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Testing the Validity and Reliability of an Instrument Measuring Engineering Students' Perceptions of Transversal Competency Levels

Mariana Leandro Cruz, Maartje E. D. van den Bogaard, Gillian N. Saunders-Smits, and Pim Groen

Abstract*—*Contribution: **This study reports on a reliable and valid instrument that measures engineering students' perceptions of their competency levels. A better understanding of students' needs in engineering curricula will support the development of engineering students' transversal competencies.**

Background: **Prior research has investigated how engineering students perceive competency levels in transversal competencies. However, limitations in the competency definition, psychometric properties, and generalizability were found.**

Research questions: **1) What is the reliability and validity of the competency level instrument? and 2) what are the transversal competency level perceptions of engineering Bachelor and Master students?**

Methodology: **A questionnaire consisting of 36 transversal competencies was designed based on an existing industry model and administered to 1087 engineering Bachelor and Master students from the University of Technology, The Netherlands. Validity and reliability were tested through exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) and Cronbach's alpha.**

Findings: **EFA resulted in five scales with reliable Cronbach's alpha values. CFA demonstrated a good model fit for the five-factor model with 25 items. Students perceived they are most competent in teamwork and lifelong learning competencies and less competent in entrepreneurial competencies.**

***Index Terms*—Competency level measurement, engineering education, reliability, student perception, survey, transversal competencies and validity.**

I. Introduction

THE POSSESSION of transversal competencies, also known as professional skills, are a standard requirement for employers of engineering graduates. To accommodate the changes and demands of society, employers of engineering graduates call for engineers to possess both technical and transversal competencies [1], [2]. Therefore, accreditation bodies such as the ABET Engineering Criteria [3] in the USA and the European Network for Engineering Accreditation [4] in Europe and engineering institutions themselves [5] have emphasized the incorporation of transversal competencies into engineering education curricula. These transversal competencies consist of competencies such as communication, teamwork, entrepreneurship, and lifelong learning.

As part of the European project PREFER (Professional Roles and Employability of Future Engineers), curriculum elements such as activities, courses, and workshops have been developed to address the competency needs of engineering students and better prepare them for employment. To better understand students' needs in engineering curricula and determine which transversal competencies and mastery levels to focus on in the design of these elements, an instrument that could measure students' competency levels according to the perceptions of the industry, lecturers and students were needed.

Previous studies have focused on graduates' perceptions of the most important competencies to the engineering field [6]–[8] and students' perception of their competency mastery levels [9], [10]. These perceptions refer to beliefs or opinions. Research studies often use perceptions because they are easy to use and alternatives are labor intensive and not always easy to implement, especially with large samples [11]. Second, it is important for students to learn to reflect on their competency levels as part of their education [12], [13] as it makes students aware of their transversal competencies and mastery levels, and hence students are able to identify weaknesses, strengths, and needs [14], which are required for a successful student and professional careers.

The instruments used in the literature to measure or research perceptions of competencies have limitations [15]. They often lack competency definitions, psychometric property analysis [12], [15], and generalizability of the results [9], [12]. The purpose of this study is to test the validity and reliability of an instrument created to overcome the limitations found in the literature. This instrument addresses five main domains: communication, teamwork, lifelong learning, innovation, and entrepreneurial competencies and provides definitions for each competency and mastery levels based on an existing industry competency model.

This study was carried out among aerospace engineering students from the University of Technology, the Netherlands. In the Dutch engineering education system, both Bachelor and Master graduates should be competent in seven areas, notably: competent in one or more scientific disciplines in research, in design, and in co-operation and communication, have a scientific approach, possess basic intellectual skills,

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and take account of the temporal and social context [16]. ABET accreditation standards use the same criteria for technical and transversal skills across all accredited engineering programs [3]. In both cases, transversal competencies are used interchangeably between engineering disciplines. Therefore, the outcomes of this study can be applied to any engineering context including electrical engineering.

