Comparison of 1st year student conceptions on their future roles as engineers between Belgium and The Netherlands

M. Pinxten
Research Associate
Faculty of Engineering Technology, KU Leuven
Leuven Engineering and Science Education Center
maarten.pinxten@kuleuven.be

G.N. Saunders-Smits[1]
Associate Professor
Faculty of Aerospace Engineering, Delft University of Technology
G.N.Saunders@tudelft.nl

G. Langie
Professor, Vice-Dean
Faculty of Engineering Technology, KU Leuven
Leuven Engineering and Science Education Center
greet.langie@kuleuven.be

Conference Key Areas: University-Business Cooperation, Engineering Skills, Curriculum Development

Keywords: Employability, Skills, Labour market entry, Professional Roles

INTRODUCTION

Triggering engineering students to reflect on their professional future is an important challenge for engineering institutions. Prior research showed that explicitly articulating student social identity and career goals has beneficial consequences for student learning [1], motivation [2,3] and retention [4].

Research by van den Bogaard [4] on first-year engineering students' study success showed that student who drop out during their first year have more trouble with the

[1] Corresponding Author: G.N. Saunders-Smits – G.N.Saunders@tudelft.nl

career perspectives of engineering than students who stay. Already from the start of their educational career, first-year students should therefore be stimulated to reflect on their identity within the engineering professional world. However, Karatas et al. [5] observed that first-year science and engineering students' beliefs about science and engineering are often flawed and unsophisticated. On the one hand, this is not completely surprising given that the engineering domain is very broad and there are endless career directions. On the other hand, to date, there is no overarching international validated framework to let engineering students reflect on their professional future.

Hofland and colleagues [6] have developed a first version of a professional roles framework for engineers based on the value disciplines of Treacy and Wiersema [7]. The study of De Norre and colleagues [8] describes some attempts to raise awareness for professional roles in the bachelor and master curriculum. Based on the results of these two papers, the central focus of the European PREFER project (Professional Roles and Employability of Future EngineeRs) was defined: the validation of a framework of professional roles for engineers and the implementation of dedicated skills education in engineering curricula to train students for this role [9]. The professional roles model is further optimized and validated based on mixed methods research at KU Leuven [10]. The study of the design and implementation of dedicated skills into the curriculum is performed at TU Delft [11]. And DIT, KU Leuven and BDO develop a test to measure the interests and the indications of the levels of mastery of the different professional skills [12].

The prime objective of the present study is to corroborate the research findings observed by De Norre and colleagues [8] and to compare the outcomes of two large representative samples of first-year students in leading engineering institutions in Belgium and The Netherlands. Additionally, we will evaluate the discriminatory power of some general learning outcomes to discriminate between the three professional roles identified by Hofland et al [6].

In this study we investigated which similarities and differences exist between the two populations on their view of their future, their preferred professional role and their preferences to work with people, objects and ideas. We also looked at which competences students feel they are already most developed at as well as the competences they feel they needed to develop most, in light of their preferred professional role.

1 PREFER FRAMEWORK

The development of an overarching framework to frame student perceptions regarding a complex engineering labour market is of paramount importance. Although conceptual frameworks often are a reduction of a complex reality, they offer very concrete opportunities to grasp particular aspects of this reality that goes beyond the engineering specialisation (e.g., electrical engineer, chemical engineer).

In strategic business management, Treacy and Wiersema [7] have put forward three different value disciplines: Operational Excellence, Product Leadership and Customer Intimacy. The main hypothesis of the authors is that companies who manage to focus their strategic vision on one of these value disciplines are more profitable than their competitors. The Treacy and Wiersema model proved be a valuable framework to look at the variety of engineering functions. Hofland et al. [6] re-engineered the model and

tailored it to the engineering profession: Operational excellence (process optimization & increasing efficiency); Product Leadership (radical innovation & research and development); Customer Intimacy (tailored solutions for individual clients). Using an extensive industry questionnaire, the authors found that 91% of the respondents were able to recognize these different roles in their company.

