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Leandro Cruz, Mariana; Saunders, Gillian

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Transversal Competency Level of Engineering Graduates Dictated by European Industry

Mariana Leandro Cruz, Delft University of Technology

Mariana Leandro Cruz received the BSc and MSc degrees in Biomedical Engineering from the Instituto Superior Técnico, University of Lisbon. She is currently developing the PhD in engineering education at the Delft University of Technology, Faculty of Aerospace Engineering in the Netherlands. Her research interests include engineering education, competencies, competency measurement, and course development.

Dr. Gillian N. Saunders-Smiths, Delft University of Technology

Gillian Saunders-Smiths is Senior Lecturer and Passionate Engineering Education Researcher and Curriculum Developer at the Faculty of Aerospace Engineering of TU Delft in the Netherlands. She teaches Research Methodologies to all Master students, runs a MOOC on the Introduction to Aerospace Structures and Materials and has previously taught Mechanics, Flight mechanics, and Design Projects and has served as Project Education Coordinator in the Bachelor and Master Track Coordinator for Aerospace Structures and Materials track and was the initiator of the successful online education program at Aerospace Engineering. She has overseen many curriculum innovation projects, most recently the overhaul of the MSc. track in Aerospace Structures and Materials. She is currently the principal investigator for TU Delft in the European Erasmus+ PREFER project on the Professional Roles and Employability of Future Engineers and serves on the Steering Committee of the European Association of Engineering Education (SEFI).

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ABSTRACT

The importance of which transversal competencies, a collective term for non-technical competencies such as problem-solving and communication skills, are required for student success in the labor market has been studied. There is no doubt that students need transversal competencies for professional practice. However, little is known about the specific competency level that graduates should hold after completion of their Bachelor or Master in Engineering.

To investigate graduates' competency levels, this article reports on the design, development, and results of an industry questionnaire, which studies the perception of industry representatives in Europe of the competency levels that Bachelor and Master engineering graduates should hold after graduation.

A total of 28 representatives who work in the engineering industry and who recruit or work with recently graduated engineers responded. Industry representatives were given a list of 36 competencies and were asked to select the most important competencies and the competency level they perceive students should have after completion of their Bachelor and Master degree for each.

Significant differences were found between the required competency levels for Bachelor and Master graduates. Industry representatives perceived that Master graduates require mostly advance level (as opposed to a lower level for bachelor graduates) for competencies such as *risk tolerance, problem-solving, listening skills, writing skills, interdisciplinary thinking, strengths/weaknesses awareness, and actively seeking learning*. These findings were unaffected by years of work experience of the industry respondents or their company size.

The findings of this study help higher education institutions, employers and lecturers to stimulate the development of competencies required by industry. More specifically, they will be used as a starting point for developing and implementing curriculum elements aimed at enhancing competency levels of students at a Dutch university of technology and its European partners in the European project funding this research.

Keywords Transversal competency level, preparing for practice, engineering education, questionnaire

INTRODUCTION

The globalization and the great change in technology of the 90s have posed different demands on the engineering profession. This shift has resulted in the industry seeking graduates equipped with both technical and non-technical competencies [1]. In this study, the latter is named transversal competencies and defined as "skills, values, and attitudes that are required for learners' holistic development and for learners to become capable of adapting to change" [2]. These competencies comprise for example communication skills, creativity, problem-solving, and reflective thinking.

Although accreditation bodies [3] stimulate the integration of transversal competencies in engineering education curricula and higher education institutions emphasized their incorporation into the curriculum to increase students' employability [4], there is still a gap between industry requirements and graduates readiness to the labor market [5, 6]. Several studies investigated the industry [7, 8] or academic perspective [9] on which transversal competencies engineering students should possess to successfully enter the labor market. In the systematic review of Passow and Passow [4], planning and time management, problem-solving, communication and teamwork were identified as highly important by engineers. Identified as less, but still important, were ethics, lifelong learning, taking initiative, thinking creatively, and focusing on goals. Does this mean that engineering students need more teamwork skills than lifelong learning skills? Or do students need to finish their educational program with an advanced level mastery of lifelong learning and an expert level mastery of teamwork? These questions raise the need to not just investigate the importance of the competencies but also of the competency levels required by industry from Bachelor and Master graduates. For this research, engineers working in the European engineering industry who recruit or work with recent graduates were approached.

The following research questions are addressed in this paper:

1. Which transversal competencies does industry require for engineering graduates?
2. Which competency levels does industry require at Bachelor (BSc.) and Master (MSc.) graduations?
3. Is there a difference between BSc. and MSc. competency level?
4. Are there differences in competency levels between respondents' experience?
5. Are there differences in competency levels between respondents' company size?

The findings of this pilot study reveal some interesting preliminary insights which are used to reflect back on the design of courses and course elements (i.e. in-course activities, small workshops and standalone courses) that can address curriculum deficiencies.

Definition and characterization of a set of transversal competencies

To reduce the skills mismatch in the field of engineering and improve employability, a consortium consisting of three European Universities, three European Engineering Industries and several other Industry and Engineering stakeholders in Belgium, Ireland and the Netherlands, set up a collaborative education and research project, that is funded through the European Union's Erasmus+ Knowledge Alliance. The project, called PREFER (Professional Roles and Employability of Future EngineerRs), [10] has as one of its aims to design innovative curriculum elements that focus on a particular set of transversal competencies and implement these elements in the curricula of participating universities. For this purpose, five transversal competencies (Entrepreneurial, Innovation, Communication, Teamwork, and Lifelong Learning) were selected, defined and characterized based on an existing framework of the Siemens company in the Netherlands (See Appendix A). A rubric for each of the selected competencies was generated with four descriptive levels (Appendix B). This rubric was chosen as a starting point for competency evaluation as part of the industry collaboration stipulated by the European Union in Knowledge Alliances. Considering Siemens is a worldwide employer of engineers and this competency framework

is used to assess personal development throughout Siemens, it was deemed a good starting point for a pilot study in the context of the project deliverables and the accompanying timeframe. In an ideal situation it would have been great to create such a rubric based on input from a broad variety of industry but that was not possible in the scope and timeframe of this project. That being said, the rubric from Siemens has not been taken as the absolute truth but formed a starting point for further refinement of the rubric. The competencies and the levels of the rubric were subsequently revised by academic experts in order to confirm that the model was suitable for academia.