II. Background Literature

A. Transversal Competencies in Engineering Education

Transversal competencies have gained importance in engineering higher education over the past decades. To understand their importance for effective professional practice, Passow and Passow [8] have studied which competencies engineering graduates of 11 engineering disciplines perceive as most important in their professional life. Saunders-Smits [7] in her doctoral thesis asked aerospace alumni of the Delft University of Technology, the Netherlands, to rate the importance of 12 competencies for their present job. Meier *et al.* [6] investigated the importance of 54 competencies to engineers according to 415 business managers. Problem-solving, communication, and teamwork were considered highly important in all these studies. These findings are corroborated in the systematic reviews of Passow and Passow [17] and Abdulwahed *et al.* [18].

Prior research was not only just focused on the important competencies necessary for a successful engineering career, but also on the mastery level in transversal competencies as perceived by engineering students. Direito *et al.* [10] generated a list of 29 skills and asked undergraduate engineering students of four Portuguese institutions to rate their proficiency in each skill and their importance for their future employment. Using a validated questionnaire, Chan *et al.* [9] investigated the perceived importance of and competency levels in 38 skills of first-year engineering students at three universities in Hong Kong. The same questionnaire was used later by Chan and Fong [19] to compare the perceptions of competency importance and levels between engineering and business students in Hong Kong.

B. Self-Perception of Transversal Competencies

All these previous studies have investigated self-perceptions as does this study. Self-perception of competencies is the reported self-efficacy in performing competencies [20]. Self-perceptions are frequently used in education research, in part due to their ease of use and also because few nonlabor intensive and workable alternatives exist, especially for large groups [11]. However, using perceptions as a measurement has a downside.

Research [13], [21], [22] has shown that students overestimate their competencies when asked to self-assess their abilities. However, studies in the medical field [23], [24] demonstrated a better correlation between self-perceived and objectively measured transversal skills compared to practical skills. It stands to argue that the same applies to engineering students, as both are applied degrees. Also, it has been demonstrated that students at higher degree levels, who likely have been more exposed to self-assessment during their degree, are better able to self-assess [25]. Therefore, self-assessment can be a reliable instrument for measurement in research studies if a mix of academic experience (i.e., students of different years of study) is present in the sample.

Next to using self-perception for research purposes, there is also a case to be made to use self-perception as an educational tool to help students learn to self-assess. There is consensus in [12] and [13] that the ability to self-assess and be self-aware is essential in the process of maturing and learning. By being able to self-assess, one can identify weaknesses, strengths, and needs. Engineering students able to recognize gaps in their learning may look for learning in areas of limited competence. Also, the ability to reflect on students' strengths and weaknesses can help them to establish expectations of themselves, goals, and future career needs [14].

Self-assessment (as a possible instrument of self-reflection) is often a requirement in both organizational and professional contexts [26]. Engineers able to recognize that they are not able to complete a task can consult and refer it to another person or recruit additional resources. In contrast, they can offer their expertise to help to solve others' problems.

In summary, students should have an awareness of their transversal competencies and mastery levels because they need to be able to identify their strengths and weaknesses in their studies and professional engineering career. To assist students in this, an instrument allowing them to reflect on their competencies would be useful.

C. Limitations of Measurement Tools in Engineering Education

Previous studies have measured students' perceptions of their competency levels [9], [10], [12]. However, these studies present some limitations. Cruz *et al.* [15], in a systematic review of competency measurement methods, identified that most studies lack definitions of the skills under study. In addition, other studies mentioned that absent [15] or broad [27] definitions make interpretation complicated and may hinder the internal structure of the instrument. Another limiting factor of the measurements was the lack of psychometric properties in studies [12], [15]. Cruz *et al.* [15] mentioned that some studies have shown efforts in this regard. They developed lists of competencies based on industry or academic literature, conducted exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) and tested the reliability of the measurements using Cronbach's α. Chan *et al.* [9] identified these limitations and designed a questionnaire to assess the perceptions of first-year Bachelor engineering students' competency levels in 38 skills based on prior academic literature. This Hong Kong-based study created a valid and reliable instrument with eight scales. However, they pointed out that their study had a limitation regarding the generalizability of the results as the instrument was only based on the perceptions of first-year students who had just started their engineering studies. As a solution, they suggested to measure the competency levels perceived by final-year students and investigate how students develop competencies during their studies.