2 PRESENT STUDY

2.1 Sample

An extensive paper-based questionnaire was administered among 197 first-year students at two campuses of the Faculty of Engineering Technology of KU Leuven, mid 2015 (response rate 41%) and 342 first-year students (response rate 83%) at the Faculty of Aerospace Engineering at TU Delft, mid 2017. The students at KU Leuven were in their 8th week of lectures and the students of TU Delft were in their 3rd week of lectures. All participating students were enrolled for the first time at university and generally did not have any industry experience (in both institutions, internships, company visits, etc. are incorporated in later stages of the engineering curriculum).

2.2 Measurement of professional roles

Using a questionnaire, we gauged students' perceptions of their professional future. Fictional job vacancies were used to measure first-year students preference for the three different professional roles. Each job vacancy consisted of a brief description of the job content and a profile sketch with required competences. For the *Operational Excellence* role, we opted for a team lead in production methods and industrialization (core tasks: analyse production process and implement optimization ideas). For the *Product Leadership* role, a stereotypical research and development vacancy was defined (core tasks: develop new concepts for industrial innovation & explore new market segments). Finally, the *Customer Intimacy* role was operationalised by a vacancy of a technical commercial representative (core tasks: tailored advice to new and existing clients & client portfolio). After choosing their top 3 job vacancies, students were asked to express their preference for working with ideas, objects, or people.

Regarding the required competences, we enquired whether they considered themselves as possessing the right competences for their most preferred job vacancy, based on their subjective perception. Additionally, the 11 official learning outcomes of the Faculty of Engineering Technology (KU Leuven) were presented to them together with a brief definition of each learning outcome (see appendix I). Students were then asked to indicate in which competence they considered themselves to be most, second most and third most competent as well as a top three of competences they felt they still needed to develop.

3 RESULTS

3.1 First-year students view of their professional future

From the answers on the students' view on their professional future (*Fig. 1*) we conclude that only a small proportion of the first-year students (i.e., 9% at KU Leuven and 12% at TU Delft), has a clear view of what they want to do with their engineering degree in the future. The large majority of the students indicate that they more or less know where to go and about 20-30% does not have a clue at all. A Mann-Whitney test was run to see

if the distributions are identical across both universities. Since $U = 27925.00$ and $p > 0.01$, there is no compelling evidence that they differ.

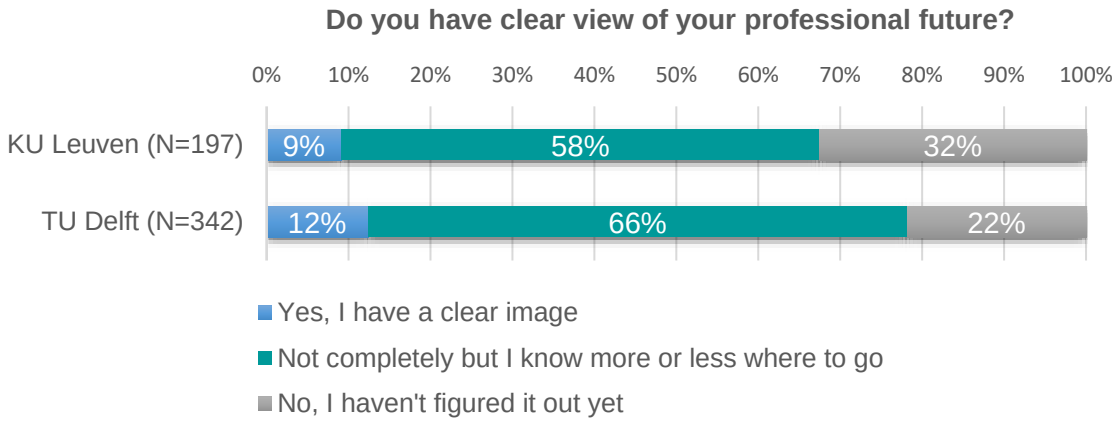

Fig. 1. First-year students' view of their professional future

These findings show that engineering institutions are in a unique position to assist students in shaping their professional future and that targeted interventions in the engineering curriculum (e.g., company visits, guest lectures) are needed.

3.2 Preferred professional role

In order to stimulate first-year students' reflection on this professional future, we offered three fictional job vacancies reflecting the three different professional roles and compared students' preferences (*Fig. 2*).

