

Fuzzy Model for Diagnosing Soft Skills in Engineering Training

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Abstract

This work presents the development of a model based on fuzzy logic to perform an evaluation and decision making based on multiple criteria intended to diagnose soft skills in Engineering courses. This scientific tool was developed using the fuzzyTECH software, which supported the calculations necessary for the delivery of the results. The hierarchical structure of the top-down tree was developed using a Systematic Bibliographic Review, based on the search databases Web of Science, Science Direct, Scopus databases and on the European Journal of Engineering Education and Journal of Engineering Education. The search comprised 15 years and combined keywords from two main fields: Engineering and Humanities. The 3951 articles obtained were ranked by the scientific ranking algorithm indexOrdinatio, which takes into account the year of the article search, the year of publication, the number of citations in Google Scholar and the JCR of the journal in which the article is indexed. At the end, 59 articles were critically analyzed, capturing the most important soft skills for Engineers to be used in the modeling composition. This robust tool has been validated and has shown the characteristics of reliability, stability, validity and consistency.

Keywords

Fuzzy Logic, FuzzyTECH®, Systematic Bibliographic Review (SBR), Index Ordinatio, Soft Skills for Engineering

1. Introduction

The authors of this study, as professors of Engineering courses, realize that often, the construction of pedagogical projects is carried out based on ruled deci-

sions without an empirical analysis, possibly due to the high complexity of the areas within the soft skills.

In the development of these pedagogical projects, it is not common to use tools that comprise soft skills in the training of engineering professionals. There is also not a wide range of instruments that assist the decision-making process in Engineering training regarding soft skills.

The choice of fuzzy logic to conceive the modeling presented in this work was motivated by the fact that it operates in a similar way to human reasoning, incorporating subjectivities intrinsic to soft skills.

There are still few tools to assist in the decision making process regarding soft skills assessment in the training of Engineers. This fuzzy modeling allows identifying strengths and weaknesses in the development of soft skills in Engineering courses, promoting measurable and specific adjustments in Engineering curricula.

Therefore, this study aims to provide a scientific modeling that supports the need to evaluate multifactorial elements, based on fuzzy logic. This model allows that the perceptions of students, professors, graduates, and Engineering contractors are considered for the development of pedagogical projects in the Engineering area. It also measures the perceptions of the Engineer contractors about the reality seen in the job market.

2. Theoretical Reference

2.1. Fuzzy Logic

According to [Martins and Martins \(2016\)](#) and [Cavalcanti et al. \(2013\)](#), it was Aristotle (384 - 322 BC), a Greek philosopher and the founder of the Logic Science, who instituted strict rules to accept premises as logically valid. From this starting point, values were attributed to the statements, considering them as true or false. It was the beginning of Boolean logic, later named binary.

[Campos Filho \(2004\)](#) states that Boole, in 1847, in his book “The Mathematical Analysis of Logic”, applied numerical values for the statements, with 1 (one) being the true premises, and 0 (zero) being the false premises. For [Sousa and Boente \(2016\)](#), since then logical thinking has been conditioned to binary logic, in which a sentence is true or false, not admitting to be partially true or partially false.

Fuzzy logic had its origin in 1903, when Bertrand Russell discovered an ancient Greek paradox, known as “Russell’s paradox”, which, when solved by Aristotelian logic, always led to contradictions. It was the fuzzy logic, which accepts partial situations, which could solve the problem. In the mid-1930s, the Polish Jan Lukasiewicz made the first multilevel essays, in which he stated that contradictions were perfectly plausible from a mathematical point of view, as long as the degrees of truth were not bivalent. The Polish scholar incorporated the fraction of logical states between 0 (zero) and 1 (one) into the logic ([Campos Filho, 2004](#); [Brayan & Brayan, 1997](#)).

But it was in the 60s that the fuzzy logic was mathematically equated and tested by Zadeh, a professor at the University of Berkeley (California-USA), who was unsatisfied with the technological resources available for the automation demands of the time. Zadeh realized that some industrial sectors, such as Biological and Chemical, were (and still are) susceptible to ambiguous occurrences that could not be fulfilled by the 1 & 0 values of the binary (Boolean) logic (Cavalcanti et al., 2013).

Fuzzy logic followed the traditional course of technological innovations: born in the United States, perfected in Europe and widespread in Japan. In the 1980s, fuzzy logic was used especially in Europe to support decision making and was applied to information analysis on research about human decisions process (Campos Filho, 2004). According to Toledo & Cosenza (2004), some industrial processes involve the human reasoning and it is safer to use of a tool that efficiently substitutes human in decision making. Still in the 1980s, according to Campos Filho (2004), companies in Europe found that the Japanese made it feasible to use the fuzzy logic in control technologies, and expanded the efforts to promote this logic in their applications.

2.1.1. Fuzzy-Rule Blocks

Rule blocks are “if-then” tables containing the strategic control of the fuzzy system (Fagundes, 2015). In these blocks, all the rules for the same context are grouped, as exemplified in Figure 1, for the index “Active Listening”. This, in turn, is defined with the same rules as the input indicators, referred in this study by the term “guidelines”, and the output, referred within this work as “indicators”, “indexes” and “final index”.

To compose the rule block, operations are carried out using fuzzy logic, generating a set of relevant results, in pre-defined thematic groups (Campos Filho, 2004). The values are following transported to the composition of other groups, until the definition of the final index, which in the present work is the diagnosis of soft skills development in Engineering training.

The production rule blocks contain the strategic control of the fuzzy system. Each of them combines all the rules into the same context. A context is defined by the same rules of the input (individual or thematic) and the output (thematic or systemic) indicators. Each rule block composition operation generates a set of results in pre-defined fields, according to fuzzy logic.

The sequence of operations transforms and carries values until the definition of the systemic indicator. The various thematic indicators can also be verified on scales of predefined reference fields, in the same way as the systemic indicator. Degree of Support (DoS) is used to assign a weight to each of the rules. These weights vary between 0 (zero) and 10 (ten) and are assigned according to the importance of these rules in the understanding of the specialist and decision makers—in this work represented by the organizational psychologists. The values assigned for the degrees of support of each of the rules for the model developed are specified in Table 7, shown in Section 4.

2.1.2. Dendogram

The fuzzy model developed to diagnose the development of soft skills in Engineering training, combines, orders and details the most important soft skills for Engineers with their respective thematic indicators and individual guidelines. According to Campos Filho (2004), the guidelines and indicators take diffuse forms and are aggregated into the rule blocks of the main Dendrogram, Top Down Induction of Decision Trees, by means of fuzzy set operations.

The complete Dendrogram used for making the fuzzy modeling, specifically developed for this work, is described and illustrated in the Methodology 3 of this research.

In this Top-Down fuzzy tree, the result, which is the diagnosis of soft skills development in Engineering training, is obtained according to the tree analogy, opening up in new “branches” until reaching information that can be sought, data that can be analyzed. The end of new branches—or “tree layers”—creation occurs at the moment the researcher gets the facts and information needed.

