professional awareness in the case studies. Professional awareness is a two-dimensional construct entailing (1) role awareness, or the knowledge and understanding of the different roles an early career engineer can take on, and (2) competence awareness, or knowledge and understanding of the professional competencies required in engineering [Chapter 3, p. 109].

2.3. Research questions

To address the skills and expectation mismatch problem of industry and young graduates, this study explores the quality of professional role choice of future engineers. The latter concept is operationalised by the construct of role choice congruence, or the similarity between a student's professional role preference, self-perceived professional competency level and the choice for a particular job vacancy. Figure 4.2 illustrates the conceptual framework of the study.

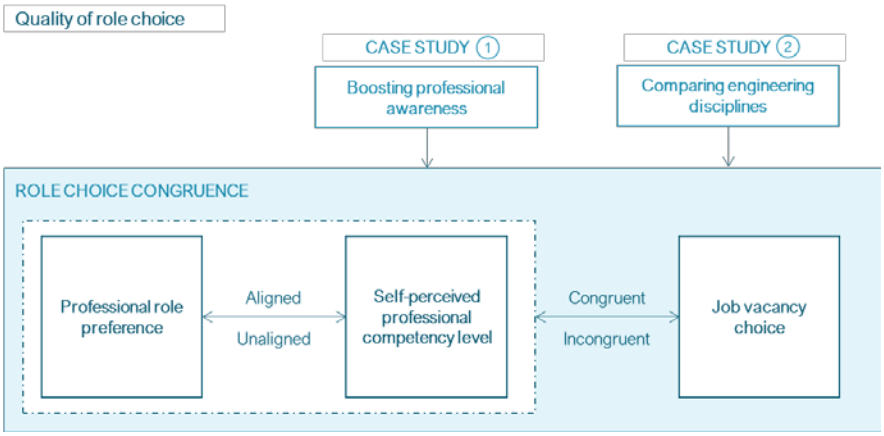


Figure 4.2. Conceptual framework for the current study.

One dimension considers (un)alignment of a student's professional role preference with his/her self-perceived professional competency level. The second dimension considers the job vacancy choice. The following research questions were formulated:

RQ1 'How aligned are engineering students' professional role preferences with their self-perceived professional competency levels?'

RQ2 'How do aligned students differ from unaligned with respect to their job vacancy choice?'

To better understand role choice congruence, this paper reports on two case studies with final year Master's students in Electronics and ICT Engineering

Technology. The first study investigates whether acquaintance with the professional roles contributes to a higher degree of role choice congruence. The second study controls for engineering discipline.

RQ3 'Does the degree of role choice incongruence decrease when engineering students are acquainted with professional roles for early career engineers?'

RQ4 'Is the degree of role choice incongruence discipline specific?'

3. Methods

3.1. Sample

In total, 219 students participated in the two studies. Ethical approval was obtained for this study from the university's Ethics Committee (G-2019-03-1596) and participants have consented to be part of this research. They were informed that their participation was voluntary, and that the analysis would be conducted anonymously.

When investigating whether boosting professional awareness contributes to a higher degree of role choice congruence (Case Study 1), the sample comprised 143 final-year students of the master's programmes in Electronics-ICT Engineering Technology at KU Leuven (Belgium) (Table 4.1). The proportion of female students (8,4%) resembles the proportion in the programme (7,8%). The research was performed in the first semester of three academic years with a first wave in 2018-2019. The cohorts of 2019-2020 (second wave) and 2020-2021 (third wave) participated in an adapted course with explicit attention to professional roles for early career engineers as described in Section 3.2. Due to ethical reasons and to sample size, it was decided to compare cohorts over time instead of comparing with a control group.

When investigating whether discipline might have an influence on the degree of role choice congruence, the sample involved final year Master students in

Electronics and ICT (*N* = 34), Electromechanical (*N* = 40) and (Bio)Chemical Engineering Technology (*N* = 23) in 2020-2021 (Table 4.1). The average age of both case studies was 22,60. No significant age difference was found between the cohorts of the different waves or disciplines.

Table 4.1. Samples of the two case studies (N).

CASE STUDY 1 Sample Students in Electronics and ICT Engineering Technology			
	Male	Female	Total
2018-2019	41	8	49
2019-2020	59	3	62
2020-2021	31	1	32
Total	131	12	143
CASE STUDY 2 Sample Students in different engineering disciplines (2020-2021)			
	Male	Female	Total
Electronics and ICT	33	1	34
Electromechanical	35	5	40
(Bio)Chemical	19	4	23
Total	87	10	97

Note: The participants of the third wave in Case study 1 (N=31) were the same participants in the Electronics and ICT discipline in Case study 2 (N=33). However, two participants did not participate in one part of Case study 1 (job interview) and were consequently excluded from the analysis in Case study 1.

3.2. Intervention

3.2.1. Context

The research was conducted in the Dutch Master's course Management and Communication. One part of the course, called 'The Engineer as a Professional Communicator', focuses on the understanding of the differences between the technical communication skills used by engineers and the way of thinking and communicating in the business world. One exercise consisted of a fictional job application process. Students were instructed to translate a critical self-analysis into a unique selling proposition. They analysed their personality and

professional skills through various freely available competence and personality tests, browsed in different recruitment channels, critically analysed job offers and responded to one vacancy. The students engaged in a role play simulating a job interview.

From each individual student, the lecturer received a portfolio including the critical analysis of their personality and qualities, the chosen job vacancy, a resume and a cover letter. In the role play job interview, the lecturer acted as an HR representative of the company that was offering the job they responded to.

3.2.2. Case study 1: boosting professional awareness

To investigate whether acquaintance with the professional roles contributes to a higher degree of role choice congruence, different PREFER instruments were introduced in three waves to Master's students in Electronics and ICT Engineering Technology.

- *PREFER instruments*

The PREFER model was introduced by the lecturer. Students analysed and discussed different vacancies in class according to different criteria, such as company information, clear job description, requirements, professional role alignment. They were invited to take two tests based on the PREFER model. The first, PREFER Explore, is a personal preference test. In this short test (5'), students are asked to rank three options, given a situation, from most to least preferred after which they get insight in their professional role preferences (Carthy et al., 2019; Pinxten et al., 2020a). The second, PREFER Match, are a series of more intense (15') Situational Judgment Tests (one per role) that give insight in role alignment and in the essential competencies (Pinxten et al., 2020b). These tests describe specific situations that early engineers can encounter. Students are asked to judge several responses to these situations in terms of appropriateness. After completion of a test, students receive automated feedback on the results by comparing how similar the responses were to those of experts in the field. Students do not get specific scores but are

ranked in quartiles compared to the responses of their peers. For example, a student's score for role alignment could be attributed to quartile 4, which represents the group of 25% of the respondents whose responses are closest to that of the experts. The feedback reports with PREFER test results served to trigger reflection and to start career dialogue. They are not part of the measurement of this study.

- *Three waves*

Table 4.2 gives an overview of the different interventions in the three waves. In **2018-2019 (first wave)** the different roles were not addressed. As such, this first wave allowed for a baseline measurement. Preliminary results have been reported by Craps et al. (2019) (Craps, Pinxten, Knipprath, et al., 2019).

Table 4.2. Overview of the intervention to boost professional awareness in three waves.

	2018-2019 first wave	**2019-2020 second wave**	**2020-2021 third wave**
PREFER model introduced		●	●
Vacancy analyses		●	●
PREFER Explore test (personal preference test)			●
PREFER Match tests (situational judgment tests)		●	●
Reflection on test results			●
Career dialogue			●

In **2019-2020 (second wave)** a pilot was running. The intention was to fully implement all tests but, due to limitations in the test development, only the PREFER Match tests were available online in one of the last classes. Consequently, students had hardly time to integrate reflection on the results in their portfolio. Participation in the tests was not mandatory.

In **2020-2021 (third wave)**, the PREFER instruments were fully integrated in the course content as from day one. Due to COVID19, the course was offered online. Students were encouraged to take the different PREFER tests (not mandatory), to discuss these results with one of their peers, friends or parents, and to include the results and reflections in their portfolio. All students received feedback on their portfolio. The different PREFER tests were available throughout the whole semester. An increased level of role choice congruence after the first and second wave was expected.

3.2.3. Case study 2: Comparing engineering disciplines

The intervention in 2020-2021 (third wave) (Table 4.2) was enrolled in the courses offered at (Bio)Chemical, Electromechanical, and Electronics and ICT Engineering Technology to control for discipline.

3.3. Analysis method

To measure role choice congruence (Figure 4.2), professional role preference, professional competency level and job vacancy choices were investigated through the job interview, a questionnaire and the analysis of the job vacancy. In order to compare the respondent's similarity between these three measures, two constructs were developed: level of alignment and level of congruency. The different measures and constructs are described in the following paragraphs.

3.3.1. Measurement Professional role preference

In Case study 1, the professional role preference was measured in the role play job interview. This interview included a question derived from a set of questions from the validated PREFER Explore test aimed at aligning students to the professional roles of the PREFER-model according to their personal preferences (Carthy et al., 2018). Participants could pick one of the three possible answers implicitly referring to the three professional roles and were invited to clarify their choice. The interviewer did not refer to the roles, nor the competencies. A question could be for example: "*Thinking of some projects*

you have been involved in, what part was typically your favourite part of the project? Brainstorming and designing [product leadership]; execution and implementation [operational excellence]; communication with stakeholders and presentation of preliminary results or final output [customer intimacy]."

In Case study 2, an explicit question regarding which role(s) the students preferred the most was included in the competence questionnaire (see next paragraph). Consequently, the second study describes a self-reported preference. A further analysis of the findings of a group of respondents that participated in both case studies (N=31) showed an 85% overlap between the preference measures by the interviewer in case study 1 and the self-reported preference in case study 2. It should be noted that the participants reported a broader preference (preference for more than one role) than the interviewer did during the role play job interview. The measurement of professional role preference is labelled ***role preference*** in the further analyses.

3.3.2. Measurement Professional competency level

After the course was finished, participants were invited to complete a competence questionnaire, containing the 19 competencies of the PREFER-model (randomly presented and each with a brief definition as described by Craps et al. (2021). They were requested to rate their self-perceived skills level for each of the competencies on a five-point Likert scale. Role scores were calculated by summing the self-reported competencies associated with each professional role. Most of the 19 competencies are unique to one role, but four are shared between two roles. For example, client focus competency is included in both Product Leadership and Customer Intimacy. In case of a missing value on one of the competencies, no role score was calculated. In this way, we obtained three role scores per participant – one for each professional role – between 7 and 40. The minimum and maximum score depended on the number of competencies included in the competency profile of the professional role (Table 4.3).

Table 4.3. Maximum and minimum possible role competence scores.

Professional role	N competencies	Min. score	Max. score
Product leadership	7	7	35
Operational excellence	8	8	40
Customer intimacy	8	8	40

A participant is categorised in a particular role when the sum of their competence scores is greater than the 66th percentile of the overall sample (role sum score$_{student}$ ≥ role sum score$_{P66}$). This measurement based on the self-perceived competency level is labelled ***role competence*** in the further analyses. Using this methodology, a participant could be classified as having one or more role competence labels.

3.3.3. Measurement Job vacancy choice

The job vacancy choice, labelled ***role job***, was operationalised by the job vacancy the participant opted for. In the course, the students were free to select any job advertisement from any recruitment channel.

The 219 chosen vacancies (one per participant) were independently positioned in the PREFER-model by three researchers, based on the job description and job requirements. Through interrater reliability, emphasizing the similarity between the reviewers (Lebreton & Senter, 2008), the outcomes were compared and each job vacancy was finally assigned to one or more professional roles indicated by at least two researchers. The interrater reliability was calculated with Fleiss' kappa with *k* between 0 (the agreement between reviewers rests entirely on chance) and 1 (complete agreement). The average Fleiss' kappa showed that there was substantial agreement between the researchers' role assignment, k=0.72 (95%CI, 0.57 to 0.88), $p < .0005$.

3.3.4. Level of alignment

The level of alignment was constructed to determine the alignment between the role preference and the role competence. Based on a categorization

adopted by Rüde et al. (2019) in their research of alignment between engineering students' job plans and postgraduation outcomes, three groups were identified: Aligned, Fluid and Unaligned students (Rüde et al., 2019). Students who showed high potential based on the self-perceived competency profile in line with their preferred professional role, were identified as *Aligned*. For example, when a student preferred role X and the role competence was assigned to role X and Y, the student was classified as *Aligned*. A one-on-one alignment between the role preference and role competence was identified as *Exclusively aligned.* If they did not have an outspoken preference and positioned themselves in the middle of the PREFER-model (preference for all the roles), they were categorised *Fluid*. If the role preference and role competence were not in line, they were classified *Unaligned*.

3.3.5. Level of role choice congruency

The level of congruency is determined by the job role. If participants opted for a vacancy that was similar to the role preference and role competence (Aligned or Fluid), the students were categorized as *Congruent.* If no alignment was observed between the three measures, they were classified as *Incongruent.* This means that all Unaligned were categorised as Incongruent. However, students might have opted for a vacancy that was in line with either the role preference or the role competence. This partial incongruence will also be investigated.

3.3.6. Further analyses

To further explore the influence of raising professional awareness on role choice congruency (RQ3), two additional questions were included in the competency questionnaire in 2020-2021 (third wave). First, a question was included whether the students took the opportunity to fill in one of the PREFER tests, and if so, which ones. A second question related to the reason why they took the test(s). The final score for the portfolio and job interview assignment, provided by the course lecturer with permission and according to

ethical guidelines, was also included in the analysis. Taking the PREFER tests and higher score on the reflective portfolios are expected to relate positively with role choice congruence.

Statistical differences between cohorts were calculated in SPSS using Chi square tests, t-tests, and between-groups ANOVA.

4. Results

This section first describes the findings of the Case study 1 investigating whether boosting professional awareness increased the role choice congruence (RQ3). This requires an analysis of how aligned the role preference is with the self-perceived competency level (RQ1) and the career choice (RQ2). Second, the results of Case study 2 investigating the relation with engineering discipline are reported (RQ4).

4.1. The influence of acquaintance with professional roles

First, the results of the influence of boosting professional awareness (Table 4.2) on (1) role preference, (2) role competence and (3) role job are explored separately[6]. Second, the influence on the level of alignment (4) and the level of role choice congruence (5) are described.

4.1.1. Role preference

During the job interview, students were implicitly asked which role(s) they preferred. Whereas first wave participants preferred the three roles rather equally (33% to 37%), the product leadership and operational excellence roles were more preferred in the following years (Figure 4.3). However, no statistical differences were found for role preferences between the three waves ($p > .05$). After being introduced to the different professional roles in the second and third wave, students tended to indicate a broader preference

[6] The abbreviations in the figures included in the Result section refer to the different professional roles: PL = product leadership, OE = operational excellence, CI = customer intimacy.

(a combination of professional roles) more often (6% (N=3) in 2018-2019, 46% (N=28) in 2019-2020, 31% (N=10) in 2020-2021), with almost one out of ten students indicating a preference for all the three roles in 2020-2021 (Figure 4.4). These students were labelled as *Fluid* as their role preference will align with all competency roles.

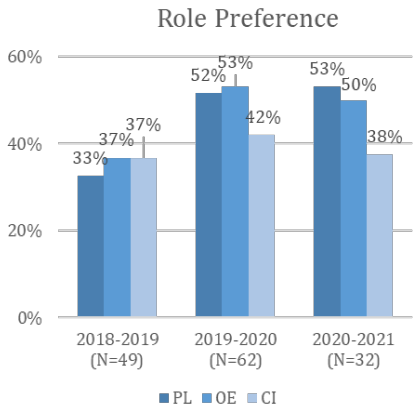


Figure 4.3. Role preference.

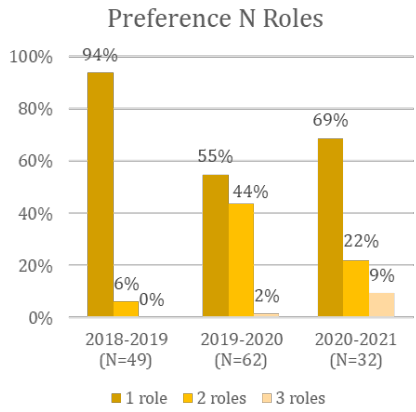


Figure 4.4. Preference for single or combination of roles.

4.1.2. Role competence

Overall, students perceived their competencies related to operational excellence to be the strongest and the mean scores stayed rather stable over the three cohorts (Table 4.4).

However, significant differences between the mean score of the product leadership ($F(2,134) = 5.06$, $p = .008$) and of customer intimacy ($F(2,134) = 6.71$, $p = .002$) were found between the first and following waves, meaning that the self-perceived competence level in product leadership decreased when students became more acquainted with the roles while it increased in customer intimacy. The most extreme minimum and maximum scores for all three professional roles were observed in the second wave.

Table 4.4. Descriptive statistics of Role competence scores

Professional Role	Cohort	N	Min. score	Max. score	Mean score	SD
Product leadership	2018-2019	49	21	31	26,0	2,6
	2019-2020	56	7	33	23,9	6,3
	2020-2021	32	16	28	23,0	2,7
	Total	137	7	33	24,5	4,7
Operational excellence	2018-2019	49	24	36	30,9	2,9
	2019-2020	56	13	39	28,4	8,2
	2020-2021	32	24	35	30,5	2,8
	Total	137	13	39	29,8	5,8
Customer intimacy	2018-2019	47	21	32	25,8	2,9
	2019-2020	56	13	38	27,9	6,8
	2020-2021	32	21	34	29,5	3,2
	Total	135	13	38	27,4	5,1

In case of a missing value, no Mean role score was calculated. Note that the maximum score of product leadership is 35 but it is 40 of operational excellence and customer intimacy (see *Table 4.3*).