The main advantage of this rubric compared to existing rubrics reported in the literature is that it is based on a competency framework used by the labor market. A second plus is that it is a 4-point Likert scale with descriptive scales (Level 0 - Absent, level 1 - Basic, level 2 - Advanced, and level 3 - Expert). The fact that these scales are described in rubrics form reduces the subjectivity from the responses, although a full elimination of all types of bias may be a Utopian quest.

In this study, this rubric is used to investigate the perception of European industry representatives of the competency levels that BSc. and MSc. engineering students should hold after graduation.

Data collection and survey structuring

A questionnaire was disseminated from January to April 2018 among representatives of European engineering industries and engineering associations (such as engineers, managers, and HR representatives) who hire or work with recently graduated engineers. For this research ethical permission was sought and granted from the university's Ethics Committee. The sampling strategy chosen in this research was snowball sampling, i.e. the authors identified individuals with the characteristics of interest within the project partnership and these informed and included others. Also, the personal network of the main lecturers involved was drawn upon. A total of 28 representatives of different engineering disciplines (e.g. 38% of Mechanical, Aeronautical & Manufacturing Engineering, 35% of Engineering & Technology, 11.6% of Material Science, 7.7% of Chemical Engineering and Life Sciences, and 7.7% of Petrochemical & Energy) based mainly in Northern Europe responded to the questionnaire and gave permission to be part of this research with some 70 people being approached overall. The response was not very high, which was to be expected given the length of the questionnaire and the time required to fill it in. Several industry contacts also declined as they indicated feeling overburdened by the many questionnaires they are asked to fill out these days, not just for education but for many other stakeholders also.

The first part of the questionnaire contained questions about the information of the industry representatives including company name, job position, and working experience. In the Netherlands, working experience is divided into 3 categories: junior (Jr.) from 0 to 3 years, medior (Mr.) from 4 to 10 years and senior (Sr.) more than 10 years. In the data set, there are 3 Jr., 8 Mr., and 17 Sr. respondents. Because of the low response rates of the junior representatives, Jr. and Mr. were combined in the analysis of the response. Using the company name, it was possible to divide respondents into small and medium-sized

enterprises (SME) – less than 250 employees, and large enterprises (LE) – more than 250 employees. In the data, there are 10 SME and 18 LE.

The second part of the questionnaire was aimed at selecting the most important competencies for engineering graduates. For this purpose, industry representatives indicated the three most important competencies (within the five competency categories: Entrepreneurial, Innovation, Communication, Teamwork, and Lifelong Learning, Appendix) they felt that engineering students at Master level should hold when they graduate. The top 3 competencies were ranked by the industry representatives and a score ranging from 3 to 1 was assigned to the top 3. Finally, the standardized sum of scores was drawn.

In the third part of the questionnaire, industry representatives indicated in the rubric the level (Level 0 - Absent, level 1 - Basic, level 2 - Advanced, and level 3 - Expert) for 36 competencies that they perceive BSc. and MSc. engineering students should have at graduation.

Data analysis

Data from the questionnaires were entered and analyzed in IBM SPSS Statistics 25. A Wilcoxon signed-rank test was carried out to evaluate the differences between the two experimental conditions (BSc. and MSc.) for each competency.

To compare the competency level at BSc. and MSc. graduation between experiences (Jr. & Mr. and Sr.) or company sizes (SME and LE) a Mann-Whitney U-test was used.

Significant differences were considered for p-values smaller than 0.05. The effect size, r , was calculated using: $r = \frac{Z}{\sqrt{N}}$ [11]. Values of $r = .01$, $.30$, and $.5$ refer to a small, medium, and large effect, respectively [11].

RESULTS AND DISCUSSION

In this section, answers to the research questions will be addressed. The data was acquired from a questionnaire delivered to European professionals who hire or work with recent engineering graduates.

Important and essential competencies

Previous studies by Saunders-Smiths [7], Passow and Passow [8], and Beagon and Bowe [7-9] tried to understand which competencies engineering graduates need for successful professional practice. They end up with results illustrating that all the competencies are important because they are above the middle of a five-point Likert scale. Therefore, the alternative used in this paper was competency ranking to differentiate further. In Figure 1 it is illustrated that some competencies, highly ranked by industry professionals (marked with an asterisk), are deemed more essential for a graduate's professional practice than others.

Competency levels at BSc. and MSc. graduation

This research also intended to find out which competency levels industry requires from BSc. and MSc. graduates respectively, or in other words which competency levels do students need when looking for a job after completing a BSc. and a MSc. degree (Table 1).

As is to be expected and predicted by the authors and confirmed by a Wilcoxon signed-ranked test, MSc. graduates require higher competency levels compared to BSc. graduates (Table 1, $p < .01$). Besides relying only on the statistical significance, the authors calculated the effect size, a standardized measure to quantify the effect in the present sample [11]. Large effect sizes ($r > 0.5$ [11], Table 1) were found for all competencies indicating the importance of the findings or in other words that the effect of the test is meaningful within the research context.

Comparing the top 10 most required competencies from Figure 1 (marked with an asterisk) with the competencies which require expert level (level 3, Table 1), it is observed that a recent graduate must not hold expert-level mastery in all of these essential competencies (e.g. *project management, engagement in teamwork, autonomous work, curious for innovation, engagement in teamwork, technology benchmarking, value/cost consciousness* and *business acumen*) selected by the industry representatives. And conversely, industry representatives perceive that students after obtaining their MSc. should have an expert level for *writing skills*, but this competency was not deemed highly important by those same representatives. Consistent with the findings in previous studies [7-9], *problem-solving* is ranked top as the most important competency. Also, expert level mastery is required from MSc. graduates for this competency. Similarly, *actively seeking learning* and *strengths and weaknesses awareness* are also in the top 10 of most important competencies and also require expert level mastery. From the findings, it can be seen that MSc. graduates also need to hold expert-level mastery in *listening skills* (Table 1). This result confirms previous findings by Trevelyan [6], who showed that young engineers are more likely to spend time listening than speaking. Listening skills as part of communication were also considered an essential skill in the study of Beagon and Bowe [9].

