Preparing Engineers for the Future by Raising Awareness of Professional Roles

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Abstract

A better understanding of the professional future has positive outcomes for student learning and job satisfaction. However, engineering students are often unaware of what kind of engineer they want to be and what professional competences it requires. It is generally agreed that different types of jobs require different competences. To support engineering students to become more aware of their future possibilities and requirements, a Professional Roles Model for Future Engineers was developed and validated by industry. Three professional roles were defined and competency profiles were developed in close cooperation with engineers and HR-representatives from different sectors. This study aims to investigate how students perceive the model and to what extent they could identify themselves with the professional roles.

Focus groups were organised comprising 32 second year Bachelors' and 35 final year Masters' students at the Faculty of Engineering Technology of KU Leuven, Belgium. First, the career perspective was discussed which supported earlier findings that, even when graduating, students find it difficult to describe their career aspirations. Secondly, the Professional Role Model was presented. Both Bachelors and Masters' students found the model rather intuitive and could easily link the roles with previous experiences. Most students could also easily align with one or more roles. However, we noticed for the Masters' students a discrepancy between the preferred role and the choice for a vacancy aligned with a role. The same result appeared when we compared their strengths and interests with the preferred role. Students appealed most strongly to the roles of operational excellence (focused on optimization) and product leadership (focused on innovation) as they recognised these roles the most from the curriculum. Although they felt least prepared for the role of customer intimacy (focus on tailored client solutions), almost 40% indicated they prefer to work in this role (single role or combined with another role).

Finally, students were asked about their perception of the educational value of the model. Students were eager to be supported in increasing career awareness. They saw several possibilities to implement the model on the premise that it was made more concrete. They suggested enriching the description of the roles with testimonies or job vacancies and integrating the model in several ways, from elective courses, to a tool or a project week. Further research is recommended investigating which educational approaches would be most effective, how teachers perceive to integrate the model and how the work field can participate in the process of professional roles awareness.

Keywords

Engineering education, employability, professional roles, job-fit, career guidance

1   Introduction

Engineering graduates are often unaware of the wide variety of career options when entering the labour market. Research indicates that, even close to graduation, many 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 practise as primarily technical, and hold narrow perceptions of the professional aspects of engineering (Brunhaver, Gilmartin, Grau, Sheppard, & Chen, 2013). Nonetheless, earlier studies have demonstrated that a better understanding of one's professional future and engineering identity not only has positive consequences for student learning and study choices (Bliuc et al. 2011; Meijers, Kuijpers, and Gundy 2013), but also increases employability and job satisfaction (Eliot & Turns, 2011; Gottfredson & Johnstun, 2009; Nilsson, 2010; Yorke, 2005).

Knowing what an engineer is and what kind of engineer students want to be, requires the ability to critically reflect on their interests and on their past and current achievements. It also requires the ability to articulate their future aspirations in the engineering profession. This presumes more awareness and a more realistic understanding of the engineering work and the competences required (Yorke & Knight, 2006).

Although there seems to be general consensus that there are different types of engineering jobs with different demands (Brunhaver et al. 2013; Male, Bush, and Chapman 2011), there has been little analysis of the typology. To support engineering students in becoming more aware of the different professional roles in the diverse engineering fields, Craps et al. (2017, 2018) developed the Professional Roles Model for Future Engineers. The PREFER-model, defining three distinct engineering roles for engineering graduates, was validated by enterprises of different sizes in different sectors. Competency profiles describing the most essential professional competences for each role were developed. Professional competences, including relating concepts in the field such as generic skills, transferable skills or soft skills, were defined as the core competences that engineers need to be successful in the engineering profession, in addition to the scientific and technological knowledge and expertise.

This study aims to examine students' perceptions of this Professional Roles Model. More specifically, we will investigate (a) how students perceive the model and (b) whether they are able to identify themselves with one or more professional roles. Additionally, we will explore students' perceptions on potential applications in the engineering curriculum to increase awareness of the engineering identity.

The paper is organised as follows. The first section elaborates on the PREFER-model describing the three professional roles and the competency profiles. The second section provides information on the interpretative research approach, the sample and data collection through focus groups. The results are discussed in the third section. The final section concludes the paper and suggest areas for future research.