Students having a role sum score at or above the 66th percentile (P66) of the overall sample are defined as possessing that role competence (sum $score_{student} \geq$ role sum $score_{P66}$ (role sum score $_{P66}$ (PL) = 27.0, role sum score $_{P66}$ (OE) = 32.0, role sum score $_{P66}$ (CI) = 30.0)). Participants aligned significantly less to the customer intimacy role in the first wave (χ^2 (2) = 27.035, p < .001, *Cramer's V* = .448), while a significant lower number was assigned to product leadership role in the third wave ((χ^2 (2) = 13.395, $p = .001, Cramer's\ V = .313$) (Figure 4.5). It was noted that the three students that could be aligned to the product leadership role in the third wave were also aligned to the competency profiles of the two other roles. These students perceived themselves as high potential engineers in a range of roles.

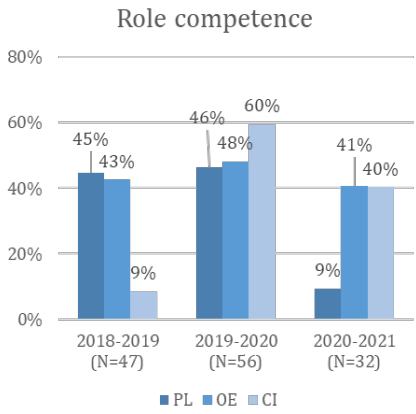


Figure 4.5. Role competence.

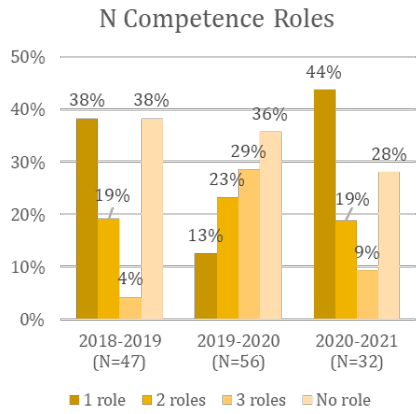


Figure 4.6. Role competence scores aligned to single or combination of roles.

Figure 4.6 shows that, in the three waves, there was a group of students that could not be aligned to a role based on their competence scores (sum $score_{student}$ < role sum $score_{P66}$). This group of students was the smallest in the third wave, when the intervention included an introduction to the professional roles and essential competencies, the encouragement to reflect on the results of the PREFER tests and to start career dialogue.

4.1.3. Role job

In all cohorts, the majority of the students chose a job vacancy related to operational excellence, focusing on optimisation (single role or combined with another role) (Figure 4.7). The interest to opt for a job vacancy in a customer intimacy role decreased significantly after the first wave ($\chi^2(2) = 7.238,\ p = .027, Cramer's\ V = .225$). These findings were opposite to the findings of Role competence where a significant increase in the alignment with a customer intimacy role was observed after the first wave (Figure 4.5). In the second and third wave, students clearly chose for jobs in which they are expected to take on one professional role over a combination of roles (Figure 4.8).

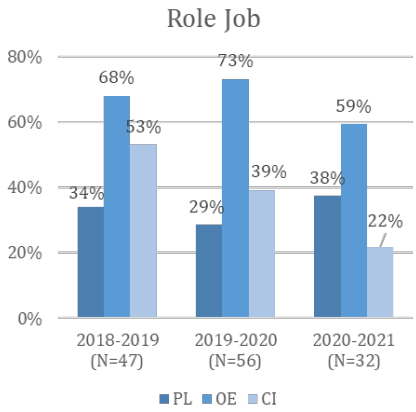


Figure 4.7. Role job.

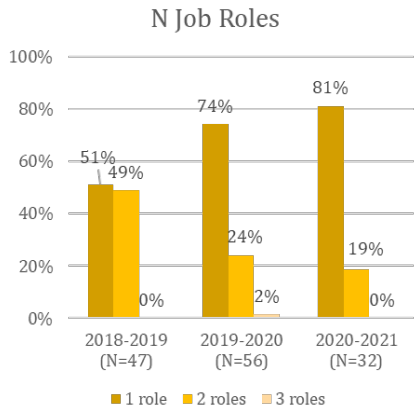


Figure 4.8. Choice for single or combination of roles in the job.

In sum, the findings of the different measures show that acquaintance with the professional roles seems to lead to small but significant changes in preferred professional roles, self-perceived competencies and choice for a job vacancy. The role preference became broader with more students indicating a preference for more than one role, while the choice for a job vacancy became clearer with more students opting for a vacancy in one particular role. The group of students that could not be aligned to a role based on their self-perceived competency level was reduced. Students ranked their competence in operational excellence the highest and a vacancy in this role was chosen the most. After the first wave, role attribution based upon the competencies significantly increased for customer intimacy but the choice for a vacancy in a customer intimacy role decreased. In the third wave, significantly fewer students could be attributed to the competence role of product leadership. But how similar are the different outcomes on an individual level?

4.1.4. Level of alignment

As shown in Figure 4.9 (arrow Aligned), as expected, the alignment between the role preference and role competence increased after the first wave, meaning that the number of students that were categorized *Unaligned*

decreased (for more details, see Appendix Table A4.I.). However, in the third wave, about half of the students (53,12%) were still Unaligned, mainly due to the fact that only few students (N=3) were assigned to the role competence of product leadership, while 64,71% (N=11) of the Unaligned expressed a preference for this innovative role. Note that the results of the second wave cohort are consistently higher because the students' competency profile was more often attributed to two or three roles. Consequently, more students could be classified Aligned.

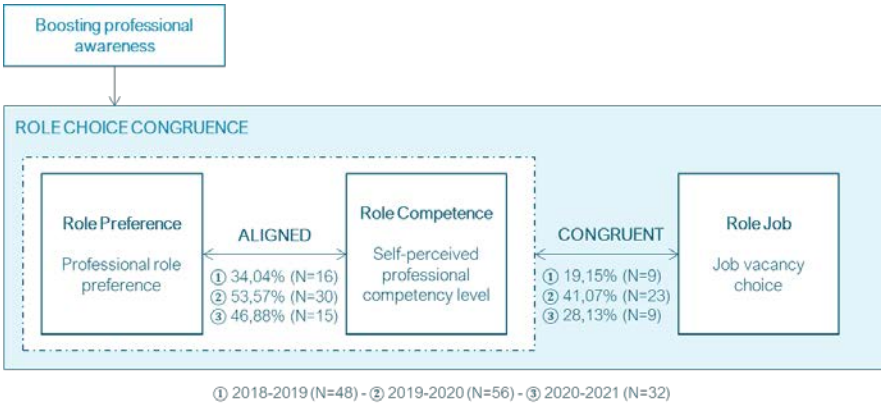


Figure 4.9. The influence of role acquaintance on role alignment and congruency.

A further exploration of the alignment between role preference and role competence showed that the students who could be categorized as *exclusively aligned* increased in the third wave (2020-2021), meaning that the role preference perfectly fitted the competency profile (see Appendix Table A4.I.). We could not observe a relation between role preferences and level of alignment.

4.1.5. Level of role choice congruency

Compared to the baseline measurement in the first wave (2018-2019) we did not only observe an increased level of alignment between role preference and role competence but also an increased level of congruency with the job vacancy choice (Figure 9 (arrow Congruent)). However, the number of

students that chose a vacancy congruent with both their preferences and strengths remains rather low (19,15% in 2018-2019, 28,13% in 2020-2021) (for more details, see Appendix Table A4.II (All)). As a consequence of the higher level of alignment in the second wave, the level of role choice congruency was also observed higher in the 2019-2020 cohort.

When further exploring the career choice of students that were labelled *Unaligned* and *Aligned* based on their preference and competence role, we noticed that in the Unaligned group, not even a fourth of the students chose a job according to their strengths (Appendix Table A4.II. (Unaligned)) while the incongruent career choices of the Aligned group were not specifically caused by incongruence with role preference nor role competence.

To better understand the difference in the job vacancy choice of the Unaligned, we further looked into their motivation to take the PREFER tests and into their course results in 2020-2021. The Aligned and Unaligned students equally took the opportunity to fill in the PREFER tests but with different goals. Where the main reason of the Aligned was to take different tests so that they could compare the results (8 out of 13 students), the Unaligned took only the PREFER Explore test that gave insight in their role preference or just one PREFER Match test to receive feedback of the role that they perceived that would fit them most (11 out of 16 students). The Unaligned seemed to have reflected less on their personality, qualities and future career as they scored less on the lecture series (M = 13.0; SD = 2.1) than the Aligned students (M = 14.7; SD = 1.9), however the difference was not significant ($t(30) = -2.3$; $p > 0,05$).

4.2. The influence of discipline

As shown in Figure 4.10 (arrow Aligned), the alignment between role preference and role competence in Electronics and ICT Engineering (58,82%) is similar to the alignment found in (Bio)Chemical Engineering (52,17%) but higher than in Electromechanical Engineering (37,50%).

A further analysis (cf. Case study 1, due to the length of the paper available on request) showed that the lower alignment for Electromechanical Engineering is due to a lower competence role attribution; 45.00% of the students could not be attributed to one of the competence profiles, which is higher than in the Electronics-ICT (29,41%) or the (Bio)Chemical (34,78%) engineering disciplines.

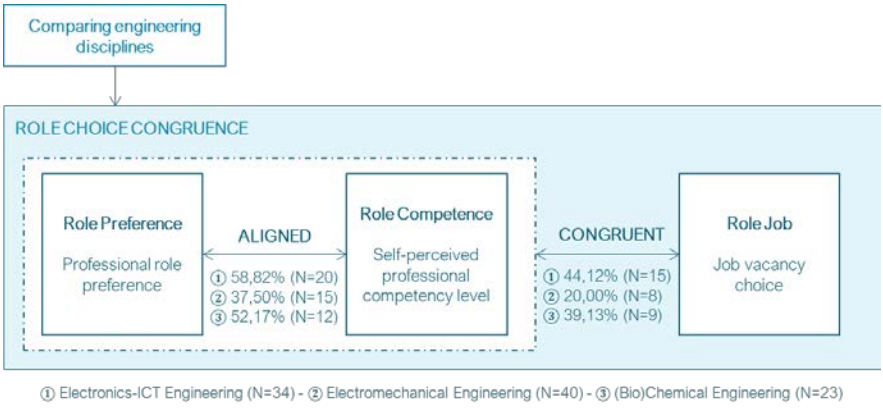


Figure 4.10. The influence of discipline on role alignment and congruency.

Although the numbers are too small to draw conclusions, the observations were similar as in Case study 1: (1) the Aligned group, regardless discipline, seemed to differ from the Unaligned in choosing a job. (2) The Unaligned chose a job mainly in line with their preference (Appendix Table A4.IV. (Unaligned)) with more than 85% having incongruency between the role competence and the role job. It was noted that only 45,55% of Unaligned (Bio)Chemical Engineering students chose a job according to their role preference whereas resp. 78,57% and 72% of the Unaligned students in Electronics and ICT, and in Electromechanics Engineering did so.

In summary, we observed some differences in alignment between role preference and role competence, with a lower level of alignment in Electromechanical Engineering compared to the other disciplines. By consequence, the role choice congruence in the latter discipline is also lower, however differences are small. Same decision-making observations were

found independent of discipline: students of whom the role preference and role competence were aligned tended to choose a job vacancy that is in line with both their preferences and strengths whereas Unaligned students chose a job vacancy in line with their preferences.

5. Discussion

It is assumed that when students are more aware of their professional identity, they will be more motivated and persistent in their study and display higher levels of employability and job satisfaction (Gottfredson & Johnstun, 2009; Meijers et al., 2013; Yorke, 2006). Self and professional awareness are important factors when choosing a profession that is congruent with one's interests and competencies. This study investigated the quality of professional role choice of final year master's students in Electronics and ICT Engineering Technology in Belgium. Through the construct of role choice congruence, we examined whether students could align their professional role preference with their self-perceived strengths and weaknesses (RQ1), and whether unaligned students differed in their job vacancy choices (RQ2). Through mixed methods in a case study design, the role choice congruence constructs were measured using the PREFER framework, a competency based professional roles model for future engineers. Two case studies were set up to investigate whether boosting professional awareness (RQ3) and engineering discipline (RQ4) influenced the level of role choice congruence.

The findings indicate that about half of the final year Master's in Electronics and ICT Engineering Technology (between 46% and 66%) could not align their professional role preferences with their self-perceived strengths in the professional competencies required in the different roles (RQ1). The Unaligned students differed from the Aligned students in choosing a job vacancy. Where the Aligned chose a job vacancy in line with their role preferences and professional competencies, the Unaligned clearly picked a vacancy of a job they prefer rather than considering a job in which they can excel (RQ2). Our findings support earlier research that calls to make explicit

the relevance of professional competencies so that students can make connections between the self, the learning and the intended field of work (Bennett & Male, 2017; Picard et al., 2021).

When boosting professional awareness by introducing the PREFER instruments, the decrease in the level of unalignment and level of role choice incongruency compared to the baseline measurement in the first wave was not significant (RQ3). A reason can be that the course including critical self-reflection and exploration of career opportunities was already well designed in creating professional awareness reducing the effect of introducing the PREFER instruments in the intervention. However, some differences were observed after the intervention was conducted. First, students showed more often a preference for more than one role. This is good news as our society and industry are in need of different engineering roles (Trevelyan & Williams, 2019). A broader range of role perspectives and preferences can contribute in decreasing the mismatch between industry's and graduates' expectations and experiences as earlier research showed that half of the engineering positions require a combination of two roles (Craps, Pinxten, & Langie, 2019). Second, we observed a lower reported competency level in product leadership while half of the participants preferred this role. In a recent study, Cruz *et al.* (2021) also found that engineering students perceived the competencies related to innovation not among the competencies they are highly competent in (Cruz et al., 2021). Third, the choice for a job vacancy became clearer with more students opting for a vacancy in one particular role. Although the competencies required in the customer intimacy role were perceived more often as strengths, the job vacancies in this role were chosen the least. Earlier research indicated that students were least familiar with this role and lacked knowledge about which competencies were most relevant (Craps, Van de Kerkhof, et al., 2019).

The findings of this study suggest that role choice congruency might be affected by engineering discipline (RQ4). Final year master's students in Electromechanical Engineering showed lower level of alignment and role

choice congruence. Choe and Borrego found in a US study that mechanical engineering graduate students had weaker engineering identities than electrical/computer engineering students (Choe & Borrego, 2019). Although further research is recommended to investigate differences between disciplines, this study showed that there are similar battles to tackle when aiming to increase the quality of choice, such as creating competence awareness when choosing a job.

There are several limitations to note. The results are based on a small sample in a single institution and a limited number of engineering disciplines. They are not generalizable to a broader engineering graduate student population. A larger sample and a research design with an experimental and control group could enrich the data to draw further conclusions on significant differences between Aligned and Unaligned respondents and background variables such as educational background, grades or gender. It can also help in explaining the observed differences in self-perceived competency level between the cohorts. In particular the cohort of the second wave (pilot intervention) perceived themselves more competent resulting in higher levels of alignment and role choice congruency.

It should be noted that the programmes at the KU Leuven Faculty of Engineering Technology are mostly focused on operational excellence. Consequently, it might not be surprising that students feel most competent in competencies related to this role. The research would benefit from case studies in different institutions with different types of engineering programmes.

This cross-sectional study measured a self-perceived competency level. This might differ from the actual competency level. For example, Dunning and Kruger (1999) found that low achieving students often overestimate their ability while high achieving students often underestimate their ability (Kruger & Dunning, 1999). Although Cruz and colleagues (2019) argue in favour of measuring students' perceptions for research purposes (Cruz, Saunders-Smits, et al., 2019), future research might benefit from using multiple measure

methods, like ranking competencies, or from measuring on different time points to obtain a more comprehensive result of the competency level. The PREFER Match tests giving feedback on role alignment and competencies might be a valuable resource in this regard (Pinxten et al., 2020b). This was not possible in this study because the tests were not mandatory, which can also have affected the results.

The findings should be interpreted carefully against the specific context. In the lecture series, students were encouraged to critically analyse their professional competence levels and to reflect on this analysis in a portfolio including peer feedback. They were instructed to select a vacancy based on those outcomes and were allowed to rewrite few requirements in order to increase job fit, which might affect the level of choice congruency. Although this kind of career intervention has positive effects on career-decision making skills and career knowledge, choosing a job vacancy as an assignment might differ from the actual career choices (Meijers et al., 2013). A follow-up study on actual career behaviour of young graduates would be recommended for future research. For example, do Congruent students choose for a job that they both prefer and excel in when entering the labour market? And to what extent does unalignment affect job satisfaction?

6. Conclusion

Industry needs highly skilled engineers in different roles. When engineering graduates choose a job that does not meet their interests or qualities, they will likely change the job leading to personal dissatisfaction and economic loss for industry. This study observed that, irrespective of discipline, students that lacked congruency mainly chose a job according to their preferences and not according to their competencies. Engineering education should encourage reflection on both professional role preferences and professional competencies so that engineering graduates choose not only for a job they like, but also for one in which they can excel.

5 | Engineering graduates' perspectives on the transition from education to the labour market: harsh realities and promising futures. A case study in Belgium.

