UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL
ESCOLA DE ENGENHARIA
DEPARTAMENTO DE ENGENHARIA DE PRODUÇÃO E TRANSPORTES

A FRAMEWORK PROPOSITION OF COMPETENCE-BASED ASSESSMENT IN ENGINEERING UNDERGRADUATE COURSES

Larissa de Oliveira Mallet (UFRGS) - larissam.mallet@gmail.com

Ângela de Moura Ferreira Danilevicz (UFRGS) – angelamfd@producao.ufrgs.br

Abstract

The current engineering training model, based on transmission and reception of knowledge, is facing many challenges in meeting the diverse needs and the growing demands of a global industrial environment. In this context, transversal competences development is gaining strength in higher education, once only mastering technical engineering competences is not enough anymore. Despite the emphasis on the importance of these competences, there is a gap in the literature on appropriate strategies for assessing them. Thus, this study aims to propose a competence-based assessment framework for engineering undergraduate courses. A literature review on transversal competences required from engineers, as well as on existing assessment strategies was made. A set of eight main transversal competences required from engineers was defined and validated through interviews with Competence-Based Education experts and engineers' recruiters. They also contributed to assessment strategies and recommendations on how to build the framework. Additionally, to find out the development and assessment level of transversal competences in their classes, engineering professors were interviewed. Finally, the competence-based assessment framework, as well as a transitional version of it is presented, combining all the obtained information in a coherent and systematic way.

Keywords: transversal competences; competence assessment; Competence-Based Education (CBE); competence rubric; Active Learning

1. INTRODUCTION

The current global scenario is being marked by transformations in the political, economic, technological, scientific, and ethical fields that, together, influence on different areas of social life, such as work organization, production forms and professional training. Continuous adaptation by individuals and organizations has become necessary to keep up with such transformations (CASALE, 2013). According to Herrera, Muñoz, and Salazar (2017), at the corporate level, these transformations require a change in both organizational structure and companies' dynamics, which, therefore, results in a change in the way workers interact and perform their functions.

As our economy evolves, there is growing recognition of the importance of a competent workforce (KLEIN-COLLINS, 2012). At the same time, according to Henri et al. (2017), the current professional training model, based on transmission and reception of knowledge, faces many challenges in meeting the diverse needs of the complex professional performance required in today's society. Ilahi-Amri, Cheniti-Belcadhi and Braham (2017) state that the continued growth and importance of this issue is shaping the new learning environments, posing new challenges, fostering the need for new models and approaches both at the learning and assessment levels. Given this context, the need for change in the field of education becomes evident, especially in higher education institutions, responsible for training professionals to work in today's labor market (BAUGHMAN; BRUMM; MICKELSON, 2012).

Libâneo (2011) points out that higher education institutions that are concerned with meeting the demands and needs of learning in this changing scenario need to reflect on their objectives and the ways of teaching and evaluating. Once recognized the inadequacy of current traditional knowledge-based education model in higher education, there is the need to rethink how new assessment models could be designed to be able to respond effectively to the corporate requirements of the 21st century, promoting a more dynamic interaction between labor demand and education supply (JANG, 2016).

Casale (2013) states that the teaching methodology of engineering courses generally follows an old and traditional perspective, making use of deductive teaching approaches, privileging the transmission of contents in the classroom, usually in a decontextualized way, where the theoretical content has little or no connection with reality. However, according to Cordeiro, Queirós, and Borges (2010), engineering professionals of the 21st century are much less required the technical knowledge and skills of their areas of expertise, and much more the

so-called “soft skills”, which are the ability to solve problems, make decisions, work in teams, and effectively communicate, which is understood by a competence-based approach. There is even a consensus in the engineering community about what those competences should be: communication skills, business skills, teamwork skills, innovation skills, lifelong learning skills, and problem solving skills (BRUNHAVER et al., 2016).

Froyd, Wankat, & Smith (2012) state that, in the last two decades, in response to student and industry demands, Competence-Based Education (CBE) has received increasing attention in engineering education not only in the United States, but also in many universities in Europe, Asia, Australia, and South America. Evidences suggest that CBE can help meet the growing demands of industry for competent engineers by ensuring that graduates have mastered the necessary skills to be successful in the labor market (HENRI et al., 2017). According to Nelson (2013), CBE can be broadly defined as a pedagogical approach that focuses on the mastery of measurable student outcomes. Under the CBE framework, mastery of competences includes the ability to apply knowledge in practical real-life situations and, what sets this system of learning apart from the others, is the shift in focus to behavioral outcomes. Gaertner and McClarty (2015) mention that the credibility of this education system rests on reliable and valid assessments methods of learning outcomes, with evidence-based performance levels.

Despite the emphasis on the importance of developing “soft skills” during engineering undergraduate courses, there is a gap in the literature on clear purposeful strategies for helping students acquire them and appropriate ways for assessing them. Currently, there are no uniformity or agreement upon assessments for engineering competence-based courses; practices differ among universities, and little work has focused on identifying best practices (HENRI et al., 2017). Given this context, and aiming to contribute to the improvement of the teaching and learning process of future engineers, this study intends to answer the following research question: how to assess engineering undergraduate students’ competences? Therefore, the goal is to propose a competence-based assessment framework for engineering undergraduate courses, with potential application to other areas of teaching.

This article is structured into five sections as follows. After this introduction, section two presents the literature review on the following topics: Engineering Students Competences, Existing Approaches to Competence-Based Assessment, Competence-Based Education (CBE) Assessment Strategies, and Framework for Determining Mastery of Competences. Following, in section three, the methodology for the development of this research is addressed. The fourth

section presents the discussion of the obtained results. Finally, in section five, the conclusions of the study are presented, and future research directions are suggested.

2. LITERATURE REVIEW

Over recent years, there has been an increased interest in incorporating competences into educational curriculum to ensure that teaching methods meet industry required needs (BENNANI; HNIDA; IDRISSI, 2016). Bolívar (2015) points out that this fact has involved an interesting debate on what is understood by competence and how to evaluate them.

A Competence-Based Education (CBE) focuses on the outcomes of learning by defining goals and processes to achieve them. It contributes to student's career readiness since the main goal is to let students progress at their own pace and measure their achievement against a standard of performance (EL FALAKI et al., 2010). According to Jang (2016), educational programs based on competences describe skills and capacities that one needs to achieve and should be align with both industry and academic standards.

Blömeke, Gustafsson, & Shavelson (2013) present that competences' assessment within undergraduate courses presents a substantive and methodological challenge, once it comes to learners' cognitive skills, which are considered as unobservable traits, hard to conceive and objectively measure. However, competence-based assessment is an important research topic which might be divided into two open problems: (i) assessment design, which consists in formulating a competence structure to assess and clearly link each competence to an appropriate situation, problem and material; (ii) assessment implementation, that includes means and tools used to capture measurable attributes of competence (BENNANI; HNIDA; IDRISSI, 2016).

Regarding competences, literature offers a variety of definitions to the term. Broadly, a competence can be defined as an intrinsic characteristic of an individual casually related to a high level of knowledge, ability and behavior in executing one or more defined tasks (FERNANDES et al., 2014).

2.1 Engineering students' competences

Winters and Matusovich (2015) state that engineers' competences can be shaped especially while they are still studying. Thus, in order to help new engineers prepare for a successful transition to the labor market, engineering practice is vitally important to understand

what elements shape early career engineers' decisions. The study done by Zaharim et al. (2009) shows that there is a need for engineering programs to improve in all areas, especially in non-technical aspects of engineering education. Moreover, continuously updating and improving the technical engineering skills and knowledge are very important for changes in the technologies growth (GINTERS, 2008).

Given the broad range required from engineering professionals nowadays, generic and specific competences have been put forward by professional engineering bodies. The prevalent approach establishes two categories: transversal competences and technical competences. The first one is related to "soft skills", aspects such as the ability to engage in teamwork, project management, life-long learning, communication, command of a foreign language, among others; while the second one covers the knowledge and skills needed of a specific industry or profession (ROUVRAIS et al, 2006).

Transversal competences are not directly related to the theoretical content of the curricula. They are related to attitudes and values (know how to be), and to procedures (know how), and can be transferred outside of the specific professional field. These competences are of a great importance to enterprises that recruit students after their graduation, and look for trained professionals, thoroughly prepared not only to solve practical problems but also to be successfully integrated in a team work and that have interpersonal skills (SANCHEZ; ALAYÓN; GONZÁLEZ, 2013).

Any engineering pedagogy, including CBE, should not only be effective in producing engineers proficient in technical knowledge and skills, but also those ready to compete in a global economy by possessing the ability to successfully work with diverse groups of people in diverse contexts. A large body of literature on CBE in engineering education addresses the transversal competences, that all engineering students should have by the time they graduate in all areas of engineering across the globe. In this review, those competences are briefly summarized and discussed in Table 1.

