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**DOI**
10.1080/03043797.2021.1909539

**Publication date**
2022

**Document Version**
Final published version

**Published in**
European Journal of Engineering Education

European Journal of Engineering Education

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ceee20

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**To cite this article:** Mariana Leandro Cruz & Gillian N. Saunders-Smits (2022) Using an industry instrument to trigger the improvement of the transversal competency learning outcomes of engineering graduates, European Journal of Engineering Education, 47:1, 30-49, DOI: 10.1080/03043797.2021.1909539

**To link to this article:** https://doi.org/10.1080/03043797.2021.1909539



Published online: 05 Apr 2021.

EUROPEAN JOURNAL OF ENGINEERING EDUCATION
2022, VOL. 47, NO. 1, 30–49
https://doi.org/10.1080/03043797.2021.1909539



# Using an industry instrument to trigger the improvement of the transversal competency learning outcomes of engineering graduates

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**ABSTRACT**
To assist in resolving the perceived lack of transversal competencies (TCs) of engineering graduates by industry, this study investigates the characteristics of transforming an existing industry TC instrument for use in engineering education. The instrument consists of 36 nuanced sub-competencies with the corresponding definitions and descriptive mastery levels. This instrument was first used to determine required TCs mastery levels for BSc and MSc graduates by European industry and subsequently, using two representative curricula as case studies to map TCs course outcomes and lecturer perceptions of TCs course outcomes, using interviews for further exploration. The main findings are that the TC instrument is suitable to determine desired industry mastery levels as well as to map TCs course outcomes both in formal documentation and by lecturers. Also, a gap between the formal and perceived curriculum was found i.e. discrepancies in reported TC learning outcomes between formal documentation and lecturer-reported TCs in courses.

**ARTICLE HISTORY**
Received 27 September 2019
Accepted 23 March 2021

**KEYWORDS**
Transversal competency levels; employability; Engineering Education; industry perception; lecturer perception

## Introduction

Government bodies, industry and universities are putting great emphasis on improving the employability of future engineers to guarantee competitiveness in the fast-changing knowledge based-economy. In addition to technical competencies, engineering curricula have expanded curricular and pedagogical arrangements to include transversal competencies to prepare graduates for employment (Winberg et al. 2020). In the context of this paper, we define transversal competencies (TCs) as 'skills, values and attitudes that are required for learners' holistic development and for learners to become capable of adapting to change' (Care and Luo 2016).

Several literature studies on TCs that students should possess to be successful in the labour market have been conducted in Europe (Spinks, Silburn, and Birchall 2006; Saunders-Smits and de Graaff 2012), the USA (Passow and Passow 2012; Passow and Passow 2017; Meier, Williams, and Humphreys 2000; Brumm, Hanneman, and Mickelson 2006) and Australia (Nair, Patil, and Mertova 2009; Male, Bush, and Chapman 2011; Scott and Yates 2002) over the past decades. They all show that these competencies are deemed important for engineering graduates. However, little is reported about the specific level for each TC that graduates should master for each competency before entering the labour market. By investigating the TC levels required by industry, engineering educators can

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learn to what extent TCs should be addressed in the curriculum and, as a consequence, they can provide interventions to ensure the desired levels are reached. This way, engineering educators are preparing students for the labour market taking into account the needs of their future employers. Although studies exist (Chassidim, Almog, and Mark 2018; Beagon, Niall, and Ní Fhloinn 2019) that report on the introduction of certain TCs in the engineering curriculum and evaluate the effectiveness of these interventions they do so by reporting on the opinion of students. However, few studies, if any, systematically analyse how the TCs are embedded in courses and formulated in the formal learning outcomes of the courses, how the achievement of the learning outcome by students in the course is evaluated or report on how lecturers feel they are implementing TCs in their classes.

This study aims to assist in resolving the perceived lack of TCs of engineering graduates by industry, by investigating the transforming of an existing industry TC instrument for use in engineering education. First, the perspectives of European industry on the important TCs engineering students should hold at graduation and at which level of mastery are investigated using the instrument.

To see if the instrument can also be used in an educational setting, two representative curricula, a BSc and a MSc of a Dutch university of technology will be used as case studies with a focus on the extent to which the TC levels indicated by industry are covered in a representative engineering degree both formally, and in the perception of lecturers, and what educational practises and methods are used to address these competency levels. We will come, if possible, to recommendations on the use of the instrument in engineering education in the capacity as course evaluation instruments as well as (self-)assessment instrument by lecturers in assessing course design and student's learning outcomes and students in assessing their progress in developing these TCs.

This study is part of the European project PREFER (Professional Roles and Employability of Future EngineeRs), conducted by a consortium consisting of three European Universities, three European Engineering Industries and several other Industry and Engineering stakeholders in Belgium, Ireland and the Netherlands funded through the European Union's Erasmus+ Knowledge Alliance, that was set up as a collaborative education and research project aiming to improve the employability of future engineers and reducing the skills mismatch in the field of engineering.

The main research question of this study is: to contribute towards solving the problem of lack of TCs in engineering graduates as perceived by industry, what are the characteristics of an instrument that can be used in engineering education to effectively measure perceptions of TCs?

This leads to the following sub-questions:

(1) Using the instrument what are the desired TC levels of BSc and MSc graduates by European industry?
(2) Using the instrument what are the most important TCs European industry desires that MSc graduates should hold?
(3) Can the instrument be used to map TC learning outcomes against reported learning outcomes in formal course documentation?
(4) Can the instrument be used by lecturers to map TC learning outcomes in their courses?
(5) Can the instrument be used by lecturers to indicate desired practices and methods to reach the TCs levels required by industry?

## Research literature

### *Employability & competency gap*

Changes in the engineering industry have occurred in the last decades. They include the shift from single components to customer solutions, the increasing complexity of technology, the global mobility of the engineering profession, the concern with sustainability and social responsibility and the need for innovation and creativity (Spinks, Silburn, and Birchall 2006). These future developments within engineering have caused employability issues and impacted graduate readiness for the labour market.

A study conducted by Spinks, Silburn, and Birchall (2006) in the UK has recognised a lack of qualified graduates available for recruitment (skill shortage) and documented that those graduates available have deficiencies in their competencies (skill gap). Similar gaps were reported by the Institute for Engineering and Technology in 2016 (IET 2016). This mismatch between the competencies acquired by engineering students during their studies and those necessary for the labour market was also identified in other studies (Meier, Williams, and Humphreys 2000; Nair, Patil, and Mertova 2009). The gap was verified in competencies like *customer expectations and satisfaction*, *commitment to doing one's best*, *listening skills*, *sharing information and cooperating with co-workers*, *team working skills*, *adapting to changing work environments*, *customer orientation and focus*, *ethical decision making and behaviour* (Meier, Williams, and Humphreys 2000), *oral and written communication skills*, *interpersonal skills with colleagues and clients*, *capacity to analyse and solve problems*, *ability to develop new or innovative ideas, directions, opportunities or improvements*, *time management skills*, *capacity for co-operation and teamwork*, *ability to apply knowledge in the workplace*, *ability to cope with work pressure and stress*, *capacity to learn new skills* (Nair, Patil, and Mertova 2009) and *managing people* (Carvalho and Tonini 2017). Discrepancies between the TCs acquired at university and the work place were found in Brunhaver et al. (2018). In this study, young engineers reported they learned TCs, such as *communication skills*, *working with people* and *time management skills*, more on the job than at university. These studies show that engineering universities are not meeting the needs of industry when it comes to TCs.