Furthermore, mastery levels of BSc. students in teamwork and communication competencies are higher than the mastery levels required for BSc. students in innovation and entrepreneurial competencies (Table 1). This is not surprising. Early jobs often require working in teams and learning from each other. This requires more skills than just engagement in teamwork and oral and written communication. This result can be compared with the findings in a complementary study conducted by Hundley and Brown [12] who investigated the top attributes of student upon graduation from high school, college or university and early-career engineering professionals (with up to 5-years of work experience) [12]. They found that early-career professionals were expected to possess higher proficiency levels for the attribute *possesses the ability to think both critically and creatively* than students upon university graduation. For MSc. graduates, besides reaching expert level in communication and teamwork, industry requires higher levels of mastery in innovation competencies (Table 1).

Comparing the ten highest means of required mastery at BSc and MSc levels (grey cells in Table 1), it can be observed that they share seven competencies. These seven competencies: *time management, risk tolerance, listening skills, writing skills, interdisciplinary thinking, strength and weakness awareness*, and *actively seeking learning* are obviously competencies that must be addressed in both BSc. and MSc. engineering degrees. At the same time, similar attributes like *shows initiative* and *demonstrates a willingness to learn* and *communicates effectively in a*

variety different ways, methods and media were in the top 5 for both university graduates and engineering professionals in the study of Hundley and Brown [12].

Remarkably, English language skills, collaborative goal oriented and engagement in teamwork are only in the top 10 for BSc. students. Perhaps these are expected as mastered entities at master level, hence the emphasis shifts at the master level to different competencies being listed as most important.

Problem-solving, critical thinking and presentation skills are only in the top 10 for MSc. graduates. This is perhaps indicative of what industry expects of MSc. graduates: more independent abilities and the ability to orally present your findings appropriately by yourself.

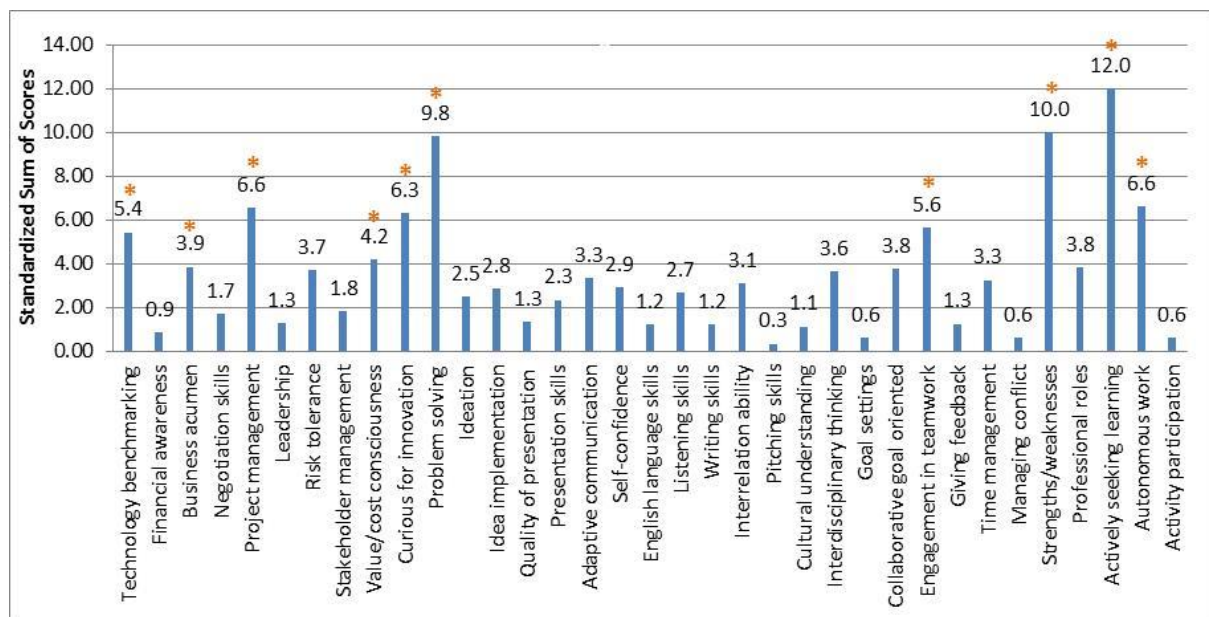


Figure 1 - Competencies and their respective standardized sum of scores of importance obtained from industry representatives. Asterisks indicate the ten highest scores i.e. the most essential competencies for MSc. graduates according to the industry.

Table I – Differences between BSc. and MSc. competency levels. z-score: z, p-value: p (significant level $p < .05$), and effect size: r. Grey cells represent the ten highest mean competency levels for BSc and MSc. and asterisks indicate the competencies which require advanced level mastery (Median = 3).

Competencies		Wilcoxon signed-rank test								
		Median		Mean		SD		z	p	r
		BSc.	MSc.	BSc.	MSc.	BSc.	MSc.			
Entrepreneurial	Technology benchmarking	1	2	1.04	1.89	.53	.50	-4.60	<.01	.9
	Financial awareness	1	1	.58	1.36	.58	.56	-4.38	<.01	.9
	Business acumen	1	2	1.08	1.82	.63	.86	-3.88	<.01	.8
	Negotiation skills	1	1.5	.65	1.46	.69	.69	-4.30	<.01	.8
	Project management	1	2	1.31	2.25	.55	.65	-4.73	<.01	.9
	Leadership	1	2	.81	1.61	.69	.83	-4.58	<.01	.9
	Risk tolerance *	2	3	1.77	2.46	.82	.64	-3.82	<.01	.7