Table 1 – Summary of Transversal Competences found in the literature

Transversal Competences	Discussion	Author (Year)
Ethical issues, problem-solving skills, interpersonal skills, leadership, adaptability, teamwork skills, safety issues, interdisciplinary application, communication, and environmental awareness.	These competences were identified as important in the literature for Construction Graduate from an industry perspective.	Ahn, Annie, and Kwon (2012)

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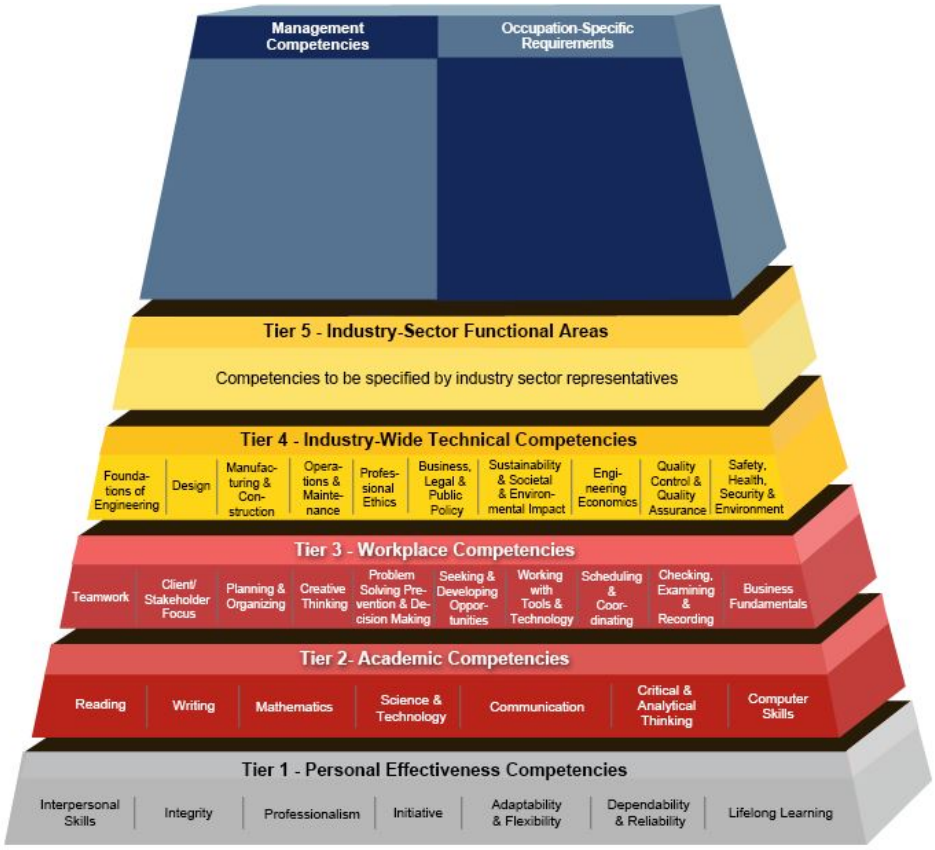
Transversal Competences	Discussion	Author (Year)
Cross-cultural communication, coming up with innovative solutions, world knowledge, ability to solve problems, teamwork skills, leadership and management, emotional awareness, and engineering specific cross-cultural competences.	This study approaches a set of global engineering competences, which were validated by professionals, industry experts and academics.	Ball et al. (2012)
Self-management, problem solving, recognition of life long learning need, teamwork, leadership, communication, corporate and social responsibility, emotional awareness, and coping with pressure.	The nine clusters of competences identified provide the skills engineers need to work efficiently in the global industry.	Bish, Newton, Browning, O'Connor, and Anibaldi (2014)
Foreign language proficiency, leadership, cross-cultural adaptability, innovative thinking, personal autonomy, flexibility and openness, and emotional resilience.	This article discusses orientation strategies designed to improve student readiness for global practice and suggests assessment tools for necessary global competences	Jesiek et al., (2014)
The ability to work in multidisciplinary teams, the capability of efficient oral and written communication, the pursuit of life-long learning, creative thinking, contemporary issues awareness, and ethical principles.	Strategies to promote the development of professional skills are discussed. Challenges and problems that typically arise when implementing those strategies are also discussed and several solutions are proposed.	Lantada, Bayo, and De Juanes Marquez Sevillano (2014)
Ability to solve problems, work in teams, manage time, resolve conflict, flexibility, work autonomously, appreciate multiculturalism, and capacity to generate innovative ideas and learn continuously	The goal was to develop a list of professional competences for all engineering programs in Russia.	Lunev, Petrova, and Zaripova (2013)
Contemporary knowledge, working under pressure, develop innovative ideas, emotional intelligence, leadership and prioritizing tasks.	These competences, rather than being targeted by instructors, they tend to be taught incidentally.	Walther et al., (2011)

Source: (summarized by the author)

The American Association of Engineering Societies and the U.S. Department of Labor have developed the Engineering Competency Model (Figure 1), which outlines the core competences needed for workers to perform successfully in the Engineering profession, into five tiers.

Figure 1 – Engineering Competency Model



Source: American Association of Engineering Societies (2015) – http://www.aaes.org/model

According to the Employment and Training Administration – U.S. Department of Labor (2015), the model is depicted as a pyramid consisting of several tiers so as to represent the increasing specialization and specificity of proficiencies covered. Tiers 1 to 3 are named "Foundational Competences", and represent the "soft skills" and work readiness skills that most employers demand in all industries. Tiers 4 to 5 are named "Industry-Specific Competences", and show the industry-wide technical competences needed to allow a worker to move easily across industry sub-sectors.

Each tier covers a different group of competences:

- **Tier 1 – Personal Effectiveness Competences** are personal attributes essential for all life roles. Often referred to as "soft skills", this kind of competences are generally learned at home or in the community, and improved at school and in the workplace.
- **Tier 2 – Academic Competences** are primarily learned in a school setting and include cognitive functions and thinking styles. Academic competences are likely to apply to all industries and occupations.

- **Tier 3 – Workplace Competences** represent motives and traits, as well as interpersonal and self-management styles. They are generally applicable to a large number of occupations and industries.
- **Tier 4 – Industry-Wide Technical Competences** cover the knowledge, skills, and abilities from which workers across the industry can benefit, regardless of the sector in which they operate.
- **Tier 5 – Industry-Sector Technical Competences** represent a sub-set of industry technical competences that are specific to an industry sector.

While the model attempts to cover a wide range of industry competences, the model is not intended to be a definitive list of all engineering knowledge, skills, and abilities; nor it is intended that all workers in the field possess all competences listed. The Engineering Competency Model is instead intended as a resource for further explorations of the competences needed in this critical field (ETA – U.S. DEPARTMENT OF LABOR, 2015).

2.2 Existing approaches to competence-based assessments

Assessment quality has been an important research topic since competence-based programs first existed (GAERTNER; MCCLARTY, 2015). A study carried out by John Harris and Stephen Keller, in 1976, concluded that the major development effort in competence-based education should not lie in design of instructional materials, but in design of appropriate performance assessments. In addition, institutions should not commit themselves to competence-based curriculum unless they possess means to directly assess students' performance. According to Gaston (2014), nearly 45 years later, that imperative persists.

When developing competence assessments, there are two crucial stages. The first one is defining a relevant set of competences for evaluation. The second stage is defining a competence-based assessment strategy, which means, to identify the best way through which the student will demonstrate the application of the competences being evaluated (GAERTNER; MCCLARTY, 2015).

2.2.1 Competence-Based Education (CBE) assessment strategies

Whenever possible, competence-based assessments must do more than just measure what a student knows. It must also determine whether the student can apply what he or she knows to real life programs and situations (KLEIN-COLLINS, 2013). Ewell (2013) also suggests that assessments should measure whether students are able to tackle "nonstandard, unscripted problems and questions" because universities must prepare learners to deal with the complex and uncertain, not just with the rote and routine. This way, a multiple-choice standardized test is likely inadequate to assess most competences.

According to Voogt and Roblin (2010), transversal competences can be assessed through summative and formative assessments. Formative assessment is part of the instructional process and it occurs during learning activities conducted, while summative assessments are given periodically to determine at a particular point in time (usually in the end of a lesson or module) what students know and do not know (DIXSON; WORREL, 2016). As in Vonderwell & Boboc (2013), the feedback in formative assessment can foster student engagement, improved achievement and enhance motivation to learn.

Different instruments can be used to support formative and summative assessment. Standardized tests, essays and student's presentations at the end of a course or unit are typically regarded as summative assessment instruments; whereas portfolios, self-assessment, peer-assessment, and systematic observations of learning are most commonly used as formative assessment instruments (VOOGT; ROBLIN, 2010).

The CBE assessment strategies found in the literature are summarized and discussed in Table 2.

Table 2 – Summary of assessment strategies found in the literature

Assessment Strategy (AS)	Discussion
AS1. Project-Based	Systematic pedagogical method that engages students in learning knowledge and skills through an extended inquiry process structured around complex, authentic questions. It facilitates efforts at what has become known as "bridging the gap" between academics of a profession and practice of that profession, as it connects factual knowledge, principle and skills to their application within a profession (VERMA et al., 2011). Share (2013) presents that students at Southern New Hampshire University (SNHU) demonstrate mastery of competences by completing projects that are "authentic tasks that enable students to learn by doing."