TABLE I
INFORMATION OF THE NUMBER OF STUDENTS PARTICIPATING IN THE STUDY PER DEGREE (BSC1, BSC2, AND MSC1), GENDER (FEMALE, MALE, AND OTHER), AND NATIONALITY (INTERNATIONAL AND DUTCH) IN THE YEARS 2018 AND 2019. PERCENTAGES REFER TO THE TOTAL NUMBER OF COMPLETED QUESTIONNAIRES ($N = 1087$)

Total	Complete	Gender	Nationality
BSC1 2018 (461)	BSC1 2018 (314; 28.9%)	Female (45; 4.1%) Male (267; 24.6%) Other (2; 0.2%)	International students* (162; 14.9%) Dutch (152; 14.0%)
BSC2 2019 (347)	BSC2 2019 (223; 20.5%)	Female (35; 3.2%) Male (188; 17.3%) Other (0)	International students* (127; 11.7%) Dutch (96; 8.8%)
MSC1 2018 (315)	MSC1 2018 (279; 25.7%)	Female (31; 2.9%) Male (248; 22.8%) Other (0)	International students* (124; 11.4%) Dutch (155; 14.3%)
MSC1 2019 (385)	MSC1 2019 (271; 24.9%)	Female (34; 3.1%) Male (236; 21.7%) Other (1; 0.1%)	International students* (156; 14.4%) Dutch (115; 10.5%)

* From 53 countries of which 3 are African, 7 American, 11 Asian, 2 Australia and 30 European.

D. Industry Competency Model

This study uses a 36 competency instrument with four descriptive levels of mastery created based on the competency model developed by Siemens, a worldwide employer of engineers and partner in the authors' project. This instrument fitted well into the context of the project deliverables and the accompanying time frame. Also, this industry competency framework was chosen because it qualitatively defines skills and skill levels which are being used to assess employees' skills development throughout Siemens.

The Siemens model divides competencies into five domains as shown in Cruz and Saunders-Smits [28]. The first domain, entrepreneurial competencies (ENTREP; seven items), consisted of competencies related to managing and leading people to achieve goals as well as awareness of markets, finances, and business opportunities. The second domain, innovation competencies (INOV; seven items), is defined by items that lead to the generation of ideas and solutions, including thinking critically and solving problems as well as taking into consideration stakeholders and costs. The third domain, communication competencies (CM; nine items), covers oral and written communication and interpersonal skills necessary to convey information and influence audiences. The fourth domain, teamwork competencies (TW; eight items), is characterized by the ability to work in groups and teams related to the well-functioning of a team. The last domain, lifelong learning competencies (LLL; five items), is defined by self-regulation, adapting performance, and search for continuous improvement.

III. METHODS

A. Participants and Data Collection

A paper-based questionnaire was administered to all first- and second-year Bachelor and first-year Master students in aerospace engineering at the University of Technology, the Netherlands, in the first week of the academic years 2018/2019 and 2019/2020. In this article, from here on, all first- and second-year Bachelor students are referred to as BSC1 and BSC2, respectively, and first-year Master students as MSC1.

As stated earlier, within the Netherlands, the four research-based universities of technology have created a set of common learning outcomes which includes transversal skills generic for all engineering disciplines [16]. As all engineering degrees (including degrees in electrical engineering and applied computer science) offered by these institutes are accredited according to these standards, the results of this sample can be seen as representative. Also, this population is well-mixed in terms of nationalities (more than half of the students are non-Dutch and come from five different continents) and years of study (BSC1, BSC2, and MSC1), as well as gender-balanced considering the engineering field.

Ethical permission was granted for this study by the university's Institutional Review Board, and participants were asked for informed consent. A total of 1087 students (72% of the total student population approached to participate) completed the questionnaire and gave consent (Table I).

B. Questionnaire Design and Structure

Participants were asked to indicate what level of expertise on a four-point descriptive Likert scale (0—absent, 1—basic, 2—advanced, and 3—expert) they think they hold for the 36 transversal competencies. The administration time was approximately 15 min.

C. Data Analysis

To answer the first and second research questions, respectively, the psychometric properties (reliability and validity) of the questionnaire and the descriptive statistics (mean and standard deviation of students' self-perceived scores) were calculated and analyzed at factor and item level.

Before starting on the factor analyses, the dataset was randomly split into two groups. As proposed by Hair *et al.* [29], EFA was conducted to assess the initial item structure of the competency questionnaire using the first dataset followed by CFA to examine the structure of the factors obtained in the EFA and determines the fit of the model using the second dataset.