Innovation	Stakeholder management	1	2	1.12	1.89	.59	.57	-4.38	<.01	.9
	Value/cost consciousness	1	2	1.19	2.07	.49	.60	-4.41	<.01	.9
	Curiosity for innovation	1	2	1.38	2.14	.57	.45	-4.47	<.01	.9
	Problem solving *	2	3	1.62	2.57	.64	.57	-4.13	<.01	.8
	Critical thinking	1	2	1.46	2.43	.51	.50	-4.73	<.01	.9
	Ideation	1	2	1.04	2.07	.60	.60	-4.51	<.01	.9
	Idea implementation	1	2	.81	1.64	.63	.62	-4.38	<.01	.9
Communication	Quality of presentation method	2	2	1.68	2.21	.55	.42	-3.74	<.01	.7
	Presentation skills	1	2	1.50	2.36	.58	.62	-3.23	<.01	.6
	Adaptive communication style	2	2	1.62	2.14	.64	.45	-3.5	<.01	.7
	Self-confidence	2	2	1.54	2.11	.76	.63	-3.42	<.01	.7
	English language skills	2	2	1.73	2.18	.60	.39	-3.46	<.01	.7
	Listening skills	2	2.5	2.00	2.46	.63	.58	-3.46	<.01	.7
	Writing skills *	2	3	1.81	2.50	.69	.58	-4.12	<.01	.8
	Interconnection/interrelation ability	1	2	1.27	2.04	.72	.43	-3.88	<.01	.8
	Pitching skills	1	2	1.35	2.00	.69	.54	-3.82	<.01	.7
Teamwork	Cross-cultural understanding	2	2	1.58	2.25	.70	.59	-4.03	<.01	0.8
	Interdisciplinary thinking *	2	3	1.96	2.71	.66	.46	-3.88	<.01	0.8
	Goal settings	2	2	1.62	2.29	.50	.46	-4.24	<.01	0.8
	Collaborative goal oriented	2	2	1.77	2.14	.43	.45	-3.16	<.01	0.6
	Engagement in team work	2	2	1.81	2.18	.49	.48	-3.16	<.01	0.6
	Giving constructive feedback	1	2	1.58	2.11	.64	.57	-3.74	<.01	0.7
	Time management	2	2	1.85	2.32	.46	.55	-3.46	<.01	0.7
	Managing conflict	2	2	1.62	2.04	.64	.58	-3.46	<.01	0.7
Lifelong Learning	Strengths and weaknesses awareness *	2	3	2.15	2.79	.73	.50	-3.82	<.01	0.7
	Professional role awareness	1	2	1.42	2.11	.58	.69	-4.15	<.01	0.8
	Actively seeking learning *	2	3	1.88	2.64	.65	.56	-4.30	<.01	0.8
	Autonomous work	2	2	1.50	2.11	.58	.57	-4.00	<.01	0.8
	Non-credit activity participation	1	2	1.04	1.50	.72	.84	-3.36	<.01	0.7

Competency level differences between years of working experience

The authors also researched whether the amount of work experience of the respondents effected their opinion on competency levels. A distinction was made between Jr. & Mr. (less than 10 years of work experience) and Sr. (more than 10 years of work experience). A Mann-Whitney U-test found no significant differences between respondents based on their years of work experience with regard to their opinion on competency levels of BSc. and MSc. graduates. Therefore, there is general agreement between less and more experienced industry representatives regarding the level of competencies of BSc. and MSc. graduates.

Competency level differences between SME and large enterprises

The same test was carried out to test whether the competency levels were different based on the respondents' company size (SME and LE). The results show that there is a significant difference between company size with regard to *risk tolerance* for BSc. graduates ($p < 0.05$). SME require students to have a higher level of mastery in *risk tolerance* (Mdn = 2.5) than LE (Mdn = 1.5). This in itself is not surprising as the size of these companies means that risks affect their everyday business more than larger companies who are likely more robust. Furthermore, no other significant differences were found for the other competencies and the company size. The findings show that SME and LE require similar levels of almost all the competencies for BSc. and MSc. graduates.

Limitations of the study

The low sample size (N= 28) of industry respondents in this study prevents validity and reliability measurements. It is the intention of the authors to create an online survey, to be will be administered over 2019 to scale up the pilot study and as a resulting effect of the increased number of responses address the validity and reliability analyses accordingly. Another limitation of this work is the reliance as a starting point on a rubric developed based on an existing unpublished framework used to measure the personal development engineers by Siemens. However, within the scope of the research presented, and by scaling up the pilot study, the authors feel they have done enough to negate any possible oversights.

RECOMMENDATIONS FOR ENGINEERING CURRICULA

The outcomes of this pilot study provide engineering educators with preliminary insights on what competency levels industry expects graduates to enter and perform successfully in the labor market. These outcomes may also inspire the field of engineering education to come up with curriculum adaptations to better match the needs of future employers and thus produce graduates with the desired competencies. To aid lecturers in this development, the authors make some preliminary observations and recommendations for engineering curricula in this section, that they feel may address some of the current mismatch.

Teamwork

In terms of teamwork, the authors worry, based on their own teaching experiences, that developing teamwork competencies by just putting students in teams is not enough. Students may be benefit from being explicitly mentored on how to manage time, tasks and

responsibilities, and set common expectations and goals when working in groups. This way, they may improve on competencies such as *time management*, *engagement in teamwork*, *collaborative goal oriented*. In addition, because when working as engineers, they do not solve problems alone, students may benefit from working in different teams (i.e. background studies, culture) from the start so that they can learn to relate to and depend on others [14]. Research shows that this is best done with explicit instruction in interpersonal skills [15] and open discussions about differences in cultural behaviors and approaches to work in teams [13].

Communication

The teaching of communication skills should perhaps not be limited to just being able to give oral presentations and write a written report at the end of a project. Encouraging practices such as suggested in Leandro Cruz and Saunders-Smiths [16] in which students experience a wide spectrum of ways to communicate, such as describing, listening, questioning, answering, and drawing. Next to that, engagement of students, for example by interviewing customers to understand their problems and needs, or by exposing students to non-technical/societal issues, would help students to develop other communication competencies that are currently often unaddressed, such as their sense of community and how to deal with non-engineering thinking and communication.

Method of Delivery

The authors also suggest that, in order for students to acquire and master competencies, curricula may also include learning activities that are varied in terms of learning tasks to satisfy students' diverse competency needs and that using student centered activities imposes responsibility and autonomy of students' learning [17].

Previous studies [17] showed that project-based learning improves communication, teamwork, understanding of professional practice. To also address innovation and creativity, ensure when designing project-based learning that assignments allow students the opportunity to produce real(istic) products or services (ideally with real clients) that trigger their creativity and innovation as well as their entrepreneurial abilities.

Problem Solving

It may also be worthwhile to consider exposing students to many different kinds of problems throughout their degree. Problems should be open-ended, ill-structured, ambiguous and complex, in which not only the technological answers need to be considered, but also non-engineering contextual factors/constraints such as costs, time, functionality, as it happens in real engineering life [14].