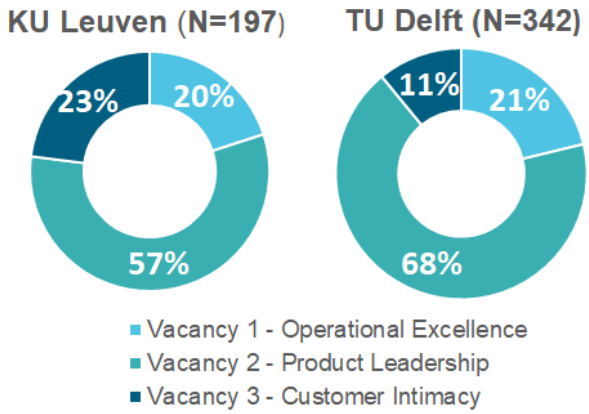

Fig. 2. First-year students' professional role preference at KU Leuven and TU Delft

A Chi-Square test of Homogeneity confirms that the frequency counts are distributed identically across the two populations ($\chi^2(2) = 16.955$, $p < 0.001$). In both engineering institutions, first-year students had a clear preference for the Product Leadership vacancy. This is in line with our expectations since the innovative conceptualisation aspect triggers a substantial proportion of engineering students. Especially at TU Delft,

the Customer Intimacy role (i.e., technical commercial representative) was the least preferred vacancy. In both universities, the Operational Excellence role appealed to one-fifth of the respondents. Altogether, these results indicate that already in an early stage of their educational career at university, students can be successfully triggered to reflect on their professional future. Interestingly, both at KU Leuven and TU Delft the majority of the students indicates there is no vacancy they would not apply for, 64% and 65% respectively. This finding shows that first-year engineering students are very open to their professional future. As a consequence, there are ample opportunities for engineering institutions to guide students towards the labour market entry.

3.3 Preference on working with ideas objects or people

Students with a preference for the customer intimacy role generally indicate that they prefer to work with people (*Table 1*). Both at KU Leuven and TU Delft, students who chose the Operational Excellence vacancy prefer to work with objects and people and to a lesser degree with ideas. For the Product Leadership role, our findings show mixed results. At TU Delft, 50% of these students prefer to work with ideas (and to a lesser extent with objects and people). At KU Leuven, however, this profile is rather flat with high preferences to work with ideas, objects, and people. Also, TU Delft students often only indicated 1 preference, whereas KU Leuven students often indicated multiple preferences.

Table 1. Preference to work with idea, objects or people per professional role

	KU Leuven (N=197)				TU Delft (N=342)		
	Ideas	**Objects**	**People**		**Ideas**	**Objects**	**People**
Operational excellence	31%	82%	56%		37%	43%	50%
Product Leadership	67%	72%	66%		50%	45%	29%
Customer Intimacy	35%	50%	92%		25%	14%	69%
General	**52%**	**69%**	**71%**		**45%**	**41%**	**39%**

Note: Students can indicate multiple preferences in working with ideas, objects and people, each counted as a choice. The percentage was then calculated over the number of respondents not the number of different answers.

Another Chi-square analysis was carried out to see if a significant relationship existed between the two groups of student's preferred roles and their preference to work with ideas, people or objects. Again, a highly significant relationship was found with $\chi^2(4) = 40.690$, $p < 0.001$.

3.4 Self-perceived mastery levels competences

When asked about their self-perceived mastery levels of the required competences of their most preferred vacancy, first-year students generally display high confidence levels. Especially at TU Delft, 48% of the respondents indicate that they already have the required competences (*Fig. 3*). Only a small proportion of students (2% and 13%) states that they do not yet possess the right skills.