EFA was done in SPSS 25 with 544 cases. Correlation between variables and the determinant of the correlation matrix, which should be above 1E-5 to avoid multicollinearity, was investigated [30]. Also, Kaiser-Meyer-Olkin (KMO) and Bartlett's tests were considered. They indicate sampling adequacy and a correlation between items significantly large, respectively. KMO values above 0.9 are considered superb, and KMO values of individual variables are acceptable above 0.5 [30]. Then, the factors were extracted and the eigenvalues and variance within variables calculated. Kaiser's criterion of eigenvalues greater than 1 was assumed because of the large sample size (>250 according to [30]). The underlying factors were evaluated using orthogonal rotation (varimax) to avoid dependency between the factors [30] as the constructs in the initial instrument were not correlated. A cutoff score for the factor loadings of 0.4 was used. Also, factors with fewer than three items were removed [31].

TABLE II
FACTOR LOADINGS DERIVED FROM THE EFA OF 36 ITEMS AND ABOVE 0.4 ARE SHOWN ($N = 544$)

Factors and items	Rotated factor loadings/scales 1	2	3	4	5
Communication Competencies					
Presentation Skills	**0.75**				
Pitching Skills	**0.68**				
Presentation Method	**0.67**				
Adaptive Communication Style	**0.67**				
Self-confidence	**0.65**				
Innovation Competencies					
Ideation		**0.71**			
Curious for Innovation		**0.62**			
Critical Thinking		**0.61**			
Problem Solving		**0.61**			
Idea Implementation		**0.58**			
Entrepreneurial Competencies					
Financial Awareness			**0.71**		
Stakeholder Management			**0.68**		
Business Acumen			**0.63**		
Technology Benchmarking			**0.54**		
Value/Cost Consciousness			**0.46**		
Lifelong Learning Competencies					
Actively Seeking Learning				**0.69**	
Strengths & Weaknesses Awareness				**0.59**	
Autonomous Work				**0.57**	
Time Management				**0.56**	
Professional role awareness				**0.50**	
Teamwork Competencies					
Cross-Cultural Understanding					**0.72**
Managing Conflict					**0.63**
Listening Skills					**0.58**
Interdisciplinary Thinking					**0.58**
Interrelation Ability					**0.42**
Number of items	5	5	5	5	5
Eigenvalue	5.58	2.07	1.59	1.39	1.21
% of variance	22.30	8.30	6.38	5.56	4.82
Item-total correlation	.52-.65	.46-.53	.39-.48	.36-.49	.34-.48
Cronbach's alpha	**0.79**	**0.74**	**0.70**	**0.71**	**0.70**

CFA was tested in SPSS AMOS 25 with 543 cases. Maximum likelihood estimation was used. To assess model fit, comparative fit index (CFI), root-mean-square error of approximation (RMSEA), and the ratio of χ^2 to its degrees of freedom (χ^2/df) were considered. Threshold values of CFI above 0.90, RMSEA below 0.06, and χ^2/df below 3.0 were indicative of a good model fit [32]. The Chi-squared statistic (χ^2) was included in this study but not used as a model fit indicator because it is sensitive to sample size, and it rejects the model for large samples [32].

The internal consistency of each scale was measured through Cronbach's alpha. Item-total correlations lower than 0.3 were pin-pointed as items that do not correlate with the overall score from the scale. Reliable scales were assumed for $\alpha > 0.70$ [30].

IV. RESULTS

A. Questionnaire Construct Validity Evidence

EFA was carried out on the 36 items with varimax rotation. A KMO value of 0.89 was obtained, meaning adequate sample size. The Bartlett's test of sphericity $\chi^2(630) = 4809.9, p < 0.001$ demonstrated that correlations between items were large. In the first exploratory phase, five items were removed as two items (English language and writing skills) loaded to a single factor, the item risk tolerance had a negative loading, and the other two items (collaborative goal-oriented and negotiation skills) had factor loadings below 0.4. Therefore, a second analysis was performed with 31 items. Two other items (giving constructive feedback and noncredit activity participation) were deleted as they had factor loadings below 0.4. Another item (engagement in teamwork) was removed in a third analysis for the same reason. In the following analysis, a sixth factor composed of three items (leadership, goal settings, and project management) was deleted because it did not meet the reliability threshold. The final model had five factors: communication (CM; five items), innovation (INNOV; five items), entrepreneurial (ENTREP; five items), lifelong learning (LLL; five items), and teamwork (TW; five items) competencies with eigenvalues over Kaiser's criterion of 1 and together they explained 47.4% of the variance. Their factor loadings are shown in Table II. The total explained variance is 47.4%.