### Transversal competencies in engineering

To address this gap, many changes were made to engineering education around the world in the last decades. TCs were first thrust onto the forefront in 1996 by McMasters and Matsch (1996) when they proposed the 'Desired Attributes of an Engineer' such as *good communication skills: written, verbal, graphic, listening, ability to think both critically and creatively, curiosity and a desire to learn for life, and profound understanding of the importance of teamwork* (McMasters and Matsch 1996). The broadening of education to include more TCs rather than technical competencies was strengthened later on by accreditation bodies such as the Accreditation Board for Engineering and Technology (ABET) (Commission 2000) in the USA and the European Network for Engineering Accreditation (ENAEE 2008) in Europe which have defined similar programme outcomes as part of their requirements.

Other studies have also highlighted the importance of TCs for the success of future engineering graduates. In the study conducted by Scott and Yates (Scott and Yates 2002), 20 graduates and 10 supervisors from different engineering fields were asked to rate the most important capabilities for the successful practice of young engineers. The top selected capabilities were: *being able to develop and contribute positively to team-based projects*, *being willing to face and learn from errors and listen openly to feedback*, *being able to organise work and manage time effectively* and *understanding own personal strengths and limitations*. Another study in Australia (Nair, Patil, and Mertova 2009) has identified *oral and written communication*, *capacity to learn new skills*, *capacity for cooperation and teamwork* and *interpersonal skills with colleagues and clients* as the most important attributes within a list of 23 attributes according to the perspectives of 109 employers. Again in Australia, Male, Bush, and Chapman (2011) have focused on which competencies engineering graduates need for future work careers in the perspective of experienced engineers. Similar competencies (i.e. *communication*, *working in diverse teams* and *self-management*) to the two previous studies have emerged from the responses of 300 participants.

To orient academics in the selection of what competencies to integrate into the curriculum, Passow and Passow (2012) have investigated the importance of the ABET competencies in the professional career of alumni undergraduates in the Midwestern University's College of Engineering, USA. A top cluster which contained competencies such as *teamwork*, *communication*, *data analysis*, and *problem-solving* have emerged from the data. Two other studies in the USA have surveyed stakeholders. In the study of Meier, Williams, and Humphreys (2000) at Illinois State University, 415 business managers rated the importance of 54 competencies to engineers. Competencies including *committed to doing their best*, *customer expectations and satisfaction*, *listening skills*, *appreciating punctuality, timeliness and deadlines*, *planning work to complete projects on time*, *team working skills*, *complex problem solving* were considered important. The study of Brumm, Hanneman, and Mickelson (2006) on 14 competencies and 61 key actions at the Iowa State University has involved 212 employers, faculty members and students. Communication and teamwork were likewise important competencies to engineering emerging in this study. Similar results were found in the systematic review of Passow and Passow (2017). A sample of 27 studies representing practising engineers, engineering faculty members and undergraduate alumni from different countries has identified *problem solving*, *communication* and *teamwork* as the top most important competencies for engineers followed by *ethics* and *lifelong learning*.

Also, studies in Europe have been interested to understand which competencies are important for future engineers. In the UK, 444 companies were involved in a study for the Royal Academy of Engineering (Spinks, Silburn, and Birchall 2006). Communication, teamwork, business and commercial competencies, creativity and innovation were required by stakeholders. In Saunders-Smits and de Graaff (2012), aerospace engineers were asked to rate the importance of 12 competencies for their current jobs as engineering specialists and engineering managers. On the top of the most important competencies were *problem-solving skills*, *analytical skills*, *ability to synthesise*, *written and oral communication skills*, the *ability for lifelong learning* and *ability to work in teams* (Saunders-Smits and de Graaff 2012).

Although literature focuses on the important TCs, they present issues: competencies lack definitions (Leandro Cruz, Saunders-Smits, and Groen 2019) and are contextualised to the purpose of the investigation (Carthy, Gaughan, and Bowe 2019). This raises issues in the interpretation of the results, i.e. if two papers mentioned that 'communication' is the most important TC for an engineer to possess, they might not mean the same thing, as the definition of communication is subjected to a context and is conceptually dense. To solve this issue, Carthy, Gaughan, and Bowe (2019) suggest that TCs should be stratified into more nuanced skills. Another issue pointed out by Carthy, Gaughan, and Bowe (2019) is the use of Likert scales as an equal measures scale and the use of the results as objective. For instance, what does it mean when problem solving is rated 4 (in a 1–5 Likert scale) and teamwork is rated 3? As a solution, more objectively and discretely measurable scales are needed.

## *Development of a TC instrument*

The instrument created in this study is based on the existing transversal competency model of Siemens, the Netherlands, a partner in the PREFER project. The instrument divides competencies into five domains (entrepreneurial, innovation, teamwork, communication and lifelong learning) and provides definitions for each competency (Annex A). A rubric for each competency with three descriptive mastery levels (basic, advanced, and expert) was copied from the Siemens model and an 'absent' level was added as engineering students and graduates may not be as competent in skills yet as engineers in later career stages (Annex A). We use the Siemens framework as it is a good example of how industry assesses employees' skills and skill levels. It also fitted well into the context of the project deliverables and the accompanying timeframe. Considering Siemens is a worldwide employer of engineers and this competency framework is used to assess personal development throughout Siemens, it was deemed an appropriate starting point. Also, the instrument addresses the limitations of the literature mentioned above (Leandro Cruz, Saunders-Smits, and Groen 2019; Carthy, Gaughan, and Bowe 2019) because it (1) defines the TCs, (2) stratifies them into more nuanced sub-competencies and (3) presents a more objective measure as the Likert scale is replaced by a descriptive scale.

## Methods

This study is divided into three phases: the instrument described in the previous section is used (1) to find out what the desired TC levels and the most important TCs of graduates are according to industry, (2) to map the TCs in the course learning outcomes of a BSc and a MSc programme at a Dutch university of technology and (3) to investigate the TC levels lecturers perceive their students acquire in their courses and which educational practises and methods lecturers use to address the TC levels.

Ethical approval was sought and obtained for this study from our university's Ethics Committee and participants have consented to be part of this research. They were informed that their participation was voluntary and that the analysis would be conducted anonymously.