2.1.3. The FuzzyTECH Software

The FuzzyTECH Software is a tool developed to use of fuzzy logic, with a graphical interface for the illustration of its components. It has features for editing rules, which can be explained in matrix form or in spreadsheet form. It also allows the analysis of each stage of the system in operation, through the construction of graphics in both 2D or 3D formats (Arruda et al., 2013).

Still according to the authors, the tool was developed by INFORM, in 1987, with the intention of domestic use and it was later shared with the European market. The available features include maximum and minimum operators for aggregating the input data for each rule, editing with analysis of various relevant functions and many methods for defuzzification—including the high center and the area center. It also generates the documentation of the project is being executed, including graphics and rule blocks.

The choice to use fuzzyTECH to build the model to diagnose the development of soft skills in Engineering training was due to some reasons: friendly interface, non-requirement of specific programming knowledge, worldwide support and use (e.g. Berlin airport, for air traffic control) and finally, because the authors of this study acquired the version 5.54 license.

As this study is related to the Human Sciences, the variables involved are not binary variables, such as “yes” or “no”, “right” or “wrong”, “true” or “false”, but rather variables that resemble human thought, which involves ambiguity, imprecision and belonging to different situations at the same time.

Finally, with the intention of diagnosing the development of soft skills in Engineering training, the use of a logical and mathematical treatment of the data was used. These were obtained through verbal information of imprecise and vague impressions, as well as subjective quality. For this purpose, the fuzzy logic was used, as this tool manages to treat variables in a rational manner; for being based on human reasoning modeling and not restricted to values.

#	IF D10	D9	THEN DoS	active_listening
1	low	low	1.00	low
2	low	medium	1.00	medium
3	low	high	1.00	medium
4	medium	low	1.00	low
5	medium	medium	1.00	medium
6	medium	high	1.00	high
7	high	low	1.00	medium
8	high	medium	1.00	medium
9	high	high	1.00	high
10				
11				
12				
13				
14				
15				

Figure 1. Example of rule block using the indicator “Active Listening”. Own authorship (2019).

3. Methodology

3.1. Development of a Bibliographic Portfolio

To determine which soft skills are significant for the Engineering training, a Systematic Bibliographic Review (SBR) was conducted. To develop the SBR, the methodology developed by [Pagani, Kovaleski and Resende \(2015\)](#), called Methodi Ordinatio was chosen due to its consistency and results obtained, as can be seen in [Campos et al. \(2018\)](#), among others authors. The methodology steps are detailed below.

Step 1 and 2—Establishing the intention of research and preliminary search: the intention of this research is to understand the relation between two huge research areas: Humanities and Engineering. Therefore, for each of these two areas, two fronts of research were defined: Human Sciences and Human Skills for the first one, and Engineering Education and Graduate to the second one. The structure of these combinations is illustrated in [Figure 2](#).

Steps 2 and 3—Definition of keywords and preliminary explanatory search: Keywords were defined for each research front. These keywords were grouped and crossed, forming 20 combinations as follows:

- Humanities and Engineering Education
- Humanities and Engineering Teaching
- Humanities and Degree in Engineering
- Humanities and Alumni* Engineering
- Humanities and Former Engineering Student*
- Human* Science* and Engineering Education
- Human* Science* and Engineering Teaching
- Human* Science* and Degree in Engineering
- Human* Science* and Alumni* Engineering
- Human* Science* and Former Engineering Student*

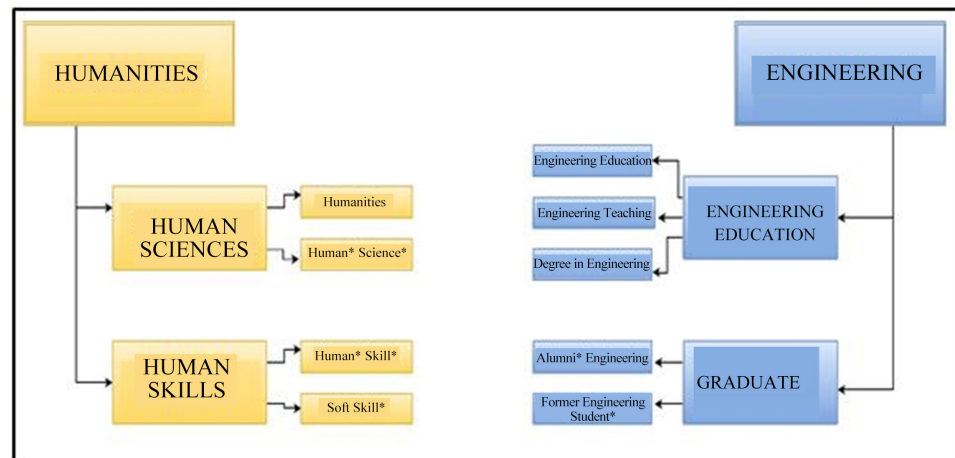


Figure 2. Keywords for SBR. Own authorship (2019).

- Human* Skill* and “Engineering Education”
- Human* Skill* and Engineering Teaching
- Human* Skill* and Degree in Engineering
- Human* Skill* and Alumni* Engineering
- Human* Skill* and Former Engineering Student*
- Soft Skill* and Engineering Education
- Soft Skill* and Engineering Teaching
- Soft Skill* and Degree in Engineering
- Soft Skill* and Alumni* Engineering
- Soft Skill* and Former Engineering Student*

For the articles search, from these 20 combinations, the databases which demonstrated greater proximity to the research area were chosen, namely: Science Direct, Web of Science and Scopus. Although the European Journal of Engineering Education (EJEE) is indexed in the Scopus scientific base, it was also used as a reference for searching individual articles, due to its self-indexed scope. Furthermore, an analysis was made of the articles published from 2006 to 2015, from the Journal of Engineering Education (JEE), because it is the magazine with the greatest impact factor (2.638) within the Engineering Education area, and is not indexed in these data base.

Steps 4 and 5—Final search on databases and selected journals: After the first search with the 20 combinations, 3951 articles were obtained. The journals which were exclusively related to the health area (or very specific areas) were discarded. With this, 2788 articles remained.

As some articles were indexed in more than one databases, it was necessary to remove duplicates, which lead to 2638 articles.

The next step was to read the 2638 titles and abstracts to see if they were in line with the proposed theme. Of these, 335 were in line with the expectations of the study scope, in **Appendix 7**. The number of articles collected, the filters used e the final number of articles that compose de database of the present work are shown in **Table 1**.

From this point, categories were proposed to better analyze the articles. This categories were created based on the combination of two major areas of the Humanities field and two major areas of the Engineering field, as described in **Table 2**.

From this combination, 4 categories were obtained: Human Skills & Graduate; Human Skills & Engineering Education; Human Sciences & Engineering Education; Human Sciences & Graduates. Based on the scope of each of these 335 articles, they were classified into one of these 4 categories, as explained in **Table 2**.

Step 6—Identifying Impact factor, year and number of citations: The metrics of the article (Impact Factor) were obtained from Thomson's Reuters/Clarivate Analytics website. The number of citations was obtained from Google Scholar. These information—metrics and number of citations, along with the year of publication—is necessary to calculate the InOrdinatio, which is explained in details in the Step 7.