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Assessment Strategy (AS)	Discussion
AS2. Problem-Based	According to Savery (2015), it is a learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined, real-world problem. Problem-Based Learning facilitates the development of key professional competences such as problem-solving, critical thinking, communication skills, independent learning, teamwork, cooperation and collaboration skills (CHAVES et al., 2006).
AS3. 360 Degree	According to Henri, Johnson and Nepal (2017), this flexible, low-cost assessment tool that can be applied in any educational setting, involves observation methods integrated with feedback about a student's performance from various sources, such as self, peer, faculty members, instructor and external experts in the field. Woodrow (2013) points out that its primary purpose is to improve learning by providing the students with various perspectives of the strengths and weaknesses of their work. The benefits of 360 Degree Assessments exist regardless whether the feedback from different sources is repetitive or unique. If is repetitive, it serves to reinforce the credibility of it; if it is unique, it sets additional information about a student's performance (DE LOS RIOS-CARMENADO et al., 2015). According to the literature, this sort of assessment has been used either exclusively or in conjunction with other methods to enhance the acquisition of content-based skills and professional skills such as communication, critical thinking, and time and task management. (DE LOS RIOS-CARMENADO et al., 2015; ZOU & KO, 2012).
AS4. Self-assessment	Self- assessment allows students to think more carefully about what they do and do not know, and what they additionally need to know to accomplish certain tasks. It promotes metacognition about what is being learned, and effective practices for learning. It also imparts reflective skills that will be useful on the job or in academic research (MACDONALD; SAVIN-BADEN, 2014). Self-assessment places students in an active role by forcing them to become autonomous learners, to think about how and what they should be learning. Having learned how to do a self-assessment, students can continue to apply them in their career and in other contexts throughout life. In self-assessment, as in other kinds of assessment, a good rubric is essential to a good review process. It will include detailed criteria, to draw students' attention to important aspects of the work (GEHRINGER, 2017).
AS5. Portfolios	Portfolios are a purposeful collection of student's work exhibiting evidences of their mastery of several competences. Competence-driven portfolios in engineering programs have been successfully implemented at a variety of institutions, including the Rose-Hulman Institute of Technology, the University of Texas at Austin, the University of Wisconsin-Superior, and Alverno College (BRUMM, MICKELSON, et al., 2006). Blicblau (2008) states that one of the benefits of this kind of assessment is that they are self-directed and must involve self-reflection. Further, they encourage students to be responsible for their own learning and engage them in the learning process by allowing them to choose which works to select and present. According to Badilla Quintana et al. (2014), some institutions use them to increase motivation and autonomy in learning while giving students the opportunity to demonstrate such professional competences as writing and communication skills.

Source: (summarized by the author)

2.2.2 Rubric as an authentic assessment marking tool

A rubric (AS6) is an authentic assessment tool used to measure students' work. It is a scoring guide that seeks to evaluate a student's performance based on the sum of a full range of criteria rather than a single numerical score. In a university context, the assessment rubric is considered to be an innovative educational instrument used to obtain evidence of the acquisition of competences and to offer responses to the new educational paradigm proposals (PANADERO; JONSSON, 2013). In addition, according to Hattie and Timperley (2007), they become a guide for students to develop and demonstrate competences to reach a specific level of achievement, so that they have the potential to learn through a student-centered assessment.

Cuenca et al. (2016) state that rubrics facilitate the measurement of student performance in those areas that are complex to evaluate, through a set of graduated criteria for assessing learning, knowledge and/or skills gained by the student. The main advantage of this technique for students is to show them the different levels of achievement that can be achieved in a job, providing the aspects that must be met to achieve higher skill levels. Moreover, rubrics allow teachers an objective, fair and impartial evaluation by a scale that measures the skills and student performance.

According to studies carried out by Serrano-Tierz et al. (2014), in the field of engineering, the rubric is a very useful tool for assessing both technical and transversal competences of projects in distinct areas/specialties. So, its potential lies in the ability to issue adjusted assessments regarding the quality of the works in a wide range of subjects or tasks, assuring that each student will be assessed according to the same criteria as his/her colleagues, overcoming arbitrariness, inconsistency or subjectivity in the assessment and thereby decreasing the margin of error in grading (RAPOSO; SARCEDA, 2010). Rubrics also help students self-regulate their learning, allowing them to reflect on the feedback offered, plan their tasks, verify their progress and review their work before its presentation, resulting in an improved performance and a decrease in anxiety levels. This type of assessment goes beyond a mere confirmation of results, permitting students to identify their strengths and weaknesses (ESHUN; OSEI-POKU, 2013).

Rubrics are currently used to measure a wide range of higher-order skills or evaluate assignment such as a long-term project, an essay, an exhibit, a lab work, an online course, a demonstration of problem solving, a teamwork or a research report that may vary across discipline. Therefore, scoring rubrics are designed to evaluate the quality of a process - not just the quality of a final-product. (AL-ZUMOR, 2015; LU & ZHANG, 2017).

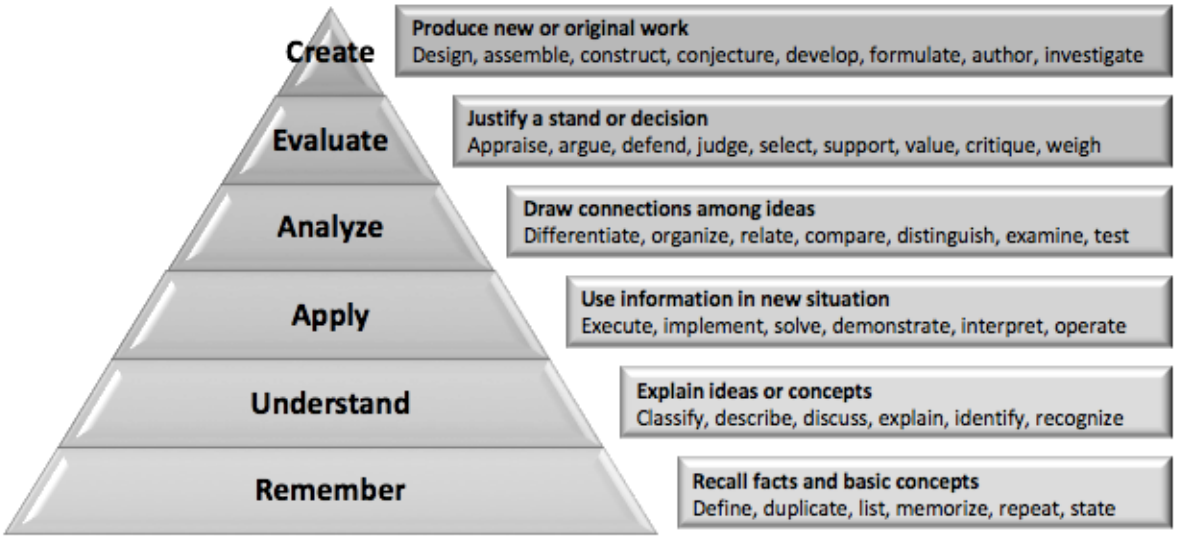
According to Rowan (2015), in practice, a minimum of two reviewers are required to score each student's real-world, performance-based assessment using a well- vetted rubric. If the reviewer's scores are not the same or within 1-2 points of one another, a third reviewer must grade the project.

2.2.2 Blooms Taxonomy within the classification of learning

Taxonomy, in a broad sense, is defined as a science of classification or a systematic framework. Consequently, it means the quality assurance of proper assessment because it leads to the elimination of the mismatch between what is intended and what is achieved. In education, it is crucial to have clear links between learning objectives, assessment and outcomes. Therefore, the need of taxonomies is obvious (BRILINGAITE et al., 2018).

The Accreditation Board for Engineering and Technology (ABET) requires that CBE programs devise multiple Performance Indicators (PI's), which are specific descriptions of concrete, measurable skills and knowledge that students should possess. They should be meaningful to the students, reliable and valid for assessment, and describe observable, measurable behaviors (ABET, 2015). ABET recommends that performance indicators utilize the revised Bloom's Taxonomy of the cognitive domain to describe expected performance. The revised taxonomy is divided into six hierarchical levels, going from the simplest to the most complex one, according to Figure 2.

Figure 2 – Bloom's Revised Taxonomy Hierarchical Levels



Source: Vanderbilt University Center for Teaching (2016)

Conklin (2005) states that every teacher must incorporate a taxonomy at the level of learning, assessment and teaching. Indeed, Bloom's taxonomy is used by educators and curriculum developers. Bloom's revised taxonomy has been applied to a wide variety of assessment practices in engineering, including forming the framework for assessment of a new Optical Engineering program (MEAD; BENNETT, 2009), creating learning outcomes for an entrepreneurship course (WHEADON; DUVAL-COUETIL, 2013), and assessing instructional modules for teaching various skills of an electrical engineering program (PIMMEL, 2003).