Cronbach's alpha was calculated for each scale to test the reliability of the instrument. Cronbach's alpha values ranged from 0.66 to 0.79 (Table II). The item-total correlation ranged from 0.34 to 0.65 indicating that the items correlated with the overall score of each scale. The findings showed that five scales: CM, INNOV, ENTREP, LLL, and TW demonstrated moderate to high consistency.

CFA was performed to test the factor structure of the instrument. The five-factor model obtained from the EFA presented a $\chi^2 = 581,5, df = 265, p < 0.001$ and it showed good fit: $\chi^2/df = 2.194$ (<3.0), RMSEA = 0.047 (<0.06), and CFI = 0.901 (>0.90). The standardized estimates of this model ranged from 0.43 to 0.77. Therefore, this instrument is valid.

B. Descriptive Statistics

The means and standard deviations for the perceptions of the combined students' competency levels for the (new) five-factor instrument (including the individual items) are reported in Table III.

The highest competency levels were found for teamwork and lifelong learning competencies and the lowest for entrepreneurial competencies. When looking at the item level, the five highest competency levels perceived by students were listening skills, strengths and weaknesses awareness, cross-cultural understanding, actively seeking learning, and problem-solving (marked in Table III with *), while the five lowest competency levels were stakeholder management, business acumen, financial awareness, idea implementation, and technology benchmarking (marked in Table III with #).

V. DISCUSSION

The original competency model comprised 36 items loading to five scales [28]. After EFA and CFA, the model is still composed of the same five scales: CM, INNOV, ENTREP, LLL, and TW. However, with fewer items and with some differences in each scale. When comparing the initial model (five factors with 36 items) with the new model (five factors with 25 items), the former shows redundancy in the context of this

TABLE III
DESCRIPTIVE STATISTICS OF THE PERCEIVED STUDENTS' COMPETENCY LEVELS OF THE 25-ITEM FIVE-FACTOR INSTRUMENT ($N = 1087$). THE FIVE HIGHEST AND LOWEST COMPETENCY LEVELS PERCEIVED BY STUDENTS ARE HIGHLIGHTED WITH A * AND #, RESPECTIVELY

Competencies	Mean	SD
Communication Competencies	***1,81***	***0,68***
Presentation Skills	1,90	0,74
Pitching Skills	1,57	0,70
Presentation Method	1,85	0,61
Adaptive Communication Style	1,82	0,58
Self-confidence	1,92	0,75
Innovation Competencies	***1,84***	***0,62***
Ideation	1,63	0,67
Curious for Innovation	2,05	0,56
Critical Thinking	2,04	0,64
Problem Solving *	2,12	0,57
Idea Implementation #	1,34	0,66
Entrepreneurial Competencies	***1,30***	***0,71***
Financial Awareness #	1,31	0,69
Stakeholder Management #	1,16	0,77
Business Acumen #	1,24	0,75
Technology Benchmarking #	1,37	0,66
Value/Cost Consciousness	1,41	0,69
Lifelong Learning Competencies	***2,10***	***0,66***
Actively Seeking Learning *	2,23	0,63
Strengths & Weaknesses Awareness *	2,48	0,63
Autonomous Work	2,07	0,60
Time Management	1,92	0,75
Professional role awareness	1,81	0,69
Teamwork Competencies	***2,13***	***0,68***
Cross-Cultural Understanding *	2,30	0,73
Managing Conflict	2,09	0,65
Listening Skills *	2,49	0,65
Interdisciplinary Thinking	2,06	0,69
Interrelation Ability	1,73	0,67

study as 11 items were measuring more than needed and the latter robustly measures engineering students' perceptions of mastery levels.