### *Phase 1: European industry exploration*

#### *Questionnaire structure*

The questionnaire was structured in three parts. The first part was designed to collect personal data about the participants such as name, company, job position and years of working experience, to describe the sample. The second part required participants to rate the 36 TCs on the levels of mastery they perceive students in engineering should fulfil at BSc and MSc graduation. The last part of the questionnaire asked participants to indicate the three most important TCs in the five domains students in engineering should hold at MSc graduation.

#### *Sample and data collection*

European companies and individuals were approached to include engineers, managers and HR representatives who hire or work with graduate engineers with different working years of experience belonging to small, medium and large enterprises. They were selected as stakeholders because they best know the work performed by young engineers. Approximately 70 invitations for participation were made through the project partners' networks. A total of 28 (40%) responses from different engineering disciplines (38% of Mechanical, Aeronautical and Manufacturing Engineering, 35% of Engineering and 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 were received and used.

#### *Data analysis*

The descriptive statistics (means and standard deviation) of the required mastery levels of BSc and MSc graduates rated by the industry for the 36 TCs were calculated to answer the first sub-research question. A Wilcoxon signed-rank test was carried out to evaluate the differences between the BSc and MSc mastery levels for each TC. The distinction between BSc and MSc graduates was explored as differences between the labour market entrance exist, for instance engineering students in the USA and UK are more likely to go to the labour market with a BSc degree than to continue to the MSc degree, as in European countries such as the Netherlands and Portugal.

Significant differences were considered for $p$-values smaller than 0.05. The effect size, $r$, was calculated using: $r = \frac{Z}{\sqrt{N}}$ (Field 2009). Values of $r = .10$, .30, and .50 refer to a small, medium, and large effect, respectively (Field 2009).

To answer to the second sub-research question, a score ranging from 3 to 1 was assigned to the top 3 of the most important TCs perceived by the industry for MSc graduates within each domain and the summed values were normalised with respect to the maximum number obtained. *Critical thinking* was left out from the domain innovation by mistake, so respondents could not select it as an important competency.

A more detailed report on the outcomes of this questionnaire and the validation of the questionnaire can be found in Leandro Cruz, et al. (2020).

### *Phase 2: Course mapping against TCs*

Phase 2 and 3 were conducted in a representative 3-year BSc engineering degree and a 2-year MSc-programme at a Dutch university of technology to test the instrument in an educational setting. Phase 2 investigated the extent to which these programmes address the 35 TCs listed (the competency *non-credit activity participation* was left out because it referred to activities outside of the curriculum and did not make sense in the context of this part of the study). To do so, the two authors went through the study guide (Delft University of Technology) listing all BSc and MSc courses and individually analysed the stated learning outcomes against the 35 TCs. The Cohen's kappa was calculated to see if there was agreement between the two authors' judgements (McHugh 2012). There was almost perfect agreement, $k = 0.931$, $p < 0.05$.

### *Phase 3: TCs in the BSc and MSc engineering programmes according to lecturers*

Because in the previous phase the course learning outcomes reported only a few TCs, the authors suspected a gap between the formal curriculum (i.e. *intentions as specified in curriculum documents and materials* (van den Akker, Kuiper, and Hameyer 2003) and the perceived curriculum (i.e. *curriculum as interpreted by its users* (van den Akker, Kuiper, and Hameyer 2003) existed. That is the students were practising competencies in courses that are not formally specified in the learning outcomes of the courses by the lecturers in the study guide. Hence, a questionnaire was sent out to all course instructors of both programmes to ask them which TCs they think their students acquire/practise in the courses they teach and supervise and to what level. This questionnaire contained the same 35 TCs as in phase 3. Responses covered 30 out of 39 courses in the BSc degree (in total accounting for 150 ECTS with 30 ECTS of electives excluded) and 30 out of 34 courses in the MSc degree (18 mandatory and 16 elective courses accounting for 120 ECTS). Two programme components: the BSc capstone design and the MSc thesis project were analysed separately as these are not courses but proof of mastery and most lecturers (in their role of supervisor) gave a response about the TCs in these projects (25 and 30 respectively). TC levels perceived by lecturers were listed on an Excel spreadsheet and medians were extrapolated when more than one lecturer from the same course responded.

Next, we wanted to find out if the lecturers were able to provide concrete examples of how their students achieve the TC levels, they indicated using the instrument. To do so, 5 lecturers were interviewed by the first author. The criteria to select these participants were: (1) they must be lecturing both BSc and MSc courses (2) supervise as a minimum either the capstone BSc course or the MSc thesis project, (3) work in different departments within the faculty, (4) have different levels of academic experience and academic position and (5) gender. The final sample was composed of 1 woman and 4 men among them 1 assistant, 3 associate and 1 full professor. They stemmed from 3 of the 4 different departments, lecture 2–7 courses each and have 9–33 years of academic experience.

The individual semi-structured interviews were conducted via *Skype for Business™*. The first author shared the TC levels indicated by the lecturers in the questionnaire phase. Fourteen TCs were selected in this phase: the common TCs present in the top 10 highest and 5 lowest mastery levels indicated by the industry for BSc and MSc graduates (*actively seeking learning*, *self-knowledge awareness*, *risk tolerance*, *time management*, *listening skills*, *writing skills*, *interdisciplinary thinking*, *financial awareness*, *negotiation skills*, *leadership*, *ideation* and *idea implementation*) and *problem-solving* and *critical thinking*, which are considered key TCs for engineers but were only present in the top 10 highest mastery levels for MSc students.

The 1-hour interviews were audio-recorded in *Skype for Business™*, transcribed verbatim and the coding was done as stated in Creswell [ (Creswell 2009, 2010)]: the first author (1) read the scripts to get the first ideas, (2) coded scripts one by one assigning a combination of predetermined codes (used in literature e.g. open-ended problems) and emerging codes (unexpected codes that emerged from the data) to parts of the text, (3) gathered similar codes in a list, (4) took the list and went back to the data, (5) found the most descriptive wording and grouped codes into categories. Quotes are provided to explain themes that emerged from the analysis. They are between quotation marks and are associated with the correspondent lecturer named L1 to L5. The interview was piloted with one lecturer, who also participated in the questionnaire and met the criteria listed earlier. This was done to test the questions to be used in the interview, as well as to see if the interview would not become too long. It also allowed the interviewer to practice interviewing, which adds to the validity and reliability of the results.

## Results

### *European industry exploration*

The TC levels industry requires from BSc and MSc graduates, respectively can be found in Table 1. As was expected by the authors and confirmed by a Wilcoxon signed-ranked test, MSc graduates require higher competency levels compared to BSc graduates ($p < .01$, Table 1). Moreover, large effect sizes ($r > 0.5$ Field 2009, Table 1) were found for all TCs indicating the importance of the findings.