3. METHODOLOGY

This section is divided into two different topics that address the methodology procedures applied in the present study. The first item classifies the research as to its nature, approach, objectives, and procedures. The last item details each of the six stages used to elaborate the present work.

3.1 Research Classification

Firstly, this is an applied nature study, since it consists of a systematic study motivated by the search for solutions to concrete problems and that aims to contribute to practical purposes (CASTRO, 1978; GIL, 2008), in this case, the development of a competence-based assessment framework for engineering undergraduate courses. According to Richardson (1999), this study is classified as a qualitative one, through which the complexity of a problem is described, and the interaction of certain variables is analyzed, contributing to the change process of a given group. This assumption guided the present research, which sought to understand the competences of an engineer that the labor market requires today, as well as to analyze the bibliography about competence-based education and, with this, to identify possible ways to evaluate these competences within engineering undergraduate courses.

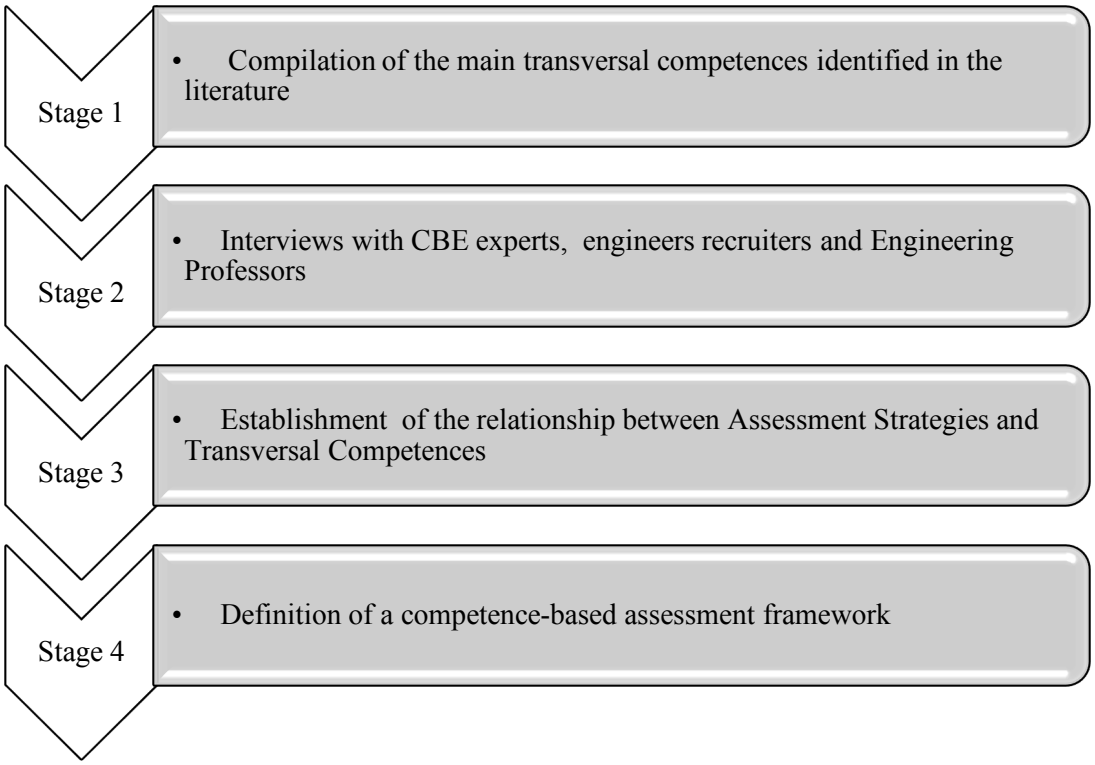
As for its objectives, this study can be classified as an exploratory research, which, according to Gil (2008), aims to seek greater familiarity with a subject still little known or explored, in this case, competence-based education, as well as with the ways to assess these competences. It consists of an exploratory research because it also involves a bibliographical research, interviews with experts in the field and analysis of existing competence-based assessment strategies. Finally, in relation to the technical procedures used in this research, this is classified as a case study, which, according to Fonseca (2002), can be characterized as the

study of a well-defined entity as a program, an institution, an educational system, a person, or a social unit. In the case of this study, it is sought to know in depth the education system based on competences focused on engineering.

3.3 Research Methodology

The research methodology to accomplish the study is divided into four stages as shown in Figure 3.

Figure 3 - The four-stage Research Methodology



(**Source**: created by the author)

In stage 1, the main transversal competences ("soft skills", attributes that could be generalized to any degree) required from engineers found in the literature are identified, listed and described in a table. At this stage, this is considered as a previous list, to be validated in the next stage before being incorporated in the assessment framework.

During the second stage of this study, interviews with two CBE experts, two engineers' recruiters, and four engineering professors are conducted. For the experts, an interview script is elaborated (Appendix A) to identify subjects related to competences they consider relevant

for undergraduate courses in general, and then specifically for engineering courses. Moreover, which practices normally occur in CBE classrooms to assess these competences and validate the set of transversal competences defined in stage 1. For the recruiters, another interview script is elaborated (Appendix B), with the aim to include in this study the perspective of someone who is familiar with the competences organizations are requiring from engineers nowadays. The interview with recruiters also aims to evaluate if the set of transversal competences defined in stage 1 are in accordance with the labor market demands.

Interviews with professors from different Engineering courses at the Federal University of Rio Grande do Sul (UFRGS) are also conducted. An interview script is built (Appendix C), composed by open-ended questions to verify which transversal competences they believe should be developed and evaluated in their engineering classrooms, and how they are being evaluated. Convenience sampling composes the sample of experts, recruiters and professors interviewed, which is a specific type of non-probability sampling method that relies on data collection from population members who are conveniently available to participate in the study (ETIKAN et al., 2016).

Next, in stage 3, a table is built to show the relationship between each transversal competence and existing methods to assess competences identified in the literature and through the interviews. In stage 4, through a qualitative analysis of the outcomes of the previous stages, a framework for competence-based assessment is proposed. In this stage, the goal is to unite, in a coherent and systematic way, all the information obtained through the literature review and interviews to create a new method to assess competences focused on Engineering undergraduate courses.

4. RESULTS AND DISCUSSIONS

This section is divided into five items that address the study results and discussions. The first item presents a brief research scenario. The second item defines the main transversal competences required from engineers found in the literature, composing a previous transversal competences list to be validated through the interviews before being incorporated in the framework. The next item discusses the interviews results, followed by the fourth item that shows the relationship between each transversal competence and the assessment strategies found in the literature and raised in the interviews. In the last item, a competence-based assessment framework is proposed and discussed.

4.1 Research Scenario

The Federal University of Rio Grande do Sul (UFRGS) is a Brazilian higher education institution that offers more than 90 undergraduate courses, also possessing an expressive number of postgraduate courses. In 2018, for the seventh consecutive year, UFRGS was named as the best federal university in Brazil, according to a report released by the Ministry of Education (MEC), which is attributed to the quality of the courses offered by the university, as well as the number and quality of research carried out within the institution.

In 2018, the Industrial Engineering Department submitted an institutional project of modernization and innovation of its curriculum in the Brazil-United States Undergraduate's Modernization Program. That is due to a will to maintain its good ranking in the long term, as well as stand out for containing a teaching methodology that can serve as a reference for other universities in the future. That Program aims to modernize the engineering degree in Brazil, and is funded by Capes and Fulbright Foundation.

The Industrial Engineering Department at UFRGS was one of the eight selected courses to receive a grant to carry out the Undergraduate's Modernization Program (PMG). The undergraduate commission leads this research, considering: (i) the labor market, teachers, and students' demands; (ii) innovative pedagogical practices, and active learning application; (iii) curricular changes; (iv) infrastructure improvements; and (v) professors training. Therefore, this research contains partial results of the PMG in the Industrial Engineering undergraduate course at UFRGS.

4.2 The Engineers' main transversal competences

The transversal competences found in the literature were put together with the purpose of defining which ones would be considered in this study. The selection criterion used was the number of researches in which they were cited. Therefore, the transversal competences mentioned in the largest number of studies were considered as the most relevant to compose the set of competences to be assessed by the framework. Seven studies were considered (Table 1) as well as the Engineering Competency Model (Figure 1) proposed by the American Association of Engineering Societies, resulting in eight sources. Competences that appeared in less than half the sources were eliminated, and those that had the same meaning but different names were unified.

A list of eight main transversal competences required from engineers nowadays resulted from this analysis:

TC1. Teamwork
TC2. Effective communication
TC3. Leadership
TC4. Innovation
TC5. Complex problem-solving
TC6. Adaptability / Flexibility
TC7. Emotional intelligence
TC8. Lifelong learning

Table 3 shows the association between these eight transversal competences and the studies' authors.