Life Long Learning

Although little evidence as yet exists on the effectiveness of discovery or guided learning [17], this inquiry-based approach may benefit students' *actively seeking learning* because students self-directly work to discover knowledge (without or with guidance) to answer questions, to solve problems or to explain observations. In addition, the authors feel that

actively seeking learning as well as *strengths and weaknesses awareness* may be stimulated with the introduction of reflections in the curriculum, because they may support students to reflect on their strengths and weaknesses and consequently seek for learning to fulfill the needs [18].

Industry Exposure

Finally, to better prepare students for the industry we, as educators, should also considering whether students are sufficiently exposed to industry during their degree: Inform students about professional engineering roles and provide moments to experience them throughout courses. Involve students with industry from the start by inviting guest speakers from industry, with projects that require client interaction, and stimulating students going on industry internships [19].

CONCLUSION

The major difference between this research and previous studies is that it focuses not only on which transversal competencies industry requires graduates to have, but also on the competency level that BSc. and MSc. graduates need to successfully enter into the labor market. This study showed that competencies, including *problem-solving*, *strengths and weaknesses awareness*, and *actively seeking learning*, were considered very important and required expert-level mastery when a student obtains their Master. Competencies such as *risk tolerance*, *listening skills*, *writing skills*, *interdisciplinary thinking*, *time management*, *strengths and weaknesses awareness*, and *actively seeking learning* all require high mastery levels for both Bachelor and Master graduates with Master graduates being held to a higher level than Bachelor graduates. These show the necessity of addressing these competencies in engineering curricula.

When examining the background of the respondents, years of work experience of industry respondents were shown to have no influence on the desired competency levels of BSc. and MSc. Graduates, and only one competency level, *risk tolerance*, was found to be affected by the company size of the respondents. A number of recommendations are given in this paper to aid educators in teaching competencies in engineering education based on the results found.

In terms of further research, the pilot will now be expanded to a larger study involving more industry participants in order to get a deeper understanding of the skills gap. Also, current curriculum elements that have introduced over the past 20 years at the institution the authors work at will be evaluated for their effectiveness in teaching the competencies they set out to teach. Next to that, the authors will continue to develop learning activities for students specifically aimed to aid student in the development of competencies such as *listening skills*, *time management*, *strengths and weaknesses awareness*, and *actively seeking learning* and publish them as OpenCourseWare in order to continue to educate the engineers of tomorrow.

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REFERENCES

- [1] Shuman, L.J., M. Besterfield-Sacre, and J. McGourty, "The ABET "professional skills" - Can they be taught? Can they be assessed?", *Journal of Engineering Education* Vol. 94, No. 1, 2005, pp. 41-55.
- [2] Care, E., and Luo, Rebekah "Assessment of Transversal Competencies: Policy and Practice in the Asia-Pacific Region.", Paris, France: UNESCO, 2016.
- [3] Engineering Accreditation Commission, *Criteria for Accrediting Engineering Programs*, Baltimore, 2000.
- [4] Passow, H.J., and C.H. Passow, "What competencies should undergraduate engineering programs emphasize? A systematic review", *Journal of Engineering Education* Vol. 106, No. 3, 2017, pp. 475-526.
- [5] Almi, N.E.A.M., N.A. Rahman, D. Purusothaman, and S. Sulaiman, "Software engineering education: The gap between industry's requirements and graduates' readiness", *Computers & Informatics (ISCI), 2011 IEEE Symposium on: IEEE*, 2011, pp. 542-547.
- [6] Trevelyan, J., "Mind the gaps: engineering education and practice", *Proceedings of the 21st Annual Conference for the Australasian Association for Engineering Education*, Sydney, Australia, 2010, pp. 383.
- [7] Saunders-Smits, G.N., "The Secret of their Success: What factors determine the career success of an aerospace engineer trained in the Netherlands?", *ASEE Annual Conference and Exposition*, Portland, Oregon, 2005.
- [8] Passow, H.J., and C.H. Passow, "Which ABET competencies do engineering graduates find most important in their work?", *Journal of Engineering Education* Vol. 101, No. 1, 2012, pp. 95-118.
- [9] Beagon, U., Bowe, B., "The Academic Perspective: A study of academic's perceptions of the importance of professional skills in engineering programmes in Ireland", *46th SEFI Annual Conference*, Copenhagen, Denmark, 2018.
- [10] Craps, S., Pinxten, M., Saunders-Smits, G. N., Leandro Cruz, M., Gaughan, K., and Langie, G., "Professional Roles and Employability of Future Engineers", *45th SEFI Annual Conference*, Azores, Portugal, 2017.
- [11] Field, A., *Discovering Statistics Using SPSS*, London, United Kingdom: SAGE publications, 2009.
- [12] Hundley, S., and L.G. Brown, "The Attributes of a Global Engineer Project: Updates, Inputs, Faculty Development Considerations", *ASEE International Forum*, Atlanta, Georgia, 2013.
- [13] Oakley, B., R.M. Felder, R. Brent, and I. Elhadj, "Turning student groups into effective teams", *Journal of student centered learning* Vol. 2, No. 1, 2004, pp. 9-34.
- [14] Jonassen, D., J. Strobel, and C.B. Lee, "Everyday problem solving in engineering: Lessons for engineering educators", *Journal of engineering education* Vol. 95, No. 2, 2006, pp. 139-151.

- [15] Prince, M., "Does active learning work? A review of the research", *Journal of engineering education* Vol. 93, No. 3, 2004, pp. 223-231.
- [16] Leandro Cruz, M., and G.N. Saunders-Smits, "Design and Implementation of New Communication and Lifelong Learning elements in a Master Engineering Course", *46th SEFI Annual Conference*, 2018.
- [17] Prince, M.J., and R.M. Felder, "Inductive teaching and learning methods: Definitions, comparisons, and research bases", *Journal of engineering education* Vol. 95, No. 2, 2006, pp. 123-138.
- [18] Mann, K., J. Gordon, and A. MacLeod, "Reflection and reflective practice in health professions education: a systematic review", *Advances in health sciences education* Vol. 14, No. 4, 2009, pp. 595.
- [19] Haag, S., E. Guilbeau, and W. Goble, "Assessing engineering internship efficacy: Industry's perception of student performance", *International Journal of Engineering Education* Vol. 22, No. 2, 2006, pp. 257.

Appendix A

Definition and characterization of the five selected competencies.