**Table 1.** Differences between BSc. and MSc competency levels. *z*-score: z, *p*-value: *p* (significant level $p < .01$), and effect size: *r*. Boldfaced cells represent the 10 highest mean competency levels for BSc and MSc, respectively, and * indicate the TCs which require advanced level mastery (Median = 3).

| | | Wilcoxon signed-rank test | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Median | | Mean | | SD | | | | |
| Transversal competencies | | BSc. | MSc. | BSc. | MSc. | BSc. | MSc. | z | *p* | *r* |
| **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 |

Comparing the 10 highest means of required mastery at BSc and MSc levels to each other (boldfaced cells in Table 1), it can be observed that they share seven TCs: *strengths and weaknesses awareness*, *listening skills*, *actively seeking learning*, *interdisciplinary thinking*, *time management*, *writing skills* and *risk tolerance*. Examples of TCs which were in the top 10 with highest mastery levels for MSc graduates and not for BSc were: *problem-solving*, *critical thinking* and *presentation skills* and vice-versa not present in the highest mastery levels for MSc but present for BSc were: *engagement in teamwork*, *collaborative goal-oriented* and *English language skills*.

Furthermore, mastery levels of BSc graduates in teamwork and communication competencies are higher than the mastery levels required for BSc graduates in innovation and entrepreneurial competencies (Table 1). For MSc graduates, besides reaching the expert level in communication and teamwork, industry also requires higher levels of mastery in innovation competencies (Table 1).

We also intended to find out in this exploratory research which TCs are deemed most important for MSc graduates according to industry. We compared the 10 most important competencies indicated by industry to the 10 highest mastery levels required by industry for MSc graduates (Table 2). It is observed that *problem solving*, *actively seeking learning* and *strengths and weaknesses awareness* are present in both top 10s. Interestingly, seven TCs differ from the top most important competencies and those requiring the highest levels of mastery. Master graduates are expected to possess these most important TCs but not at very high levels yet at graduation. On the other hand, Master graduates need to be very competent in the TCs requiring the highest levels, however, other competencies are considered more important by industry.

## TCs and mastery levels acquired and practised in BSc and MSc courses

### Course mapping against TCs

The mapping of the published learning outcomes of the courses in the study guide (Delft University of Technology) of each programme against the TCs and mastery levels showed that TCs are rarely explicitly specified in the learning outcomes of the BSc and MSc courses. Only 27 out of 61 courses (11 in BSc and 16 in MSc) reported at least one TC in their learning outcomes, with 21 courses covering only 4 out of the 36 TCs of our instrument. These limited results made the authors wonder if there was a gap between the formal and perceived curriculum (van den Akker, Kuiper, and Hameyer 2003), where lecturers perceive that their students practise TCs but do not make the TCs explicit learning outcomes in their course description in the study guide. Hence, lecturers were surveyed to identify which TCs they feel their students practise in each of their courses and to what level.

### TCs in the BSc and MSc programmes according to lecturers

Our suspicion about the gap between the formal and perceived curriculum (van den Akker, Kuiper, and Hameyer 2003) was confirmed by the results of the questionnaire. According to lecturers, 95% of the BSc and MSc courses addressed at least 5 TCs listed (data not shown). This means that lecturers

**Table 2.** Comparison of the 10 most important TCs with the 10 highest mastery levels required by industry for MSc graduates.

| TOP | Importance | Mastery level |
|---|---|---|
| 1 | Actively seeking learning | Strengths and weaknesses awareness |
| 2 | Strengths and weaknesses awareness | Interdisciplinary thinking |
| 3 | Problem solving | Actively seeking learning |
| 4 | Autonomous work | Problem solving |
| 5 | Project management | Writing skills |
| 6 | Curious for innovation | Listening skills |
| 7 | Engagement in teamwork | Risk taking |
| 8 | Technology benchmarking | Critical thinking |
| 9 | Collaborative goal oriented | Presentation skills |
| 10 | Adaptive communication style | Time management |

feel their students practise TCs in their courses even though they do not include them in the official learning outcomes.

The lecturers' perceptions of the mastery levels of the 35 TCs that students practise in 30 out of 39 mandatory BSc courses, including the BSc capstone design project which is listed separately, compared to the TC levels required for BSc graduates according to the industry are shown in Figure 1. For the MSc degree, we analysed the lecturers' perceptions of the mastery levels of the 35 TCs that students practise in 15 mandatory and 14 elective courses and the individual Master's thesis. The TC levels indicated by the lecturers for the mandatory and elective courses compared to the TC levels required for MSc graduates according to the industry are shown in Figure 2.

Looking at Figures 1 and 2, it is interesting to see that according to the combined opinion of the lecturers surveyed, graduates are taught to at least the level required by industry in at least one but often more courses. This is in sharp contradiction to the low number of TCs listed as official learning outcomes. It also raises questions on whether these TCs that are perceived by lecturers to be

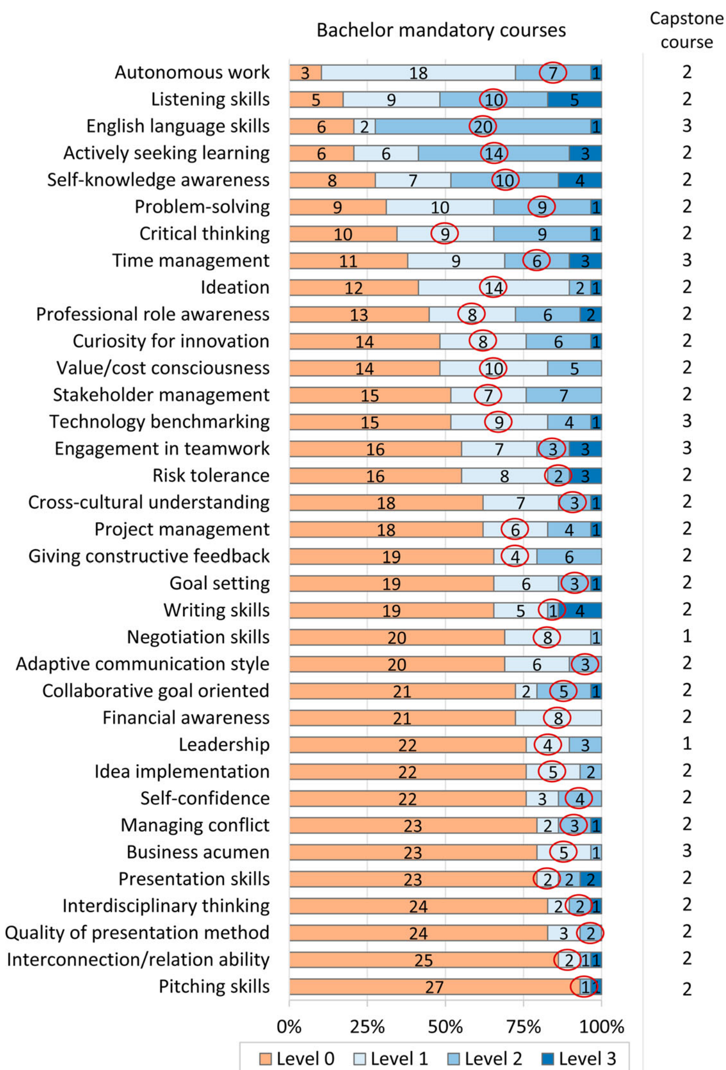


**Figure 1.** Mastery levels of 35 TCs that students practise perceived by lecturers in 30 of the 39 mandatory BSc courses. Circles represent the mastery levels required for BSc graduates according to industry.