In the new model as listed in Table III, the first scale (CM) is defined by oral communication and ability and confidence to express information to different audiences. A scale involving oral communication and the use of influential communication is present in the study of Lizzio and Wilson [12]. The CM scale in the new model has lost four items present in the initial model. Two of them (English language skills and writing skills) were deleted as they loaded to a single factor in the first step of EFA, and the other two items (listening skills and interrelation ability) loaded to the TW scale. Although listening to others was considered part of communication in the study of Lizzio and Wilson [12], listening skills seem to fit well in the TW scale as engineers need to listen when working in teams.

The second scale (INNOV) of the new model is characterized by items that lead to the generation of ideas and solutions. Again similarities were found between this study and Lizzio and Wilson [12]. Both studies suggested an interaction between problem-solving and critical thinking. Although in Chan *et al.* [9] these items belonged to two distinct scales (academic and problem-solving skills and critical thinking), in their new instrument [33], items related to the identification and solving problems and thinking critically loaded to the same scale as in Lizzio and Wilson [12] and in this study.

The INNOV scale of the new model compared to the initial model excluded skills such as stakeholder management and value/cost-consciousness. They load to the ENTREP scale. This finding makes sense as the ENTREP scale includes items related to finances, markets, and business opportunities. Thus, the awareness of stakeholders and value and costs seem to be related to them. The ENTREP scale gains two items but loses four. Two of them (project management and leadership) loaded to an extra factor which was deleted because it showed low reliability, and the other two items were deleted as risk tolerance showed a negative factor and negotiation skills seemed to be redundant due to similarities with pitching skills. This scale seems to be not considered in the previous literature. This gives value to this instrument as it can measure items related to entrepreneurship, important for engineering roles [34].

The fourth scale (LLL) is characterized by self-management, in terms of professional needs, strengths and weaknesses, stick to time frames, and search for continuous improvement autonomously. In this scale, the new model has four items in common with the initial model. One item non-credit activity participation present in the initial model was deleted in the new model as it seemed to have issues shown by the factor loading lower than 0.4. On the other hand, in the new model, this scale has an extra item time management. This item was left on this scale as it is also present in a similar scale named self-management skills of the study of Chan *et al.* [9]. A scale including adaptability, self-management, and self-understanding was also present in Lizzio and Wilson [12] and in the new instrument by Chan and Luk [33].

The fifth scale (TW) in the new model is defined by the ability to work in groups respecting cultural differences and disciplines of knowledge, listening attentively, and managing issues. Three items were maintained from the initial model, and two other items were added. The item listening skills was discussed above. The item interrelation ability was considered appropriate in this scale as teamwork requires interaction and relationships between people. The four items deleted (collaborative goal-oriented, engagement in teamwork, and giving constructive feedback) seemed to show redundancy in the initial model in the context of this study.

This study and the study carried out by Chan *et al.* [9] have similarities which show that the competency levels' perceptions of engineering students in the Netherlands and Hong Kong are alike. However, dissimilarities were also present. The scale interpersonal skills of Chan *et al.* [9] consisted of items related to interaction and communication with others, teamwork, and flexibility. However, in this study as well as in Lizzio and Wilson [12], three distinct scales (CM, TW, and LLL) were demonstrated. The reason presented by Chan *et al.* [9] for this difference between their study and Lizzio and Wilson [12] was discipline generalizability (engineering versus behavioral science, engineering, and management, respectively). Considering the results of this study, the reason may be the different cultural educational background in terms of location and student population of the three studies: 90% Asian in Chan *et al.* [9] versus Western in Lizzio and Wilson [12] and this study (80% Australian and 84% European, respectively). This may be explained by similarities between the European and Australian systems, which have 3-year Bachelor programs and 2-year Master programs combining broad interdisciplinary knowledge and deep core engineering disciplines, versus the Hong Kong system, which after the reformation in 2006 included a student holistic development approach, i.e., "a progressive process through which the intellectual, physical, professional, psychological, social, and spiritual capacities of an individual can be holistically enhanced" [35], which is not implemented in the degrees in Europe and Australia [36]. The fact that students are exposed to different education systems and consequently differently exposed to transversal competencies may influence the way they perceive their competency levels. Thus, more similarities between the system may mean more similarities between students' perceptions.