	Sub-competencies	Definition
Entrepreneurial Competencies	Technology benchmarking	Demonstrates awareness of market drivers, emerging technologies, competitions, pricing and customer needs, regulations and standards
	Financial awareness	Demonstrates awareness of financial capital (funding, cash flow, taxes, wages, etc.)
	Business acumen	Identifies business opportunities and applies business modeling and problem solving to implement strategic responses
	Negotiation skills	Demonstrates knowledge of negotiation methods and negotiates under risk, long-term and international business environments
	Project management	Plans, controls and orients strategies, and instructs and coordinates people
	Leadership	Provides guidance, instruction, direction, and leadership to a group and is considered charismatic among members
	Risk tolerance	Withstands risk and overcomes failure learning from it
Innovation Competencies	Stakeholder management	Demonstrates knowledge about stakeholders' needs, concerns, and desires
	Value/cost consciousness	Demonstrates awareness of project values and costs when creating, designing, implementing and operating it
	Curiosity for innovation	Demonstrates curiosity to identify and to explore innovative ideas/products/services which give market value
	Problem-solving	Identifies problems and estimates risks, evaluates the different options and weights the alternatives
	Critical thinking	Considers issues, develops strategies to overcome obstacles, estimates their risk, and implement solutions
	Ideation	Uses creative tools and processes, and others' advice to create functional new ideas or to improve existing ideas
	Idea implementation	Implements activities which enable creative ideas to move from the design to the marketplace
Communication Competencies	Quality of presentation method	Develops presentation methods and mediums depending on topic and target group
	Presentation skills	Gives a clear, organized and logic speech and answers questions adequately and with elaboration
	Adaptive communication style	Communicates properly, adapting style and language to the purpose, context, and environment
	Self-confidence	Possesses confidence in formal and informal settings and maintains eye contact with the audiences
	English language skills	Has fluency in the English language
	Listening skills	Listens and understand verbal messages, and consequently acts on what someone says or does
	Writing skills	Develops a logical, accurate, detailed, and organized report/paper without grammar mistakes and with accurate references
	Interconnection/ interrelation ability	Builds and retains formal and informal relationships or networks
	Pitching skills	Conveys and persuades audiences within a short time speech (1-3 minutes)

Teamwork Competencies	Cross-cultural understanding	Understand cultural differences, recognizes their importance or benefit and stimulates cooperative teamwork among people of different cultures
	Interdisciplinary collaboration	Collaborates with team members of engineering disciplines and of other disciplines, and clients
	Goal setting	Establishes goals balancing self and team interests
	Collaborative goal oriented	Demonstrates a collaborative working spirit towards common goals
	Engagement in teamwork	Shares information and knowledge with team members and shows engagement with teamwork
	Giving Constructive feedback	Gives constructive feedback to improve team members' performance
	Time Management	Prioritizes, determines tasks, schedules appointments, allocates team roles and meets deadlines
	Managing conflict	Manages conflicts between team members by stimulating healthy debates to reach agreements
Lifelong Learning Competencies	Self-knowledge awareness	Possesses an awareness of strengths and weaknesses, and seeks constant self-knowledge
	Professional role awareness	Possesses an awareness of personal and professional needs and of professional engineering roles
	Actively seeking learning	Recognizes responsibility for own learning and seeks and develops strategies and practices to increase learning
	Autonomous work	Works and studies with autonomy, has responsibility for tasks, manages projects, and supervises people
	Extracurricular activity participation	Participates in volunteering activity or paid work (non-credit giving) which involve responsibility

Appendix B

Generated rubric with four descriptive levels for each of the selected competencies.

Entrepreneurial competencies

Criteria	Absent (Level 0)	Basic (Level 1)	Advanced (Level 2)	Expert (Level 3)
Technology benchmarking	Not aware of market drivers, emerging technologies, competitions, pricing and customer needs, regulations and standards <input type="checkbox"/>	Little awareness of market drivers, emerging technologies, competitions, pricing and customer needs, regulations and standards <input type="checkbox"/>	Awareness of market drivers and emerging technologies, but little awareness of competitions, pricing and customer needs, regulations and standards <input type="checkbox"/>	Awareness of market drivers, emerging technologies, competitions, pricing and customer needs, regulations and standards <input type="checkbox"/>
Financial awareness	Not aware of financial capital (funding, cash flow, taxes, wages, etc.) <input type="checkbox"/>	Little awareness of financial capital (funding, cash flow, taxes, wages, etc.) <input type="checkbox"/>	Awareness of financial capital (funding, cash flow, taxes, wages, etc.) <input type="checkbox"/>	Deep awareness of financial capital (funding, cash flow, taxes, wages, etc.) <input type="checkbox"/>
Business acumen	Not able to identify business opportunities nor to apply business modelling and problem solving to implement strategic responses <input type="checkbox"/>	Difficulties with identifying business opportunities and applying business modelling and problem solving to implement strategic responses <input type="checkbox"/>	Identifies business opportunities but has difficulties with applying business modelling and problem solving to implement strategic responses <input type="checkbox"/>	Identifies business opportunities and applies business modelling and problem solving to implement strategic responses <input type="checkbox"/>
Negotiation skills	No knowledge of basic negotiation methods nor ability to negotiate in low risk business environments <input type="checkbox"/>	Knowledge of basic negotiation methods but no ability to negotiate in low risk business environments <input type="checkbox"/>	Knowledge of negotiation methods and ability to negotiate in low risk business environments <input type="checkbox"/>	Knowledge of negotiation methods and ability to negotiate in medium-high risk, long-term and international business environments <input type="checkbox"/>
Project management	Not able to plan, monitor and oriente strategies, and instruct and co-ordinate subordinates <input type="checkbox"/>	Difficulties with planning, monitoring and orienting strategies, and instructing and co-ordinating people <input type="checkbox"/>	Plans, monitors and orients strategies, but has difficulties with instructing and co-ordinating people <input type="checkbox"/>	Plans, monitors and orients strategies, and instructs and co-ordinates people <input type="checkbox"/>
Leadership	Not able to provide guidance, instruction, direction and leadership to a group <input type="checkbox"/>	Difficulties with providing guidance, instruction, direction and leadership to a group <input type="checkbox"/>	Provides guidance, instruction, direction and leadership to a group <input type="checkbox"/>	Provides guidance, instruction, direction and leadership to a group and is considered charismatic among members <input type="checkbox"/>
Risk tolerance	Not able to withstand risk nor to overcome failure <input type="checkbox"/>	Difficulties withstanding risk and overcoming failure <input type="checkbox"/>	Withstands risk but has difficulties overcoming failure <input type="checkbox"/>	Withdtands risk and overcomes failure learning from it <input type="checkbox"/>