This study is submitted as : Craps S., Smits T., Knipprath H. & G. Langie (2022): Engineering graduates' perspectives on the transition from education to the labour market: harsh realities and promising futures. A case study in Belgium. (In Australasian Journal of Engineering Education)

Abstract

It is not always clear for graduates what role they can take on in industry and what is expected in that role. Consequently, graduates risk choosing a job that does not match their personality and abilities leading to feelings of dissatisfaction and job turnover. This study sheds new empirical light on how early career engineers experienced their journey into the labour market and their initial career choice. The quality of the choice was evaluated by job fit and job satisfaction. The findings provide contextualized evidence through qualitative research related to how early-career professionals develop their professional identities. The study was conducted in Belgium. Twenty early career engineers were interviewed about their knowledge and understanding of different engineering roles (professional awareness), how they explored their career opportunities and selected their first job, how they perceived their job fit and job satisfaction and what their plans were for the future. Data were analysed in NVivo using a thematic analysis approach. The findings illustrate how professional awareness and career exploration support students in making well thought out career choices. The interviews illuminate different

strategies of engineers when they experience a mismatch with their interest or abilities. We discuss implications for career guidance and professional development in engineering education and in industry and conclude with directions for future research.

1. Introduction

In engineering education, employability is high on the agenda. There is a global need for engineers that has never been greater (Cervantes, 2003; Eurostat, 2020; Michael Page, 2021; U.S. Congress Joint Economic Committee, 2012). The Mc Kinsey report *The Future of Work* estimates that, due to the COVID19 pandemic, STEM-related, business and legal professional roles could grow by more than 20 percent in the coming decade and that many of the growing occupations require a higher level of skills (Smit et al., 2020). The competition to hire engineers is tough for companies. The high demand is, for example, reflected in the relatively high wage differential for STEM compared to other fields (Machin & McNally, 2007). One would imagine that the search for a job that fits with the graduate's ability, personality and occupational preference is a rather smooth project for most final year engineering students. However, the education-to-work transition seems rather challenging.

In this paper, we explore engineering graduates' perceptions on their education-to-work transition and whether they are satisfied with the career choices they made. Our analyses are performed for Belgium, that, as other OECD countries like Australia or the UK, has reported regularly a shortage in engineering (Machin & McNally, 2007). The unemployment rate is low: in 2019, only 1,2% of graduated engineers who aimed for a job, were unemployed one year after graduation (VDAB, 2020). However, a report from five Belgian universities also shows that 23 % of the engineering graduates, aged less than 26, changed jobs within the first year. Sixty percent of those citing job content as a reason (KU Leuven, 2016). It seems that engineering graduates are not always adequately prepared to enter the workplace and

their conceptions and expectations may not correspond with the real professional practice, an observation shared among research conducted in other knowledge-driven economies (e.g., Dias, 2011; Kövesi & Kálmán, 2020; Llorens et al., 2010; Matusovich et al., 2009). For companies, this leads to economic loss as they invested in recruiting and training new employees. For engineering graduates, this might result in feelings of frustration, uncertainty, or disappointment in their new jobs (Korte et al., 2015; Trevelyan, 2019). Hence, Belgium provides an interesting case study to explore the education-to-work transition beyond the perspective of employers, that is often focused on the skills mismatch (Deters et al., 2020; Mourshed et al., 2013).

Research regarding the education-to-work transition has been increasing since the 1980s. However, as recently described by Brunhaver et al. (2021), research on the early stage of the engineering career has remained limited in scope due to the fast changing society (change in demographics of students, dynamic nature of engineering practice, globalisation etc.). Therefore, new insight in the actual lived experiences of early-career engineers remains necessary to further explore the education-to-work relation and how to prepare future engineers. Also, surprisingly, little is known about the experiences of fresh engineers regarding possible dilemmas and complex transitions of their personal and professional identification (Stevens et al., 2014) as research tends to focus on what competencies students perceive as important to or as missing in their transition to work (Deters et al., 2020). This lack in understanding hinders, on the one hand, academics and corporate stakeholders in improving career development, career satisfaction, productivity and job tenure, and, on the other hand, engineers themselves in realizing the full potential of the roles they are expected to play in their organization or in society more generally (Jesiek et al., 2021).

Realizing the full potential of a role entails professional awareness: knowing what professional roles an engineer can take on and understanding what industry expect from these different roles. Professional awareness is important in developing a professional identity where one tries to find out

what kind of engineer he or she wants to be. Research has shown that professional identity development is positively related with persistence in engineering education and with staying in engineering after graduation (Choe & Borrego, 2019; Van Hattum-Janssen & Endedijk, 2020). The present study contributes to a better understanding of possible dilemmas young engineers encounter regarding their professional identity when entering the labour market. The study is focused on the specific question:

> RQ 'How do early career engineers experience their choice for an engineering job, i.e., the professional role they fulfil?'

To address this question, we draw on data of twenty early career engineers that were interviewed about their knowledge and understanding of the different professional roles an early career engineer can take on (further referred to as professional awareness), how they explored their career opportunities (career exploration), selected their first job, and how they perceived their job fit and job satisfaction.

The remainder of this paper begins with background literature regarding professional identity and related concepts used in this study (Section 2), and then presents the method (Section 3). The Results (Section 4) highlight how early career engineers experiences resulted in adapting their perception of their professional preferences and abilities and become attuned to their professional roles. The paper closes by critically discussing the results and drawing implications for engineering education and professional development.

2. Background

2.1. The importance of professional awareness and career exploration

Professional identity reflects how people define themselves in professional roles according to attitudes, beliefs, experiences, and motivations (Schein, 1978). Developing such an identity is the fundamental aim of career guidance

in education. To fully understand professional engineering, students should learn and know what engineering is, but also who they are as engineers (Stevens et al., 2014). Although higher education institutions increasingly acknowledge their responsibility to guide students both in their academic growth and in their career development (Burke et al., 2017), many engineering students, even close to graduation, lack an understanding of what engineering is and what engineers do and are not aware of the myriad career options (Bennett & Male, 2017; Lichtenstein et al., 2009; Matusovich et al., 2009). Whereas some students see engineering practice as primarily technical (Brunhaver et al., 2018), others have career aspirations mainly centred around management and leadership (Gerwel Proches et al., 2018; Kinnunen et al., 2018).

Although the importance of adjusting misconceptions about professional roles in professional identity development is noted in earlier research (e.g., see review study Branch (2002)), the predominant biases in engineering education is still on understanding engineering as a form of technical rationality (Bennett & Male, 2017; Morelock, 2017; Stevens et al., 2014; Tymon, 2013). However, a realistic understanding of the future work is required for students to critically reflect on their thoughts and prior achievements and to articulate future aspirations in the engineering profession (Yorke & Knight, 2006). Hence, a lack of professional awareness makes it difficult to develop a professional identity and to make well informed choices. It impedes the transition to the labour market (Trevelyan, 2019). For example, new engineers who identify strongly with the dominant technical ideology of engineering are likely to struggle to understand who they are as an engineer when they encounter what they perceive as 'non-engineering' work in practice (Faulkner, 2007). Similar experiences were observed in architecture students seeing the designer as the dominant identity during their education. However, as practicing early career architects, they hardly come to designing but focus on other aspects such as negotiating and coordinating with clients and contractors (Stevens et al., 2014).

Recent studies suggest that knowledge of future professional roles does not necessarily entail knowledge of different professional competencies required in these engineering roles (Direito et al., 2014; Saunders-Smits et al., 2021). Hence, in an earlier study investigating the importance of professional awareness and career exploration in increasing professional role confidence [Chapter 3, p. 109], the authors suggested two dimensions of professional awareness: (1) role awareness, or the knowledge and understanding of the different roles an early career engineer can take on, and (2) competence awareness, or knowledge and understanding of the professional competencies required in engineering. The two-dimensional concept allows to investigate the experiences of young graduates in a way that acknowledges but goes beyond the focus on competencies, as suggested earlier by Deters et al. (2020).

Career exploration is important to gain professional awareness and develop an identity as an engineering professional. Career exploration, conceptualized as active career information gathering through (extra) curricular activities and experiences, including work experiences and career guidance (Kracke, 2002; Meijers et al., 2013), enables students to discover what is possible and achievable within an engineering context and to give shape to their future professional role and career path (Tomlinson & Jackson, 2019). The intensity of career exploration is perceived as the crucial prerequisite for a mature, well thought-out career choice (Bridgstock, 2009; Jackson & Wilton, 2017; Super, 1980) and for a satisfactory commitment to a career choice (Kracke, 2002; Kroger et al., 2010; Perez et al., 2014). Higher career exploration would result in more realistic expectations of and fewer mismatches in the labour market.

2.2. The quality of choice: job fit and job satisfaction

Experiencing a mismatch between the personal characteristics and those of the job or tasks performed at work (a person-job misfit (Kristof-Brown et al., 2005)), can lead to dissatisfaction and likely lead to thoughts of job change (Carless & Arnup, 2011; Weiss & Merlo, 2015). Person-job fit includes both

demands-abilities fit (one's knowledge, skills and abilities are congruent with the job requirements) and supplies-values fit (one's needs, desires or preferences are met by their job) (Kristof-Brown et al., 2005). People will search for work environments where they can optimally use their competencies and express their values and attitudes (Holland, 1997). Regardless of the many job offers, if engineering students are not aware of the variety in engineering roles and have difficulties in understanding what competencies are required, it can be challenging to choose for a job that fits their personality and qualities. This might affect their job satisfaction, which is typically defined as the feelings one has about one's job or job situation (Carless & Arnup, 2011), and lead to job turnover.

2.3. Purpose of the study

The present study builds on and extends prior literature by investigating how early career engineers experienced their choice for an engineering role in a context where the need for engineers is high and graduates can easily find a job. The quality of their choice is investigated through job fit and job satisfaction and its relation with professional awareness (role awareness and competence awareness) and career exploration. These insights will contribute to career guidance in engineering education and better prepare engineers for the labour market.

3. Method

A social constructivist research paradigm was used to understand the experiences of early career engineers, relying as much as possible on the participants' views of their choices for engineering job (Creswell, 2009). A qualitative study was carried out, based on the phenomenographic approach as recommended when one wants to characterise how things appear to people (Case & Light, 2011; Savin-Baden & Major, 2012). Twenty semi-structured interviews with early career engineers were organised between September and November 2020. The following paragraphs describe (1) how the

participants were selected, (2) how the interview protocol was set up and (3) how the data were analysed. All data collection was carried out with the full approval of the KU Leuven Privacy and Ethics Committee (G-2019 03 1596) and with informed consent of the participants.

3.1. Selection of participants

The sample for this study comprised of fresh engineering graduates in Belgium who have been employed for less than three years in a range of professional contexts. The "less than three-year employment" was chosen as a criterion in order to strike a balance between the participants' ability to recall their experiences as an engineering student and their ability to meaningfully assess the current work experiences. A group of 100 randomly selected graduates, identified through assistance from the Alumni coordinator of the KU Leuven Faculty of Engineering Technology, was invited by email. A call was posted on the faculty's social media such as Facebook and LinkedIn and distributed via the lead author's network. When responding, the content and practicalities of the interview, and the informed consent were further explained in detail. We aimed for a diverse sample to maximise the potential variation of experiences. Of the 20 interviewees, 8 identified as female and 12 as male. Consequently, female participants were overrepresented in our sample, i.e., 40% versus 13% in the population of graduating engineers at the KU Leuven Faculty of Engineering Technology in 2020. The participants held Master's degrees in Chemical, Biochemical, Construction, Electromechanical, and Electronics and ICT Engineering. They were active in small, medium sized and larger companies in different sectors with an average of 16,5 months of work experience. Five candidate-participants were rejected due to more than three years of work experience (two candidates) or due to be still in education (three candidates were following an advanced master or postgraduate programme). Table 5.1 presents the descriptive of the sample.

Table 5.1. Descriptive of the participants.

Participants (N=20)	**N**

Gender	M	12
	F	8
Engineering discipline	(Bio)chemical	3
	Construction	1
	Electromechanical	8
	Electronics-ICT	8
Job experience (jobs)	1	14
	2	4
	3	2
Job experience (years)	Less than 1 year	7
	Between 1 and 2 years	10
	Between 2 and 3 years	3
Company size	Small and medium sized	8
	Large (>250)	12

3.2. Interview procedures

Semi-structured interviews including open-ended questions were drawn up to explore the participants experiences, reflections and feelings in their specific context (Creswell, 2009). Online interviews were conducted by one researcher. The recorded 45-60 minutes conversations were transcribed verbatim by a second person. The interviews were piloted (N=3) resulting in deleting some questions due to the length of the interview and scope of the study. The interview protocol is included in Appendix Table A5.1.

The PREFER model was used to guide the interview conversations. This recently developed competency based model describes three professional roles that an engineer can take on early in the career: product leadership (focus on radical innovation), operational excellence (focus on process or product optimisation) and customer intimacy (focus on client tailored solutions) (Craps et al., 2021). In close collaboration with industry, competencies were identified that are essential to be successful in each role, irrespective of discipline. For example, for an engineer in an innovative role, competencies such as creativity or perseverance are essential, whereas the ability to negotiate is required to be successful in a role focusing on client

tailored solutions. The model was validated in industry and education and included clear role definitions and visuals that were used in the interview.

The interview was divided in three parts (Appendix Table A5.1). The first part focused on role awareness and discussed exploration of different roles and job fit considering the professional role preferences. The second part focused on competence awareness and discussed exploration of competencies and job fit considering their abilities. The third part focused on job satisfaction and plans for the future. This part included one question about job satisfaction where the participants were asked to give a score on a 5 point Likert scale from very satisfied to very dissatisfied (Weiss & Merlo, 2015). The participants were also triggered to reflect on the quality of their career choices, e.g., "Imagine you can do it all over again, would you make the same choices, or would you do things differently?"

3.3. Analytical approach

The data analysis was conducted in Nvivo. We began with broad themes as put forward in the literature. Then, the data were categorized in more narrow themes. Specific analytic codes were developed based on what themes were emerging. It was essentially iterative in nature, while being focused on data reduction and interpretation (Creswell, 2009; Savin-Baden & Major, 2012). It is important to note that the findings offered as themes, which emerged from the analysis of interview data, present an interpretation of the opinions and experiences (Smithson, 2000). The codebook with categories and themes can be found in Appendix Table A5.2.

4. Results

The graduates thought and reflected on their education-to-job transition and the quality of their career choices so far by looking back to their education and looking forward to future career opportunities. The following topics are highlighted in the analysis of the interviews below: professional awareness and career exploration, as important factors of professional identity

development, job fit and job satisfaction, as parameters to evaluate the quality of their career choice.

4.1. Professional awareness

Participants first discussed their professional role preference and reflected on their role awareness before and after graduation. Second, they reflected on their professional competencies and competence awareness. In line with previous studies, when graduating, half of the participants had difficulties in understanding what engineers do or what kind of engineer they wanted to be, as illustrated in the following quotes:

> *"It was difficult to know exactly: this is what I want to do. That's how I ended up there. Everything appealed to me, so I just went for it, and I would see how it would turn out." (04_ Junior Project Manager)*

> *"I have to be honest, when I graduated, it was not at all clear to me what the options were and I was still under the impression that […] only operational excellence [role focusing on process optimization] existed." (01_Junior in Legal Tax & Business Unit)*

The others had already concrete ideas of their future career, like Participant_10:

> *"I wanted to work intensively with technology and be very involved in communicating that to customers, and in social contact for sure." (10_Project Engineer)*

When reflecting on their professional role preferences, some participants mentioned that they never had thought about different engineering roles. However, they could easily come up with examples to illustrate their current professional interest and align their mere preferences when graduating with one or more roles. Work experience made some participants (*N*=5) to adjust their preference. For example, Participant_15 who is working in the biomedical sector and preferred a combination of more innovative role and a role focusing on optimising when graduating, said:

> *"I think now, because I have a lot of experience in the real world, I would be more towards operational excellence [focus on process optimization] than the product leadership role [focus radical innovation]. […] When working in an innovative role, you need to be able to see the bigger picture, have bigger views, I think. I realise now that is not really something for me." (15_Software Engineer)*

Or Participant_05, who broadened her perspective on being an engineer, explained :

> *"I think my talents or competencies certainly are in the area of optimization and customer orientation. I had anticipated that correctly. But I have to say: along the way I have become more and more interested in innovation, which I also come into contact with a lot. So, the step to R&D has actually become smaller and seems less challenging and less unfeasible to me now." (05_Catenary Engineer)*

For most participants, reflecting on the professional competencies seemed more difficult than reflecting on their role preferences. Although most of them could illustrate their strengths and align these with essential competencies in one or more roles, most participants indicated that they were not aware of the broad range of professional competencies by the time they graduated, nor the importance was clear. Like one participant said:

> *"Graduates picked up somewhere that companies also hire you more for your soft skills, and your basic attitude. But that's it." (17_Adoption and change Engineer).*

Most participants indicated that engineering students would benefit from an increased competence awareness.

> *"I didn't really think about it at the time, but what I do think now, is that more attention should be paid to these competencies in education. To focus more on what is expected of you in practice, instead of a lot of theory about the technical aspects of concrete (in my case). […] I have the feeling*

that I was not aware enough and that I wasn't informed enough of the importance." (04_ Junior Project Manager)

Participants who showed more insight in their professional preferences and strengths as graduates (further referred to higher self-awareness) (*N*=10), seemed more conscious of their learning opportunities in education. For example, they referred more often and more spontaneously to situations or examples where they learned and experienced what they are good at or what they liked, both in the curriculum (such as project work, labs and the master's thesis) and in extracurricular activities (guest lectures and company visits but most often engagements outside education like youth movement or student job). Participants who showed lower professional awareness (*N*=10) were more often explicitly triggered by the interviewer to share examples for illustration or clarification.