When looking at the outcomes of the descriptive statistics, students perceived they were most competent in teamwork and lifelong learning competencies and less competent in entrepreneurial competencies. Previous studies [6]–[8] have shown that engineers highly require teamwork and lifelong learning competencies as in their careers engineers are constantly working with other people engineers and nonengineers, and these competences need continuous development.

Looking at studies that investigated students' competency levels, Chan *et al.* [9] and Direito *et al.* [10] showed that engineering students perceived they were most competent in listening skills. In this study, this competency belonged to the TW factor and students indicated they were highly competent too. High levels for actively seeking learning and problem-solving were also found in Direito *et al.* [10]. In this study, they belonged to LLL and INNOV factors, respectively, and students also perceived high levels of competency. These three competencies are essential for future engineers who need to solve problems constantly and be attentive to the needs of people around them including colleagues but also the wider society and look continuously for opportunities to develop themselves. Although students already feel they are highly competent in these competencies, it is the role of the university to further prepare future engineers with the ability to problem solve, listen to others, and actively looking for more knowledge so that students are prepared for the real-life environment of the labor market.

As innovation is considered a key competency for future engineers by stakeholders [37], it is interesting to see that the INNOV factor was not among the factors that students perceived they were highly competent in. This is mainly due to students feeling they were not very competent in ideation and idea implementation. This outcome was also verified in the following studies [10], [12], [33]. Another similar outcome of the four studies (this study and [10], [12], [33]) was that engineering students felt less competent in pitching and negotiation skills. In this study, this item presented the lowest competency level in the CM factor. Attention to the development of students' ideation, idea implementation and pitching skills should be given by the university, as students felt less competent and these competencies are important for the engineering professional roles developed by Craps *et al.* [34]. Their model highlights the need for the customer intimacy engineer to be able to negotiate with clients and the product leadership engineer to develop new ideas and execute them.

Moreover, the focus of the university should not only be limited to the previous competencies but also entrepreneurial competencies because first engineers are expected to become leaders of the top organizations, refine markets, solve major technological problems, and economic crisis at national and global levels [38], second entrepreneurial competencies were considered important for future engineers by stakeholders [37], and finally, students in this study perceived they were less competent in these competencies. Although the development of entrepreneurial competencies has grown interest in engineering education [39], universities should continue to emphasize the development of these competencies for instance through inductive teaching methods with real-life problems [40].

The transversal competency instrument presented in this study measures students' perceptions of their competency levels to overcome the limitations of the instruments of the previous studies [9], [15]. This is done by providing descriptions for each competency and mastery levels based on an industry-based competency model. The model has been tested using a wide selection of students of different ability in self-perception skills by including students from different years of studies and different nationalities, even though only aerospace engineering students took part in this study. In doing so the study differs from the study of Chan *et al.* [9] that only used first-year engineering students, who have a limited understanding and experience of the engineering disciplines and transversal competencies [13], [41]. Moreover, this sample included a range of different cultural pre-university education backgrounds, i.e., students from several parts of the world participated in this research.

Finally, the results of the EFA and CFA have shown that after a reduction in items, a valid and reliable five-scale, 25-item instrument that measures competency levels has been achieved which can be used both for educational research and as a self-reflection instrument for students.

VI. LIMITATIONS AND FUTURE WORK

The main limitation of this study was that the data collected on the mastery of competency was based on students' perceptions on a list of competencies. Prior research [13], [21], [22] has demonstrated that students are biased when they assess themselves. To reduce this issue of bias, in this research, more mature students (not only first-year Bachelor) were included in the sample as they are considered to have a better understanding and practice of the engineering discipline and transversal competencies [41] and more exposed to self-assessment [25].

For future research, interviews and observations exploring the level of mastery in competencies of Bachelor and Master students may yield additional outcomes on the perceptions of students' competency levels.

The similarities and differences between this study and the studies of Lizzio and Wilson [12] and Chan *et al.* [9] showed that there is a potential role of disciplines and cultural educational background influencing the perceptions of students' competency levels, which can be explored further.

In conclusion, this study has provided a valid and reliable instrument consisting of 25 competencies divided over five scales that can be used to research the mastery levels of engineering students as well as being used as a self-assessment instrument. For the authors, this instrument will help them address the needs of their students and develop their transversal competency levels.

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