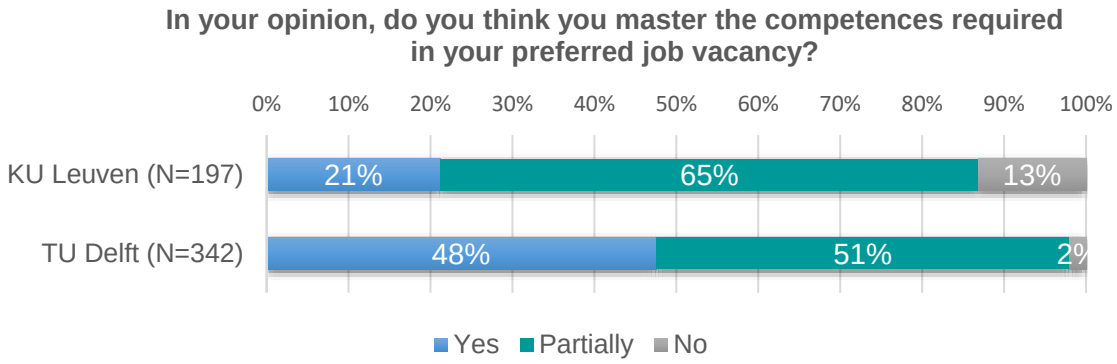

Fig. 3. Self-perceived mastery levels of listed competences

To see if these distributions were significantly different a Mann-Whitney test was carried out. This found that the two distributions differ significantly, $U = 21419$, $p < 0.01$, further research into the possible reasons for this is needed.

However, even per institution this remains an interesting find. If first-year students are already very confident in their own competences, they may perceive certain forms of learning as superfluous and therefore uninteresting, which may in turn have an effect on student motivation. It may therefore be good to have students experience whether or not they actually have mastered all the competencies they need for their preferred job vacancy. This will lead them to make better decisions about their educational choices.

3.5 Most competent and least competent competences

As stated above, each student was also requested to indicate the 3 competences they considered themselves to be most competent in, selected from a given list (appendix I). Based on a weighting scheme (1st Competence: 3 points; 2nd Competence: 2 points; 3rd Competence: 1 points), sum scores were calculated for each of the 11 competences. These sum scores were then ranked within the professional role student expressed their first preference for. The top 5 competences for each professional role are given in *Table 2*.

At KU Leuven, the listed competences for the Operational Excellence and Product Leadership roles were identical except for one competence: design competence (product leadership) and communication (operational excellence). Students with preferences in one of those two roles estimate their problem solving and team work at a very high level. Interestingly, students with a preference for the Customer Intimacy role considered themselves more communicative compared to their peers with a preference for the other two roles.

For TU Delft, we were unable to discriminate between the Operational Excellence and the Product Leadership role based on the listed competences. For these two roles, problem solving, team work, design, critical reflection and professionalism were observed as the most listed. Interestingly, the designing competence appeared higher in the list in the Product Leadership Role (like at KU Leuven), whereas team work was more pronounced in the Operational Excellence role. Students with a preference for the Customer Intimacy role considered themselves to be more competent in entrepreneurship and communication compared to the other two roles.

Table 2. Top five competences students felt they were most competent in grouped per preference for each professional role.

	Operational Excellence	Product Leadership	Customer Intimacy
KU Leuven (N=197)	1. Problem solving - 54	1. Problem solving - 113	1. Communication - 55
	2. Team work - 41	2. Team work - 111	2. Team work - 46
	3. Professionalism - 29	3. Designing - 89	3. Critical reflection - 45
	4. Critical Reflection - 27	4. Critical Reflection - 88	4. Professionalism - 26
	5. Communication - 21	5. Professionalism - 57	5. Ethical behaviour - 26
TU Delft (N=342)	1. Problem solving - 90	1. Problem solving - 298	1. Team work - 30
	2. Team work - 54	2. Design - 212	2. Problem solving - 29
	3. Design - 39	3. Teamwork - 125	3. Entrepreneurship - 27
	4. Critical Reflection - 38	4. Critical Reflection - 119	4. Communication - 24
	5. Professionalism - 36	5. Professionalism - 115	5. Critical reflection - 21

Note. Ranking of competences based on the sum scores for each competence (most competent 3; second most competent 2; third most competent 1).

The competences listed by both sample of first-year students show a high degree of consistency. The competences mentioned in the column of product leadership are identical. Interestingly, a number of competences were listed significantly less (e.g., application-oriented research, entrepreneurship, and information processing). Potentially, these competences are not well-known or are not addressed in secondary education.

Table 3. Top five competences students feel they still need to develop further grouped per preference for each professional role.