Table 3 – Main Transversal Competences and authors

Transversal Compet. (TC) / Authors	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8
Ahn, Annie, and Kwon (2012)	x	x	x		x	x		
Ball et al. (2012)	x	x	x	x	x		x	
Bish, Newton, Browning, O'Connor, and Anibaldi (2014)	x	x	x		x		x	x
Jesiek et al., (2014)			x	x		x	x	
Lantada, Bayo, and De Juanes Marquez Sevillano (2014)	x	x		x				x
Lunev, Petrova, and Zaripova (2013)	x			x	x	x		x
Walther et al., (2011)			x	x			x	
American Association Of Engineering Societies	x	x			x	x		x

Source: (author)

In this stage, this was considered as a previous list, which needed to be validated with CBE experts and engineers' recruiters through the interviews, before being incorporated in the assessment framework proposed in this study. In Table 4, each competence is described.

Table 4 – Transversal Competences descriptions

Transversal Competence	Description
TC1. Teamwork	Working in multidisciplinary teams in a collaborative way with different types of people. Involves thinking analytically and systematically, reflectively and critically, participating in decision-making and in management of objectives and projects to reach a common goal (ABET, 2009).
TC2. Effective communication	Being effective in conveying ideas, knowledge and feelings through words. Orally, the ability to speak clearly, with well-structured discourse suited to the audience, body language that matches and corroborates what is being said, good tone of voice and means of support. In writing, the capacity to convey ideas and information with the right choice of words, avoiding imprecision and ambiguities; conciseness, avoiding useless repetitions and wordy phrasing (SÁNCHEZ et al., 2008).
TC3. Leadership	The capacity to influence individuals and/or groups, anticipating the future and contributing to their personal and professional development, bringing out the best in them in order to achieve desired results. Also, capacity of vision and coordinating projects (SÁNCHEZ et al., 2008).
TC4. Innovation	The ability to incrementally or boldly change and improve products, processes, services, or solutions in a way that creates distinctive value for people (CUENCA et al., 2016).
TC5. Complex Problem solving	The ability to identify problems, to define them, to gather necessary information, to follow a methodology, to develop different alternative solutions and to devise and follow an action plan (SÁNCHEZ et al., 2008).
TC6. Adaptability / Flexibility	The ability to modify and adjust according to the different situations and according to unexpected changes. Ability to identify solutions to unforeseen problems (FOURTANÉ, 2019).
TC7. Emotional Intelligence	The ability to monitor your own emotions as well as the emotions of others, to distinguish between and label different emotions correctly, and to use emotional information to guide your thinking and behaviour and influence others (GOLEMAN, 1995; SALOVEY & MAYER, 1990).
TC8. LLL (Life Long Learning)	The ability to stay current as new technological advances continue to transform the workplace at a very rapid pace. Life long learners know how to analyse their own performance, identify gaps in their learning and plan for improvement. Assessment for lifelong learning rewards students' ability to reflect on and critically evaluate their own learning, to assess the quality of their performance against agreed standards and to build the capacity to use these skills of judgment to influence their future learning and practice (BOUD &FALCHIKOV, 2006).

Source: (author)

4.3 Interviews results

This item, which is divided into three topics – CBE Experts interviews, Engineers' recruiters' interviews, and Engineering Professors' interviews -, discusses the interviews results and their consequent contributions to the present study.

4.3.1 CBE Experts' interviews

The aim of the CBE experts' interviews was to identify and discuss key transversal competences that should be assessed in undergraduate courses, as well as to come up with assessment strategies and recommendations on how to build the framework. The interviews were conducted with two experts, named A and B, for identity secrecy purpose.

Expert A. Professor and coordinator of the Mechatronics Engineering undergraduate course at Insper, a higher education institution known as a national reference for bringing to Brazil unprecedented teaching methodology in engineering, based on the development of competences. He has been the project's head since the beginning.

Expert B. Industrial Engineer, who has extensive experience in Engineering Education and Systemic Thinking, having directed his work to the study and application of curricular reform models focusing on the use of active learning methodologies.

The interview was guided by the Interview Script made for CBE Experts (Appendix A). The interview with Expert A was conducted by Skype as he is based in the city of São Paulo, and the interview with Expert B was conducted in person in the city of Porto Alegre. Both interviews were recorded with the interviewees consent.

When asked about transversal competences that should be developed within any undergraduate course, Expert A raised two: communication and teamwork. While Expert B mentioned complex problem-solving, self-advocacy, and empathy. Specifically for Engineering undergraduate courses, Expert A indicated innovative vision and leadership, arguing that the first has become a central value for the survival and development of organizations, and the second calls for a holistic vision of things, where technical challenges are combined with good interpersonal skills. Expert B maintained the transversal competences previously mentioned, arguing that all other competences are ramifications of those three. It was agreed that self-advocacy can be considered as a high level of effective communication (TC2), and empathy is covered by Emotional Intelligence (TC7). Therefore, the transversal competences previous list established in stage one was validated without the need to incorporate changes

Both experts emphasized rubrics as a way to measure and assess transversal competences. It was stated that rubrics work well as a formative assessment method applied during the semester to verify the evolution of certain competences. Moreover, they should be applied by, at least, two different evaluators in, at least, two different moments during the semester. Portfolios assessment was raised as a way to collect competence evidence and

measure evolution throughout the semester. Expert B also brought up evaluation through cases resolution (problem-based assessment) as a practice to assess transversal competences. Students are given a period of time to solve a business case and present the solution in front of the classroom.

When asked about practices they are aware of in international education institutions, Expert A affirmed that the tool is always the same: rubric. What varies are the strategies of how to systematize these rubrics and how to document the evidences of learning. Expert B, who recently had and experience at the Massachusetts Institute of Technology (MIT), mentioned that there a high percentage of the final grade is related to participation in class (in some MIT classes, this percentage can reach 60%), resulting in a class environment where everyone is co-teaching each other, and professors become a learning facilitator.

Project-based learning was recognized as a really effective strategy as it enables professors to evaluate several competences together, such as project management, time management, teamwork and leadership. On the other hand, true or false assessments, as well as multiple choice assessments, were considered effective in evaluating how much knowledge was acquired during a period of time, but not in assessing transversal competences (applied knowledge and behavioral skills).

4.3.2 Engineers recruiters' interviews

The aim of interviewing engineers' recruiters was to include in this study the perspective of someone who is familiar with the competences organizations are requiring from engineers nowadays, and evaluate if the set of transversal competences defined in stage 1 are in accordance with the labor market demands. The interviews were conducted with two recruiters, named A and B for identity secrecy purpose. Both of them have their works focused on recruitment and selection of engineering professionals.

Recruiter A. Recruitment and Selection Coordinator with 10-year experience in the engineering market, who works for a human resources agency located in Belo Horizonte.

Recruiter B. Talent Acquisition Advisor with a 12-year experience, being the last five years dedicated to the acquisition of engineers in a multinational technology company, located in Eldorado do Sul.

The interviews were guided by the Interview Script made for engineers' recruiters (Appendix B). The interview with Recruiter A was conducted by Skype as he is based in the city of Belo Horizonte, and the interview with Recruiter B was conducted in person in the city

of Porto Alegre. Both interviews were recorded with the interviewees consent.

When asked about the main transversal competences required by organizations when hiring engineers nowadays, Recruiter A raised teamwork, collaboration, communication, creative problem-solving, and resilience. Recruiter B mentioned flexibility, leadership, and emotional intelligence. According to them, transversal competences that are hard to find in a candidate and should be better developed by universities are mostly resilience, leadership, communication skills, negotiation, and creativity. It was agreed that collaboration is covered by teamwork (TC1), creative problem-solving is covered by complex problem solving (TC5) and innovation (TC4), and resilience is covered by emotional intelligence (TC7). Creativity is closely related to innovation (TC4) and negotiation can be considered as a high level of communication (TC2). Therefore, the transversal competences previous list established in stage one was validated without the need to incorporate changes.

Both recruiters agreed that transversal competences are gaining strength. Recruiter A estimates that, currently, the labor market is demanding about 70% technical competences and 30% transversal competences. But with technology development and many processes being automatized, the percentage of transversal competences should increase around 10% to 15% in the next 5 years. Recruiter B added that many professionals with a high level of technical expertise are not succeeding in selection processes due to lack of transversal competences.

When asked about methods used to evaluate transversal competences during selection processes, Recruiter A mentioned that psychological and emotional intelligence tests (EQ Tests) are applied in the early stages of the processes with the intention of assessing self-awareness skills (understanding how someone responds to certain situations), social awareness (recognizing and understanding how others feel), and relationship management (the ability to communicate effectively with others and express emotions rationally). Group dynamics are commonly applied to evaluate competences such as teamwork, leadership, collaboration, communication, working under pressure, and problem-solving. The candidates who pass to the interviews stage need to “sell themselves” (usually through a pitch), talk about their abilities, qualities, and why they should be hired. According to Recruiter B, this is a good strategy to assess communication abilities, persuasion, synthesis and self-knowledge.