Step 7—Ranking and selection of articles: In order to have a scientific support of which articles are the most relevant for the reading and elaboration of the theoretical framework, an algorithm for the relevance ranking after SBR was used, the Methodi Ordinatio from **Pagani, Kovaleski and Resende (2015)**, expressed in Equation (1):

$$\text{InOrdinato} = (F_i/1000)\alpha \left[10 - (\text{Year}_{\text{search}} - \text{Year}_{\text{pub}}) \right] + \sum C_i. \quad (1)$$

where:

F_i : Impact Factor

$\text{Year}_{\text{search}}$: Year of search

Year_{pub} : Publication year

C_i : Number of citations in Google Scholar

A research in the Scielo database was also carried out, but no relevant articles were found.

As some articles were indexed in more than one scientific database, it was necessary to remove duplicates. The numbers of the articles captured, according to the keywords, are shown in **Table 2**.

The ranking and selection process was only necessary for the categories “Human Skills & Engineering Education” and “Human Sciences & Engineering

Table 1. Summary of the SBR with the keyword used to the present study.

	Number of articles
Number of articles without filter	3951
Number of articles with disposal filter (journals and key words out of the scope)	2788
Number of articles after removal of duplicates	2638
Number of articles after Titles and Abstract reading	335

Source: Campos, 2019.

Table 2. Distribution of the articles from the final portfolio into categories.

Category	Number of articles
Human Skills & Graduate	00
Human Skills & Engineering Education	85
Human Sciences & Engineering Education	242
Human Sciences & Graduate	08
Total number of articles selected	335

Source: Campos, 2019.

Education”. For the category of “Human Sciences & Graduate”, due to the low number of articles, all articles were read; for the “Human Skills & Graduate” no articles were selected.

To define the threshold for which articles would compose the final portfolio for the “Human Skills & Engineering Education” and “Human Sciences & Engineering Education”, the accumulated Index Ordination was used as a reference.

For this purpose, the articles of each of these categories were ordered in descending order according to their IO value (refer to Equation (1)). After ordering the articles, it was possible to calculate the accumulated IO (simple sum of the IO's of each article), as well as the relative percentage from each IO—100% corresponded to the accumulated IO to each of the categories.

Table 3 and **Table 4** show the ten first articles for the “Human Sciences & Engineering Education” and “Human Skills & Engineering Education”, respectively. Columns 3 to 5 show the values used to calculate the IO. Column 6 shows the IO calculated for each article, Column 7 the accumulated IO and Column 8 the percentage of the accumulated IO.

It is important to notice that both tables are just a cutout of all the articles from each of the categories (242 for **Table 3** and 85 for **Table 4**).

From the IO, accumulated IO and % accumulated IO values, the graphics shown in **Figure 3** and **Figure 4** were constructed. The articles are shown in the horizontal axis, with the blue bar representing their IO. The orange curve illustrates the accumulated IO value. From this, it was established that the threshold for the articles that would compose the final portfolio would be 50% of the accumulated IO. This value is represented in both graphics by the pink horizontal line.

This percentage was a choice from the authors of the article, as per Pegani, Kovaleski e Resende (2015) statement that the threshold line is to be the author's choice and responsibility. With this threshold, a final portfolio from 59 articles was obtained.

3.2. Bibliometric

Bibliometric is a field of the area of the Library Science and the Information Science which applies statistical and mathematical models to analyze and con-

struct indicators about the dynamics and evolution of the scientific information (Zupic & Čater, 2015).

Table 3. Calculation of the Index Ordinatío for the keyword group of “Human Sciences” & “Engineering Education”.

Article	Journal	Impact Factor	#Citations in Google Scholar	Publication year	Numerical Order in the Master Table	InOrdin	iO Accumulated	% Accumulated
El Impacto del Desarrollo de Habilidades para la Competitividad: Evidencia Empírica de una Comparación entre Países	El Internacionalismo Moderno	0	183	2010	273	213	213	3.12
The Humanities and Their Effect on Engineering Education	IEEE Communications Magazine	5.125	13	1990	747	148.1	361.1	5.30
Introducing Professionalism and Ethics in Engineering Curriculum	Journal of Engineering Education	0.538	15	1991	3205	140.5	501.7	7.37
Integrating Communication and Engineering Education: A Look at Curricula, Courses and Support Systems	Journal of Professional Issues in Engineering Education	0.559	73	2003	425	138.6	640.2	9.40
When Science should be a Humanity	New Scientist	0.285	0	1991	2945	125.3	901.4	13.2
Teaching “Soft” Skills to Engineers	International Journal of Electrical Engineering Education	0.302	57	2003	312	122.3	1023	15.0
Requirements upon Human Competencies in Globally Distributed Manufacturing	Computers in Industry	1.685	29	1998	3506	120.7	1144.4	16.8
Humanities for Undergraduate Engineers: A Rich Paradox	Journal of Engineering Education	0.559	05	1993	3471	120.6	1264.9	18.6
The Good Engineer: Giving Virtue its due in Engineering Ethics	Science and Engineering Ethics	1.454	78	2008	636	119.5	1384.4	20.3
Non-Ethical Subjects in the German Engineering Curriculum: A Historical Overview	Technology in Science	0.185	0	1993	459	115.2	1499.6	22.0
Strengthening Human Resources for New and Renewable Energy Technologies of the 21 st Century—UNESCO Engineering Education and Training Programme	Renewable Energy	3.404	13	1997	3701	111.4	1726.0	25.4
Course on Engineering Leadership	Journal of Professional Issues in Engineering Education and Practice	0.538	24	1999	251	109.5	1835.6	27.0

Own authorship (2019).

Table 4. Calculation of Index Ordinatío for the keywords group of “Human Skills” & “Engineering Education”.

Article	Journal	Impact Factor	#Citations in Google Scholar	Publication year	Numerical Order in the Master Table	InOrdin	iO Accumulated	% Accumulated
The Networking Company Antecedents for Coping with Relationships and Networks Effectively	Industrial Marketing Management	1.93	417	1999	2766	503.9	503.9	12.1
Project Management Education: The Human Skills Imperative	International Journal of Project Management	2.885	201	2008	2060	243.9	747.8	18.0
A Skills Audit	Training & Development Journal	0	1	1980	1848	181	928.8	22.3
Curriculum for an Engineering Renaissance	IEEE Transactions on Education	1.33	85	2003	1600	151.3	1080.1	26.0
Flexible Firms, Skills and Employment	MPT Metallurgical Plant and Technology International	0	45	1996	2239	145	1375.0	33.1
Engineers Learn “Soft Skills The Hard Way”: Planting a Seed of Leadership in Engineering Classes	Leadership Management in Engineering	0	92	2007	1408	137	1512.0	36.4
NASA’s Educational Programs	Government Information Quarterly	2.515	02	1990	1878	134.5	1646.5	39.6
Engineering as a Liberal Education for the 21 st Century	Technical Paper—Society of Manufacturing Engineers	0	0	1996	2233	100	1746.5	42.0
Coaches Safety Orientation and Training Skills Program	ASTM Special Technical Publication	0	01	1997	2257	96	1842.5	44.3
Globalization, Curricula Reform and the Consequences for Engineers Working in an International Company	European Journal of Engineering Education	0.89	44	2006	1327	94.9	1937.4	47.0
Social Competences and Personal Ethical Development—Soft Skills or a Need For Survival?	Technology and Society	0	05	2000	2644	85	2114.8	50.9
Enhancing Individual Employability: The Perspective of Engineering Graduates	Education + Training	0	49	2010	1379	79	2193.8	52.8
Engineers of Tomorrow and Beyond Knowledge, Insight and Skills that Need to Work Across Borders	Age	2.5	02	2002	1631	74.5	2268.3	54.5

Own authorship (2019).