	Operational Excellence	Product Leadership	Customer Intimacy
KU Leuven (N=197)	1. Problem solving - 63	1. Problem solving - 134	1. Problem Solving - 68
	2. Designing - 49	2. Designing - 107	2. Designing - 50
	3. Communication - 30	3. Application Oriented Research - 87	3. Professionalism - 38
	4. Entrepreneurship - 26	4. Professionalism - 75	4. Application Oriented Research - 30
	5. Teamwork - 18	5. Entrepreneurship - 63	5. Entrepreneurship - 26
TU Delft (N=342)	1. Problem solving - 65	1. Problem solving - 202	1. Problem Solving - 38
	2. Communication - 47	2. Designing - 159	2. Designing - 37
	3. Entrepreneurship - 44	3. Teamwork - 155	3. Entrepreneurship - 30
	4. Critical Reflection - 42	4. Communication - 148	4. Communication - 16
	5. Professionalism - 41	5. Entrepreneurship - 136	5. Professionalism - 21

Note. Ranking of competences based on the sum scores for each competence (most competent 3; second most competent 2; third most competent 1).

Finally, students were asked to give a top 3 of competencies they feel they need to develop the most. Again, we calculated sum scores per preference and ranked them

within the professional role the student expressed their first preference for. The results can be found in *Table 3*.

Again, we see little real distinction between choices in every profile. Problem solving remains number 1 in all the lists. There is an apparent contradiction here, if we also take into account the outcomes reported in table 2. Students on the one hand feel most competent in problem solving but on the other hand also prioritize this competency when asked which competency they feel they need to develop further. This is also the case for at least two more competences in each role. This requires further investigation. On the other hand, we can see the desire by students to learn about entrepreneurship and application-oriented research. Although included in the KU Leuven curriculum, entrepreneurship is not mandatory included in the TU Delft curriculum. This may be something for TU Delft to consider given the outcomes. It is also worthwhile to mention that the competency the students least feel they need to develop further is ethical behaviour, which is in stark contrast with current universities', governments' and public opinion. Perhaps this is also indicative of their (in)ability to critically reflect as shown by their contradictory answers to the question whether they have mastered the competences required for their preferred future role.

If we assume that the competences students deem themselves good at, as well as those students feel they need developing, are predictive of the competences needed to carry out their professional role and given the high degree of consistency in the listed competencies, the general learning outcomes of the Faculty of Engineering Technology at KU Leuven do not appear to lend themselves to empirically discriminate between the three professional roles. This is especially true for the difference between the Operational Excellence and Product Leadership role. This finding suggests that more fine-tuning is required with more detailed behavioural indicators. Another possible explanation is that the three vacancies are not well described and do not distinguish enough between the three roles.

4 CONCLUSIONS AND RECOMMMENDATIONS

In the present study we examined first-year students' perceptions of their professional future at two leading engineering institutions in European countries. Our findings (see Fig. 1) indicate that first-year students across both universities feel they do not have a clear view on their professional future. Since this lack is one of the contributing factors in student drop-out during the first year, we advise to increase the attention spent on the future disciplinary self during the first year at university.

Based on fictional job vacancies we let students reflect on different professional roles. We saw no differences between the two institutions. Product leadership seems to be the most attractive professional role. This can be explained since 'innovation' is a very popular term resulting in frequent use during classes.

The self-assessed level of preparedness for student's future roles is high, especially at TU Delft. This may lead to a dangerous form of students overestimating themselves and therefore denying themselves the acquisition of required competences. It may be worthwhile to have students reassess their actual competence level against a set standard so that they may verify their perception and adjust their learning strategies accordingly. This may be particularly true for their ethical behaviour skills as students overwhelmingly do not list them in their top three competences for development.

Students also indicate their need to develop their entrepreneurial competences as well as application-oriented research. Application-oriented research skills are part of both curricula; however, entrepreneurship is not mandatory at TU Delft. The outcomes of the survey may give reason to reconsider this.

Finally, the generally defined learning outcomes used in this research appear not to be sufficiently fine-tuned to empirically discriminate between the three different professional roles. More research is needed to identify the defining elements, skills, and competences of each professional role.