2   Professional Roles Model for Future Engineers

Engineering jobs and engineering careers are usually too narrowly defined. Perlow and Bailyn (1997) indicate that engineers uniformly subscribe to the idea that 'real' engineering (by which they refer to the technical work) is only one aspect of the job. Therefore, we need to probe beyond homogenous constructions and develop ways of recognising existing differences. The concept of the professional role is relevant for explaining the importance of different competences in the engineering work (Nilsson, 2010).

2.1   Professional Roles

Research on professional roles for engineering graduates is scarce. A systematic literature review was performed to explore frameworks that categorise engineering positions based on expectations from the work field regarding the value of engineering and the professional competences required to fulfil the position successfully (N=24) (Craps, Pinxten, Knipprath, & Langie, 2019). The review indicated that there seemed to be high divergence between three frameworks focusing on graduate engineers and independent of disciplines (Hofland et al., 2015; Kamp & Klaassen, 2016; Spinks, Silburn, & Birchall, 2006), Two studies stressed the flexibility of a threefold model allowing to combine roles within one job (Hofland et al., 2015; Spinks et al., 2006).

The PREFER-model further elaborated on these results and refined the framework suggested by Hofland et al. (2015) including three roles (Figure 1): Operational Excellence (focus on process optimization & increasing efficiency); Product Leadership (focus on radical innovation & research and development); Customer Intimacy (focus on tailored solutions for individual clients).
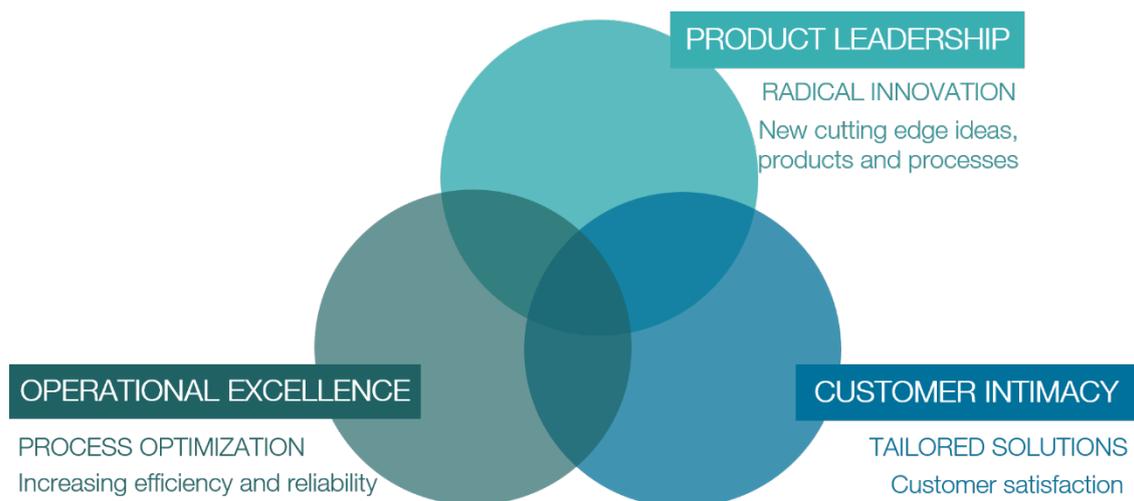

Fig. 1: Professional Roles Model for Future Engineers (PREFER-model)

The PREFER-model was validated by industry in Flanders, Belgium (188 engineers and HR representatives). Overall, the industry professionals responded positively to the model: 66% (strongly) recognised the 3 professional roles in their respective company and about 60% could easily classify positions for young engineers in this framework. The majority (55%) of the industry professionals indicated that most engineering positions in their company required a combination of two roles. No statistical differences were observed in this respect between small, medium sized and large companies. (Craps, Pinxten, & Langie, 2019)

2.2 Competency profiles

Recent research questions the assumption that the required professional competences are the same for all engineering jobs (Brunhaver et al., 2013; Fernandez-Sanz, 2010; Kinoshita, Young, & Knight, 2015; Lauwers, Bonte, & Vanmaercke, 2013). Male et al. (2011) observed that competences are interrelated and their importance varies across job tasks and work contexts. However, the available literature offers little information about the range of essential or typical professional competences required in a particular role.