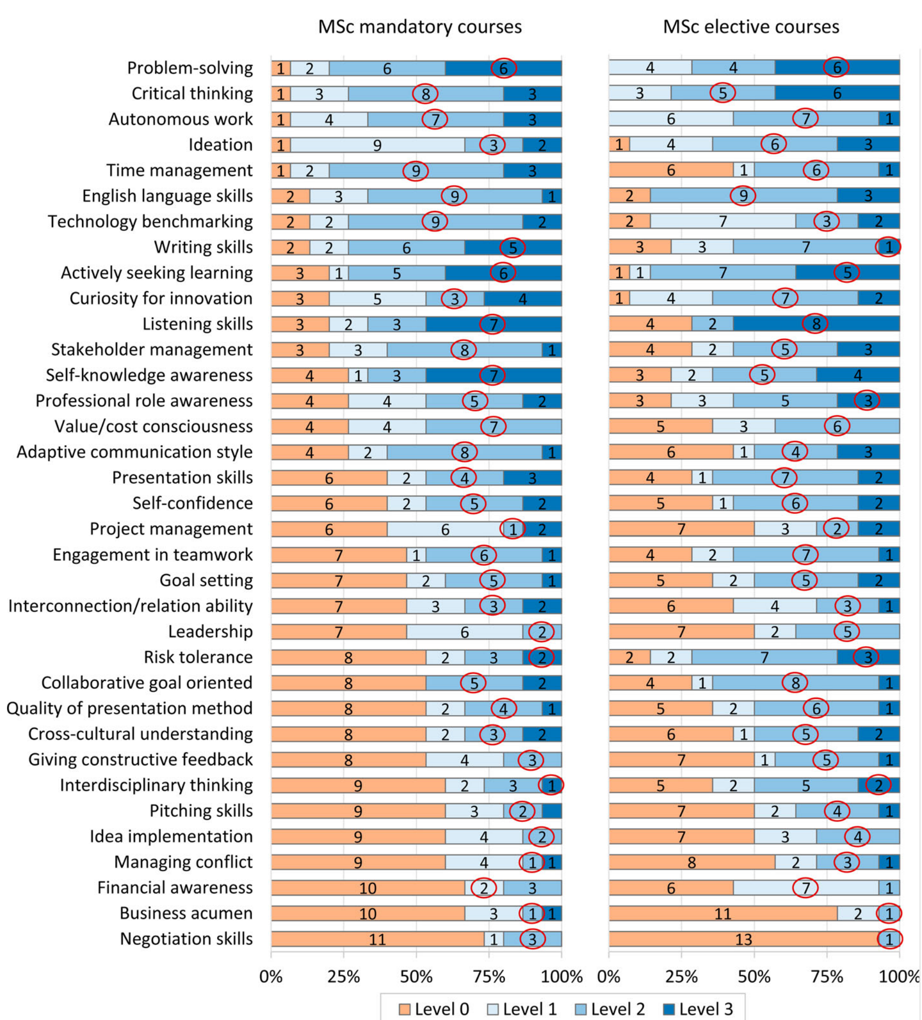


**Figure 2.** Mastery levels of 35 TCs that students practise perceived by lecturers in 30 (16 mandatory and 14 elective) of the 35 MSc courses. Circles represent the mastery levels required for MSc graduates according to industry.

practised by students are (appropriately) assessed and whether students are aware that they are being taught these TCs let alone being assessed on their mastery.

What was also apparent from the questionnaire is that the lecturers had no problem using the instrument to map the level at which TCs are being practised and taught. It is impossible from our finding to state whether the TCs are sufficiently taught in the complete curriculum. For that much more in-depth research into curriculum content is necessary.

## *Educational practise and methods to address TCs*

To further investigate the suitability of the instrument for lecturers to map and assess TCs, 5 lecturers were interviewed. Four categories: (C1) problem-solving, (C2) teaching activities, (C3) coaching and (C4) student-centred activities emerged from the analysis of the interviews on the lecturers' perspectives on how students reached the levels required by the industry in the following TCs: *problem-solving*, *critical thinking*, *actively seeking learning*, *self-knowledge awareness*, *risk tolerance*, *time management*, *listening skills*, *writing skills*, *interdisciplinary thinking*, *financial awareness*, *negotiation skills*,

**Table 3.** Analysis of lecturers' perspectives on how students reached the levels required by the industry in the following competencies: *problem-solving*, *critical thinking*, *actively seeking learning*, *self-knowledge awareness*, *risk tolerance*, *time management*, *listening skills*, *writing skills*, *interdisciplinary thinking*, *financial awareness*, *negotiation skills*, *leadership*, *ideation* and *idea implementation* using the instrument created.

| | Categories | Themes |
|---|---|---|
| **Lecturers' perspectives** | C1: Problem-solving | Type of problems<br>Formulate problems<br>Brainstorm and generate ideas<br>Assess and mitigate risk<br>Develop and evaluate solutions<br>Show feasibility of ideas<br>Verify and validate findings<br>Implement ideas<br>Defend/Justify choices<br>Analyse cost |
| | C2: Teaching activities | Lecturing<br>Homework<br>Reports<br>Exams/tests<br>Assignments<br>Quizzes<br>Exercises<br>Interviews |
| | C3: Coaching | Feedback<br>Asking questions<br>Reflection<br>Help/guidance<br>Role-play<br>Availability |
| | C4: Student-centred activities | Work independently<br>Responsibility<br>Interaction with people<br>Mix of expertise<br>Plan<br>Roles<br>Deadlines/milestones<br>Appointments<br>Tasks |

*leadership*, *ideation* and *idea implementation*. The most prominent themes were grouped under one category as shown in Table 3. The findings of the interviews show that lecturers were able to use the instrument to identify practices and methods they use to reach the TC levels industry required for engineering graduates.

### *C1 – Problem-solving*

Themes in this category relate to the nature of problems lectures give to students identified with the instrument and the process used to solve them.

Using the instrument, lecturers identified they used multiple types of problems from well-defined to open-ended, ill-defined and authentic real-world problems to develop students' *problem-solving*, *critical thinking*, *ideation*, *idea implementation* and *negotiation skills*. The instrument encouraged them to specify how these competencies are practised. They mentioned that when solving these problems with multiple possible solutions, students go through a learning cycle in which they are given a challenge (problem, scenario or case) with or without requirements to be fulfilled, they have to brainstorm and generate ideas, assess and mitigate their risks and converge to one idea which they have to justify their choices, prove its feasibility and verify and validate the results so that it can be implemented. An example of how L3 uses the instrument to address *ideation* is:

> So, they reach level two because […] they find out the gaps that exist in the literature and they have to be creative to address those gaps during their thesis.