Innovation competencies

Criteria	Absent (Level 0)	Basic (Level 1)	Advanced (Level 2)	Expert (Level 3)
Stakeholder management	No knowledge about stakeholders' needs, concerns and desires <input type="checkbox"/>	Little knowledge about stakeholders' needs, concerns and desires <input type="checkbox"/>	Knowledge about stakeholders' needs, concerns and desires <input type="checkbox"/>	In-depth knowledge about stakeholders' needs, concerns and desires <input type="checkbox"/>
Value/cost consciousness	Not aware of project values and costs when creating, designing, implementing and operating it <input type="checkbox"/>	Little awareness of project values and costs when creating, designing, implementing and operating it <input type="checkbox"/>	Awareness of project values and costs when creating, designing, implementing and operating it <input type="checkbox"/>	Manages project values and costs <input type="checkbox"/>
Curious for innovation	No curiosity to identify and to explore innovative ideas/products/services which give market value <input type="checkbox"/>	Little curiosity to identify and to explore innovative ideas/products/services which give market value <input type="checkbox"/>	Curious to identify and to explore innovative ideas/products/services which give market value <input type="checkbox"/>	Besides being curious, motivates others to identify and explore innovative ideas/products/services which give market value <input type="checkbox"/>
Problem solving	Not able to identify problems, generate and evaluate the risk of alternatives <input type="checkbox"/>	Difficulties with identifying problems, and with generating and evaluating the risk of alternatives <input type="checkbox"/>	Identifies problems in the real world, but requires help to generate and evaluate the risk of alternatives <input type="checkbox"/>	Identifies problems and estimates risks, evaluates the different options and weighs the solutions <input type="checkbox"/>
Critical thinking	Not able to consider issues, develop strategies to overcome obstacles, estimate risks and implement solutions <input type="checkbox"/>	Difficulties with considering issues, developing strategies to overcome obstacles, estimating risks and implementing solutions <input type="checkbox"/>	Considers issues, develops strategies to overcome obstacles, but requires help to estimate risks and to implement solutions <input type="checkbox"/>	Considers issues, develops strategies to overcome obstacles, estimates risks and implement solutions <input type="checkbox"/>
Ideation	Lacks of creativity tools and processes and others' advices to create functional new ideas or to improve existing ideas <input type="checkbox"/>	Uses little creative tools and processes and others' advice to create functional new ideas or to improve existing ideas <input type="checkbox"/>	Uses creativity tools and processes, and others' advice to create functional new ideas or to improve existing ideas <input type="checkbox"/>	Besides being creative, encourages others to come up with new functional ideas by applying their creativity and innovation methods <input type="checkbox"/>
Idea implementation	Not able to implement activities which enable creative ideas to move from the design to the marketplace <input type="checkbox"/>	Little ability to implement activities which enable creative ideas to move from the design to the marketplace <input type="checkbox"/>	Implements activities which enable creative ideas to move from the design to the marketplace <input type="checkbox"/>	Manages the implementation of activities which enable creative ideas to move from the design to the marketplace <input type="checkbox"/>

Teamwork competencies

Criteria	Absent (Level 0)	Basic (Level 1)	Advanced (Level 2)	Expert (Level 3)
Cross cultural understanding	Not able to understand cultural differences, recognise their importance/benefit nor stimulates teamwork among different cultures <input type="checkbox"/>	Understands cultural differences but does not recognise their importance/ benefit nor stimulates teamwork among different culture <input type="checkbox"/>	Understands cultural differences and recognises their importance/ benefit but does not stimulate teamwork among different culture <input type="checkbox"/>	Understands cultural differences and recognises their importance/ benefit and stimulates cooperative teamwork among different culture <input type="checkbox"/>
Interdisciplinary thinking	Not able to collaborate with team members of engineering disciplines and of other disciplines, and clients <input type="checkbox"/>	Difficulties collaborating with team members of engineering disciplines and of other disciplines, and clients <input type="checkbox"/>	Collaborates with team members of engineering disciplines, but not with members of other disciplines nor clients <input type="checkbox"/>	Collaborates with team members of engineering disciplines and of other disciplines, and clients <input type="checkbox"/>
Goal settings	Not able to establish goals taking into account team interests <input type="checkbox"/>	Difficulties establishing goals taking into account team interests <input type="checkbox"/>	Establishes small goals for the group or group members considering some other's perspectives <input type="checkbox"/>	Establishes challenging collective goals balancing self and team interests <input type="checkbox"/>
Collaborative goal oriented	Not able to collaborate with team members to achieve common goals <input type="checkbox"/>	Difficulties of collaboration with team members to achieve common goals <input type="checkbox"/>	Demonstrates a collaborative working spirit towards common goals <input type="checkbox"/>	Collaborates, inspires and motivates others to contribute to common goals and to step out of comfort zones <input type="checkbox"/>
Engagement in team work	Not able to share ideas and knowledge with team members nor show engagement with team work <input type="checkbox"/>	Shares some ideas and knowledge with team members but shows little engagement with team work <input type="checkbox"/>	Shares information and ideas with team members and shows engagement with team work <input type="checkbox"/>	Fosters sharing of information and knowledge and encourages members to be engaged with team work <input type="checkbox"/>
Constructive feedback	Not able to give feedback to improve team member performance when asked <input type="checkbox"/>	Difficulties giving constructive feedback to improve team member performance when asked <input type="checkbox"/>	Gives constructive feedback to improve team member performance when asked <input type="checkbox"/>	Gives constructive feedback to improve team member performance even without being asked <input type="checkbox"/>
Time Management	Not able to prioritize, determine tasks, schedule appointments, allocate team roles and meet deadlines <input type="checkbox"/>	Difficulties in prioritizing, determining tasks, scheduling appointments and meeting deadlines <input type="checkbox"/>	Prioritizes, determines tasks and schedules appointments, but sometimes has difficulty to meet deadlines <input type="checkbox"/>	Prioritizes, determines tasks, schedules appointments, allocates team roles and meets deadlines <input type="checkbox"/>
Managing conflict	Not able to accept others opinions generating conflicts between team members <input type="checkbox"/>	Difficulties accepting others opinions generating some conflicts between team members <input type="checkbox"/>	Accepts and respects others opinions but has difficulties managing conflicts between other team members <input type="checkbox"/>	Manages effectively conflicts between team members by prompting healthy debates to reach agreements <input type="checkbox"/>