To address this problem, Craps et al. (2018) organised 13 qualitative expert panels in industry (different sectors, small and larger companies) through an extensive Delphi design. The output resulted in three competency profiles reflecting the professional competences that engineering graduates need to possess in order to be successful in one of the roles (Figure 2).
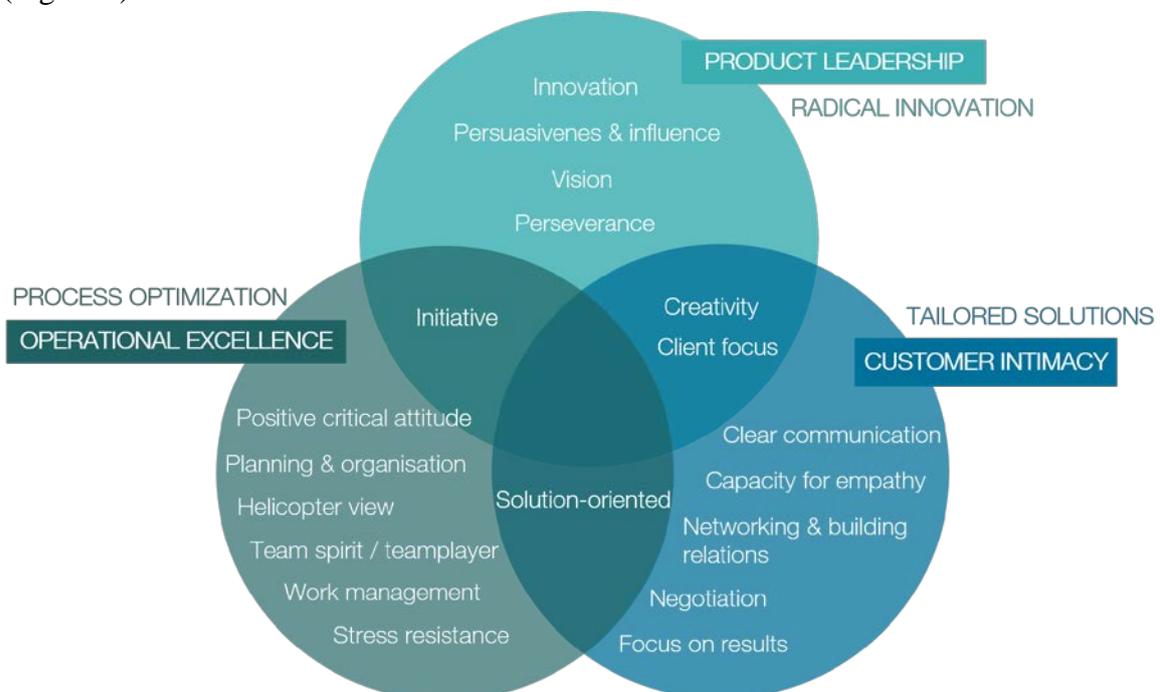

Fig. 2: Competency profiles of the PREFER-model

2.3   Research questions

The Professional Roles Model including the competency profiles was developed and validated in close collaboration with industry. However, when supporting students to become aware of their future possibilities as an engineer, the students should also recognise and understand these roles. Hence, following research questions will be addressed in this paper:

> **RQ1**   *How do students perceive the professional roles for future engineers?*
>
> **RQ2**   *Are students able to identify themselves with one or more professional roles?*

3   Method

To address the research questions, a qualitative study is carried out, based on the phenomenographic approach as recommended when one wants to characterise how things appear to people (Savin-Baden & Major, 2012). The differing ways in which students perceive and understand the concepts of the professional roles was investigated by focus group interviews with Bachelors and Masters' students. Individual in-depth interviews were organised with Masters' students in follow up of the focus group discussions to examine to what extent students are able to identify themselves with one or more professional roles,

This Method section describes (1) how the participants were selected, (2) how the focus group discussion was set up and (3) how the data was analysed.

3.1   Sample

The research was conducted at KU Leuven, Belgium. Second year Bachelors' and final year Masters' students of the Faculty of Engineering Technology were invited to participate after class or during lunchtime, halfway the first semester of the academic year (November).