At this stage, bibliometric was performed on the 59 articles which compose the final portfolio of the research and bibliometric analysis.

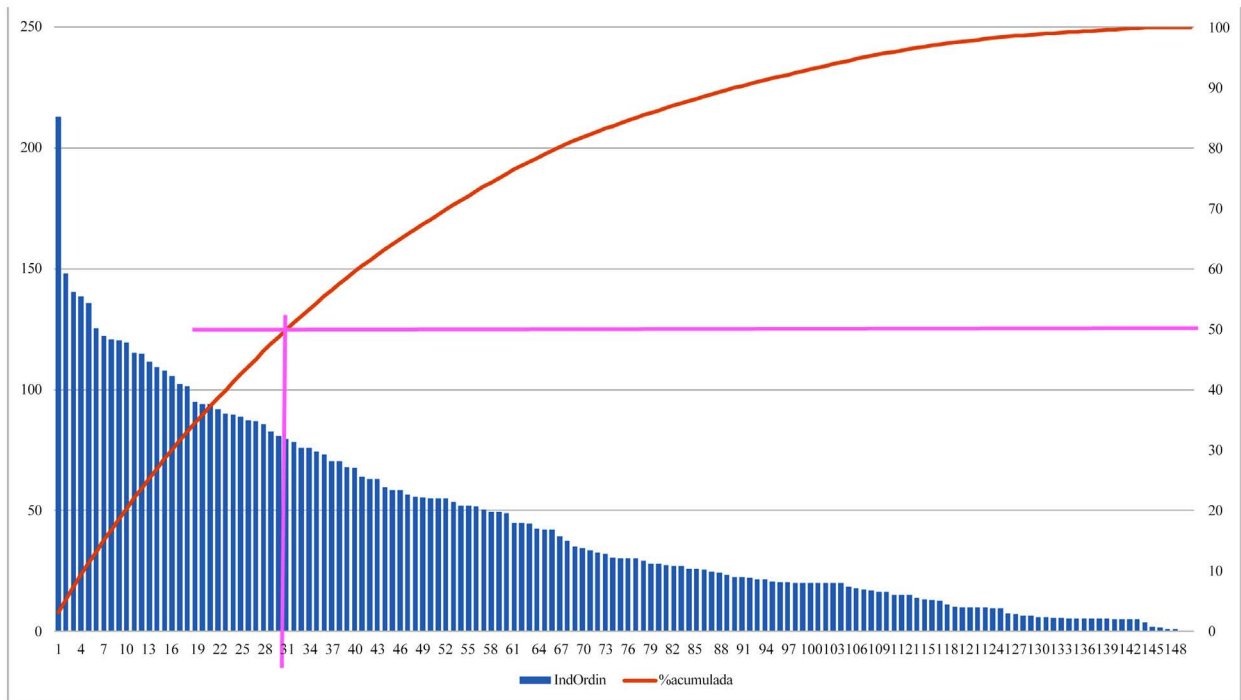


Figure 3. IO, accumulated IO and % accumulated IO for the “Human Sciences & Engineering Education” category. Own authorship (2019).

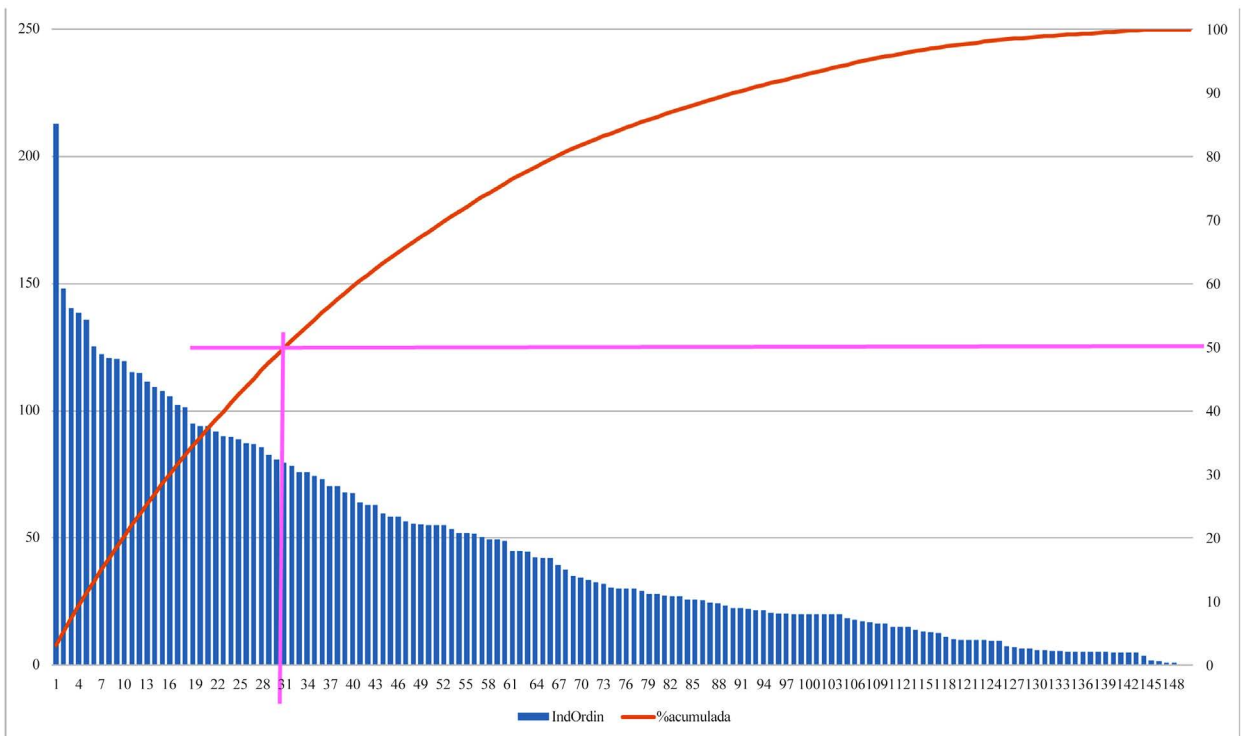


Figure 4. IO, accumulated IO and % accumulated IO for the “Human Skills & Engineering Education” category. Own authorship (2019).

The detailed study of the articles showed the soft skills, which were later classified into categories. Each time an article cited a given soft skill, this was com-

puted into the research. Therefore, at the end of each article, the list of soft skills perceived as relevant in that work was obtained.

Moreover, for each article, it was also tracked how many times a given term, was cited either as a hard skill or a soft skill, as well as the number of times the term was said to be “necessary”, “important” or as “neutral” or “unimportant”.