Lecturers also identified with the instrument that students practise *self-knowledge awareness* and *actively seeking learning* when students are confronted with the formulation of problems because they need to define the gaps existing in literature and evaluate different options. L4 expresses this as:

> They end up doing a, taking stock of where their own gaps in skills and abilities relevant for their thesis are and they realize that they have to catch up.

Also, in the process of problem-solving, lecturers use the instrument to reflect on the practice of *risk tolerance* and *financial awareness*. This is shown by L1 in the following statements:

> It was a bit of difficulty choosing between level two and level three, but a risk analysis, a risk assessment and risk mitigation is an integral part of the DSE. We want that in the early design phase, but also in a detailed design phase […]. That's why I chose more than level two.

> Well, we require them to make a cost analysis and give it some thought. Really at the minimum level. I'd say little awareness of financial capital, cash flow, etc.

Moreover, because of time and resources constraints, lecturers perceived that students reach the minimum level indicated by the industry in *idea implementation* (even though they did not implement the idea generated) if students prove that their idea is feasible. L5 expressed this as follows:

> So, the idea implementation in the DSE, once they have an idea and they've narrowed down to a concept […] and really check the feasibility of it. They need to do the calculations to show that it is indeed feasible that if someone would take that further into manufacturing and flying that would be feasible.

However, in other courses lecturers indicated higher levels, as expressed by L5:

> Students are really implementing it and […] from the ideation and the design phase they need to make it into a model or experiments and then get the conclusions out of it.

### *C2 – Teaching activities*

This category focuses on the teaching activities lecturers recognised using the instrument they practise to address the TC levels.

When presented the TCs, lecturers mentioned they use lecturing to teach or create awareness of TCs such as *critical thinking*, *ideation*, *financial awareness* and *writing skills*. Examples of these were:

> [We] explain a little bit the pros and cons [of the design choices] and how this goes in a design process. (L1)

> We talk about brainstorming sessions with also ideation phases, design thinking. (L1)

> I tell them, for instance, a little bit about how big aerospace projects are run, how the investments and the money within capital is needed. (L2)

> They have had previous training in written communication. (L1)

The instrument was also used by lecturers to identify homework and exams/tests as a method to develop students' *actively seeking learning*. An example of how L4 uses homework to address *actively seeking learning is*:

> They are assigned much more complicated practice problems and homework problems, and they really have to struggle and discuss with their peers about the solution approaches.

Lecturers also recognised using the instrument that they use exams and tests to practise students' *time management* as reported by L4:

> To sort of facilitate that, we've tried to create some structure with the more frequent tests to create sort of a motivation to keep up with the study.

The same lecturer uses assignments to address *time management* too. In his course, students 'are on the clock' (L4) to solve a 2-hour case study every week. Assignments also develop students' critical *thinki*ng, *problem solving*, *ideation and idea implementation* according to lecturers. L2 uses the instrument to express how his students achieve *ideation* in the capstone BSc course as follows:

> In the DSE, I think it is a three because they are very creative. They have to come up with concepts. We give them an assignment where we do not have a solution. So, they have to sort out their own ideas and they have to work on that.

Lecturers were also able to identify other teaching activities using the instrument. Lecturers use a system of peer feedback on the written reports to develop students' *writing skills*. L5 mentioned she uses anonymous live quizzes in large classes to address *listening skills*. L4 covers *negotiation skills* with teaching and practising interviewing skills.

### *C3 – Coaching*

This category is concerned with the lecturers' role as facilitators of students' practise of TCs identified with the instrument.

Lecturers mentioned they use coaching when they have the role of supervisors in project-based courses and regular lecturing courses. They recognised using the instrument that coaching helps students to acquire *problem solving* and *critical thinking* because lecturers guide how to address problems that emerge instead of giving the answers. Also, using the instrument, lecturers stated that they help students recognise and develop students' self-knowledge and learn from failure. In this way, they feel students practise *self-knowledge awareness* and *risk tolerance*, respectively. L1 and L4 address these TCs, respectively, as:

> I would just like to know what they think their strengths and weaknesses are (…) we can actually also try to work on strengthening the strengths, but also developing those weaknesses. (L1)

> The other aspect is failures. That is one I spent a lot of time coaching on because students are really upset if their hypothesis is wrong. So, you have to spend a lot of time in trying to separate them from their ego, in wanting to be right, to looking at, well, what can I actually learn from the fact that I wasn't right from the beginning. A lot of talking and sharing my own personal experience. (L4)

With the instrument, lecturers reflect that optional help sessions (sometimes also taught by teaching assistants), where students can discuss doubts about exercises, can develop students' spirit of looking for more knowledge (i.e. *active seeking learning*).

Lecturers also used the instrument to identify questioning as a practice to address *problem solving*, *critical thinking* and *actively seeking learning*. Lecturers ask questions to students before and after solving problems to encourage exploration of meaning, consequences and applications of solutions and to guarantee and check understanding. The following statements, express how L5 addresses *critical thinking* and *listening skills*, respectively:

> And once we have done that step, ask them basically like, does this make sense? Or what we also do is even before we start that step is by looking at the structure, what do you think should be the answer before you actually start calculating?

> I always ask questions whether they understood, so trying to have them rephrase what I said, for instance, just to make sure.

When presented with the competency *interdisciplinary thinking* of the instrument, lecturers stated they use the interaction with clients (real or role-played by supervisors) in project-based courses to practise this competency.

Feedback on students' efforts, skills and learning was also identified as a practice by lecturers using the instrument to develop students' *listening skills*, *actively seeking learning* and *leadership*. An example of how L4 addresses *leadership* is:

> After each of these activities [case-studies] every week we focus, we do a debrief and we focus not on their outcome, but on the process and what went wrong, where, you know, was their communication issues, was their direction issues and identify the barriers to them working as a team and discuss strategies that a leader could use to circumvent those challenges.

Another theme that arose from the interviews was lecturers' availability which develops students' *actively seeking learning*. L3 uses the instrument to reflect on his own practice. He creates specific timeslots e.g. at the end of the class and some hours during the weeks before the exam so that students can come and ask questions and he encourages students to ask questions by email, especially in large classes where often there is no time in the class or students feel too intimidated to ask question in front of their peers.

### *C4 – student-centred activities*

This category relates to students' tasks and interaction with people when they work individually or in teams.