ACKNOWLEDGEMENTS

This work was supported by Erasmus+ programme of the European Union (grant agreement 575778-EPP-1-2016-1-BE-EPPKA2-KA) and is part of the PREFER project. The authors would like to thank their colleagues in the project as well as those colleagues who assisted with the rolling out of the questionnaire.

REFERENCES

[1] Bliuc, A, Ellis, R. A., Goodyear, P. and Hendres, D.M. (2011). The role of social identification as university student in learning: relationships between students' social identity, approaches to learning, and academic achievement. *Educational Psychology, 31*, 559-574.

[2] Hock, M.F., Deshler, D.D., & Schumaker, J.B. (2006). Enhancing student motivatic through the pursuit of possible selves. In C. Dunkel & J. Kerpelman (Eds.), Possib selves: Theory, research and application (pp. 205-221). Hauppauge, NY: Nova Scienc Publishers.

[3] Frymier, A. B., & Shulman, G. M. (1995), "What's in it for me?": Increasing content relevance to enhance students' motivation, *Communication Education, 44*, 40-50.

[4] Bogaard, van den, M.E.D. (2015). Towards an action-oriented model for First Year Engineering Student Success, PhD Thesis, Delft University of Technology.

[5] Karataş, F. Ö., Bodner, G. M., & Unal, S. (2016). First-year engineering students' views of the nature of engineering: implications for engineering programmes, *European Journal of Engineering Education*, *41*, 1-22.

[6] Hofland E., Pinxten M., Wauters D., Langie G. (2015). "Roles" in the Bachelor's and Master's programmes in Engineering Technology. Definitions and corresponding learning outcomes. Proceedings of the 43rd Annual SEFI Conference. Annual Conference of the European Society for Engineering Education. Orléans, France, June 29 - July 2, 2015.

[7] Treacy, M., & Wiersema, F. (1993), Customer intimacy and other value disciplines, *Harvard business review*, *71*, 84-93.

[8] De Norre, J., Pinxten, M., Langie, G., (2016). Raising awareness for Professional Roles in the Bachelor's and Master's Programmes in Engineering Technology. Proceedings of the 44th SEFI conference. Annual Conference of the European Society of Engineering Education, Tampere, Finland 12-15 September 2016.

[9] Craps S., Pinxten M., Saunders-Smits G., Leandro Cruz M., Gaughan K., Langie G. (2017). Professional Roles and Employability of Future Engineers. *Proceedings of the 44rd Annual SEFI Conference*. Annual Conference of the European Society for Engineering Education. Azores Portugal, 18-21 September 2017.

[10] Craps, S., Pinxten, M. and Langie, G. (2018). Wanted: super(wo)man. A study to define professional roles for future engineers by distinctive professional competences. Submitted to SEFI 2018.

[11] Leandro Cruz, M. and Saunders-Smits, G.N. (2018). Design and Implementation of New Communication and Lifelong Learning elements in a Master Engineering Course. Submitted to SEFI 2018.

[12] Carthy, D., Bowe, B. and Gaughan, K. (2018). What are the engineering professional competences? Submitted to SEFI 2018.

APPENDIX I

	Competence	*Description*
1	**Problem solving and analysis**	Analytical thinking – A systematic approach for solving complex problems – Master complexity
2	**Designing and developing**	Plan and execute a creative design/development project
3	**Application-oriented research**	Formulate problem statement – plan a research project – selecting research methods
4	**Ethical behaviour**	Responsible behaviour for society and environment
5	**Entrepreneurship**	Taking initiative and have an eye for economical and organizational boundary conditions
6	**To make operational**	Executing basic, practical, discipline-specific acts and managing processes, systems and installations.
7	**Information processing**	Looking up, evaluating and processing scientific and technical information, and correctly referring to the information.
8	**Communication**	The correct usage of scientific and discipline-specific terminology and communicating in a second language that is relevant to the programme; Adequately documenting the results of one's own research, for both engineers and non-engineers.
9	**Teamwork**	Working as a team member in one or several roles and taking (shared) responsibility for establishing and achieving the team's goals.
10	**Professionalism**	working meticulously and demonstrating scientific and technical curiosity. Attention to planning and feasibility
11	**Critical reflection**	critically reflecting on one's own functioning and shortcomings independently; Dealing with contradictory sources critically and independently