Finally, it was also tracked the number of times that the definition of soft skills was given and the number of times the term appeared in the articles analyzed.

Table 5 shows the soft skills cited in the articles, as well as the values for each of the parameters mentioned in the previous paragraph.

Table 5. Calculation of Index Ordinatío for the keywords group of “Human Skills & Graduate”.

	Soft skills obtained from Systematic Bibliographic Review	Number of articles in which the soft skill appears	Number of times of term appears as “hard skill”	Number of times of term appears as “soft skill”	Number of times of term suggests “necessity”	Number of times of term suggests “importance” or “neutral”	Number of time the term is “not relevant” appears as a result of a research	Number of times of term appears as a definition	Total number of times of term appears in the articles	
Communication	Oral Communication	47	0	165	147	18	24	0	0	354
	Written Communication	45	0	130	108	21	25	1	0	285
	Active Listening	16	0	44	34	10	7	0	0	95
	Reading	19	0	19	15	4	30	0	0	68
	Foreign Language	7	0	16	11	5	33	0	0	65
Critical Thinking	Problem Solving	27	45	99	0	0	5	0	0	149
	Open Mind	23	0	16	11	5	33	0	1	66
	Critical Thinking <i>per si</i>	10	0	23	22	0	6	1	2	54
Creative Thinking	Creativity	25	0	60	20	35	16	5	1	137
	Innovation	20	5	219	209	15	16	3	0	467
Emotional Intelligence	Emotions Control	22	0	36	14	12	3	10	0	75
	Lifelong Learning	18	0	55	21	34	3	0	0	113
	Motivation	17	0	33	14	12	3	10	0	72
	Self-Direction	1	0	1	1	0	0	0	0	2
Ethic Perspective	Ethics	36	0	607	475	131	424	1	0	1638
	Professionalism	13	0	50	21	28	19	1	0	119
	Social Responsibility	18	0	56	32	24	11	0	0	123
Team Work	Multiculturalism	55	0	215	125	59	25	18	0	442
	Leadership	34	0	108	69	36	47	3	0	263
	Networking	19	0	33	16	17	13	0	0	79

Own authorship (2019).

Based on bibliometrics, a top-down tree-shaped model (shown in **Figure 11**) was elaborated with fuzzy logic to evaluate the soft skills that most appeared in the Systematic Bibliographic Review (Campos et al., 2020a), combined with those ordered by the OECD employability reports (OECD, 2015; OECD, 2016a, 2016b) and the report P21 (Casner-Lotto & Barrington, 2006), as already explained in the Section 2—Theoretical Reference.

The fuzzy logic operates through the intersection of fuzzy sets, considering degrees of pertinence for each set. The classical proposition differs from the fuzzy fundamentally by its truth zone values. In traditional set theory of classical logic, an element may or may not belong to a set. However, in the theory of fuzzy sets, an element of a given U Universe can be defined mathematically by a value representing its degree or level of belonging to the set. This membership value is in a range that goes from: “this element does not belong to the set” (0) to “this element belongs 100% to the set” (1) (Bonventi & Costa, 2000; Boutros & Chen, 2011; Takáč, 2014).

An example of how fuzzy logic was used for this specific work, is in the fuzzification of the soft skill “critical thinking”, which assumes truth-values by means of fuzzy sets with the other thematic soft skills “communication”, “team work”, “ethical perspective”, “emotional control” and “creative thinking”, according to the degrees of pertinence. According to Campos Filho (2004) and Chakraverty & Behera (2013), a fuzzy set is completely characterized by its membership vector, with individual multivalent degrees of membership within the 0.1 numerical range. These degrees of pertinence can be considered as a measurement to express the possibility of a given element being a member of a fuzzy set. Thus, a fuzzy pertinence vector is also called a possibility vector or a possibility distribution vector.

As the name already suggests, this logic is fuzzy, and it is interesting to notice that, differently from the Boolean logic, when the sets are represented using the Veen Diagram, they do not need to cross to have an intersection region. **Figure 5** shows a demonstration of this phenomenon, in which the clouds of the fuzzy sets intersect, forming a fuzzy intersection.

In **Figure 5**, the elements of the cloud of set A intersect with the elements of the cloud of set B, forming an intersection of sets of the fuzzy type, which is not exact, but rather diffuse, similar to human reasoning.

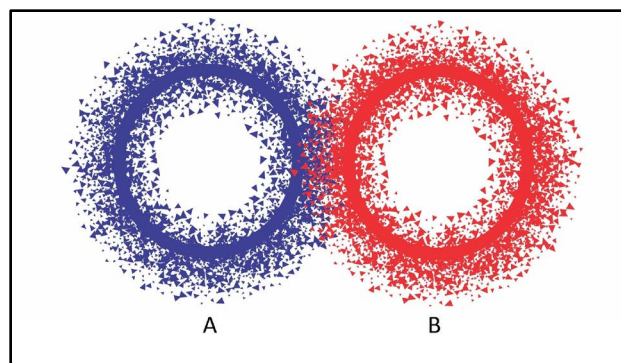


Figure 5. Fuzzy sets with intersecting clouds. Own authorship (2019).

In this sense, fuzzy logic is a way to manage uncertainties (Caiado et al., 2021; Takáč, 2014) and its use is very appropriate to treat data collected from the Human Sciences and measure the levels of uncertainty inherent to human communication.

The advantage of Boolean logic, with its crisp values, is accuracy. The disadvantage is In **Figure 6**, the letters “D” represent the input data, that is, the questions asked to the participants to feed the hierarchy constructed with the FuzzyTECH software. The fuzzy logic calculates the existing pertinence between D3 and D4, for example, to form the soft skill “open mind” encountered in the SBR. Afterwards, the fuzzy operation calculated how much “open mind” and “problem solving” impact the fuzzy sets, to form the thematic group which is also a soft skill: “critical thinking”.

This process is repeated for all the thematic groups, forming the other soft skills of this modelling. Later, “critical thinking” will be fuzzyfied with the other 5 macro soft skills (those which compose the thematic group) to generate a result, which is the level of that soft skill within the investigated Engineering course. This illustrated in the hierarchical scheme called top-down tree.

The construction of the Top-down Tree was based on the intended result, and has 4 hierarchical levels (**Figure 7**). The fourth level, which represents the Result (diagnosis in soft skills development in Engineering training), comes from the aggregation of the indexes. The indices obtained from the aggregation of soft skills from thematic groups (indicators) make up the third level. The indicators constitute the second level and are the soft skills obtained from the bibliometric of SBR, broken down into guidelines inspired by the P21 report (Casner-Lotto & Barrington, 2006), which represent the first level, as well as the tree’s input data.

This hierarchy represents a simplified cut of the Model mounted on the fuzzyTECH tree, showing the logical sequence to achieve the result, which is the diagnosis of soft skills development in Engineering training.

Calibration of the FuzzyTECH Software

In order to feed the data into the software used in this research, the blocks were weighed by the “Degree of Support” or DoS, which is a calibration function of the fuzzyTECH Software itself.