When presented with the instrument, lecturers mentioned that students develop *actively seeking learning* and *time management* by giving them responsibility and autonomy. This spirit of responsibility and working independently is stimulated in the assignments and exams and tests with fixed and strict deadlines to be fulfilled by the students as well as in the MSc thesis in which students need to set their own milestones because 'there are no real deadlines' (L5). According to lecturers, *time management* is also achieved at high levels when assignments are built without a predefined plan, roles and tasks and preliminary appointments so that students have to be independent and responsible for that. L5 expresses this as follows:

> So, they could basically structure that themselves in terms of time management. They were able to identify the tasks because we didn't give the tasks to them. So, they need to figure out what they needed to do in order to get to the final aim. And that's what we expected. They could reach us if they wanted to. So, they could schedule an appointment with us, but they didn't use that too often. So, that's why I put it at a two rather than a three.

When presented with the competency *leadership*, most of the lecturers mentioned that students have different leadership roles and because of that they achieve different levels. Examples of these were:

> Not all of them [students] will take up a leadership role (L1)

> Actually, what you often see in the DSE team is, you see both level one and two, but I think the better ones can achieve two here. If you have a team of 10 students, then usually three or four will achieve level two and maybe two or three will stay at level one. (L2)

However, L4 makes sure that all students reach the level required by industry, as mentioned:

> I try and ensure that everybody within the team, at least for one of those weeks, has to take the role of the investigator in charge, the IIC, in a leadership role.

Using the instrument, lecturers recognise that working in groups and working with external advisors is beneficial for students to recognise their strengths and weaknesses and thus develop *self-knowledge awareness*. An example of how L3 reflects on how students achieve the highest level for *self-knowledge awareness* with external advisors is:

> Their [external advisors] line of questioning is often different from the line of questions that we have at the university (…) they help also the students to be aware of what is what will be expected from them when they finish their studies and have to look for a job.

Other lecturers stated that the interaction with experts should be used to look for knowledge, thus with the instrument, they recognised that students practise *actively seeking learning*.

Finally, lecturers indicated with the instrument that students practise *interdisciplinary thinking* in teams (often arranged by lecturers) when there is the possibility to mix students from different backgrounds. In the curriculum, this happens in the capstone BSc project and in some elective courses of the MSc where students from more than one aerospace engineering track can attend. An example of L1 is:

> They have to integrate with all the aerospace disciplines and every now and then, also look beyond their borders and go into other fields, electrical engineering, but also management, maybe civil engineering.

## Discussion

In this study, an instrument was developed to contribute towards solving the problem of lack of TCs in engineering graduates as perceived by industry. This instrument is characterised by providing definitions for each transversal competency, dividing them into sub-competencies and presenting objective descriptive scales. This instrument was then given to both industry and academic stakeholders to see if it was useable. In this discussion section, the answers to the sub-research questions are discussed.

### *European industry perspective*

The instrument was used to find out the desired TC levels of BSc and MSc graduates according to European industry. The findings showed a common agreement between the TCs with highest levels for BSc and MSc graduates perceived by the industry, as seven transversal competencies: *strengths and weaknesses awareness*, *listening skills*, *actively seeking learning*, *interdisciplinary thinking*, *time management*, *writing skills* and *risk tolerance* were in the top 10 highest mastery levels for both. Nonetheless, small differences in the top TCs of highest levels exist. TCs in the top highest mastery levels of BSc graduates are perhaps expected to be mastered by the time they start the MSc degree. Hence, the emphasis shifts at the MSc level to different competencies that are possibly more advanced competencies. It seems that there is a natural order of development of competencies, i.e. students need to develop some TCs first to be able to develop other competencies. For example, BSc students should reach high levels of *English language skills* to be able to successfully present their work and reach high levels for *presentation skills* required by industry at MSc graduation.

This instrument was also used to identify the most important transversal competencies for engineering graduates, which include *actively seeking learning*, *strengths and weaknesses awareness*, *problem solving*, *autonomous work*, *project management*, *curious for innovation*, *engagement in teamwork*, *technology benchmarking*, *collaborative goal oriented* and *adaptive communication style*.

The new approach taken in this study, of investigating not only the important competencies for engineering graduates but also to look into the mastery levels required, makes direct comparison with previous studies in literature difficult as literature mainly focused on the most important TCs. However, consistent with previous studies, *problem-solving* (Saunders-Smits and de Graaff 2012; Passow and Passow 2012; Passow and Passow 2017; Meier, Williams, and Humphreys 2000; Male, Bush, and Chapman 2011), *actively seeking learning* (Nair, Patil, and Mertova 2009) and *self-knowledge awareness* (Scott and Yates 2002) are ranked in the top of important TCs and in our study, they were considered both the most important TCs and requiring the highest levels.

Interestingly, the tops of the most important TCs and the TCs with the highest levels differ substantially. TCs present in both tops must be the focus of engineering institutions. Universities should expose students frequently to the TCs which require high mastery levels from the start of engineering degrees so that students possess high levels when they graduate. The most important TCs, not requiring high levels, should not be discarded. Perhaps, they should be introduced at a later stage in the MSc degree where students have consolidated other TCs and can be open to more TCs. However, research needs to be conducted to investigate the potential relationships between the most important TCs and the TCs with the highest levels and how they complement one another.

In our study, *curious for innovation* and *technology benchmarking* were considered important TCs. Similar findings were shown by Spinks, et al. (Spinks, Silburn, and Birchall 2006), where business and commercial competencies, creativity and innovation were requirements for future engineers according to stakeholders.

Communication as a whole (Spinks, Silburn, and Birchall 2006; Passow and Passow 2012), or divided into sub-components such as written and oral communication (Saunders-Smits and de Graaff 2012; Nair, Patil, and Mertova 2009) and listening skills (Meier, Williams, and Humphreys 2000; Scott and Yates 2002), was considered one of the essential TCs for engineers' success. As described by Trevelyan (2010), young engineers spend a great part of their working time communicating in several forms such as writing, listening, having meetings and phone calls. Corroborating these findings are the fact that industry requires high mastery levels in *listening skills*, *writing skills* and *presentation skills* for graduates and industry also thinks it is important that graduates are able to adapt their communication style.

Another competency recognised in previous studies (Spinks, Silburn, and Birchall 2006; Saunders-Smits and de Graaff 2012; Passow and Passow 2012; Meier, Williams, and Humphreys 2000; Brumm, Hanneman, and Mickelson 2006; Nair, Patil, and Mertova 2009; Male, Bush, and Chapman 2011; Scott and Yates 2002) as very important for engineering graduates is teamwork. In our study, *collaborative goal-oriented* was also considered a key competency and it should already be mastered during the BSc. The importance of working in diverse teams was identified by employers in Male, Bush, and Chapman (2011) and in our study, this competency (called *interdisciplinary thinking*) was pointed out by industry as requiring high levels for BSc and MSc graduates.

More advanced TCs, such as *idea implementation*, *stakeholder management*, *leadership*, *negotiation skills*, *financial awareness* and *activity participation* were considered less important and lower levels of mastery were required. This could be an indication that less focus by the university may be given to them. Perhaps, students are not expected to develop them at university but at a later stage in their life, when they have already entered the labour market and are working as engineers.