Communication competencies

Criteria	Absent (Level 0)	Basic (Level 1)	Advanced (Level 2)	Expert (Level 3)
Quality of presentation method	Not able to use a presentation method and medium <input type="checkbox"/>	Uses the same presentation method and medium without adaption to topic and target group <input type="checkbox"/>	Uses the appropriate presentation methods and medium depending on topic and target group <input type="checkbox"/>	Develops innovative presentation methods and mediums depending on topic and target group <input type="checkbox"/>
Presentation skills	Gives unclear, disorganized and monotonous speech and does not answer questions from the audience <input type="checkbox"/>	Gives clear, organized and logic but monotonous speech and answers questions rudimentary <input type="checkbox"/>	Gives clear, organized and logic speech and answers all questions adequately but without elaboration <input type="checkbox"/>	Gives clear, organized and logic speech and answers all questions adequately and with elaboration <input type="checkbox"/>
Adaptive communication style	Not able to communicate properly, adapting style and language to the purpose, context and environment <input type="checkbox"/>	Difficulties communicating, adapting style and language to the purpose, context and environment <input type="checkbox"/>	Communicates properly, adapting style and language to the purpose, context and environment <input type="checkbox"/>	Masters communication, adapting style and language to the purpose, context and environment with ease <input type="checkbox"/>
Self-confidence	No confidence when talking in formal or informal settings and maintains no eye contact with the audience <input type="checkbox"/>	Confidence requires development when talking in informal settings and little eye contact is maintained, only with part of the audience <input type="checkbox"/>	Has confidence in talking in informal settings but little in formal settings, maintaining eye contact with part of the audience <input type="checkbox"/>	Has confidence in all situations both in formal and informal settings and easily maintains eye contact with the whole audience <input type="checkbox"/>
English language skills	No fluency in English language (B1 <) <input type="checkbox"/>	Basic English language fluency (B2) <input type="checkbox"/>	English language requires minor corrections (C1) <input type="checkbox"/>	Fluent ability in English language (C2 or native) <input type="checkbox"/>
Listening skills	Does not pay attention nor acts on what someone says or does <input type="checkbox"/>	Is sometimes not paying attention and not acting on what someone says or does <input type="checkbox"/>	Listens and understands verbal messages, but hardly acts on what someone says or does <input type="checkbox"/>	Listens and understands verbal messages, and consequently acts on what someone says or does <input type="checkbox"/>
Writing skills	Not able to develop a logical and accurate report/paper and lacks organization and details, and has few grammar errors and missing/inaccurate references <input type="checkbox"/>	Develops a logical and accurate report/paper but lacks organization and details, and has few grammar errors and inaccurate references <input type="checkbox"/>	Develops a logical, accurate, detailed, and organized report/paper without grammar mistakes but with missing or inaccurate references <input type="checkbox"/>	Develops a logical, accurate, detailed, and organized report/paper without grammar mistakes and with accurate references <input type="checkbox"/>
Interconnection/interrelation ability	Not able to understand the importance of networking nor how to get knowledge to interconnect and create links among individuals <input type="checkbox"/>	Understands the importance of networking but has little knowledge of how to interconnect and create links among individuals <input type="checkbox"/>	Understands the importance of networking and pays attention to building formal and informal relationships <input type="checkbox"/>	Builds and retains formal and informal relationships naturally and fosters others' networking <input type="checkbox"/>

Pitching skills	Not able to convey and persuade an audience with a short time speech (1-3 min) <input type="checkbox"/>	Difficulties with conveying and persuading an audience with a short time speech (1-3 min) <input type="checkbox"/>	Able to convey and persuade an audience with a prepared short time speech (1-3 min) <input type="checkbox"/>	Able to convey and persuade an audience with a spontaneous short time speech (1-3 min) <input type="checkbox"/>
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Lifelong learning competencies

Criteria	Absent (Level 0)	Basic (Level 1)	Advanced (Level 2)	Expert (Level 3)
Strength and weakness awareness	Not aware of own strengths and weaknesses and no interest in getting more self-knowledge <input type="checkbox"/>	Little awareness of own strengths and weaknesses and no interest in getting more self-knowledge <input type="checkbox"/>	Awareness of some strengths and weaknesses but no interest in getting more self-knowledge <input type="checkbox"/>	Awareness of some strengths and weaknesses and interest in getting constant self-knowledge <input type="checkbox"/>
Professional role awareness	Not aware of personal and professional needs and engineering professional roles <input type="checkbox"/>	Limited awareness of personal and professional needs and engineering professional roles <input type="checkbox"/>	Concrete personal and professional needs but little awareness of engineering professional roles <input type="checkbox"/>	Concrete personal and professional needs and awareness of engineering professional roles <input type="checkbox"/>
Active learning	No responsibility for own learning and no proactivity to develop learning strategies and practices <input type="checkbox"/>	Little responsibility for own learning and little proactivity to develop learning strategies and practices <input type="checkbox"/>	Recognises responsibility for own learning but has little proactivity to develop learning strategies and practices <input type="checkbox"/>	Recognises responsibility for own learning and continuously seeks and develops strategies and practices to improve learning process <input type="checkbox"/>
Autonomous work	No autonomy when working and studying, no responsibility for simple tasks, and does not manage projects nor supervises people <input type="checkbox"/>	Works and studies with little autonomy, has little responsibility for simple tasks, and does not manage projects nor supervises people <input type="checkbox"/>	Works and studies with autonomy, has responsibility for routine tasks, manages simple projects and supervises people <input type="checkbox"/>	Works and studies with autonomy, has responsibility for complex tasks, manages complex projects, and supervises people <input type="checkbox"/>
Non-credit activity participation	No participation in volunteering activity or paid work (non-credit giving) <input type="checkbox"/>	Participation in volunteering activity or paid work (non-credit giving) with no responsibility <input type="checkbox"/>	Participation in volunteering activity or paid work (non-credit giving) with limited responsibility <input type="checkbox"/>	Participation in volunteering activity or paid work (non-credit giving) with extensive responsibility <input type="checkbox"/>