Participants who followed an engineering programme that included mandatory courses on management and communication, referred to these courses as relevant learning experiences. Where the technical courses learned to be critical about technical specificities, the design, the efficiency of a solution etc., the communication and management courses learned to be critical about the self. However, several graduates indicated that they had never taken these courses seriously and only realised the relevance of these courses after graduation. Due to the heavy workload in the programme, they prioritised the technical 'real engineering' assignments. Also, these courses were not always well integrated in the context of engineering and, consequently, the relevance was not always clear.

4.2. Career exploration

During the interviews, participants reflected about career exploration and the ease of finding a job on the one hand and the applied methodologies and the intensity of their job searching activities on the other hand. Participants, who showed higher professional awareness as engineering students (*N*=10),

realised early in education that they would benefit from active career exploration, as demonstrated in the following quotes:

> *"I've always been very active, because since my second Bachelor's year, I've have been keeping track of companies. So, I participated in several activities such as company visits, guest lectures or business events and I collected business cards, names, e-mail addresses, telephone numbers. I have been putting all that systematically into an Excel list, and when graduation came around, I started calling and contacting them." (16_Young graduate)*

> *"I thought regularly about what I'm good at and what I'm not good at. I did go on a coaching course, knowing that, if you end up in a team leader position, that is actually something that is very important." (02_Teaching assistant)*

Companies start pulling engineering students months before they graduate, which is perceived as rather annoying. One participant signed his job contract already in December (but only graduated in September the year after) in the company where he did an internship for his Master's thesis, but most graduates started to actively explore possible jobs during the job fair (which is traditionally in February or March, at the beginning of the final semester). A fourth of the participants (*N*=5) restricted their applications to contacts collected during a job fair but half of them (*N*=10) explored job vacancies more intensively and involved their network. Whereas some participants restricted their efforts of effectively applying to a single or a few (<4) companies (*N*=9) (because they contacted specific companies (N=3) or accepted a first offer (*N*=6)), others searched in a broader range because they wanted to know their possibilities and train their job interview and negotiation skills (*N*=11).

Some participants rejected job offers until they received one for a job that really fitted their career goals. They knew what they wanted and explored their opportunities until they found it. Others (*N*=7), mainly participants that

had lower professional and self-awareness, simply accepted a first offer after a good job interview.

All the graduates signed a contract before or just after they obtained their engineering degree. Preparing the transition from education to practice was exciting for some participants, while, for others, this stage was very stressful. They got a bit lost in the wide variety of job options and the often very vague job descriptions. The negative or lack of responses from companies resulted in feelings of doubt and insecurity.

> *"I actually found a job relatively quickly, but the search itself was not pleasant at all. Although there are so many websites and so many possibilities nowadays, I found that there was very little structure in it. I couldn't see the forest for the trees. I felt sometimes a bit alone in this search." (02_Teaching assistant)*

> *"I had sent around some letters in May or so, and I also got a lot of negative responses. Negative or just no responses. I started my first job in September, perfect timing actually but, at that time, it didn't feel like a smooth process at all." (03_Water specialist)*

Some participants mentioned that they felt not very confident that they were fully prepared for engineering practice (*N*=6). However, most of the participants considered this a normal feeling as they were about to enter a completely new world. They recognized that they still needed to learn a lot and they hoped there would be time for learning in the job and for integrating in the company. Except for three participants who continued in an advanced master programme after their Master's degree, most participants were looking forward to continuing their learning in practice. They didn't believe that staying longer in education would prepare them better to start working as an engineer. However, Participant_5 indicated that the lack of confidence had an influence on her career choice:

> *"I don't think I would have felt ready for any job at that time. I therefore hesitated for a while whether to continue studying. [...] I went for a safer*

choice, for straight programming, because you had a good basis for that anyway and I also realised that I could improve myself quickly. Although I did want to move more in the customer direction, I chose to start otherwise." (05_Catenary Engineer)

4.3. Job fit and job satisfaction

Once participants had chosen for a job, they experienced whether their job fitted their personality and abilities, managed their expectations and decided whether they had made a satisfying job choice. About a third of the participants experienced a misfit in the first job (*N*=6). Some of them chose a job that did not fit their role preference (*N*=4), not even partly, while others chose a job that did not fit their competency profile (*N*=4). For two participants, the misfit was both on preference and competencies. A larger group experienced somewhat misfit (*N*=10) meaning that their role preference was broader or narrower than the role they fulfilled in their job (*N*=9) or that their competency profile only partly matched with the competencies required in the job (*N*=9)

A mismatch with the role preference seemed to lead to thoughts of job change, however, only one participant who experienced a complete preference misfit actually had changed job. The five other job switchers felt somewhat misfit as their role preference was broader than the role they could fulfil in the job. All job switchers (*N*=6) perceived their current roles more congruent with their current professional preferences.

Regarding the misfit with the competencies, we noticed two strategies. When the participant had not the required (level of) competencies, these competencies were considered as something that could be improved or worked on. When the participant perceived that they could not use their competencies, they rather felt disappointed and considered to change job. Five of the six job switchers indicated that they experienced somewhat misfit regarding the competencies.

When entering the labour market, half of the participants indicated that they did not clearly know what to expect due to a lack of understanding of engineering practice but also due to poorly written job vacancies. Some seemed very demanding with long lists of equally important requirements while others were described rather broad and generic and could go in any direction.

> *"It was extremely confusing for me. Because when you read a job advertisement, I expect very clear things from it, those are the things they expect from me. But then you see very strange things, for example, a vague description or a lot of requirements they just put in balanced proportions and then you think, what exactly do they want from me?" (09_Service Sales Engineer)*

Even after the job interview, it remained often unclear what to expect. Consequently, up to one third of the participants mentioned to be in doubt of what was expected when starting their first job. As a result, the first days at work could be really hard and confronting, like Respondent_12 demonstrated:

> *"When I just graduated, I was like, okay I'm ready, I'm ready to work, here I come. And the first day I started, I thought, wow, I don't know anything." (12_Automation Engineer)*

Soon, the participants experienced that their school projects differed from business projects which required, for example, flexibility, quick thinking and good communication. These first months, working as engineers, made some participants unsure and anxious. It was unclear whether they were still in training or whether that certain (less attractive) tasks were structurally part of the job. Indeed, all participants discovered that engineering also included less pleasant tasks, such as administrative work or routine.

> *"Learning new things has always been appealing to me, but it was soon after a month and a half that it all fell back into the same nature, the same thing, nothing new, no chance. It was really an operational role, where I couldn't develop anything myself." (19_Developer)*

> *"There was still a lot of administrative work involved, such as producing quotations and finding replacements for components that were obsolete. I had expected that this would actually be much better documented and that a lot of administrative work would not have to be done." (10_Project Engineer)*

Of course, some encountered also positive first job experiences that were beyond expectations. For example, they got autonomy and responsibility a lot quicker than expected. Those experiences strengthened their confidence in their role as an engineer, as demonstrated in the following quote:

> *"I expected that a junior profile like mine wouldn't be allowed to work with customers so quickly. […] I had expected to be active behind the scenes at first. So, I think it is positive. They have confidence in my work." (01_Junior in Legal Tax & Business Unit)*

The participants were overall (very) satisfied with their current jobs. On a scale from 1 (very dissatisfied) to 5 (very satisfied), only five participants rated their current work situation 3,5 or below (*M*=3,9). Three of them showed low professional and self-awareness and conducted a rather limited job search (*N*=3). They all pointed that out as one of the reasons of their current, dissatisfying, situation. For example, Respondent_04, who was only active for three months and in doubt of his job choice said:

> *"I do think that when I apply for a job in the future, I will consider more what is expected of me and what kind of person they are looking for. To be honest, at the time, that didn't really play a role." (04_ Junior Project Manager)*

Three of the five participants who expressed lower job satisfaction were job switchers. Although they changed job, they indicated that they did not yet find a role according to their preference (*N*=1) or competencies (*N*=2).

The main reasons for job satisfaction were related to the role they fulfilled as an engineer, such as interesting job content, variation in tasks, value or

contribution of their work to the enterprise and society. Recognition for their work, autonomy, feedback and support from colleagues, and learning and development opportunities offered by the company strengthened them to grow in their role. The company culture (good atmosphere, flexible workspaces etc.) was also an important factor. Although, not unimportant, wage was not mentioned amongst the main reasons for job satisfaction.

The main reasons to change or to have thoughts of change were, on the one hand, related to the role they could not fulfil as expected due to repetitive work, very restricted tasks and responsibilities, feeling useless or overqualified for the job. On the other hand, job change was related to the company culture, work pressure, and career trajectories with few to no perspectives.

Not all experiences were positive and successful but almost all perceived their career story so far as an interesting learning experience. Most of them would make the same choices again, although some mentioned they would reflect more deeply on their future self to make better choices and to be more confident. Also, some indicated that they would make the decision to change jobs more quickly when experiencing a job misfit.

When reflecting on their choices and future plans, respondents were highly aware of the importance of lifelong learning. Some had a lot of learning opportunities in the company, others spent their free time on courses on both technical expertise and professional competencies. While some of them have the ambition to take on a management role in the future or even want to start up one's own business, the main conclusion was that all these early career engineers are eager to learn and work hard, take up their responsibility as engineers in the company and in society more generally. But they also want to have a little bit of fun, in enjoying their work as engineers and in their private lives.

5. Discussion

This study aimed to investigate how the engineering graduates' perspective on their professional identity and future has developed through their education-to-job transition and how that relates to job satisfaction. Twenty early career engineers were interviewed about their journey into the Belgian labour market that is in high need of engineers. They were triggered to evaluate their job choices by reflecting on their (1) professional awareness and career exploration and (2) job fit and job satisfaction. We discuss the main findings, drawing implications for education and industry.

5.1. Key findings with implications for education

In line with earlier research (Bennett & Male, 2017; Kövesi & Kálmán, 2020; Lichtenstein et al., 2009; Matusovich et al., 2009), this study showed that half of the engineering students lack insight in who they are as an engineer and what career path they want to pursue when graduating. They realised that engineers could end up in a wide variety of jobs, which is interesting but can also be overwhelming when looking for a first job. The PREFER model can be a reference in this regard. Langie and Craps (2020) showed how the framework describing three professional roles for early career engineers can be implemented in education to offer engineering students a grip on the wide variety of engineering jobs in a developmental way: from first year bachelor's to master's.

Although most engineers were (very) satisfied with their career at the time being interviewed, the journey was sometimes a bumpy road. Blustein (1992) indicated earlier that young adolescents tend to explore their choices based on what they know or prefer and tend to neglect other options. The early career engineers in this study who showed good understanding of the different roles and competencies (half of the participants) also showed a more active exploration behaviour and were more confident to enter the labour market. Their choice for a job was often more thought through: they knew

exactly what they were looking for or they explored different career opportunities before accepting a job offer.

It was observed that participants who were dissatisfied with their job showed low professional awareness or had hardly explored career opportunities. Most of them regretted that they had not reflected on the different roles they could fulfil as an engineer or had not explored and thought about what role would fit them during their education more actively. This finding supports the suggestion of Scott and Willison (2021) to put reflection more central when preparing students for the labour market.

About a third of the participants experienced a misfit with their role preferences or abilities. The mismatch with role preferences led to thoughts of job change. A mismatch with competencies was perceived as an opportunity for further development and learning (when they lacked competencies) or a cause for disappointment (when they felt overqualified). These observations contribute to earlier findings of a longitudinal study of European higher education graduates (excl. Belgium): not being able to use knowledge and competencies at work lead to disappointment and produces dissatisfaction (Mora et al., 2007). All job switchers were currently active in roles that were more congruent with their preferences and competencies, however experiencing a role misfit was not always a reason to change job. Work pressure or bad company culture were other main reasons.

On the one hand, the participants in this study did not feel fully prepared when graduating but, on the other hand, they recognized that education cannot fully prepare them for all possible jobs in the field. For some, their first experiences ware rather harsh. They found out that engineering practice is less constrained than education which gave new meaning to professional competencies. Also, some participants' role preferences changed based upon their experiences. Some things were more or less interesting than anticipated or they realised that their perceptions did not correspond with reality. This made some of them unsure about the role they were expected to fulfil, while positive experiences made them confident to grow in their role. These results

indicate that professional identity development continues after education and cannot be fully translated into the curriculum (Flening et al., 2021). However, the findings also recommend that education should make the relevance of professional competencies more explicit for students. As shown in earlier research (Craps, Van de Kerkhof, et al., 2019; Direito et al., 2014; Flening et al., 2021; Karataş et al., 2016) engineering students can be unsure about which competencies are most relevant or about the required level of performance, although they acknowledge that professional competencies are important. The engineering graduates in this study amplify the call for integration of professional skills in the curricula to complement the disciplinary expertise (De La Harpe et al., 2000; Morelock, 2017; Scott & Willison, 2021). Universities may need to change the curriculum and how it is taught in order to explicitly demonstrate the intended learning outcomes. Exemplified by Alpay et al. (2008, p. 583): 'working in a project team does not necessarily teach teamwork, unless there is critical reflection on the process and some awareness of the ideas relating to group dynamics and team roles'. This is also beneficial for education itself because students' perceptions of the relevance of skills to their future work is a strong predictor of their motivation for further learning (Lizzio et al., 2004).

5.2. Key findings with implications for industry

Employers benefit from employees who are occupied in a job that fits theirs interest and competencies. A study from Aronsson and Göransson (1999) showed for example that employees who were not in their preferred occupation experienced higher levels of burnout. Although they are in high need to hire engineers, recruiters benefit from selecting an engineer that fits the job.

In view of the large attendance of final year engineering students, companies that participate at the university's job fairs have a clear recruitment advantage. Although the graduates were aware that they should broaden their scope, a job fair is also an easy way to get access to a lot of companies at once.

A fourth of the graduates in this study did not look any further. This might be to the benefit of large companies that have the resources to participate in several, often fully booked, job fairs charging high fees.

Expectations from industry were far from clear for these young graduates. They call for clear job vacancies stating explicitly what will be expected. They do not expect an all-inclusive job description but one "*that goes beyond stereotypical problem solvers that can work in teams and communicate efficiently*". Some job interviews were perceived as "*a waste of time"* and they would not have applied if the vacancy had been more clearly described. As indicated by Tilli and Trevelyan (2008, p. 68) 'on-the-job learning and industry specific training will always be necessary. A better understanding of the engineering job could help graduates to make an easier and more productive transition into their careers and also help make employers understand which training will be most effective'.

A few graduates participating in the study mentioned they did not choose for a job because the follow up of the selection procedure. Some did not hear from the company for weeks or they hardly received an answer to questions. It was perceived as a lack of interest in their employers which negatively affected their perception of the company. That is also the case for the first few days and months in a job, as they can make a lasting impact on the graduate's perception of their workplace, and their commitment to it. Therefore, it is particularly important that organizations should live up to the expectations process (Perrone & Vickers, 2003).

For early career engineers, an important factor in job satisfaction was the opportunity to improve themselves, to gain new knowledge and competencies through new experiences and training, as was also found in a quantitative study with business graduates (N=128) by Jusoh et al. (2011). Companies with clear learning and development strategies and career opportunities for their employees have an advantage in the recruitment and retention of engineers. Several engineers indicated they also used their spare time for learning or

reading state of the art, which is a promising lifelong learning attitude in this fast-changing economy.

5.3. Limitations and future research

As all studies, this one had also its limitations. Although we aimed for a representative sample with a variation of experiences, we were bound to the voluntary response of the participants. Although one engineer was included who recently decided to leave engineering and to move towards education, it is possible that graduates with a successful career story were more willing to participate. The findings should be interpreted within these boundaries.

In this study, the focus was on the professional identity which is only one of many identities in the social context (e.g., gender, cultural identity, etc.). It is known that contextual factors also influence the career choices (Lent et al., 2002). For example, one graduate mentioned that the choice for a job nearby was not a requirement, but one that was considered when she had the choice between two options. More insight in what was prioritised in the choice decision would be interesting.

Although the PREFER model was developed as a reflective instrument for engineering students (Craps et al., 2021), the model also was perceived a valuable instrument for engineers in the field. For some, the interview itself was an eye-opener to start reflection on their future career paths. Further research is recommended in this regard.

6. Conclusion

This study contributes to more recent research focusing on the importance of career development learning and identity formation. In this study we explored how twenty early career engineers in Belgium reflected on their initial career choices and the professional role they fulfil. Although the labour market is in high need for engineers, some faced harsh realities when making the transition from education and would have benefit from an increased

professional awareness and more active career exploration. Different strategies were used when a mismatch with interest or abilities was observed. A third of the participants choose to change job due to not being able to fulfil their role or due to bad company culture. Overall, the first work experiences were perceived as interesting learning experiences to become attuned to their professional roles. An interesting finding was that graduates recognize the importance of lifelong learning. Companies who offer such opportunities are highly valued, but some engineering graduates also deepened their knowledge in their free time leading to promising futures in a fast-changing economy.

Acknowledgment

The authors would like to thank the engineers for their time, effort and interesting stories. Also thank you to Yves Persoons and Lieze Rombauts for the support in contacting alumni and to Elise Geudens for the transcription of the interviews with the greatest care and precision.