This calibration occurs through the assignment of weights, according to the data obtained by the interviewees’ opinions, being 40 organizational Psychologists, chosen at random. For Gondim, Borges-Andrade and Bastos (2017), this area of Psychology is responsible for promoting strategies for improving the work environment. These people have a greater proximity to the environment of the organizations, being then elected to assess the inferences of the soft skills among themselves.

For this purpose, the Psychologists answered the questionnaire included in **Appendix 1**. For the weighting of the data, the Likert scale was used, associated with the Delphi method with scores from 0 to 10, in which values were provided related to their respective perceptions about the inferences that soft skills present.

For *Vieira and Dalmoro (2008)*, when the answers and results are dispersed, the Likert scale may not be the most appropriate methodological tool, which suggests the need to have a complementary measurement strategy. In order to have greater reliability in the answers, the Delphi methodology was used, which, for *Fagundes (2015)*, associated with the Likert scale, allows the results converging, reducing the dispersion of the obtained values.

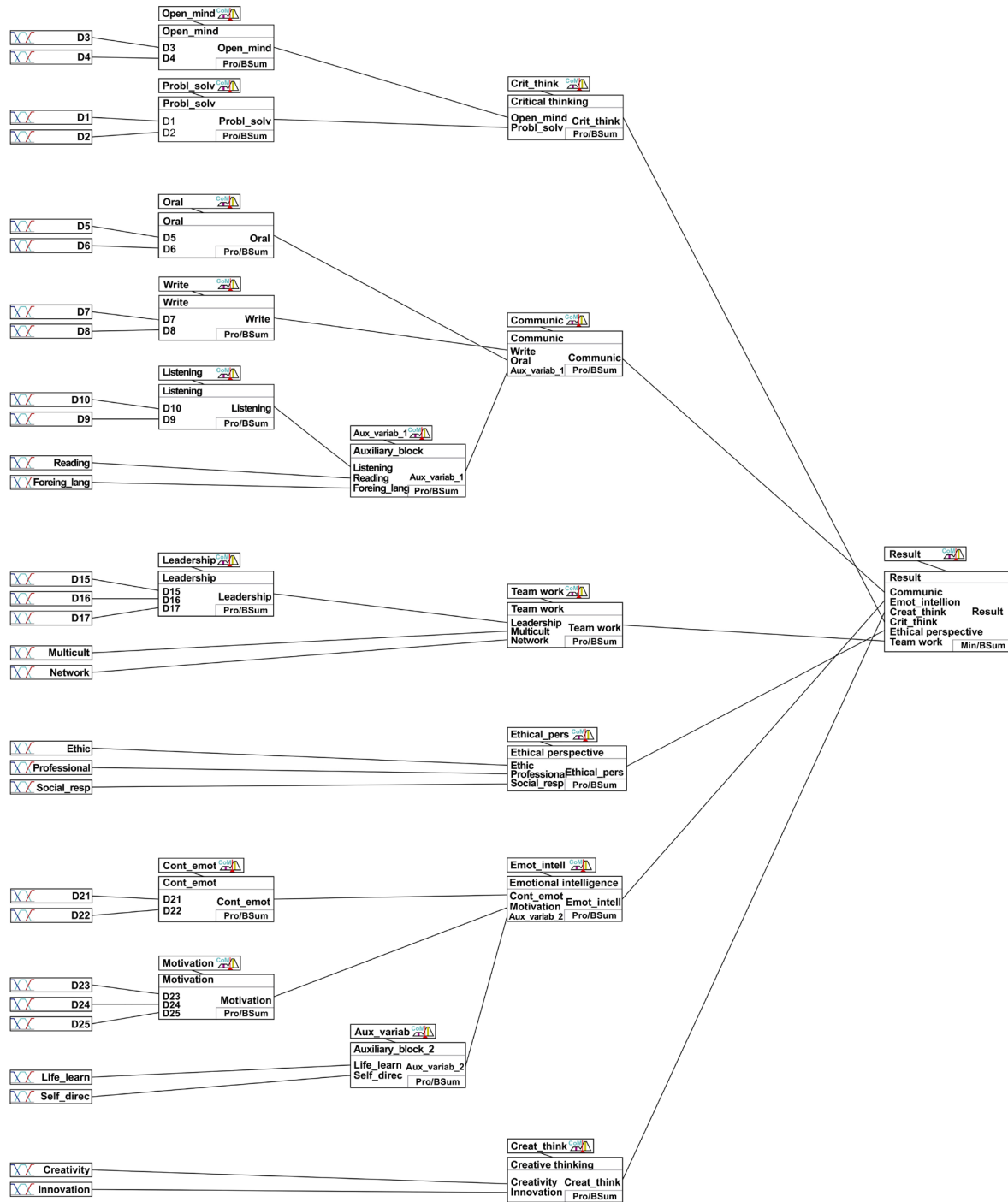


Figure 6. Top-Down tree model. Source: Campos (2019).

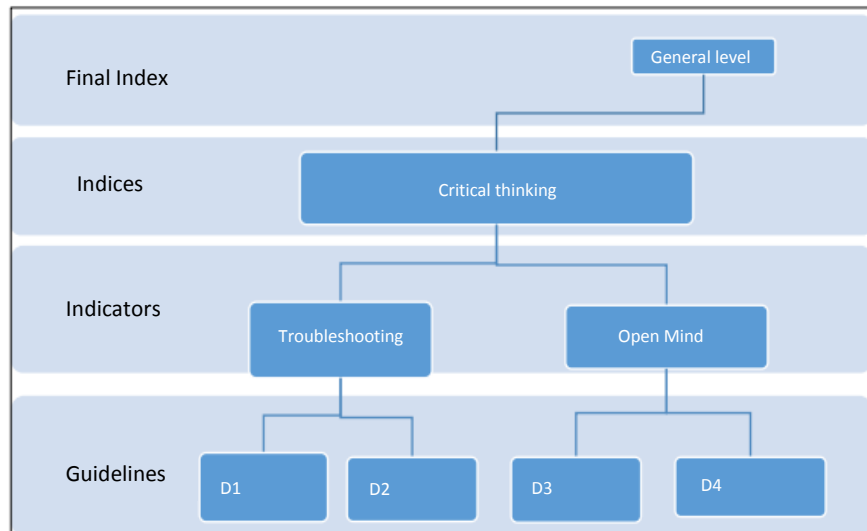


Figure 7. Simplified scheme of the proposed model. Source: Own authorship. Legend: D1—Find Solutions using multidisciplinary knowledge; D2—Use knowledge, data and facts to solve problems at work; D3—Ability to solve problems in a pacific manner; D4—Openness to suggestions, new ideas and contrary opinions.

For Fagundes (2015), the Likert scale is carried out using the weighted average, as shown in Table 6, which exemplifies the model that will be used for data valuation and insertion in the FuzzyTECH software.

Equation (3) demonstrates the calculation based on the results of Table 6.

$$\text{Weighted average} = (2 \times 5) + (4 \times 6) + (3 \times 7) + (1 \times 8) = 63$$

$$AR = 63 / (2 + 4 + 1 + 3) = 6.3 \quad (3)$$

The Delphi method aims to bring responses closer to a collective consensus, reaching a more representative value than that of the isolated opinions. Leading opinions may have an influence on the results of the entire group (Giovinazzo, 2001).