The second year Bachelors' students were still enrolled in the common core programme and were about to choose a specific major in (bio) chemical, civil, electronics and ICT, or electromechanical engineering technology. They were selected as they were assumed to have rather limited professional experiences or career aspirations. Only a few weeks before the focus group discussions were organised, the students went on a company visit.

The final year students were enrolled in the Master of Electromechanical Engineering Technology. By that time, they were assumed to have more (extra) curricular professional experiences and future aspirations (as they were at the doorstep of the labour market). For example, they could have opted for an elective internship for their Masters' Thesis or could have enrolled in courses on professional competences or career guidance.

The sample comprised 32 Bachelors' and 35 Masters' students who participated in 10 focus groups with a representative gender distributions in comparison with the complete student population at this faculty. (Table 1).

	Participants (N)			Focus Groups (N)
	M	F	Total	
2nd Bachelor's students	29	3	32	6
Master's students	28	7	35*	4*
Total	57	10	67	10
› Gender Sample %	85.07%	14,93%		
› Gender Real %	87,00%	13,00%		

Table 1: Participants of the focus groups by gender

* 16 Master students participated also in semi-structured interviews

3.2   Setup focus group discussions

The focus groups were moderated by a researcher of the team using a semi-structured moderator's guide to ensure consistency with the study objectives. The guide included open questions allowing the discussion to move in different directions, yet avoiding moving away from the topic. The discussions were recorded which allowed the moderators to focus on facilitating and observing the discussion.

In accordance with guidelines proposed by Mortelmans (2013), and Savin-Baden and Major (2012) around six people participated in each of the focus group discussions lasting for around an hour. Although three to four focus groups are generally considered sufficient to draw meaningful conclusions, six focus groups were organised with Bachelors' students and four with Masters' students (Table 1).

To investigate whether students are able to identify themselves with one or more professional roles, follow-up in-depth interviews with Masters' students were also organised. Sixteen Master's students participated in both a focus group discussion and an individual interview.

Participants were informed on the purpose of the study and requested to complete an informed consent. Participants were reassured on matters of confidentiality and ethics and informed that there were no right or wrong responses.

The focus group discussions were divided into three parts. First, we discussed the perception of the professional future to investigate to what extent students can picture themselves as future engineers.

Secondly, we introduced the PREFER-model. The professional roles were briefly explained supported by a visual representation as shown in Figure 1. To test whether the

students understood the different roles, a competence mapping exercise was performed. Bachelor's students were asked about professional competences they considered essential in each of the professional roles. Students discussed and positioned themselves in one of the roles if they agreed with the model.

This exercise was more elaborated with the Master's students to match their role preference with their strengths and weaknesses. The students were asked to select five competences out of the list including all the competences from the PREFER-model (Figure 2) which they considered as a strength and five they considered most interested in.

Thirdly, we discussed the (possible) need of students to be better prepared for the labour market and the usefulness of the PREFER-model as a framework in career guidance.

3.3 Data analysis

Data analysis was primarily conducted by searching for themes and patterns. It was essentially iterative in nature, while being focused on data reduction and interpretation.

It is important to note that the findings offered as themes, which emerged from the analysis of the focus group data, present an interpretation of the opinions and experiences (Smithson, 2000).

4   Results

In order to gain information regarding students' perception of the model and students' identification with the professional roles, we first gained information about the essence of their experience: the future career. These three themes are presented as follows: (1) perceptions of the future career; (2) perceptions of the professional roles for future engineers; (3) identification with the professional roles. We end this section with (4) students' perceptions of educational implications.

4.1 Perceptions of the future career

Overall, students found it difficult to describe their future career. Most Bachelor's students had a vague idea regarding discipline or hierarchy.

> *"I have no idea yet. I prefer electromechanical engineering, so I think I would like to do something in that area."*   *BA_06_01*

> *"I want to be a leader. I image myself coordinating a team and having responsibility."*   *BA_01_02*

However, most students are unable to provide a more detailed answer to questions like "*How* would you manage your people?" or "Become a manager *in what area?*". Their ideas seemed to be mainly based on the few experiences they had in their education like a company visit, or relatives like their parents who are engineers. Clear role models helped students to picture what they (do not) want in their future career.