It was agreed by the recruiters that, although technical competences are essential, the mastery of soft skills is becoming and will become more and more important. Therefore, there is the need for educational institutions to revise their curricula and incorporate teaching and assessment techniques that are closer to the labor market reality.

4.3.3 Engineering Professors' interviews

The aim of interviewing Engineering Professors was to verify which competences they believe should be developed and evaluated in their classrooms, and how they are being evaluated. The interviews were conducted with four Professors at UFRGS, named A, B, C, and D for identity secrecy purpose.

Professor A. Industrial Engineering Professor. As a researcher, she is the leader of different projects focused on entrepreneurship, social, and product and service development. Has been acting as an Engineering Professor since 2007.

Professor B. Chemical Engineering Professor. Has been acting as an Engineering Professor since 2012.

Professor C. Mechanical Engineering and Energy Engineering Professor. As a researcher, she is part of the Thermal and Aerodynamic Tests Laboratory (LETA) and the Solar Energy Laboratory (LABSOL). Has experience in Engineering Education and has been acting as an Engineering Professor since 2013.

Professor D. Electrical Engineering Professor and Coordinator. He worked in the private sector as an engineer, project manager, and executive in the areas of computer science and industrial automation between 1985 and 2004. Has been acting as an Engineering Professor since 2004.

The interviews were guided by the Interview Script made for Engineering Professors (Appendix C). All interviews were conducted in person at UFRGS, and recorded with the interviewees consent.

When asked about transversal competences they consider important for engineers to have nowadays, leadership, communication, emotional intelligence, conflict management, adaptability, learn to learn, and innovation were mentioned. It was identified that most of these competences are already being developed within their classes, although sometimes this happens accidently and with frequency variations among Professors. Despite that, there is no concern in applying proper assessment methods to measure students' level of mastery.

It was found that the four Professors apply Project-based learning at some point within their subjects, and two of them also use the Problem-based approach. Oral presentations (seminars, class debates, final Project presentation) are also held by all of them. Only one mentioned to provide written feedback throughout the semester, and another one indicated the development of a subject where the last half of the classes happens is a distance learning module. Therefore, the students take responsibility for their learning. None of them believe to be applying assessment methods that evaluate transversal competences, as they still use the

traditional knowledge-based assessments, such as true or false tests, multiple choice, calculus, descriptive tests, etc. When assessing the projects, mostly technical competences are evaluated.

It is a consensus that the development of technical competences should not be reduced or substituted by transversal competences under no circumstances. First of all, technical knowledge must be provided, so that students have the theoretical background well fostered to develop activities that involve active learning, such as projects.

The four Professors agree that implementing CBE requires a cultural change in the university. Firstly, Professors need to understand the transversal competences relevance and be trained, motivated and encouraged to leave their comfort zone by modifying the way they educate and assess. Once done that, students will feel more committed as they will take more responsibility over their learning process. To finish, it was verified a fear of having the Professor role reduced if more focus was given to transversal competences.

4.4 Relationship between Assessment Strategies and Transversal Competences

Through the interviews stage, it was possible to finally validate the transversal competences list to be assessed by the framework, as well as to raise other assessment strategies: oral presentations (e.g. pitches, seminars, debates) (AS7) and written presentations (e.g. essays, reports) (AS8).

Table 5 shows the relationship between assessment strategies (AS) identified in the literature and through the interviews, and each transversal competence (TC). This relationship, signed by "x", means that a given TC can be assessed through certain(s) AS.

Table 5 – Relationship between Assessment Strategies and Transversal Competences

	AS1	**AS2**	**AS3**	**AS4**	**AS5**	**AS6**	**AS7**	**AS8**
TC1	x	x	x			x		
TC2	x	x	x		x	x	x	x
TC3	x	x	x			x		
TC4	x	x	x		x	x	x	x
TC5	x	x	x			x		
TC6	x	x	x			x		
TC7	x	x	x			x		
TC8				x		x		

Source: (author)

4.5 Competence-based assessment framework

Once defined the set of transversal competences (TC) to be assessed by the framework, as well as the assessment strategies (AS), and having established the relationship between them, it is time to put all the pieces together. The framework is divided into six elements: transversal competence (TC); activity (means); moment (when); assessment method (how); evaluator (who); and rubric. The first five elements are shown in Table 6, and explained as follow.

The first element consists on *what* the framework is assessing, and it is represented by the set of eight transversal competences (TC) defined. The second element indicates the *means* through which these competences are going to be assessed, and corresponds to active learning activities such as Project-Based, Problem-Based, oral presentations, written presentations (e.g. essays, reports), and portfolios. The third element specifies *when* the assessment is going to be carried out. The literature and the experts stated that competence-based assessment must be applied, at least, in two different moments during the semester, evaluating not only the final product, but instead, the evolution of the learning process. Therefore, the framework establishes that the assessment will be applied in two moments: in the middle of the semester (partial assessment) and in the end (final assessment). The partial assessment will work as a formative assessment, in which the main objective is to provide feedback; while the final assessment will work as a summative assessment and a final grade will be provided.

The fourth element indicates *how* the competences are going to be assessed, that means which methods are going to be applied. In accordance with what was found in the literature review, and in the experts' interviews, rubrics (adapted for each TC) will be the assessment basis. Another possibility to leverage the assessment is to combine rubrics with 360-Degree method. The exception is self-assessment applied isolated when assessing Lifelong Learning (TC8). The fifth element defines *who* is going to carry out the assessment. As we are giving greater responsibility to students for their own learning, then it makes sense for them to take more responsibility for judging whether they have achieved the learning goals. Similarly, given that they will be working with peers in contexts in which professional capability will be demonstrated, the range of those involved in assessment and providing feedbacks needs to be extended. Thus, it is suggested in the framework that evaluators should be the students (self-assessment), peers, professors or instructors, and experts in determined competences.

Table 6 – Competence-Based Assessment Framework Elements

TC (What)	Activites (Means)	Moments (When)	Assessment methods (How)	Evaluators (Who)
TC1. Teamwork	Project-Based Problem-Based	Partial Final	360-Degree Rubric	Student Peers Professor / Instructor
TC2. Effective communication	Project-Based Problem-Based Oral Presentation Reports / Essays Portfolio	Partial Final	360-Degree Rubric	Student Peers Professor / Instructor
TC3. Leadership	Project-Based Problem-Based	Partial Final	360-Degree Rubric	Student Peers Professor / Instructor Expert
TC4. Innovation	Project-Based Problem-Based Portfolio	Partial Final	360-Degree Rubric	Student Peers Professor / Instructor Expert
TC5. Complex problem-solving	Project-Based Problem-Based	Partial Final	360-Degree Rubric	Student Peers Professor / Instructor Expert
TC6. Adaptability / Flexibility	Project-Based Problem-Based	Partial Final	360-Degree Rubric	Student Peers Professor / Instructor
TC7. Emotional intelligence	Project-Based Problem-Based	Partial Final	360-Degree Rubric	Student Peers Professor / Instructor
TC8. Lifelong Learning	Project-Based Problem-Based Presentations Report / Essays Portfolio	Partial Final	Self-assessment Rubric	Student

Source: (author)

The sixth element, the rubric, can be divided into 3 sub elements: Performance Criteria (PC), Levels of Mastery, and Performance Indicators (PIs). Performance Criteria describe the key elements of a student work related to a transversal competence. The Levels of Mastery are the performance levels rating scale for each PC. Usually, a rate scale consists of an even number of performance levels. Otherwise, if an odd number is used, the middle level tends to become a “catch-all” category. And last, the Performance Indicators provide examples or

concrete descriptors for each level of performance, preferably utilizing the revised Bloom's Taxonomy of the cognitive domain (THE UNIVERSITY OF TEXAS AT AUSTIN, 2017).

A Teamwork (TC1) rubric example is provided in Table 7 to better illustrate the scheme.

Table 7 – Teamwork Assessment Rubric Example

		Levels of Mastery			
TC (What)	**Performance Criteria (PC)**	**Insufficient (0 points)**	**Emerging (1 point)**	**Accomplished (2 points)**	**Examplary (3 points)**
TC1. Teamwork	**Contributes to Team Meetings**	( ) Shares ideas but does not advance the work of the group.	( ) Offers new suggestions to advance the work of the group.	( ) Offers alternative solutions or courses of action that build on the ideas of others.	( ) Helps the team move forward by articulating the merits of alternative ideas or proposals.
	Fulfill team role's duties	( ) Does not perform any duties of assigned team role.	( ) Performs very little duties.	( ) Performs nearly all of the duties.	( ) Performs all duties of assigned team roles.
	Facilitates the Contributions of Team Members	( ) Not engaged in the teamwork activity.	( ) Engages team members by commenting on the contributions of others	( ) Engages team members in ways that facilitate their contributions by synthesizing all contributions.	( ) Engages team members, facilitating their contributions by building upon or synthesizing their contributions and offering original ideas. Should also notice and encourage nonparticipating members to engage with the group.
	Response to Conflict	( ) If conflict is present, the student refuses to collaborate or consider ideas other than his/her own.	( ) If conflict is present, the student passively accepts alternate viewpoints/ideas/opinions	( ) If conflict is present, the student identifies and acknowledges conflict and stays engaged with it.	( ) If conflict is present, the student addresses conflict directly and constructively, helping to manage/resolve it in a way that strengthens overall team cohesiveness and future effectiveness.