For the proper use of the aforementioned method, members of a group of experts familiar with the study themes were consulted—for the present study, the organizational psychologists were the targeted group. After the elaboration of the questionnaires, they were sent to the respondents individually, and returned to the researchers after completion. After analysis, the questionnaires were sent back to the respondents, in order to reduce the dispersion of the results (Candido et al., 2007; Wright et al., 2000). For the scientific legitimacy of this method, three points were respected: the anonymity of the participants, the statistical evaluation of the distribution of the data obtained and the return of the responses of the group members, so that the new assessment can be made (Listone & Turroff, 2002; Wright et al., 2000; Martino, 1993).

In the last round, the same questionnaire was used, for the same Psychology professionals, who then had the Weighted Average of the result of the previous stage, referring to all respondents, as well as the values assigned by themselves.

Table 6. Calculation of Index Ordinatío for the keywords group of “Human Skills & Graduate”.

Question	Attributed weighs and responses frequency											AR	
	0	1	2	3	4	5	6	7	8	9	10		
How much “Ability to present ideas clearly during a conversation” impacts “Oral Communication”						2	4	3	1				6.3

Source: Adapted from: [Fagundes \(2015\)](#).

Based on this, they decided whether they would maintain or modify their responses from the first round. This step increases the reliability of the results, as the change of some perceptions reduces the values dispersion ([Fagundes, 2015](#)).

Finally, the modeling developed by one of the authors of this study ([Campos, 2019](#)), was calibrated in all its guidelines, indexes and indicators, thus providing the final result (indicator): diagnosis of the soft skills development for Engineering training, as elucidated in [Table 7](#). This calibration is presented as complementation of the developed model and it serves to the purpose of specialists being able to determine how much a soft skill impacts another one, attending the complete development of the fuzzy logic within the present work.

The values obtained with the weighting of the Psychologists were entered in the FuzzyTECH Software to calibrate the model. Copies of the questionnaires suggested to be applied with the targeted audience composed of students, graduates, professors and employers of Engineers were also attached to this study in the [Appendices 1-6](#). This covers the entire development of the instrument for diagnosing the soft skills development in Engineering training.

4. Application Simulation

Considering a hypothetical application, utilizing the possibility of simulation that the model developed by the authors provide, using fictitious groups of teachers, graduates, students and employers of engineers to answer the questionnaires contained in [Appendices 1-6](#), the results obtained are as follows, shown in [Table 8](#).

[Table 8](#) shows that teachers are out of line with the expectations of the labor market according to the managers’ opinion. This discrepancy in results shows that there is room for improvement in order to reach indexes that meet the job market’s regarding Engineers’ soft skills. Taking into consideration the areas of each group of professors, it is clear that the “Material” is the worst rated one, with low values for “public speaking”, and “multiculturalism”, which make up the macro soft skills macro of communication and teamwork, respectively.

The scientific results show that “Communication” and “Team Work” were the skills with the lowest indexes for professors. Based on these evidences, coordinators of Engineering courses can turn their efforts to include in their course curricula the development of these skills. Investment could also be made in professor training, teaching methodology, adaptation of bibliography as well as adjustment of workload and increase or decrease in the subjects availability. Each institution has to evaluate which possibilities are feasible for them to leverage

these rates.

Each of the soft skills can be analyzed either in their macro groups or isolated to identify the weaknesses and potential for improvement of Engineering courses that aims to investigate the levels of soft skills in their students' training.

Table 7. Average of the values assigned by psychologists, after application of the Delphi method.

Guideline/Index/Indicator	Average
D1: How much "Find Solutions using multidisciplinary knowledge" using impacts "Problem Solving"	8.51
D2: How much "Use knowledge, data and facts" impacts "Problem Solving"	8.89
D3: How much "Ability to solve problems in a pacific manner" impacts "Open Mind"	7.29
D4: How much "Openness to suggestions, new ideas and contrary opinions" impacts "Open Mind"	9.46
D5: How much "Ability to talk in public" impacts "Oral Communication"	8.17
D6: How much "Ability to present ideas clearly during a conversation" impacts "Oral Communication"	9.17
D7: How much "Ability to write complex reports and documents with clarity" impacts "Written Communication"	9.23
D8: How much "Having an understandable handwriting and good domain of grammar and rules of the native language" impacts "Written Communication"	8.86
D9: How much "Ability to listen to the interlocutor and wait to speak" impacts "Active Listening"	8.91
D10: How much "Think in an articulate manner, with clear and efficient ideas" impacts "Active Listening"	8.46
D15: How much "Ability to negotiate and manage conflicts with diverse teams" impacts "Leadership"	9.14
D16: How much "Encourage others to develop their strengths to achieve a common goal" impacts "Leadership"	9.23
D17: How much "Ability to use interpersonal skills to train and develop others" impacts "Leadership"	9.06
D21: How much "Ability to learn with the own mistakes" impacts "Control of emotions"	7.97
D22: How much "Possessing self-control" impacts "Control of emotions"	9.09
D23: How much "Being persistent" impacts "Motivation"	8.34
D24: How much "Having passion for the goals" impacts "Motivation"	9.20
D25: How much "Possess self-esteem, optimism and confidence" impacts "Motivation"	9.20
ID1: How much "Problem Solving" impacts "Critical Thinking"	7.71
ID2: How much "Open Mind" impacts "Critical Thinking"	8.37
ID3: How much a "Orality" impacts "Communication"	8.66
ID4: How much a "Writing" impacts "Communication"	8.54
ID5: How much "Active Listening" impacts "Communication"	9.09
D11: How much "Reading" impacts "Communication"	8.63
D12: How much "Foreign Language" impacts "Communication"	7.43
D13: How much "Multiculturalism" impacts "Team Work"	8.20
D14: How much "Networking" impacts "Team Work"	7.51
ID10: How much "Leadership" impacts "Team Work"	8.33

Continued

ID18: How much “Personal Ethics” impacts “Ethic Perspective”	9.06
ID19: How much que “Professionalism” impacts “Ethic Perspective”	9.14
D20: How much que “Social Responsibility” impacts “Ethic Perspective”	8.54
ID14: How much “Control of Emotions” impacts “Emotional Intelligence”	9.23
ID15: How much “Motivation” impacts “Emotional Intelligence”	8.14
D26: How much “Lifelong Learning” impacts “Emotional Intelligence”	8.51
D27: How much “Self-Direction” impacts “Emotional Intelligence”	8.17
D28: How much “Creativity” impacts “Creative Thinking”	9.29
D29: How much “Innovation” impacts “Creative Thinking”	9.17
IC1: How much “Critical Thinking” impacts the soft skills of an Engineer	8.89
IC2: How much “Communication” Impacts the soft skills of an Engineer	8.57
IC3: How much “Team Work” impacts the soft skills of an Engineer	8.49
IC4: How much “Ethical Perspective” impacts the soft skills of an Engineer	8.94
IC5: How much “Emotional Intelligence” impacts the soft skills of an Engineer	8.80
IC6: How much “Creative Thinking” impacts the soft skills of an Engineer.	7.98

Source: Campos (2019).