> *"My father is a busy engineering manager in the Antwerp harbour. Working as a manager in such a large company is not very appealing to me. Sometimes, my father tells me stories about his early working years in small companies in which were great atmosphere and team spirit. That is why I would prefer to work in a start-up company. It must be very inspiring to work in a growing business environment."*   *BA_02_02*

> *"Both my parents are engineers. I am interested in creating and developing things. When I was a child, creating with LEGO was the most fun thing to do. My goal is to develop good products, get them sold so that many people can use them in their everyday life."*   *BA_02_01*

Some Bachelors' students became aware that they were very easily influenced by the type of guest lecturer or by the company visit, to which they were introduced.

> *"Listening to the others makes me realize that my perspective on engineering is influenced by just a single experience. That is rather naïve. I should seek for more information to get a more overall picture."*   *BA_04_01*

Masters' students indicated that they did not have a clear idea about their future career when entering university. However, half of the participants mentioned that choosing for a major in the Bachelor's programme or for a specific Masters' programme forced them to think about their career and to sharpen their image. The engineering experiences in the curriculum or the professional experiences during an internship or student job supported them to concretise the engineering work, as well as the stories of graduated friends.

> *"We get assignments as 'In company X you get assigned with a project in which a client asks to speed up his production process. Try to think of a solution and design (…).' You can experience whether you are a good team leader or a good communicator with the client. I also learned what designing actually entails."*   *MA_20*

> *"Last summer, I worked at a programming department. During lunchbreak, I also talked to colleagues who were making simulations and were focusing on aerodynamics of cars. This experience gave me a better overview of my future career options."*   *MA_02*

Although Masters' students had more learning and professional experiences, half of the participants still struggled with describing what it is to be an engineer or what kind of engineer they want to be. The wide variety of engineering work was appealing, but made it also difficult to get a clear image. No differences were noticed between groups who were assumed to have more or less professional experience.

> *"I know better what my options are but at the same time it is still vague. Despite the fact that I study electromechanical engineering, I still have many possibilities as an engineer"*   *MA_27*

4.2   Perceptions of the Professional Roles Model

Overall, both Bachelor's and Masters' students found the model rather intuitive. Students experienced little difficulties in placing themselves into the model. When a student was in doubt, the peers spontaneously helped the student giving examples to clarify why they thought the student was aligned with a certain role. The Bachelors' students easily connected the roles with the engineers they encountered a few weeks ago at a company visit. They clearly recognized the engineers they met in these companies.

Both Bachelors' and Masters' students recognized the role of operational excellence (optimization) and product leadership (innovation) most easily from their learning experiences. Bachelor's students selected these roles most often, while the Master's students displayed a more balanced role preference.

> *"I recognize easily the roles of Product Leadership and Operational Excellence. Customer Intimacy is less familiar to me. However, the role certainly fits in the model."*   MA_32

To check whether they clearly understood the professional roles, the Bachelor's students were asked about professional competences that are crucial in these roles. Two groups found the question rather difficult as they felt lacking experience to answer this question. However, once they started to discuss a competence, other relating competences followed automatically. The students came up with two to four competences for each role. For example, creativity, open minded, perseverance, taking initiative were competences that were easily linked to product leadership. Flexibility, capacity for empathy, communication to non-technical people or negotiating were mentioned frequently for customer intimacy. Although, they recognized the role of operational excellence most easily, specifying competences seemed most difficult for this role. Efficiency, solution oriented, responsibility, planning and giving feedback were linked most often. The competences they discussed represented clearly the different roles by which they demonstrated their understanding of the professional roles.

4.3   Identification with the professional roles

Before presenting the model, Masters' students were offered three job vacancies and asked which vacancy they preferred. The vacancy related to the customer intimacy was chosen the least (Figure 3). The students indicated they felt best prepared for vacancy 2 (operational excellence), while they thought vacancy 3 (product leadership) was the most challenging.