Source: Adapted from Stephen F. Austin State University (2010)

According to Table 6, student's teamwork competence (*what*) is assessed through Project-based or Problem-based activities (*means*), throughout the project's execution (partial assessment) and at its end as a final assessment (*when*). This competence is assessed using 360-Degree assessment, in which each evaluator should complete a Teamwork Rubric (*how*). The

participants involved in the assessment (evaluators) include, but are not limited to, students (self-assessment), peers, and Professors (*who*).

To assess the competence, evaluators must mark the appropriate indicators (one for each performance criteria) in the rubric and sum the scores. The scores range from 0 – 12. Professors would then create a grading scale as follows: A = 11-12, B = 9-10, C = 7-8, D = 0-6. The final grade is generated by (i) the arithmetic average of the evaluators' scores or (ii) by the weighted average, once the professor has the autonomy to assign weights to the scores of the different evaluators, as well as to assign different weights to the partial and final assessments.

Although this rubric structure proposed is considered as the ideal one when assessing transversal competences, it sure is highly complex to implement in universities that have not started a movement towards Competence-Based Education yet, and still evaluate their students through the traditional methods. For this reason, a transitional rubric framework is proposed in Table 8. The rubric was simplified by removing the Performance Criteria and, consequently, reducing the number of indicators descriptions needed. This way, there is the need to come up with a single general performance criterion that summarizes all the competence relevant aspects, and an indicator description for each performance level.

Table 8 – Transitional Rubric Framework

	Levels of Mastery			
TC (What)	**Insufficient (0 points)**	**Emerging (1 point)**	**Accomplished (2 points)**	**Examplary (3 points)**
e.g. Teamwork (general performance criterion)	( ) (Indicator description)	( ) (Indicator description)	( ) (Indicator description)	( ) (Indicator description)

Source: (author)

To assess the competence, the evaluators would mark the appropriate indicator in the rubric. The scores range from 0-3. Professors would then create a grading scale as follows: A = 3, B = 2, C = 1, D = 0. The final grade is generated by (i) the arithmetic mean of the evaluators' scores or (ii) by the weighted average, once the professor has the autonomy to assign weights to the scores of the different evaluators, as well as to assign different weights to the partial and final assessments.

It is important to mention the framework presented is a suggestion for the transversal competences assessment implementation. Said that, Professors have the autonomy to adapt the framework aspects (such as performance criteria, performance indicators, number of evaluators, final grade composition, etc) according to their needs and the context of the subject they teach.

5. CONCLUSION

To meet the challenges of worldwide increasing competition and to improve engineers' performance in today's labor market, universities should provide engineering professionals with not only technical competences, but also with transversal competences. These competences are related to attitudes and values that are not directly associated to technical content of the curricula. The assessment of these competences is not an easy task, and represents a common weakness within engineering education systems, that mainly apply knowledge-based assessments. Therefore, this research aimed to propose a competence-based assessment framework for engineering undergraduate courses.

From the literature reviewed, a set of eight transversal competences required from engineers nowadays was defined and validated through interviews with Competence-Based Education Experts and Engineers' Recruiters. Besides these validations, CBE Experts contributed to the definition of assessment strategies and recommendations on how to build the framework. Recruiters also contributed with their knowledge on the labor market current demands associated with engineers hiring process. Besides that, Engineering Professors at UFRGS were also interviewed to identify transversal competences, and their assessment level in their classes, as well as to verify which assessment practices they are applying.

The main findings from the experts and recruiters' interviews include performance-based assessments (project-based, problem-based, presentations) combined with rubrics, and 360-Degree assessment as an effective way to evaluate applied knowledge, behavior and attitudes from different perspectives. In the other hand, considering the Professors interviews, it was noted that they are already developing most of the eight transversal competences presented, although sometimes unintentionally. It occurs mainly

through the application of project-based learning and problem-based learning. Despite that, within their classes, there is no dedication to the application of proper transversal competences assessment.

Moreover, it is a consensus among the interviewees that the relevance of transversal competences in the labor market is increasing significantly, although technical competences remain essential. Therefore, there is a need for educational institutions to modernize their teaching methods and assessment techniques to make them closer to the labor market demands.

All the information obtained through the literature review and interviews were combined in a coherent and systematic way, resulting in the competence-based assessment framework. It is formed by elements that determine the activities through which each transversal competence (TC) should be evaluated, in which moments, by who and which assessment strategies should be applied. Also, in the transversal competences assessment framework an ideal rubric structure was proposed as well as a transitional one for institutions that are introducing CBE from scratch.

Implementing CBE requires a cultural change in the university, considering curriculum, infrastructure, staff and professors. Top-down decisions need to be taken with the purpose of training, motivating and encouraging Professors to leave their comfort zone by modifying the way they educate and assess. A suggestion for future work is to carry out a framework validation through its application within a pilot project in some engineering classes, aiming identify its practical feasibility and improvement opportunities.

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APPENDIX A – Interview Script (CBE Experts)

Date: _____

Occupation: _____

Open-ended Questions:

1. Which transversal competences do you consider as the most essential to be developed in undergraduate courses nowadays?

2. Now, specifically for engineering courses, which transversal competences engineering graduates must have upon receiving their diplomas to succeed in the labor market?

3. From the set of competences listed below, do you agree that they should be developed and properly assessed within engineering undergraduate classes? Would you add any other competence? Or would you remove any of these competences? Why?

Teamwork

Effective communication

Leadership

Innovation

Complex problem-solving

Adaptability / Flexibility

Emotional intelligence

Lifelong learning

4. Which practices have you noticed or know that occur in classroom with the purpose of assessing transversal competences? Could you explain a little bit of each?

5. Which practices do you know that international education institutions have been using to assess transversal competences that have not arrived in Brazil yet?

6. Do you know any competence assessment practice(s) that has been proven to be more effective than the others? Which are they and why?

7. Do you know any competence assessment practice(s) that has been proven to be less effective than the others? Which are they and why?

8. Which advice or suggestion would you give to institutions that are trying to develop and implement competence-based assessments in their undergraduate courses?

(**Source:** created by the author)

APPENDIX B – Interview Script (Recruiters)

Date: _____

Occupation: _____

Open-ended Questions:

1. Which are the main transversal competences ("soft skills") required by the organizations when hiring engineers nowadays?

2. Do you believe transversal competences are being more demanded than the technical ones in the labor market nowadays? Why?

3. Can you mention 3 or more transversal competences required by organizations that are hard to find in a candidate and that should be better developed by universities?

4. From the set of competences listed below, do you think they are in accordance with the labor market demands? Would you add any other competence? Or would you remove any of these competences? Why?

Teamwork

Effective communication

Leadership

Innovation

Complex problem-solving

Adaptability / Flexibility

Emotional intelligence

Lifelong learning

5. During job interviews or selection processes, how do you evaluate if a candidate has the competence required by the organization? Which methods do you use to assess candidates' transversal competences?

6. Additional placements.

(**Source:** created by the author)

APPENDIX C – Interview Script (Professors)

Date: _____

Engineering Course: _____

Working as a professor for _____ year(s)

Open-ended Questions:

1. Which transversal competences do you think are important for engineers to have nowadays in order to succeed in the labor market?

2. How often these transversal competences are being developed within your classes? And how are they being developed?

3. Which kind of method do you use to assess these competences within your classes?

4. Among the methods you apply, which ones do you consider as the most effective? Why?

5. Among the methods you apply, which ones do you consider as the less effective? Why?

6. How do you think the learning process in undergraduate courses would be benefited if more focus was given on the development of transversal competences?