Discussion and conclusion

This doctoral thesis started from the idea that increasing professional role awareness would lead to better career choices in engineering. Several studies indicated that engineering students, even close to graduation, have difficulties in understanding what engineers do and in reflecting on themselves as future engineers. This lack in professional and self-awareness can hinder the education-to-work transition, with students ending up in a job that does not correspond to their expectations or students not applying to jobs that best match their capabilities. Research in this area is often focused on the so-called skills mismatch, indicating that industry reports difficulties in finding engineers with the right (level) of competencies, and tend to neglect the different roles an engineer can take on.

This study aimed to develop a professional roles framework for early career engineers that can serve as a reflective instrument for engineering students and that captures the diversity in engineering roles. The framework also served as a research instrument to better understand career development learning in engineering.

There were two main objectives in this study:

1. To develop a competency based professional roles model for early career engineers, validated in education and industry, that can support engineering students in navigating through the broad field of engineering;
2. To explore the role of professional awareness in making well informed career choices.

The chapter starts with Section 1 that summarizes the main findings of the different studies. Section 2 presents the contributions to the research field and critically reflects on the main findings, discussing limitations and perspectives for future research. The economical or societal value of the findings and the next steps in the valorisation process are presented in Section 3, drawing

recommendations for education, and, in Section 4, discussing implications for industry. Section 5 presents a final conclusion.

1. Summary of the main findings

1.1. A competency based professional roles model

The first objective was to identify the different roles early career engineers can take on in the labour market, regardless of (sub)discipline. To reach this goal, first, a systematic review was conducted using three databases resulting in 24 relevant papers for further analyses. Based on the results of the systematic review, a theoretical framework describing three professional roles, independent of discipline, emerged. This was in particular based upon the work of Hofland et al. (2015), Kamp and Klaassen (2016), and Spinks et al. (2007). The framework, consists of the following principles:

1. Professional roles are more than job titles; they reflect the expectations of the work field;
2. The different roles are focusing on (1) radical innovation and research and development, (2) process or product optimisation and increasing efficiency, and (3) customized or tailored solutions for individual clients;
3. The different professional roles are embedded in a broader global or intercultural context;
4. The professional roles should be interpreted in a flexible manner, meaning that an engineer can operate in two or more roles or change roles in the career;
5. Professional competencies are an important attribute required to fulfil a position in a particular role successfully.

Aiming to address a mismatch in expectations and to provide universities with tools to counter this mismatch, the focus was on the early stage of the career. As a consequence, a more senior manager role was not included. A manager role was perceived as a career ladder opportunity (Betz, 2014; Hodgson et al., 2011; Saunders-Smits & De Graaff, 2012) whereas for early career engineers

it is suggested that, to some extent, there is managerial responsibility in all roles (Spinks et al., 2007).

A surprising result was that the 24 relevant articles included in the literature review used either an industry perspective or an educational perspective in their research, thus lacking the necessary multi-stakeholder perspective (Andriof et al., 2017). When aiming to reduce the mismatch in engineering, it is important to increase mutual understanding between education and the labour market and involve the perspectives of the different stakeholders (Mourshed et al., 2013). Hence, firstly, building upon the insights of the literature review and conversations with programme directors, student councils, alumni and industry representatives, the three roles were further refined (see Chapter 2, 2.1., pp. 77-78) and validated by industry representatives (via a survey, N=188) and engineering students (via focus groups and interviews, N=69).

Secondly, although the findings of the literature review indicated that different roles require different competencies, an inconsistency in methods and measurements hindered to further identify these differences in required competencies. Consequently, a mixed method study was set up aiming to identify what competencies are essential in each of the professional roles. The different steps were carefully thought out and described, leading to indispensable contributions by twelve panels, with experts in engineering and HR who were active in different fields, and the consolidation of the final results by a mixed meta panel. The findings confirmed earlier research indicating that different engineers require different (levels) of professional competencies (Brunhaver et al., 2018; Male et al., 2011; Nilsson, 2010b). The outcome consists of three competency profiles that describe the most essential professional competencies in the different roles (see Chapter 2, 5.3. pp. 94-96). For example, perseverance and creativity were deemed essential for engineers in an innovative role, whereas positive critical attitude and stress resistance were indicated essential for engineers focusing on optimisation. It is important to take into account that:

1. The importance of these essential competencies is perceived to be higher in a particular role than those who were not included in the competency profile. That does not entail that the latter are perceived as irrelevant.

2. By definition, the union of the three competency profiles (see Chapter 2, 5.2.2. p. 94) is empty since we focused on the most important competencies for each role. Engineers who relate to the three roles should have a high level of all the described professional competencies.

As such, the first objective was realised: we were able to describe unifying, detailed portraits of the three professional roles for early career engineers. This newly developed competency-based model must be interpreted as a reflective instrument, representing a more diverse perspective on engineering and making the importance of professional competencies explicit.

1.2. The importance of professional awareness and career exploration in career choices

Deciding on a future career is considered one of the most important decisions students have to make (Özek & Ferraris, 2018). In line with earlier research (Bennett & Male, 2017; Lichtenstein et al., 2009; Matusovich et al., 2009), the focus group conversations with engineering students, that were organized to validate the PREFER model, showed that the students had rather limited career perspectives and articulated difficulties in describing what an engineer is or what kind of engineer they want to be (Craps, Van de Kerkhof, et al., 2019). The PREFER model triggered immediate conversation about and reflection on the different roles they identified with. For some, the diversity in roles was a real eyeopener and some were relieved to find out that, for example, a customer-oriented role was considered as 'real' engineering. This leads to the question whether presenting these different roles would result in a better understanding of possible career choices. To date, research regarding career development learning of engineering students has broadly defined a future career as 'an engineer', neglecting students might have difficulties in envisioning its meaning and, by consequence, making well informed choices.

Hence, we formulated the second objective of this research project (explore the role of professional awareness in making well informed career choices) and we used the PREFER model as a framework to deepen our understanding of the career choices.

We investigated how future and early career engineers in Belgium make well informed career choices in different ways. Figure 6.1 summarizes the concepts used and the research set up.

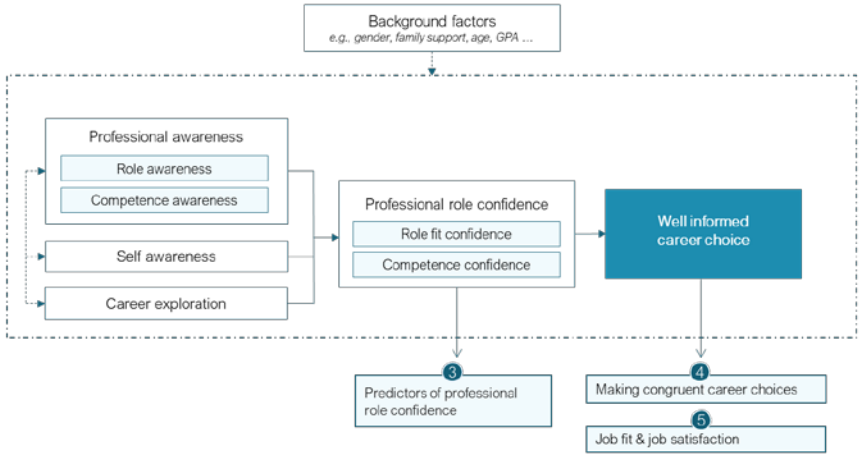


Figure 6.1. Overview of the conceptual framework and research set up for the second research objective. The numbers refer to the chapters presenting the studies.

First, we explored how confident students feel to take up their preferred professional role and what predicts this professional role confidence (Chapter 3). When students' perceptions of engineering are limited or rather stereotyped, they risk entering the labour market with lower confidence. Or they have confidence but based upon a limited perception and possibly wrong expectations. This might have negative consequences in relating to meaningful work and job satisfaction (Buch & Andersen, 2013). Therefore, a better understanding of professional role confidence and its relationship with professional awareness is needed.

Second, we explored whether final year Master's students' choice for a job vacancy aligns with their preferences and strengths (Chapter 4). Using the

PREFER model to analyse preferences and strengths could lead to a better understanding of the career decision.

Third, we interviewed early career engineers about how they explored career opportunities and how that was related to professional and self-awareness. We asked about their education to job transition and investigated whether they were satisfied with their job choices (Chapter 5).

As discussed in the following paragraphs, the findings showed the importance of a more diverse understanding and exploration of engineering roles.

1.2.1. The importance in predicting professional role confidence

The outcomes of the survey regarding professional role confidence (N=898) demonstrated the importance of professional awareness and career exploration.

We investigated two validated confidence constructs: (1) role fit confidence (the confidence that a professional role is consonant with one's interests and values) and (2) competence confidence (the confidence in the ability or competencies required to enact a professional role upon graduation). We introduced two new constructs: (1) role awareness (knowledge and understanding of the different roles an early career engineer can take on), and (2) competence awareness (knowledge and understanding of the professional competencies required in engineering) (see Figure 6.1).

The results showed that most of the variance of the two confidence constructs was explained by career exploration and additionally by one of the professional awareness dimensions. Role awareness had stronger predictive validity in explaining role fit confidence and competence awareness had stronger predictive validity in explaining competence confidence.

The findings were confirmed in the interviews with early career engineers (N=20). The engineers who showed good understanding of the different roles and competencies when graduating, also had shown a more active career exploration behaviour and had been more confident to enter the labour

market than engineering graduates with lower levels of professional awareness or career exploration.

Moreover, in the professional role confidence survey, adding the professional awareness constructs and career exploration in the linear regression model controlling for the students' characteristics, reduced the predictive value of some background variables. For example, a technical secondary education background was no longer significant for role fit confidence when role awareness, competence awareness and career exploration constructs were included. Also, programme year was no longer significant in role fit confidence nor competence confidence with the exception of first year students showing more role fit confidence than master's students. This might suggest that first year students are overly confident. The results show that engaging students in career exploration and increasing their professional awareness benefits the students' professional role confidence.

Gender remained a small but significant predictor of competence confidence with female students showing less confidence in the professional competencies that are essential to be successful in their preferred professional role. On the one hand, this is a surprising result because research in the US has shown that professional competencies are perceived more important by female students than by males (Bairaktarova & Pilotte, 2020). In a Finish study, Naukkarinen & Bairoh (2021) also observed that female early-career engineers appreciate and emphasize these competencies more than male engineers which can make the gap between perceived importance and development bigger for female students. This can affect their competence confidence. On the other hand, the gender difference in competence confidence is not so surprising as research shows that, in general, female students tend to underestimate their ability beliefs (Jakobsson, 2011; Perez-Felkner et al., 2017). A more remarkable finding, in contrast with earlier research (Cech et al., 2011; Yang et al., 2015), is that gender was no significant predictor in role fit confidence. This might be due to the survey design that presented the different roles of the PREFER model and related the confidence

questions to the participants' preferred professional role. The findings suggests that a more diverse perspective on engineering might influence the professional role confidence of female students in a positive way.

1.2.2. The importance in making congruent job choices

Having confidence in the abilities to fulfil a role that is consonant with one's interests and values does not necessarily mean that students will choose a job in that role. A case study was set up to investigate to what extent final year engineering masters choose a job that is congruent with their interests and self-perceived strengths. We organised an intervention to boost professional awareness in three waves (with the first wave as a baseline measurement) and compared the results of students in Electronics and ICT Engineering Technology with those of students in other engineering disciplines offered at the same faculty campus. Of particular interest were the cases where we observed incongruency. It was noted that about half of the students (between 66% in baseline measurement and 46% after the intervention) could not align their preference for a particular role with their strengths in the competencies essential for that role (we labelled them unaligned). The results showed that the unaligned students rather picked a vacancy of a job in a role they preferred than that they picked a vacancy of a job in a role that aligned with their strengths. Similar choice decisions were observed among the different disciplines.

Interestingly, in the interviews with early career engineers, it was noted that about a third of the engineers experienced a misfit with their preferences or abilities. In particular the misfit with role preferences led to thoughts of job change whereas a mismatch with competencies only led to thoughts of job change when they felt overqualified. When the engineers lacked (the level of) competencies, they perceived this as an opportunity for further learning and development.

Consequently, from the engineer's perspective, it can be seen as a good thing that – when unaligned – the role preference seems to affect the job choice

more than having the essential competencies to be successful in that role. However, from the perspective of industry, looking for engineers with the right (level of) competencies, the findings are not reassuring. No matter what side of the story is told, our studies show the importance of professional awareness. On the one hand, there is a need to increase role awareness in order to choose a job that is congruent with one's role preference, an important driver to stay in the job. On the other hand, there is a need to increase competence awareness in order to choose for a job that requires the right level of competencies. In line with earlier research, our findings call for making explicit the relevance of professional competencies in the different engineering roles so that students can make connections between the self, the learning and their future role as an engineer (Bennett & Male, 2017; Picard et al., 2021).

Boosting professional awareness by introducing the PREFER instruments resulted in small, yet significant changes. Students showed more often preferences for more than one role. The industry survey to validate the PREFER model demonstrated that half of the engineering positions require a combination of two roles (Craps, Pinxten, & Langie, 2019). Hence, a broader range of role perspectives and preferences can contribute to a decrease of the mismatch between industry's and graduates' expectations and experiences.

However, we also found that the choice for a job vacancy became clearer with more students opting for a vacancy in one particular role. Although the competencies required in the customer intimacy role were perceived more often as strengths, the job vacancies in this role were chosen the least. The focus group discussion with engineering students about the PREFER model indicated that students were least familiar with this role and lacked knowledge about which competencies were most relevant (Craps, Van de Kerkhof, et al., 2019).

A final interesting observation when boosting professional awareness was a lower reported competency level in product leadership while half of the participants preferred this role (often in combination with another role). In a

recent study, Cruz et al. (2021) found that engineering students perceived the competencies related to innovation not among the competencies they are highly competent in, mainly because they felt less competent in ideation and idea implementation. This finding encouraged us to further explore the data of the earlier discussed professional role confidence survey (Table 6.1).

Table 6.1. Pearson's Correlations between the preference for a professional role and the constructs used in predicting professional role confidence (N=898).

Role preference	Role fit confidence	Competence confidence	Role awareness	Competence awareness	Career exploration
Product Leadership	,187**	,075*	,056	-,008	,032
Operational Excellence	,030	-,034	,070*	,037	,020
Customer Intimacy	,010	,040	,014	,070*	,025

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Remarkably, the data of this survey show that students with a preference for the innovative product leadership role had significantly more confidence that they would fit this role and have the abilities to be successful in this role. Although the data of the professional role confidence survey did not show significantly more interest for product leadership compared to other roles, an earlier study in three institutions (KU Leuven, TU Delft and TU Dublin) showed that first year Bachelors' engineering students had a clear preference for a fictional job vacancy in the innovative role (Saunders-Smits et al., 2021). It can be suggested that students with a preference for this role are overly confident. An innovative engineering role is often perceived as the most idealistic engineering role and perhaps the reason why students choose to study engineering in the first place. We can speculate that these students might be most familiar with this role by what they know from media (who often frame engineers as innovators) and by what they learn in our research-based academic education. Nonetheless, the small but significant changes due

to the intervention to boost professional awareness seem to support these students in their self-awareness and developing more realistic expectations.

1.2.3. The importance in job satisfaction

The interviews with 20 early career engineers indicated that there is a link between job satisfaction and professional awareness and career exploration. The engineers with lower levels of job satisfaction in the first job regretted that they had not thought about and actively explored the roles they could take on when entering the labour market. The choice for a job seemed less thought through and a first offer accepted more easily.

The search for a job could be overwhelming, in particular when companies are pulling hard to recruit engineering graduates with sometimes very vague job vacancies. This made it even more difficult to know what to expect. The first days at work could be harsh and confronting, making some engineers unsure and anxious about the role to fulfil. For others, the first job experiences were beyond expectations which strengthened their confidence in their engineering role.

As described earlier, experiencing a misfit with preferences and abilities was not always a reason to change job. A third of the participants chose to change job due to not being able to fulfil their role (repetitive work, restricted tasks or very few responsibilities, feeling useless in or overqualified for the job). Other reasons were related to company culture, work pressure or career trajectories with few to no perspectives.

Even though the first experiences did not correspond to their expectations, overall, the early career engineers perceived that their career choices led to interesting learning experiences to become attuned to their professional role. They recognized the importance of lifelong learning to develop as engineers of the future. A reflective behaviour to enhance professional and self-awareness is an important driver to steer that future career.

2. Contributions to the research field

The two objectives of this doctoral thesis were to develop a professional role model and to explore the role of professional awareness in making well informed career choices. The objectives were formulated in an effort to better understand career choices of early career engineers and to better prepare them for the labour market. In doing so, this study contributed theoretically to the research field of engineering education and identity development. The following section describes the main contributions and critically reflects on the main findings, drawing perspectives for further research.

2.1. An innovative, validated framework for understanding diversity in engineering

An important contribution of this PhD research is the Professional Roles framework. Founded on (scarce) existing literature, the current framework took an innovative approach in further developing the roles and making clear what professional competencies are essential in these early career roles. Through a well thought out mixed method design (Chapter 2, 4.2), some boundaries of qualitative and quantitative research were tackled. For example, in quantitative research, competencies can be missed (Suleman, 2018) whereas in qualitative research there is more chance for bias in what the competencies mean (Bennett, 2002). The multi-stakeholder perspective was included by validating the framework in both education and industry. The literature review (Chapter 1, 4.1) showed that earlier research mostly included a single stakeholder perspective. This results in a framework independent of discipline that makes essential competencies explicit (important for competency-based education and for industry) but, at the same time, steps beyond the skills debate by bringing a more nuanced perspective on engineering (which supports students in getting a grip on engineering and on themselves as future engineers).