### *TCs required by industry addressed in the BSc and MSc programmes*

The usability of the instrument was also tested by mapping TC learning outcomes against reported learning outcomes in formal course documentation and by asking lecturers to use the instrument to list the TCs they expose students to in their courses. The instrument was also employed to indicate practices and methods used in courses by lecturers to reach the TCs required by industry. The findings showed that the instrument was suitable to map TC learning outcomes against reported learning outcomes in formal course documentation and for lecturers to map TCs in their courses. When comparing the mapping of the formal TC learning outcomes of each course in the BSc and MSc curricula studied to the mapping by lecturers of the TCs they feel they teach in their courses, a gap between the formal and perceived curriculum was revealed. This gap itself is not new and was first identified by van den Akker, et al. (2003). In the context of this study, lecturers perceived students practised more TCs in their courses than lecturers themselves wrote down as formal course learning outcomes. Consequences can arise when the content of the courses is not properly highlighted in the learning outcomes. First, students do not know what they can learn from each course and may not even feel they were taught a particular competency. Second, students have insufficient information to make informed decisions when they need to select courses. Third, students can legally not be assessed on the outcomes that are not listed in the study guide nor can quality control take place on whether the TCs are taught to a specified level. Next, if it is unclear what TCs are taught to what level in each course, it may be hard to prove to accreditation boards that the TCs in question are taught to the level specified. Furthermore, not making the TC learning outcomes' explicit can result in the delivery of such outcomes being dependent on the individual lecturers and consequently there may be incoherency in terms of the range and levels achieved by students during their degree. Finally, another vulnerability here is that when courses change lecturer due to staff changes the strategic integration of TCs will be difficult to achieve or monitor. It also appears from this finding that TCs are taught in the engineering curriculum but not seen by teaching staff nor management as necessary to incorporate in the learning outcomes.

Improvements in the description of course learning outcomes with regards to the inclusion of TCs and with that the access for students to acquiring TCs is needed. Uncovering the implicit TCs hidden in the learning outcomes and shifting to a practice of explicitly stating and assessing TCs will need significant investment from educators. Explicitly formulated TCs in the learning outcomes will also help students to develop a better lexicon for the TCs they need in the labour market. This will also clarify which TCs are included in engineering programmes and to what level, which subsequently will make the assessment by accreditation boards more straightforward. The nuanced sub-competencies with definitions and descriptive levels in the instrument have proven to be a possible aid in describing the learning outcomes for TCs as it was found that lecturers were able to qualify the TC content in their course using the instrument.

Lecturers were able to use the instrument to map the TCs in their courses and from the interviews it was apparent that lecturers could also use the instrument to identify practises and methods that they use to expose students to the TC levels required by industry. From a lecturer's perspective, students practise to at least the TC level required by industry in at least one course in the BSc and MSc, respectively. As our analysis was carried out at course level and not at a curriculum level, we cannot state whether all TCs are sufficiently taught over the whole curriculum. Also, based on the outcomes of this study we cannot quantify when students reach the required TC levels or what level of exposure and practice to TCs is needed to reach the required level. For this, further research into the curriculum and its delivery is needed. However we are able to make some statements with regards to practises currently employed by the lecturers to develop TCs in students which were identified using the instrument: first, the use of project-based learning with assignments (Saunders-Smits et al. 2012; Saunders-Smits, Schuurman, and Rans 2015) that allow students the opportunity to produce real(istic) products or services, ideally with real clients (Prince 2004) and the exposure to many different problems (open-ended, ill-structured, ambiguous and complex) throughout students' degrees. In these problems, not only the technological answers are considered but also non-engineering contextual factors/constraints such as costs, time and functionality, as it happens in real engineering life (Jonassen, Strobel, and Lee 2006). Second, lecturers used explicit coaching for students where they provide guidance and feedback in regular and project-based courses (Prince 2004) and challenge students with questioning. Finally, lecturers used student-centred activities to impose responsibility and autonomy of students' learning (Prince and Felder 2006). These concrete examples provided by lecturers provide evidence that the instrument can be used by lecturers to assess the practices they use in their courses to reach the TC levels.

## Conclusion, limitations and future work

This study reports on the development of an instrument that measures perceptions of TCs based on an existing instrument used in industry. The main conclusion of this study is that the instrument is an effective way to measure the perspectives of industry on the required TC levels for engineering graduates and to what extent these levels indicated by industry are covered in representative engineering degrees both by looking at the stated learning outcomes of the courses and by asking lecturers to reflect on the TCs taught in their courses. This instrument is effective because it provides definitions for each transversal competency, stratifies them into more nuanced sub-competencies and presents a more objective measure as the often-used numbered Likert scale is replaced by descriptive scales. We recommend educators to use this instrument to self-assess their course practises and assess students' learning outcomes. Also, the desired industry TC levels required for engineering graduates identified using the instrument help those involved in engineering education to focus on the right TCs at the level required by the employers of future engineers.

An additional finding is that lecturers report that their students practise TCs in their courses but that these TCs are not stated in the course documented learning outcomes, indicative of a gap between the formal and the perceived curriculum. We believe that the instrument is also suitable to identify any such gaps in other engineering programmes. We recommend that a detailed description of taught TCs in the learning outcomes is a step to be taken by educators in engineering. This will facilitate students in developing an awareness of the importance of TCs for their future careers, in deciding what courses are more appropriate to develop their desired competencies and to create visibility and controllability of which TCs are acquired during these courses and to what level to aid educational management.

The current study has some limitations. The industry sample was not very big, a larger sample with more industry representatives would have been desirable. Also, the focus of the interviews conducted with the lecturers was on the teaching activities and methods used to achieve students' TC levels and not on the assessment of the TCs. Future research focusing on how to assess and evaluate the TC levels that lecturers indicated their students acquire in the courses is needed to verify the constructive alignment between the learning outcomes, the teaching activities and the assessment tasks used by the lecturers. This inevitably includes a study of the transversal competencies students perceive they develop throughout their degree and compare the results of the students to the answers of the surveyed lecturers to verify the existence of differences among the formal, perceived and experiential curriculum, *i.e. learning experiences as perceived by learners* (van den Akker, Kuiper, and Hameyer 2003). Alternatively, course observations to focus on the operational curriculum, i.e. *the actual process of teaching and learning or curriculum-in-action* (van den Akker, Kuiper, and Hameyer 2003) can be used to investigate the accuracy of lecturers' perspectives and thus verify the gap identified. Finally, it may be of interest to study which TCs students feel they practise throughout their degrees and also compare these to the answers of the lecturers.

## Acknowledgements

The authors would like to thank all industry representatives and lecturers who participated in this study. Another big thank you goes to Prof. Marc de Vries of Delft University of Technology for his extremely valuable and constructive feedback on this paper. 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 (http://www.preferproject.eu/).

## Disclosure statement

No potential conflict of interest was reported by the author(s).

## Funding

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 (http://www.preferproject.eu/).

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