7. Additional questions from the respondent part.

(**Source:** created by the author)

APPENDIX D – Experts Open-ended Answers

	Expert A	Expert B
Q1.	Two essential competences: Communication (oral and written): every professional needs it nowadays. The consequences of lack of good communication are reflected in loss of time, clients, effectiveness, and also opportunities for promotions. Teamwork: teams and teamwork have become a central part of the work life. This competence is required in two-thirds of employment offerings for positions of some responsibility.	Complex problem-solving; Self-advocacy (an individual ability to sell their qualities to others, to negotiate); Empathy.
Q2.	Besides the two already mentioned, innovative vision and leadership. Innovation has become a central value for the survival and development of organizations. Development of this competence will help students to gain access to the labor market and adapt to their future jobs. Acquiring and developing the competence of leadership calls for a comprehensive, holistic vision of things, where technical challenges are combined with good interpersonal skills.	He maintains the transversal competences previously mentioned, arguing that all other competences are ramifications of those three. For example, communication. Someone that has the ability to self-advocate, certainly is a good communicator.
Q3.	Validated without the need to incorporate changes.	Validated without the need to incorporate changes. Observations: self-advocacy can be considered as an effective communication high level (TC2). And empathy is covered by Emotional Intelligence (TC7).
Q4.	Rubrics as a mean to measure soft skills: define the elements that characterize each competence and describe how these competences are expressed in different levels of mastery (e.g. beginner, intermediate, advanced, proficient). Rubrics work well as a formative assessment method applied during the semester in order to verify the evolution of certain competences. Should be applied by, at least, two different evaluators in, at least, two different moments during the semester. Portfolios as a way to collect competence evidence and measure evolution throughout the semester. Rubrics may be used to evaluate if the evidences are reflecting the level of mastery expected.	Role Play assessment. People evaluate others behaviors in a given situation. A kind of assessment that measures not only the knowledge but also de behavior of individuals. Use of rubrics as a means of assessment. Four performance descriptors: beginner, emergent, satisfactory, proficient. Evaluation through cases resolution. Students are given a period of time to solve a business case and present the solution in front of the classroom. This is known as problem-based learning. Involves 360-degree assessment (peer, professors, experts in the case and self-assessment).
Q5.	The tool is always the same: rubrics. What varies are the strategies of how to systematize these rubrics and how to document the evidences of learning. For example, oral expression. Shoot oral presentations of students, pointing out strong and weak points. This is evidence of learning, evidence of evolution, of how to do and not to do. Peer-assessment through CATME SMARTER Teamwork, web-based tool system that enable professors to implement best practices in managing student teams.	A high percentage of the final grade is related to participation in class (in some MIT classes, this percentage can reach 60%). It results in a class environment where everyone is co-teaching each other. Professors become a learning facilitator. Use of a teacher support software to measure student's participation with equity. A person is responsible for keeping track of who is participating and the contribution level provided. Then, these information is inserted into the software.

	Expert A	Expert B
Q6.	Each competence will require a type of activity. For example, to evaluate communication, students should be exposed to a situation in which he or she needs to make an oral presentation. Project-based learning is a really effective strategy as we evaluate several competences together, such as project management, time management, teamwork and leadership.	Rubrics assessment. They enable transversal competences quantification. Also, transversal competences mentoring system. Each student has a mentor to help them develop soft skills.
Q7.	True or false assessments, as well as multiple choice assessments. Those are effective in evaluating how much knowledge was acquired during a period of time, but not in assessing transversal competences (applied knowledge).	There is no good or bad way to assess transversal competences. The point is that there are three aspects that cannot be disassociated to ensure education quality: teaching practice, assessment practice and content. In the center of this triad there is the task that is given for students to perform. If those three aspects are aligned, students will be able to correctly perform the task, showing content mastery through proper assessment practices.
Q8.	Give attention to rubrics. They have proven to be a very effective soft skills assessment method. They enable instructors/professors to measure and shape student behavior, since students are aware of them beforehand, and know exactly what they must do to reach the expected levels of each competence	Educational institutions must create incentive policies to make professors change the way they teach and assess. Top-down decisions need to be made, and not the opposite.

APPENDIX E – Recruiters Open-ended Answers

	Recruiter A	**Recruiter B**
Q1.	Teamwork Collaboration Communication skills Creative problem-solving Resilience	Flexibiliy Leadership Emotional Intelligence
Q2.	Currently, the labor market is demanding about 70% technical competences and 30% transversal competences. But with the fast technology development and many processes being automatized, the percentage of transversal competences should increase around 10% to 15% in the next 5 years.	Transversal competences have gained strength in the current labor market. In a not too distant past, organizations observed only candidates' technical competences, but today this scenario has changed, and many professionals with a high level technical expertise are not succeeding in selection processes due to lack of transversal competences. The professional that the current labor market seeks is a set of technique and behavioral skills.
Q3.	Resilience Communication skills Leadership	Creativity Leadership Negotiation
Q4.	Validated without the need to incorporate changes. Observations: collaboration is covered by teamwork (TC1). Creative problem-solving is covered by innovation (TC4) and problem-solving (TC5). And resilience is covered by Emotional Intelligence (TC7).	Validated without the need to incorporate changes. The interviewee agreed that creativy is closely related to innovation skills (TC4).
Q5.	Psychological tests to identify behaviors and attitudes and draw the candidates professional profile. Those are usually multiple choice tests. Group dynamics, where candidates work in groups to solve a business case in a short period of time. During this activity, they are observed by recruiters to evaluate competences such as teamwork, leadership, communication, working under pressure, problem-solving and collaboration. The selected candidates who go to the interviews stage, need to "sell themselves", talk about their abilities, qualities and why they should be hired.	The first step is to create the candidate profile required for the position - define which competences are required to fill the position and which prerequisites a candidate should have to perform well on the job. The next step is to analyze the CVs collected to filter candidates that are going to progress onto the next stages of the process. Individual and group dynamics help to evaluate how candidate work alone and as a team. Moreover, they show if the candidate behaves according to what is expected within the company. Profile tests are useful in identifying how the candidate deals emotionally under pressure and their main personality traits. Other strategy, that usually happen in the end of the selection processes, is to ask candidates to make a pitch in front of the directors presenting themselves, their professional historic and why they should be hired (with slides presentation support). This is a good strategy to assess communication, persuasion, synthesis and self-knowledge.
Q6.	Although technical competences are essential, the mastery of soft skills is becoming and will become more and more important. Therefore, there is the need for educational institutions to revise their curricula and incorporate teaching and assessment techniques that are closer to reality.	There is a consensus that is much simpler to develop someone technically, than to change someone's habits and behaviors. Therefore, it is quite common in selection processes for recruiters to give up on some technical competence to the detriment of a professional profile with well developed transversal competences.

APPENDIX F – Professors Open-ended Answers

	Professor A	Professor B	Professor C	Professor D
Q1.	Leadership Communication Conflict management Decision-making Empathy Adaptability	Competences related to management positions, such as leadership, emotional intelligence, people management, innovation, collaboration	Oral and written communication, leadership, conflict management, lifelong learning.	Leadership, the ability to manage and mobilize people to achieve a certain goal. Communications and adaptability.
Q2.	Written feedback, classroom debates, real business cases solution in groups (problem-based learning). Group projects development that integrate students from different courses. In the project final presentation, experts and the community is invited to evaluate students` work.	Group projects development. One person in the group needs to be the leader, although they have never had a leadership class. Thus, they end up developing these skills spontaneously. They are evaluated for the Project result, not for the transversal competences they have acquired. Seminars occur once in the semester.	All discipline have seminars presentation. Students in the first year already develop projects, although in a more superficial, less rigorous way. End-of-course students develop complex engineering projects. Projects are evaluated according to three aspects: presentation, written work, and calculus memorial. Disciplines in which half of the classes happens in distance learning module, so students become more responsible for their learning.	Project-based learning and problem-based learning are highly applied throughout the course. Transversal competences are developed unintentionally. But they are not evaluated. Students exercise their communication skills, teamwork skills, innovations skills unconciously. Autonomous learning discipline, without classes and without attendance control. Students need to answer exercise lists through study groups they conduct themselves. Develops the ability of "learn to learn".
Q3.	Do not apply any transversal competences assessment method	Do not apply any transversal competences assessment method	Do not apply any transversal competences assessment method	Do not apply any transversal competences assessment method
Q4.	Do not apply any transversal competences assessment method	Do not apply any transversal competences assessment method	Do not apply any transversal competences assessment method	Do not apply any transversal competences assessment method
Q5.	Methods that evaluate only if students know how to explain concepts and its applications in theory, which differs a lot from the practice.	Assessment methods that only requires students to read and memorize content they will soon forget.	Multiple choice tests to assess students knowledge acquisition.	Traditional assessment models, such as true or false and descriptive tests, once it does not envolve behavior and atitudes evalutation.

	Professor A	Professor B	Professor C	Professor D
Q6.	At first, Professors need more motivation than students themselves. They should leave their "traditional lessons" comfort zone. They also need to understand the relevance of transversal competences and be encouraged to change.	Students would feel more engaged and confident in the projects activities if more attention was given to leadership and emotional intelligence, for example. And it is something they would take for their whole lives.	It requires a deep cultural change of both Professors and students. Professors should, firstly, receive training, while students must be more commited since they would have greater responsibility on their learning process.	Projects require a lot more time and energy from students compared to traditional assessments. There must be a balance to not overload them.
Q7.	Transversal competences assessment should not be performed only at the end of the semester, but in a continuous way. If applied only in the end, it becomes useless, once there is no way to know if there was evolution.	The labor market is increasingly demanding transversal competences. There must be maturity on the part of both students and teachers.	Students are only able to exercise their transversal competences when they are developing a task on which they have theoretical background. Therefore, theory is essential. Fear of having the Professor role reduced.	The course should have a set of core disciplines in which students must be more required and in which Project-based learning must be applied. But applying them in all disciplines is unfeasible, since it requires much more time, energy and dedication.