Since the development of the PREFER model, new research has been published aiming to support identity and career development learning of future engineers. However, still, only few studies aimed to develop frameworks or other supporting instruments. For example, Li and colleagues (2021) adapted the Utrecht-Management of Identity Commitment Scale (U-MICS) for engineering to assess the identity formation process in majoring engineering. The U-MICS examines how engineering students develop, maintain and revise their identity in majoring engineering and supports the importance of personal agency in this process. Whereas the U-MICS focuses on the commitment to an engineering major, which appeals to the disciplinary interest, the PREFER model focuses on the future role within that engineering discipline.

Another recent study aimed to develop a typology of engineering work in order to identify the minimal thread of commonality among work that can be considered as engineering (Magarian & Seering, 2021). The researchers found in their literature review (of articles between 1966 and 2016) and in their analyses of over 1000 job titles that (a level of) design responsibility could serve as a unifying work attribute over time. They distinguished between (1) engineering occupations, (2) occupations closely coupled to engineering, (3) other occupations requiring engineering related competencies, and (4) occupations that do not involve engineering competencies. The focus on this responsibility-based conception of engineering aids educators to embrace the wide variety of engineering roles, also the, perhaps, nonconventional roles in proximity to engineering by identifying the enduring common ground. The PREFER model complements this work by embracing the differences and variations in competencies required to perform engineering and, as such, adds meaningful detail to flesh out multiple formulations of work within engineering. So, the PREFER model aids to understand the myriad work that falls within that minimal common ground that was identified in Magarians and Seerings typology.

These recent studies and my PhD research are pertinent in parallel and complement each other, showing the need for validated frameworks that support students and educators in understanding the diversity in engineering and the role one can take on as a future engineer.

2.2. A research framework for guiding research and instruction

The PREFER model was developed as a reflective instrument for students and can serve as a pedagogical framework to support teachers. However, to explore the role of professional awareness in making well informed career choices (second objective), the model seemed a valuable framework for planning and executing the methods of the study. Following Magana's (2021) overview of frameworks for guiding research and instruction, the PREFER model served as a methodological framework and an analytical framework. In Chapters 3 and 5, as a methodological framework, the PREFER model provided guidelines for the method (survey design, interview protocol). In Chapter 4, the PREFER model was used to provide guidance for data analyses of interest, strengths and weaknesses, and job choices. As such, the PREFER model with a more diverse perspective on the roles an engineer can take on, shed new light on the scholarship in engineering identity as more groups can relate to one or more roles that is not necessarily the traditional, stereotyped engineering role. For example, this can explain why our findings showed no significant differences in role fit confidence between male and female students. There is an ongoing debate about inclusive research in engineering education (and beyond) (Benson et al., 2021). The PREFER model can be of inspiration in taking a more inclusive research approach when investigating the professional identity of future and early career engineers.

2.3. A better understanding of career choices by introducing clear and new concepts

In the literature review, it was noticed that very few studies defined the concept of professional roles but there seems to be an agreement that

professional roles are more than just jobs or function titles and should reflect the expectations of the work field. Hence, in the context of engineering graduates entering the labour market, we may suggest endorsing the concept of professional roles for future research as proposed in Chapter 1, 5.1 (p. 66).

In different stages, for example when identifying essential role competencies, we were hindered by a lack of or by inconsistently defined concepts. In line with previous research (Cruz, Saunders-Smits, et al., 2019; Passow & Passow, 2017; Suleman, 2018), we call for clear and consistent concepts and standards for the different competencies to move forward the research field. Throughout this study, we have consciously defined the concepts and carefully described the methods that were used. Also, the PREFER model itself clearly describes the professional roles by offering three portraits and by clearly defining the competencies (Chapter 2). Future research can build upon this work.

In the survey on professional role confidence (Chapter 3, 2.2.), we introduced professional awareness as a two-dimensional concept: role awareness and competence awareness. Both had significant predictive value in role fit confidence and in competence confidence, yet in different proportions. As such, the more refined concepts allowed to deepen our understanding of professional role confidence. In the exploratory set up of this study, taking into account the lower number of items per construct, we accepted that the Cronbach's alphas per construct (.53 and .59) fall within an acceptable range of internal consistency. For future quantitative research, the constructs would benefit from more items to increase the reliability and avoid an underestimation of the effects of the measurement (Bacon, 2004).

The concepts were also used in a qualitative set up: they were used to guide the job interviews with early career engineers. Also in this study, the concepts helped to give a more nuanced insight in the education-to-work transition and in the career choice. This shows that the concepts have potential in future research in career development learning or professional identity development.

2.4. Limitations and perspectives for future research

Despite its contributions, this study has its limitations, and the results should be interpreted within these boundaries. By critically reflecting on the outcomes, new avenues are drawn for future research.

2.4.1. Reflections on the PREFER model

We aimed to develop a reflective *professional role model, regardless of engineering discipline*. The focus group conversations with students and interviews with early career engineers showed that students from different disciplines could position themselves in this overarching framework. However, it is possible that the roles can be more refined per discipline. For example, Weston et al. (2019) developed 14 typical roles for food science and technologists graduates within the UK food industry. While some roles, like a customer support technologist can be recognized in other fields, the framework also includes field-specific roles, like a nutritional role. Some engineering programmes, like at KU Leuven, start with a common programme in the first bachelor's year before students choose their major in a specific discipline. An overarching representation of engineering roles that is not too complex, allows to start creating professional and self-awareness from day one.

The PREFER model was *developed to support engineering students* in their career development learning, as were the two PREFER tests originated from this model. However, the early career engineers in the interviews indicated that the PREFER instruments can also be valuable tools in career development once graduated. IE-Net, the Engineering Federation in Flanders, is currently piloting the tools for engineers who want or need to reorient their career. Further research is recommended to investigate whether other roles should be included when progressing in the career. For example, the PREFER model did not comprise a managerial role as this role was perceived as a career ladder opportunity and not a role an early career engineer will take when

graduating (Betz, 2014; Hodgson et al., 2011; Saunders-Smits & De Graaff, 2012).

The PREFER model was built upon insights from the literature review. The articles in the review involved research conducted in 32 countries in Europe (N=16), the US and Canada (N=11), Middle East (N=2), South-Asia (N=2) and Australia (N=1). However, the three studies that laid foundation for the model were all European studies. Also, the PREFER model was *validated mainly in Belgium*. Experts from locally and internationally oriented companies participated in the panels and two expert panels were organised in Ireland and the Netherlands. The outcomes of these latter panels did not seem to deviate; however, the model would benefit from larger samples in more countries. Also, the student focus groups were organised in Belgium. A focus group conversation with six international Master's students was organised in TU Delft with similar outcomes. BEST, the Board of European Students of Technology, set up a survey among its members (2019, N=50). The outcomes, showing that 92% indicated that the model made sense and more than 62% considered that the model provides a good starting point for reflection on what they want in their professional future, encourage the use outside Belgium.

The widespread interest in the PREFER model strengthens the confidence that the PREFER model is not bound to the Belgian context. For example, the PREFER model was of inspiration for a Master's thesis in Tecnico Lisboa (Moita, 2020) and for an internship of a PhD student from the Colombian Universidad de los Andes (2020), and is currently being used for research purposes in Bejing University. The model also finds its way for educational purposes, for example in the UNSW in Sydney. However, it would be interesting to further investigate how the roles are applied in different contexts and whether the importance of competencies might vary according to different cultures. In 2021, ESTIEM, the European Students of Industrial Engineering and Management, initiated a collaboration to explore role preferences in different universities in Europe (Heyen et al., 2021). They

encouraged students among six European universities to fill in the PREFER Explore test (N=179). It was noted that the distribution of the preferred roles varied between the studied locations, showing a non-uniform distribution that can be influenced by university-based factors, such as the curricula, or regional employment opportunities. Further analyses between different countries, university profiles but also between engineering profiles (e.g., engineering sciences, engineering technology) is therefore recommended. The latter will be part of a follow up project URGENT, supported by KU Leuven Internal C3 funding. In this project, the PREFER model and tests (See section 3.2., p. 200) are further validated. The project involves students from the three KU Leuven engineering faculties to investigate whether there is a difference between the perceptions of different (underrepresented) groups of (future) on the role descriptions or test cases. Also, the sample of engineers in the field will be expanded aiming to increase diversity in the sample to strengthen the validation of the PREFER model and PREFER test scores.

The PREFER model focuses on the different roles an engineer can take on. As a consequence of aiming to make clear what industry expects from future engineers, we *excluded non-engineering career possibilities*, from the beginning. This was also noted in the literature review where studies excluded these career possibilities from the beginning, or excluded them along the road due to low sample sizes (Kinnunen et al., 2018; Kinoshita et al., 2015). The framework should be interpreted within these boundaries, and it has to be clear for students that aiming for a job outside engineering does not necessarily entail feeling less an engineer. The typology of Magarian and Seering (2021) can help in recognizing jobs that are closely coupled to engineering or jobs that are not typically recognized as 'engineering jobs' but require engineering related competencies.

For example, a first-year Bachelor student wrote in a reflection on a job shadowing exercise:

> *"During the job shadowing day, I noticed the wide variety of career directions in engineering. At first sight it would seem that an engineer*

> *has no real place as an educator in a secondary school but that is far from the truth. The knowledge that an one has gained in its engineering education is a good basis to teach a large number of subjects that are offered secondary education." (first year Bachelor's student in Engineering Technology, 2021)*

In some conversations with students and lecturers, we discussed the *role of the educator*. In most of these conversations educators were recognized in a customer intimacy role. Pupils or students could be perceived as clients and it seemed that similar competencies were deemed essential: clear communication, capacity for empathy, aiming for learning results, building relations with students etc. As part of her Master's thesis, Van de Kerkhof (2019) classified engineering jobs that required a degree in Electromechanical Engineering with maximum two years of experience in the PREFER model, using the occupation sheets of VDAB (the public employment service in Flanders). Her results showed that an educator did fit the customer intimacy role. However, given the societal relevance of high-quality STEM educators, it might be important to make this role more visible. It can also help to increase attractiveness and a more inclusive approach of engineering education as the variety of roles make explicit that engineering is not just about creating artefacts, processes or systems (Bairaktarova & Pilotte, 2020). This will be further investigated in the follow up project URGENT focusing on the attractiveness and inclusiveness of UnderRepresented Groups in ENgineering Technology.

Similar questions can be asked regarding the inclusion of an *entrepreneurial role*. A typical characteristic for entrepreneurs who want to engage in setting up new businesses is risk taking. However, companies rather value entrepreneurial skills which include taking initiative, identifying new opportunities, responding to challenges, technology benchmarking etc. than starting up an own business (Sewell & Dacre Pool, 2010). These competencies seem to correspond most with the product leadership role (which also includes, for example, taking initiative and client (market) orientation). Cruz

et al. (2020) recently developed the COM π instrument, a professional competency perceptions instrument based upon an industry competency framework of Siemens, a worldwide employer of engineers. They also classified competencies like negotiation skills or project (work) management as entrepreneurial competencies. Those competencies relate to the roles of customer intimacy or operational excellence. The survey with industry to validate the PREFER model showed that start-up companies (N=3) and small companies (N=23) had no difficulties with the categorisation of the three roles. Moreover, the start-up companies indicated they needed engineers that combine at least two roles in the job. When organising the expert panels to identify essential competencies, two experts active in a start-up and a self-owned small business, participated in the mixed panel. Their responses did not seem to deviate from other panel members, nor did they indicate that a role was missing in the model. Although the small number of engineering graduates who wants to set up their business should be supported, the PREFER model is rather perceived as described by Kamp and Klaassen (2016, p. 5):

> '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.'

As the world is rapidly changing, one can question to what extent the PREFER model is *future proof.* Indeed, we did not ask industry what competencies are required for engineers in 2050. However, the model is based on the outcomes of the literature review showing similarities between the three models of Hofland et al. (2015), Kamp and Klaassen (2016) and Spinks et al. (2006). The latter two studies focused on what is required to prepare the engineer of the future whereas Hofland re-engineered a business model from 1993. Nonetheless, they have similar descriptions of the different roles. As mentioned in the introduction, this study was part of the European study

PREFER with a consortium of educational partners and engineering federations. We regularly presented the outcomes, such as the PREFER model and asked for feedback. One of the presentations was for the Agoria Advanced Manufacturing Comity that organizes around 20 representatives of factories of the future for discussion. The committee suggested that they perceived the PREFER model as a future proof model but that the collaboration between roles has been shifting. Whereas before engineers in different roles each worked at their department, they will more often team up in projects in the future. Investigating how the different roles relate can be an interesting future research avenue.

2.4.2. Reflections on exploring professional awareness and career choices

This study explored the role of *professional awareness as a broad concept integrating a degree of self-awareness*. Verbruggen (2020) suggests to study the effects of self-awareness separately. Self-awareness is malleable through for example career interventions but also through other features that trigger self-awareness, for example parental support or support from peers and supervisors. High levels of self-awareness is believed to be an important adaptive competence: students would more easily filter and process information in a consistent way (Morin, 2011). It is also associated with more confidence in the ability to make career choices (Betz & Voyten, 1997).

Although the focus was on professional awareness, *deciding on a future career is affected by social factors* as well. For example, in one of the interviews, an early career engineer indicated that the choice to accept a job offer was affected by home distance and by the family support. It would be interesting to further investigate the supports and barriers of making a career decision in the context where graduates easily find a job. The Social Cognitive Career Theory is a theory that has been used earlier to investigate study and career choices in engineering education (e.g., Korte et al., 2019; Matusovich et al., 2010; Rude et al., 2019; Winters et al., 2015).

Due to the *exploratory nature of the study*, we used a mixed method approach (Creswell, 2009). We organised (qualitative) interviews and focus groups with students which gave insight in their understanding of and perspective on the different professional roles. Based on these insights, we used quantitative methods when investigating students' professional role confidence (also building on earlier work of Cech et al. (2011)) and role choice congruence. We used again a qualitative approach to get more insight in the early career engineers' perspectives on how well informed they made a job choice and on their education-to-job transition. Every method has its advantages and disadvantages. For example, when analysing the interviews in an iterative way (qualitative research), it is important to note that the findings present an interpretation of the opinions and experiences (Smithson, 2000). We aimed to maximise transparency and understanding by describing the different steps and by noting and defining carefully different categories in the analyses. An example of a disadvantage of quantitative approaches is the sample size. An illustration is the case study on role congruency (Chapter 4) where the sample size is too small to draw solid conclusions when comparing different groups. The outcomes must therefore be interpreted as indications drawing avenues for further research.

The studies in Part Two were conducted in only one campus of the Faculty of Engineering Technology at KU Leuven (Campus Group T). The campus is a large, international and vibrant campus in the Leuven city centre. The results should be interpreted within that context. Future studies can build upon this work with larger samples in more diverse engineering programmes and in different contexts. Due to sample sizes, timing and set up, we were bound to comparing cohorts in the quantitative studies. A longitudinal approach would give more accurate insight in the career development learning process of engineering students.

We aimed to include a *multi-perspective approach* throughout this PhD research. In Part One, developing the PREFER model, we collaborated intensively with industry but also with students, and we gained feedback from

academics. In Part Two, exploring professional awareness in career development learning, we focused on the perspective of future engineers (students) and early career engineers. As a consequence, we could only measure their self-perceived strengths (Chapter 4) or their self-perceived job fit (Chapter 5). An interesting direction for future research would be to compare whether students' self-perceived strengths in professional competencies would be evaluated accordingly by the lecturers, or whether engineers' self-perceived job fit is perceived similarly by their employers.

3. Recommendations for education

3.1. Context matters

In engineering education research, there has been a large focus on what competencies should be taught and trained, mostly making the distinction between technical competencies and professional competencies. However, a growing body of research has been emphasizing that both competencies are intertwined because they are dependent on the learning context (De La Harpe et al., 2000) and cannot be taught in isolation (Flening et al., 2021; Passow & Passow, 2017; Shuman et al., 2005).

Our results support the holistic approach of engineering competencies and urge curriculum designers and lecturers to make the competencies explicit and the context relevant. As highlighted by Shuman and colleagues (2005), professional competencies have a strong process component. Student learning requires opportunities for students to focus on such processes, for example in project work. However, as was found by Picard et al. (2021), it can become challenging when the focus of the project is on the deliverables and even more challenging when the professional competencies are perceived as learning from doing. This was also noted in the interviews where early career engineers amplified the call for integration of professional competencies (see also De La Harpe et al., 2000; Morelock, 2017; Scott & Willison, 2021). Universities may need to change the curriculum and how it is taught in order

to explicitly demonstrate the intended learning outcomes. In this respect, Berdanier (2022) advocates to stop using the 'hard/soft' language when referring to technical and professional competencies and to finally 'elevate essential professional strengths as core engineering skills' (p. 16). Engaging students in professional competencies development during education will provide new ways to excel in engineering, in particular for those students who might feel less 'a real engineer' because they value or excel in professional competencies.