> *"I recognize myself the most in vacancy 2 [operational excellence] because I learned the most of the competences required: quality, figures, control … The knowledge I acquired in education is sufficient to start in this position. The technical skills are also more emphasized than the soft skills."*   MA_21

Preferred vacancy

Preferred professional role

- Vacancy 1 Product Leadership (PL)
- Vacancy 2 Operational Excellence (OE)
- Vacancy 3 Customer Intimacy (CI)
- Vacancy 1 or 3 (PL or OE)
- Vacancy 2 or 3 (OE or CI)
- vacancy 1 or 2 (PL or CI)

- Product Leadership (PL)
- Operational Excellence (OE)
- Customer Intimacy (CI)
- PL or OE
- OE or CI
- PL or CI

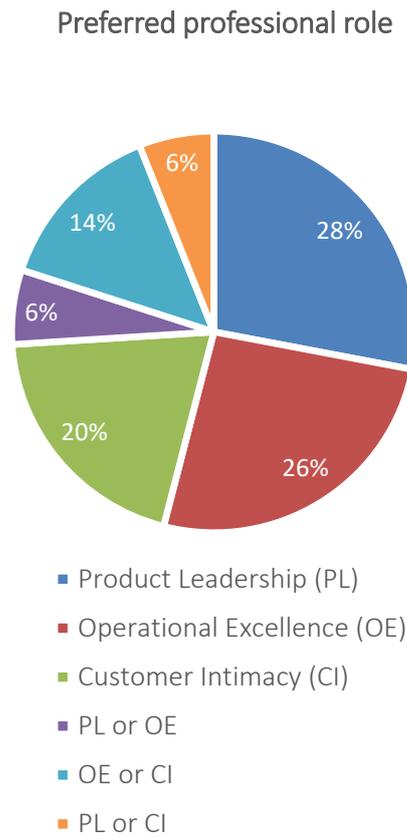*Fig. 3 Preferred vacancy of Masters' students (N=35)*

Fig. 4 Preferred professional role of Masters' students (N=35)

After discussing the model, the students were asked about their preferred role(s). The preference is more evenly distributed over the three roles, especially when the combination of roles are taken into account (Figure 4). Even when students indicate they do not feel prepared for a vacancy in a customer intimacy role, 40% of the students prefer to work as customer intimacy (single role or combined). Female students tend to choose more for a (a combination with the) customer intimacy role than their male counterparts, both in vacancy selection (71% versus 32%) as in role preference (43% versus 21%). However, it should be noticed that the number of female participants is small (N=7). The motivations of the Masters' students for role preference are shown in Table 2.

Product leadership	Operational excellence	Customer intimacy
› Independence	› Applying technical knowledge	› Using social skills in a technical environment
› Creativity	› Most diverse job tasks	› Helping people
› Best start for career development	› Part of a team	› Tailoring products and services
› Dream job for the real engineer	› Less stress because of the teamwork	

Table 2. Motivators for a professional role

Further analysis of the results revealed that about a quarter of the students (26%) did not select a vacancy that matched their role preference.

A comparable exercise was performed regarding the competences. Masters' students selected five competences they considered as a strength and five competences they are most interested in, no matter how well they achieved that competence. Some competences were hardly mentioned as strength nor interest, such as client focus, vision, helicopter view and work management. Students had difficulties in linking these competences to their experiences.

> *"Client focus is hardly mentioned in our education because we do not need to produce for real. Therefore, I think it is not really a problem. You will learn these kind of competences through work experience."*   *MA_21*

Other competences were mentioned as interest, but not as strength such as innovation, persuasiveness, networking and negotiation. By contrast, team spirit, perseverance, capacity for empathy and stress tolerance were indicated as a strength, but were not mentioned as mostly interested. Students seemed to perceive them differently in terms of strengths and interests.

4.4   Perception of educational value

Students tended to agree on the value of the PREFER-model in education. Some Bachelors' students mentioned that future awareness is important to be a good engineer in the 21st century and expressed an eagerness to be further supported in this matter. The Masters' students indicated that the job opportunities were hardly covered in their education and that they only were triggered to reflect on their future career in the final year. They value the model to become aware of their future possibilities. For example, most of them did not consider customer intimacy a 'real engineering job'. They believe the model could help them to become more aware of their future roles so they can make learning choices towards a profession they really prefer.