The PREFER model offers a more diverse image of engineering which facilitates to trigger awareness of important competencies, also of those that are less easily trained and assessed in education such as the development of vision or the ability to have a helicopter view. The competency profiles with an aspiration to career perspectives can be implemented and made explicit in existing curricula, for example, when reframing activities with industry, in project work, or elective courses on specific competencies. They can help to provide contextualisation to the professional competencies in the engineering curriculum and avoid a rather superficial 'tick box' approach (Bridgstock 2009; Tomlinson and Holmes 2017) without requiring a complete curriculum redesign, which is not always possible.

As mentioned earlier, not all competencies are easily integrated in the curriculum. The PREFER model provides lecturers an instrument to at least start the conversation about the importance of these competencies. Universities who invest in innovative learning and teaching will more easily provide opportunities to go beyond this conversation. For example, they aim to increase the level of interdisciplinary activities, to improve collaboration with industry including exposing students to real-life, active engineering problems faced by businesses, to incorporate greater levels of creativity and idea-generation, or to improve workplace experiences of students (Royal Academy of Engineering, 2019). Such activities are inherent to the integration of professional competencies. Collaboration with industry can also support lecturers in training and evaluating the competencies.

3.2. Include reflection on the future role as an engineer

Our results showed the importance of both role awareness and competence awareness in predicting professional role confidence. Having confidence in your ability to fulfil a role is important for persistence in engineering (Cech et al., 2011; Lizzio et al., 2004) and in making career choices, as was suggested in the interviews with early career engineers. For example, an engineer did not apply for a job because she was not confident enough that she would be able to be successful in that job. These findings support the suggestion of Scott and Willison (2021) to put reflection more central when preparing students for the labour market. As such, students can make vital connections between themselves and their future role as an engineer (Bennett & Male, 2017).

In the European project PREFER, two test instruments were developed to enhance this reflective process, based upon the PREFER model. First, a personal preference test was developed to help engineering students evaluate which professional role they would most like to fulfil (Carthy et al., 2020; Pinxten, et al., 2020). This PREFER Explore test is a short 10-minute test that can already be used in the first Bachelor year. Second, a situational judgment test (SJT) was developed in close collaboration with industry (Carthy et al., 2022; Pinxten et al., 2020b). The PREFER Match test provides students insight in their role alignment based on their judgment of situations in practice. The test allows feedback on role alignment and professional competencies. The PREFER model and tests can be easily integrated in the curriculum or extracurricularly. For example, in the KU Leuven Faculty of Engineering Technology, the PREFER Explore test is integrated in a Bachelor's course job shadowing activity. First-year students follow an engineer in the field for one day, share their experiences with peers and reflect on the different engineering roles and their preferences. In UGent, the PREFER tests are an obligatory part for Masters in Biochemical Engineering Technology in the course Workfield exploration and Internationalisation. An example of extracurricular use is the provision of the PREFER Match test to the Master's students in order to prepare them for the job fairs. The KU Leuven Student

Career Center uses the PREFER instruments in career guidance sessions. The instruments also help students to recognize and value their experiences in extracurricular activities, such as student challenges, student jobs or volunteering. In earlier research, students' participation in extracurricular activities was found to be important for self-efficacy and employability (Griffiths et al., 2021). Participation in these activities can be more actively encouraged.

3.3. Start from day one and be flexible

As was shown in the student survey on professional role confidence, students role and competence awareness, and related confidence, increased per programme year. Programme year remained a significant predictor of role fit confidence, even when controlling for other variables, with freshmen showing higher role fit confidence compared to master's students. The findings emphasize the importance of increasing professional awareness already early in education. It has been shown that students early in education tend to have a poorly formed idea of the world of work and do not autonomously engage in active thinking about their future careers (Bridgstock, 2009; Perrone & Vickers, 2003). Engineering students have difficulties in understanding what an engineer is and, consequently, risk to explore their career choices based on what they know – the rather stereotypical engineer – or prefer and tend to neglect other choices (Blustein, 1992).

Preparing students for an engineering career and for the education-to-job transition, is not about matching engineering graduates in jobs that fit but about expanding interest and abilities (Krumboltz & Worthington, 1999). In this rapidly changing world, jobs and the way people approach their career are also changing. Therefore, curricula should be designed in ways that will help graduates engage with different roles and shifting identities (Trede et al., 2012). From this perspective, the typically 'fixed' engineering curricula, leaving hardly any room for free choices, can certainly be questioned. Hence, accreditation bodies, such as ABET, endorse the design of customisable

curricula 'allowing students an opportunity to chart their own course, with flexibility and choice in program elements' (ABET, 2017b, p. 10).

At the Faculty of Engineering Technology, a curriculum redesign was implemented in 2020-2021. The professional roles have been introduced in this new curriculum in a gradual way. For example, in the first Bachelor year, the roles have been introduced in a job shadowing activity using the PREFER Explore test, as described in the previous section. In the following years, the focus is on creating awareness and reflection on the preferences. Currently, the Master's programme is being redesigned aiming to offer specific skills training. A more detailed description of how the PREFER model and instruments can be integrated in the curriculum is described in Langie and Craps (2020).

3.4. Support the lecturer

It is clear that, when discussing how to prepare engineers from day one in flexible curricula, the role of the lecturer cannot be overlooked. In a recent study in Ireland, Beagon (2021) directs lecturers and curriculum developers to be more aware of the importance of developing behavioural skills in engineering students in order to be successful in life and as future engineers. She notes that any interaction with a student is an opportunity for leading by example and setting standards. In her study on professional competencies' teaching approaches, she found that the role modelling was underused as teaching approach.

Lecturers should also acknowledge the limitations of the educational context and mindful motivate the need for professional competencies to students (Flening et al., 2021). When the professional competencies are not reflected in the first job, it might be discouraging. The PREFER model can support lecturers and curriculum designers in finding a good balance between what competencies can be thought in education and what competencies should be made explicit because they will be trained in the work field.

Supporting students' professional awareness and enhancing critical reflection about themselves is a process that requires feedback that facilitate students' learning. For some lecturers, this demands a change in teaching and assessing that often requires more time and effort. If the systematic change is not included in the faculty's policy, lecturers are not rewarded nor supported for innovation in teaching (Kolmos et al., 2016). Moreover, adopting new teaching and learning approaches with an explicit link to engineering practice might not be evident for all lecturers. Amiet et al. (2020) explored academics' views on supporting students' career development in three undergraduate health science programmes in an Australian university. They found that academics who had spent time working in industry and outside of university felt confident providing career information to students. However, the majority of academics had gone directly into a teaching and research position, and felt this knowledge was outside of their expertise.

To facilitate lectures in increasing students' professional awareness and engaging them in career development, making them more adaptable to new contexts, PREFER manuals and materials for lecturers were designed (www.fet.kuleuven.be/prefer/instructor). Additionally, these supporting materials also aids lecturers in their professional development as engineering educators because they get better insight in the engineering practice. For example, the manual of the PREFER Match test offers a wide range of situations that early career engineers can encounter and the reasoning of why certain reactions and behaviour in those situations are perceived more or less appropriate by engineers. The reasoning behind the test set up and test results gives insight in engineering practice, inspires lectures with examples to make professional competencies explicit, and aids to give relevant feedback to students in their professional identity and competency development. In this regard, it is also worthwhile to mention that TRAINengPDP, a new Erasmus+ project in collaboration with TU Dublin (Ireland) and Lappeenranta University of Technology (Finland), has been launched in the Spring of 2022. The project will focus on engaging and motivating students in their personal

development process and on motivating and training lecturers to engage students in this process.

4. Implications for industry

4.1. Clarify and explicit expectations

Most early career engineers mentioned during the interviews that a lack of well described job vacancies did not facilitate their job search. Moreover, some said that even after the job interview, they were still in doubt of what was expected in the job. Others experienced the job interview as a waste of time and were frustrated that the job vacancy description had not been more clearly described. In some expert panels, organised to identify the essential competencies of the professional roles (Chapter 2), it became clear that this was a deliberate strategy to attract a large pool of engineers in order to select the best candidate. Although they are in high need to hire engineers, recruiters benefit from selecting an engineer that fits the job, and not just any engineer. For example, a study from Aronsson and Göransson (1999) showed that employees who were not in their preferred occupation experienced higher levels of burnout. Our study with early career engineers showed that a misfit will lead more easily to thoughts of job change. Other companies take on a different strategy and be as detailed as possible, resulting in a long list of required competencies, in their search for the white knight. The early career engineers indicated that these vacancies were also confusing and risked creating wrong expectations. In a recent article in De Tijd, a high quality newspaper in Flanders, Agoria (2022) confirmed our findings stating that companies should move away from traditional recruitment strategies where they hold checklists to evaluate different candidates. Also, employers should no longer think in terms of functions but in terms of roles, responsibilities and team-thinking and make clear what they expect or what the job applicant can expect. There is no gain in keeping expectations vague or represent everything more beautifully in order to attract young potentials. The new employee will find out soon and perhaps leave the company within months.

The PREFER model can help recruiters in making clear and start the conversation about what is expected in a particular role. Nancy Vercammen, director of IE-Net, the engineering federation in Flanders, stated earlier that the tools are a 'benefit for applicant, engineer and company' (Vander Elst, 2019). IE-Net will include the PREFER tools on their job portal (currently being developed) so that young engineers and companies can easily have access and use the tools. The new follow up project URGENT includes a work package to set up the valorisation trajectory in close collaboration with Leuven Research & Development (LRD), the KU Leuven Tech transfer office, with ie-net and with different companies. Optimisations will be made to the PREFER tests in order to make them more adaptable for HR use (for example the possibility to link the company's open positions to the different roles), a series of services will be set up and piloted, and a fee-for-service model will be developed in order to guarantee a high quality service provision in the long run.

4.2. Engage in personal development and lifelong learning

A better understanding of the engineering job could help graduates to make a more productive transition into their career and helps to make employers understand which training will be most effective (Tilli & Trevelyan, 2008). On-the-job training will always be necessary. Although education should make the relevance of professional competencies more explicit, competency development and more generally professional identity development continues after education (Flening et al., 2021). It cannot be fully translated in the curriculum (Thornton & Nardi, 1975)

Some companies that clarify their expectations but also the opportunities for the engineering graduates have a recruitment advantage. Opportunities for personal development and lifelong learning were highly valued by the early career engineers that were interviewed. It was a positive finding that some of these engineers spend their free time on keeping up with the state of the art and learning new knowledge and skills. Also, the prospect of different career

opportunities in the company was perceived as important. Companies that could not fulfil the expectations were perceived negatively, and this already in the selection process. For example, not following up the application as promised or returning a phone call or email within an appropriate time was a good reason for not accepting the job.

Industry can support education to reduce the mismatch in expectations and skills. In a recent EJEE editorial, Buckley, Trevelyan and Winberg (2021) describe that bringing the worlds of engineering education and engineering practice into a closer relationship poses many challenges. However, this PhD experience showed the value of an industry-education/research collaboration. The PREFER model as such could not have been developed without industry collaboration. It did indeed ask courage and persistence, as Buckley and colleagues write, in particular in networking, planning and organising but a lot of companies and engineers were willing to contribute to this educational research. They recognized the value and benefit in the long run. Collaboration with industry also ensures that engineering programmes stay current and future oriented, or that students can get exposed to real life project cases. However, companies can step forward more actively to contribute to the process of becoming engineering professionals already in education. For example, they can offer to organise (extracurricular) workshops to introduce students to specific competencies like negotiation or to facilitate train-the-trainer sessions to support lecturers. By doing this, they engage students also in their lifelong learning competencies early in education.

5. Final conclusion

At the beginning of this thesis, I outlined the motivation for this study. To reduce the skills or expectation mismatch in engineering, we need to better prepare students for the labour market and enhance identity and career development learning. A better understanding of different roles an early career engineer can take on is required in order to increase the students'

professional and self-awareness. Students with higher professional and self-awareness are more likely to make well informed career choices. This motivation resulted in two main objectives (the development of a professional roles model and the exploration of professional awareness in making well informed career choices). This chapter has critically discussed findings, drawing recommendations for research, education, and industry.

In conclusion, this PhD thesis has made several achievements in relation to career development learning of engineering students that have allowed to progress the discussion to some extent in different areas:

1. by developing a reflective instrument for students to get a grip on the myriad of job opportunities for early career engineers and to help them think about themselves as future engineers.
2. by expanding our understanding of engineering students'/graduates' career choices, making explicit that both dimensions of professional awareness (role awareness and competence awareness) are important to address in education;
3. by showing the importance of professional awareness and career exploration in educating confident engineers that are more likely to enter the labour market with the right expectations and competencies from the start which benefits their job satisfaction.

The outcomes offer new insights and instruments that:

1. support students to reflect on their future as an engineer, already early in education;
2. aid educators to support career development learning, making professional roles and competencies more explicit;
3. encourage policy makers' conversation to develop innovative, flexible curricula;
4. guide future research in this field and offer insights to build upon;
5. inspire industry in education-industry collaboration in closing the gap.

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Appendices

Appendix Table A1. Identifying competencies per role

Study	Sample	Method	Competencies retrieved from…	Measure	Role 1	Role 2	Role 3	Role 4	Role 5
Brunhaver et al. (2013)	N=543 engineers (max. 4 years of experience)	Questionnaire	20 competencies from ABET Criterion 2011-2012 and Engineering 2020	Perception about importance of competencies in the current work	**Practitioners**	**Managers** Business knowledge Leadership Management skills Engineering techniques/ tools* Communi-cation Managing uncertainty	**Consultants** Design Planning and conducting experiments*		
Hofland et al. (2015)	N=5 HR managers	Mixed method:	13 KU Leuven Engineering	Perception about	**Operational Excellence**	**Product Leadership**	**Customer Intimacy**		

	N=121 company representatives working with engineers	interviews and survey	Technology learning outcomes 2014-2015	importance of competencies in the professional roles	Problem analysing and solving Operationalisation Basic technical knowledge Basic scientific knowledge	Design and development Basic scientific knowledge Specialised technological knowledge	Professionalism Entrepreneurship (taking initiative and sense for business) Communi-cation Basic scientific knowledge* Ethical responsibility		
Kamp & Klaassen (2016)	N=12 full, associate and assistant professors, senior lecturers, programme directors, members of the valorisation centre and student bodies from all disciplines	Design thinking	/	Unravel the capabilities and knowledge the future engineer in different scenario's	**Specialist** Fundamental science knowledge In-depth disciplinary knowledge Research and experimentation skills Problem defining skills Critical thinking skills	**Front-end Innovator** Product knowledge and design process Customer and market trends knowledge Business economics knowledge Critical questioning	**System Integrator** Broad technical knowledge Complex systems knowledge Understanding engineering languages System thinking skills Structured project skills	**Contextual Engineer** Role of the environment knowledge Cultural, legal and political knowledge Broad technical knowledge Networking skills Leadership	

	of the institution				Analytic engineering mind-set Independent Curious Language (e.g., communication skills, design literacy …)	skills Entrepreneurial skills Innovative skills Open-minded Empathic Explorative Creative risk-taking Language (e.g., communication skills, design literacy …)	Integration skills Object oriented attitude Pragmatic Organised Responsible Language (e.g., communication skills, design literacy …)	skills Conflict and negotiation skills Resilient Visionary Perseverance Language (e.g., communication skills, design literacy …)	
Spinks et al. (2007)	N=30 (experienced industry practitioners) N= 28 (recent engineering graduates) N=444 (engineering companies)	Mixed method: in-depth expert interviews, focus groups, and a large-scale survey	6 skills presented in the survey, based in results of interviews and focus groups	Higher level synthesis of the findings of the research into a depiction of the engineering graduate of the future	**Specialist** Technical expertise	**Change agent** Creativity Innovation Leadership Managing uncertainty	**Integrator** System thinking perspective (interdisci-plinary thinking, commercial awareness, business awareness)		

Itani et al. (2016)	N=306 senior engineering students	Questionnaire	49 items (5 questions) based on literature (Rynes (2017), Meier et al. (2000), ABET (2011), Lang et al. (1999))	Perceptions of soft skills between students with technical (TA) and non-technical career aspirations (NTA)**	***Technical career aspirations***		***Non-technical career aspirations***		
					Engineer in charge of mainly technical tasks *(e.g., design, operations)*	**Consultant in the technical field**	**Engineer performing both technical and administrative tasks**	**General or nontechnical consultant**	**Opportunity involving management or supervisory training**
					Engaging in self-development and continuous learning involving technical knowledge		Communication and presentation skills Basic accounting/finance and basic marketing (Project) management Creativity and optimism Risk-taking propensity		

Kinoshita, Young, and Knight (2014)	N=1339 alumni engineers (max. 3 years of experience)	Questionnaire	4 skills: 1) engineering design, 2) teamwork, 3) communication, and 4) leadership	Relative to the technical job function category (the reference):	**Technical**	**Supervisory**	**Consultant**	**Non-technical**	**Other**
				1. Perception of senior-year skills		Design skills Communication skills Leadership skills	Design skills	Leadership skills	
				2. Perception of three years post-graduation skills, relative to the technical job function category (the reference)		Design skills* Leadership skills	Communication skills	Design skills* Communication skills	Design skills* Communication skills* Teamwork*

** Significantly less important*
*** Itani et al. (2016) excluded the category 'job rotation program' in this part of the research due to position will be determined at a later stage*

Appendix Table A2. PREFER competency profiles: definitions of the professional competencies.

Competence	Definition
Innovation	...has and encourages new, original ideas, working methods and applications. Focusses on future innovation in strategy, products, services and markets with an inquiring and inquisitive mind.
Persuasiveness	...obtains buy-in for ideas and proposals by making the right arguments - at the right time and in an appropriate manner and so has an influence on others.
Vision	...develops and carries out an idea of the future. Can distance him/herself from day-to-day practices. Identifies facts, trends and future developments and places them within a broader context and long-term perspective of his/her own field of work, specialty and/or organisational unit.
Perseverance	...brings a launched task to a successful conclusion within a reasonable timeframe, despite difficulties.
Initiative	...undertakes actions on his/her own initiative and makes proposals. Instead of waiting, he/she takes the lead, anticipates, seeks and sees opportunities, identifies bottlenecks and acts accordingly.
Creativity	...approaches problems from different angles, contributes new and original ideas and solutions, and breaks through established thinking patterns.
Client focus	...attunes his/her own actions to the feelings, needs and wishes of internal and external clients, even when these are not directly expressed.
Positive critical attitude	...reflects on the methods, techniques and strategies used by the company. Questions them in a positive manner.
Planning and organisation	...determines goals and priorities effectively. Indicates the time, activities and resources needed to achieve goals.
Helicopter view	…can take important decisions and assess the consequences of these decisions in terms of both space and time.
Team player	...makes an active contribution to a collective result (organisational goal) or to the resolution of problems or conflicts. Does this also when the collaboration concerns a subject that is not of direct personal interest.
Work organisation	...can work according to an efficient and practical method, either by him/herself or with a group.

Stress resistance	...continues to perform effectively under work pressure, time pressure, despite setbacks, resistance, disappointment and/or criticism. Acts in a well-balanced manner and believes in his/her own ability.
Solution-oriented	…thinks in terms of solutions, does not ignore problems and does not unnecessarily consider a given situation a problem.
Clear communication	...communicates using the proper language and in a clear manner adapted to the situation and the target person or audience, both verbally and in writing.
Capacity for empathy	...listens to and thinks along with others. Acknowledges the feelings and needs of others, puts him/herself in others' shoes and consciously deals with different backgrounds and interests.
Networking and relation building	...builds relationships and networks with people within and outside of the organisation, at different levels and from different cultures that are important for the goals of the organisation or organisational unit.
Negotiation	...achieves goals in consultation with other interested parties. Can come to an agreement without losing sight of both parties' interests in a manner that leads to agreement and acceptance by both sides.
Focus on results	...is focussed on translating - concretising - goals and achieving results in accordance with timeframes, standards and agreements.

Appendix Table A3. Pearson's Correlations between the variables used in the analyses (N=898)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Role fit confidence	--													
2. Competence confidence	,285**	--												
3. Role awareness	,286**	,176**	--											
4. Competence awareness	,208**	,245**	,269**	--										
5. Career exploration	,291**	,312**	,141**	,161**	--									
6. Female	-,065	-,074*	-,007	-,010	,020	--								
7. Parent engineer	,028	,017	,018	,009	0,010	-,089**	--							
8. Technical secondary education	,088**	-,024	,032	-,011	,071*	-,125**	,037	--						
9. Bachelor 1	,003	-,088**	-,055	-,110**	-,255**	,000	-,023	-,011	--					
10. Bachelor 2	-,063	-,056	-,045	-,005	-,137**	-,043	-,029	,0186	-,370**	--				
11. Bachelor 3	-,008	,061	,047	,042	,077*	-,048	,026	-,103**	-,375**	-,308**	--			
12. Transfer	,012	,001	,016	-,003	,107**	,087**	,043	,235**	-,174**	-,143**	-,145**	--		
13. Master	,071*	,110**	,057	,099**	,319**	,048	,003	-,044	-,288**	-,236**	-,240**	-,111**	--	
14. GPA	,023	,051	,003	,071*	,168**	,027	-,048	-,134**	-,344**	,033	,117**	-,097**	,328**	--

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix Table A4.I. Level of alignment of cohorts with zero to integrated professional role acquaintance (Case study 1).

	2018-2019		**2019-2020**		**2020-2021**	
	N	%	N	%	N	%
Preference x competence						
Aligned	16	34,04%	30	53,57%	15	46,88%
Exclusively	6	12,77%	4	7,14%	7	21,88%
Fluid	0	0,00%	1	1,79%	3	9,38%
Unaligned	31	65,96%	26	46,43%	17	53,13%
Total	47	100,00%	56	100,00%	32	100,00%

Appendix Table A4.III. Level of alignment of cohorts of different disciplines (Case study 2)

	Electronics-ICT		**Electromechanical**		**(Bio)Chemical**	
	N	%	N	%	N	%
Preference x competence						
Aligned	20	58,82%	15	37,50%	12	52,17%
Exclusively	8	23,53%	3	7,50%	6	18,75%
Fluid	2	5,88%	1	2,50%	1	4,35%
Unaligned	14	41,18%	25	62,50%	11	47,83%
Total	34	100,00%	40	100,00%	23	100,00%

Appendix Table A4.II. Level of role choice congruency (All, Aligned and Unaligned) of cohorts with zero to integrated professional role acquaintance (Case study 1)

	ALL						**ALIGNED**						**UNALIGNED**					
	2018-2019		**2019-2020**		**2020-2021**		**2018-2019**		**2019-2020**		**2020-2021**		**2018-2019**		**2019-2020**		**2020-202**	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Preference x competence x career choice																		
Congruent	9	19,15%	23	41,07%	9	28,13%	9	56,25%	23	76,67%	9	60,00%	0	0,00%	0	0,00%	0	0,00
Exclusively	2	4,26%	2	3,57%	1	3,13%	2	12,50%	2	6,67%	3	20,00%	0	0,00%	0	0,00%	0	0,00
Incongruent	38	80,85%	33	58,93%	23	71,88%	7	43,75%	7	23,33%	6	40,00%	31	100,00%	26	83,87%	17	100,0
Total	47	100,00%	56	100,00%	32	100,00%	16	100,00%	30	100,00%	15	100,00%	31	100,00%	26	83,87%	17	100,0
Preference x career choice																		
Aligned	32	65,31%	46	74,19%	17	53,13%	9	56,25%	24	80,00%	10	66,67%	21	67,74%	17	65,38%	8	47,06
Exclusively	19	38,78%	17	27,42%	9	28,13%	5	31,25%	10	33,33%	5	33,33%	13	41,94%	6	23,08%	0	0,00
Unaligned	17	34,69%	16	25,81%	15	46,88%	7	43,75%	6	20,00%	5	33,33%	10	32,26%	9	34,62%	9	52,94
Total	49	100,00%	62	100,00%	32	100,00%	16	100,00%	30	100,00%	15	100,00%	31	100,00%	26	100,00%	17	100,0
Competence x career choice																		
Aligned	20	42,55%	31	55,36%	16	50,00%	13	81,25%	28	93,33%	11	73,33%	7	22,58%	3	11,54%	4	23,53
Exclusively	4	8,51%	6	10,71%	6	18,75%	4	25,00%	5	16,67%	4	26,67%	1	3,23%	1	3,85%	1	5,88
Unaligned	27	57,45%	25	44,64%	16	50,00%	3	18,75%	2	6,67%	4	26,67%	24	77,42%	23	88,46%	13	76,47

Appendix Table A4.IV. Level of role choice congruency (All, Aligned and Unaligned) of cohorts of different disciplines (Case study 2)

	ALL						ALIGNED						UNALIGNED					
	Electronics-ICT		Electro-mechanical		(Bio) Chemical		Electronics-ICT		Electro-mechanical		(Bio) Chemical		Electronics-ICT		Electro-mechanical		(Bio) Chemical	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Preference x competence x job choice																		
Congruent	15	44,12%	8	20,00%	9	39,13%	11	55,00%	8	53,33%	8	66,67%	0	0,00%	0	0,00%	0	0,00
Exclusively	2	5,88%	2	5,00%	2	8,70%	2	10,00%	4	26,67%	2	16,67%	0	0,00%	0	0,00%	0	0,00
Incongruent	19	55,88%	32	80,00%	14	60,87%	9	45,00%	7	46,67%	4	33,33%	0	0,00%	0	0,00%	0	0,00
Total	34	100,00%	40	100,00%	23	100,00%	20	100,00%	15	100,00%	12	100,00%	0	0,00%	0	0,00%	0	0,00
Preference x job choice																		
Aligned	24	70,59%	27	67,50%	14	60,87%	13	65,00%	9	60,00%	9	75,00%	11	78,57%	18	72,00%	5	45,45
Exclusively	4	11,76%	9	22,50%	2	8,70%	0	0,00%	3	20,00%	2	16,67%	3	21,43%	6	24,00%	0	0,00
Unaligned	10	29,41%	13	32,50%	9	39,13%	7	35,00%	6	40,00%	3	25,00%	3	21,43%	7	28,00%	6	54,55
Total	34	100,00%	40	100,00%	23	100,00%	20	100,00%	15	100,00%	12	100,00%	14	100,00%	25	100,00%	11	100,0
Competence x job choice																		
Aligned	17	50,00%	17	42,50%	11	47,83%	15	75,00%	14	93,33%	10	83,33%	2	14,29%	3	12,00%	1	9,09
Exclusively	5	14,71%	4	10,00%	2	8,70%	4	20,00%	2	13,33%	2	16,67%	0	0,00%	2	8,00%	0	0,00
Unaligned	17	50,00%	23	57,50%	12	52,17%	5	25,00%	1	6,67%	2	16,67%	12	85,71%	22	88,00%	10	90,91
Total	34	100,00%	40	100,00%	23	100,00%	20	100,00%	15	100,00%	12	100,00%	14	100,00%	25	100,00%	11	100,0

Appendix Table A5.1. Interview protocol.

Part I | Role awareness, exploration, fit

Explaining the three professional roles for early career engineers, as described in Craps et al. (2021), incl. visual.

1. Thinking about your **personal preferences (regardless your job)**, in what role would you position yourself?
    - Can you remember which role you wanted to take on when you graduated? Why?
    - Which role do you prefer now? Why?
    - Are they different? If so, why?
2. Take a look at your **first job**. Which professional role(s) fit(s) best with your first job?
    - Can you give a few examples of tasks or responsibilities to support this?
    - Was the content of your first job in line with the role you chose at the time?
    - Is/was the job content of your first job what you expected? What appealed to you in choosing this job?
    - Was this a reason to change jobs?
3. What role(s) do you take on in your **current job**? Can you give some examples to support this?
4. Have you thought about yourself as an engineer in this way before?
    - If so, did this play a role in your job search?
    - How actively did you search for a job? How easy was the job search?
5. Looking back at the moment you graduated, did you have the necessary confidence to be successful in this role? Did you feel ready for the job?

Part II | Competence awareness, exploration, fit

Explaining the three competency profiles, describing essential competencies to be successful in the different professional roles for early career engineers, as described in Craps et al. (2021), incl. visual.

1. In general, to what extent can you recognise these competencies in yourself as a strength or a weakness?
    - Does the interpretation/meaning of these competencies only become meaningful through your work experience or is this already meaningful for students?
2. Thinking about your **personal** preferences, would you still position yourself in the same position?
3. Does your **first/current job** still occupy the same position?
4. To what extent did you consider your strengths and weaknesses regarding professional competencies during your job search?
    - Why? Did anyone or anything encourage you to think about this?
    - Were these competencies explored in the recruitment process when you applied?
5. Did you expect these competencies to be important in your job?

6. Looking back at the moment you graduated, did you have the necessary confidence that you were good at the competencies of your preferred role(s)?
7. Did you feel ready to enter the labour market after your education?
    - If not, which competencies were missing? Did you take the initiative in this, e.g., by continuing your studies?

Part III | Job satisfaction and future plans

1. What makes your work valuable for your company or society? Can you give an example?
2. What gives you the necessary job satisfaction?
3. In general, how satisfied are you with your current job? Imagine a scale from 1 to 5 on which 1 is very dissatisfied and 5 is very satisfied.
    - What makes you (un)satisfied with your job?
4. Imagine you can do it all over again, would you make the same choices, or would you do things differently?
5. What are your plans for the future?
    - What skills would you like to develop further?
    - How do you see your career developing in the next few years?
    - Will you take the initiative?

Thank you for the interview.

Appendix Table A5.2. Code book

Professional awareness	Role awareness	High/low	
	Competence awareness	High/low	
Self-awareness	Insight in role/career path	High/low	
	Insight in strengths and weaknesses	High/low	
Career exploration	Job search	Broad/narrow	
	Reflections on career preparation		
Job expectations	Role expectations		
	Competence expectations		
	Selection process		
Confidence	Role-fit confidence	Upon graduation	High/low
		Current	High/low
	Competence confidence	Upon graduation	High/low
		Current	High/low
Job fit	Job role	1st job	
		Current job	
	Role preference	Upon graduation	
		Current	
	Competence profile	Self-perceived profile	
		Job profile	
	Fit	Role fit	Congruent/ semi-congruent/ not congruent
		Competence fit	Congruent/ semi-congruent/ not congruent
Job satisfaction	Reasons for satisfaction		
Quality of choice	Reasons for job choice		
	Reasons for job change		
	Reflections on choice		
Future plans	Lifelong learning		
	Career paths		

About the author

Curriculum Vitae



Sofie Craps was born in Leuven, Belgium on 6 September 1980. Studying Math and Sciences in high school, she chose for the KU Leuven Bachelors programme in Political and Social Sciences (2002). In 2004 she graduated as Master in Communication Sciences. For her dissertation, she applied the Cultural Theory of Mary Douglas to compare popular and elitist communication in Western European and African press. In 2005 she obtained the academic Teaching degree.

After her studies she was actively involved behind the scenes of science shows at the National Television (Hoe?Zo!, De Grote Geschiedenisshow) and became a project coordinator in a private telecom business supporting the 2G to 3G swap in Belgium. Missing the link with humanities and education, she started to work as a recruitment officer at KU Leuven in 2006. The focus was on study guidance and science communication. Six years later, she became the communication officer of the new Faculty of Engineering Technology. Since then, she has been providing career guidance to Masters' students and has been teaching communication skills to engineers. In 2021 she became chair of the faculty's Teacher's Team Professional Competencies.

In August 2017, Sofie started her PhD research in Engineering Education at KU Leuven. This research project was part of the European project PREFER | Professional Roles and Employability for Future EngineeRs. Her research

interests focus on professional identity development, professional competencies and diversity in engineering. As a PhD Candidate, she became a member of the Study Guidance Research Group of the Leuven Engineering & Science Education Center (LESEC) and has been actively participating in the SEFI Special Interest Group Gender and Diversity. As a BAP-AAP representative, she is also a member of the Faculty Board and Faculty Council and of the KU Leuven Diversity Council. During her PhD, together with her co-authors, she was awarded the Best Student Paper Award at SEFI 2019 and the Prof. Susanne Ihsen Award for Best Paper on Diversity and Inclusiveness at SEFI 2021.

Overview of publications in relation to this study

Articles, presentations and reports are accessible via http://lirias.kuleuven.be/cv?Username=U0039119. Articles with ** are not peer reviewed.

- *Articles in journals*

Langie, G., Craps, S., De Cock, M., Van Soom, C. (2022). A taste of the future career: discovering professional roles through online tests. *Europhysics News*, *53* (2), 30-32. doi: 10.1051/epn/2022207 **

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challenging, enlightening – and lasting?, Berlin, Germany, 13 Sep 2021-16 Sep 2021. Brussels. ISBN: 978-2-87352-023-6. – *Suzanne Ihsen Award for Best Paper on Diversity and Inclusiveness*

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Craps, S. (2021). What kind of engineer are you? Invited by ESTIEM. Presented at the IEM Conference: Breaking down Industry 4.0, Online, 05 Mar 2021-06 Mar 2021.

- Presentations and posters

Cannaerts, M., Craps, S. (2022). Role of professional awareness and the sense of belonging in inclusion of engineering students. Presented at the LESEC Conclaaf, Heverlee, Belgium, 02 Sep 2022.

Craps, S., Cannaerts, M. (2022). Breaking through stereotypes. PREFER instrumenten helpen toekomstige ingenieurs na te denken over hun toekomst. Presented at the Bridge the Gap! Conference, Enschede (The Netherlands), 30 Jun 2022-01 Jul 2022.

Craps, S., Langie, G. (2022). Right from the start. The importance of supporting professional and self-awareness in making well informed career choices. Presented at the Bridge the Gap! Conference, Enschede (The Netherlands), 30 Jun 2022-01 Jul 2022.

Craps, S. (2022). Ken jezelf... als ingenieur. Ontwikkelen van (future) self awareness bij industrieel ingenieurs. Presented at the Dag van de Onderwijsondersteuner, Heverlee, Belgium, 07 Jun 2022.

Craps, S. (2022). So, what role do you PREFER? Supporting professional and self-awareness of future engineers. Presented at the LESEC Annual Event 2022, Heverlee, Belgium, 31 May 2022.

Craps, S. (2021). Preparing students for the labour market. Presented at the Development of practically oriented student-centred education in the field of modelling of Cyber-Physical Systems - Training School for Tutors, Online, 09 Sep 2021-10 Sep 2021.

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Craps, S., Carthy, D., Tack, M. (2020). Know yourself. Two tests: PREFER Explore and PREFER Match. Presented at the LESEC Annual Event 2020, Leuven, Belgium, 04 Feb 2020.

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FACULTY OF ENGINEERING TECHNOLOGY
LEUVEN ENGINEERING & SCIENCE EDUCATION CENTER
W. de Croylaan 56 – E box 2203 -3001 HEVERLEE, BELGIUM
tel. + 32 16 32 00800
sofie.craps@kuleuven.be
www.fet.kuleuven.be