> *"The model can help to think about what you want in the future and to make the right choices to get there. It's not hard to find a job as an engineer, but I think it is hard to find the job that fits you best."*   *MA_17*

> *"I find the model very useful. Participating in this focus group already gave me more insight in what it can be like when we graduate and in what I prefer the most."*   *MA_27*

The students strongly recommended that the curriculum should give opportunities that support them to increase awareness and to train professional competences. However, they emphasized that it is important (1) to frame the professional roles, (2) to give the necessary explanation and (3) to link the model more explicitly to real job vacancies or testimonials.

Both Bachelors' and Masters' made suggestions spontaneously for implementation. The Masters' students suggested an interactive methodology at a moment that the students have had some industry experiences. This is important in order to fully grasp the roles, especially when the competency profiles are included. Following specific recommendations for inclusion in the curriculum were listed by the students:

› in project work (as a small project or integrated in a bigger project)
› a tool that helps students to identify their preferred role
› as part of portfolio to trigger reflection on professional preferences
› to offer elective courses that enables the students to differentiate in specific professional competences
› in a future career project week including solicitors training
› to label Masters' Thesis topics
› …

Besides the opportunities in the curriculum, some students emphasized that engineering students also need to take initiative to develop professional competences outside the curriculum.

> *"I am always occupied with several extracurricular activities and that surely contributed to the competences I developed today."*   *MA_29*

5   Conclusions and recommendations

The present study examined how engineering students perceived the Professional Roles Model for Future Engineers (PREFER-model) and to what extent they could identify themselves with one of the roles.

The results of the focus group discussions support earlier findings that engineering students have rather limited career perspectives (Bennett & Male, 2017; Lichtenstein et al., 2009; Matusovich et al., 2009). Even final year Masters' students regularly articulated difficulties in describing what an engineer is or what kind of engineer they want to be. Similar to the findings of Gerwel Proches et al. (2018) and Kinnunen et al. (2018) technical and management or leadership career paths were perceived as career possibilities. Masters' students recognized the wide variety of career options as appealing but at the same time as hindering in getting a grip on the engineering reality.

Clear role models helped students to picture what they (do not) want to be, especially parents, friends, or engineers they met for example during company visits. Their thoughts about career options were strongly swayed by a single experience, such as a company visit or an internship. One student called himself even naïve in this matter. Lichtenstein et al. (2009) highlight a positive side of this finding, as the student decision-making is malleable. Curricula should expose students to a range of engineering responsibilities and jobs that could attract them to engineering careers.

In both Bachelors' and Masters' discussions, students indicated they realized that professional competences are important for engineers. However, they were unsure about which competences were most relevant or about the required level of professional competences, as was also found in the research of Karataş et al. (2016). This uncertainty is reflected in the mismatch of role preference and competency profiles. Over a quarter of the Masters' students identified a preferred professional role that did not match with their strengths and weaknesses regarding professional competences.

Despite the mismatch, both Bachelors' and Masters' students find the model rather intuitive. Especially the operational excellence and product leadership roles were easily recognised based on their prior learning experiences. Nevertheless, up to 40% of the Masters' students preferred a role in customer intimacy (single role or combined with a second role), especially female students. Although the numbers are small, they might be align with what Faulkner (2007) describes as the conventional gendering of the technical/social dualism. Explicitly describing heterogeneous professional roles as 'real' engineers will be more appealing than the perception of the 'real' harsh technical engineer. Future research might further interrogate this issue. The latter result also supports the perception of most of the students that the Professional Roles Model can facilitate in increasing awareness of the future career possibilities and trigger reflection on what kind of engineer they want to be.

The value that engineering students give to professional competences is due to their career aspirations (Itani & Srour, 2016). When presenting the competency profiles, some competences were hardly selected as strength or weaknesses because the students did not experienced them. Students indicate that engineering programs should make more effort to explain to students, through courses, learning experiences, and career advising, the importance of gaining certain competences in the workplace. Establishing relevance enables students to make vital connections between self, learning and their intended field of work (Bennett & Male, 2017). The students suggest that the PREFER-model could be a valuable instrument in this regard and spontaneously indicate opportunities to implement the model in the engineering curriculum, for example, project work, elective courses on professional competences or in career advice sessions. They advise to make the theoretical model more student-oriented, with for example concrete job vacancies. Further research is recommended to investigate which educational approaches would be most effective, how teachers perceive to integrate the model and how the work field can participate in the process of professional roles awareness.

6   Acknowledgement

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