Table 8. All fuzzy averages for all socioemotional guidelines and skills.

	Professors											Students		Managers		
	Projects	Industrial Engineering	Chemistry	Physics	Mathematics	Fabrication	Human Sciences	Materials	Fluids	Interdisciplinary	Thermodynamics	Average	Students	Graduates	Expectation	Reality
D3—Ability to solve problems in a pacific manner	6.00	6.40	6.00	6.57	8.13	5.57	7.67	7.50	9.00	7.00	6.33	6.92	7.16	6.75	6.50	6.50
D4—Openness to suggestions, new ideas and contrary opinions	7.44	8.60	8.50	5.57	8.13	6.86	8.33	8.75	9.00	8.50	5.83	7.77	7.45	8.04	8.5	6.50
Open Mind	7.42	9.08	9.17	6.66	9.12	6.71	9.17	9.17	9.17	9.16	6.58	8.31	8.09	9.06	9.14	6.64
D1—Find solutions using multidisciplinary knowledge	9.00	7.80	8.50	7.43	7.88	7.43	8.67	8.50	8.43	8.25	8.05	8.22	6.41	7.18	8.50	6.50
D2—Use knowledge, data and facts to solve problems at work	8.89	7.80	8.0	9.00	8.38	8.00	8.67	8.50	8.86	7.00	8.17	8.30	6.45	7.18	8.50	6.50
Problem Solving	9.17	8.78	8.40	9.17	9.17	9.03	9.17	9.17	9.17	9.17	9.17	9.05	6.63	7.59	9.17	6.64
Critical Thinking	9.17	9.08	9.17	9.15	9.17	9.03	9.17	9.17	9.17	9.17	9.02	9.13	8.04	9.06	9.17	6.64
D5—Ability to talk in public	7.78	6.80	5.50	5.29	2.75	3.71	5.33	5.00	7.86	4.25	5.00	5.39	6.03	7.33	7.00	7.50
D6—Ability to present ideas clearly during a conversation	8.33	7.00	8.00	6.86	5.5	4.29	8.00	5.75	8.00	6.25	6.17	6.74	6.88	7.62	7.5	8.00
Oral Communication	9.17	6.85	9.02	3.84	3.56	3.45	6.80	5.67	9.03	5.693	6.41	6.32	6.72	8.51	8.36	9.03
D7—Ability to write complex reports and documents with clarity	7.44	5.20	4.50	5.86	6.38	5.14	7.33	6.5	5.71	5.00	6.00	5.91	5.87	6.89	7.50	4.00

Continued

D8—Having an understandable handwriting and good domain of grammar and rules of the native language	6.44	5.60	4.00	6.00	5.25	4.71	4.67	6.00	5.86	4.75	4.17	5.22	6.24	6.60	7.50	5.50
Written Communication	6.67	5.45	3.73	6.27	6.60	4.94	6.65	6.35	6.14	4.95	5.20	5.72	6.51	6.73	8.33	4.32
D10—Think in an articulate manner, with clear and efficient ideas	8.89	7.20	8.50	8.29	8.88	5.29	9.00	8.00	8.00	7.75	8.50	8.03	7.12	7.69	7.00	5.00
D9—Ability to listen the interlocutor and wait to speak	6.78	6.60	7.50	6.43	7.38	4.29	6.33	7.50	8.14	6.25	7.83	6.82	7.34	7.22	5.50	5.00
Active Listening	9.11	7.12	9.17	9.09	9.17	4.52	9.02	9.03	9.13	8.28	9.17	8.44	7.79	8.62	7.02	5.000
Reading	8.89	7.00	7.5	8.86	9.13	6.86	8.33	8.25	8.43	7.75	7.33	8.03	7.36	8.09	8.50	6.5
Foreign Language	4.78	1.60	3.00	2.29	1.38	4.71	3.00	5.75	5.14	4.5	6.67	3.89	5.1	4.29	5.50	5.50
Auxiliary Variable	6.67	5.44	6.57	6.62	6.67	5.18	6.57	7.69	6.68	6.44	7.35	6.53	6.68	6.63	7.00	5.25
Communication	6.67	5.95	6.35	5.41	5.22	4.95	6.65	6.65	6.69	5.58	5.94	6.00	6.69	6.72	7.92	5.89
D15—Ability to negotiate and manage conflicts with diverse teams	8.78	6.20	3.50	6.43	5.88	5.29	6.67	7.50	6.71	5.25	4.67	6.08	6.87	7.15	6.50	6.00
D16—Encourage others to develop their strengths to achieve a common goal	8.78	6.20	3.00	6.57	7.38	5.43	6.67	6.75	7.29	5.25	6.00	6.30	6.37	6.67	6.00	5.00
D17—Ability to use interpersonal skills to train and develop others	9.22	7.00	4.50	7.14	7.00	4.57	6.67	6.75	8.29	5.25	6.17	6.60	6.20	6.58	6.00	5.00
Leadership	9.17	6.64	3.35	6.67	6.72	5.01	6.67	6.67	7.33	5.00	5.92	6.29	6.657	6.67	6.50	5.00
Multiculturalism	5.00	4.80	8.50	5.43	6.25	4.43	6.67	5.50	8.14	4.00	4.00	5.70	7.51	7.76	7	4.50
Networking	9.22	6.00	7.00	7.43	8.13	6.43	6.67	7.25	8.86	5.00	5.33	7.03	7.47	7.93	5.5	8.00
Team work	6.67	6.11	6.67	6.67	6.71	5.005	6.67	6.67	9.135	5	5.01	6.39	8.44	8.44	6.54	6.32
Ethics	9.33	7.00	6.00	8.86	8.38	6.71	9.00	6.00	9.00	7.50	7.83	7.78	7.89	8.07	9	8.50
Professionalism	9.56	7.00	9.00	8.57	8.88	7.56	9.00	7.75	9.29	8.50	7.50	8.42	8.19	8.24	8	8.00
Social Responsibility	9.78	6.60	8.50	7.86	7.88	5.57	8.33	7.00	8.71	4.25	6.83	7.39	7.44	7.85	6.5	5.50
Ethical Perspective	9.17	6.80	9.17	9.17	9.17	6.67	9.170	6.929	9.17	6.67	7.65	8.16	8.86	9.06	8.96	7.013
D21—Ability to Learn with the own mistakes.	9.11	6.60	8.00	8.14	8.63	7.29	9.33	7.50	8.57	7.50	8.17	8.08	7.97	7.87	6.5	7.00
D22—Possessing self-control	8.9	5.2	9.0	6.7	7.3	5.7	6.7	6.0	8.6	6.5	8.2	7.15	6.9	7.5	6.5	6.0
Control of Emotions	9.166	6.663	9.166	9.124	9.166	7.187	9.167	7.499	9.166	7.886	9.148	8.49	8.995	8.880	6.647	6.805
D23—Being persistent	9.33	3.80	9.50	8.43	8.25	7.29	8.67	6.50	9.43	6.50	8.67	7.85	7.23	8.38	7	7.50
D24—Having passion for the goals	9.33	3.00	7.00	7.57	8.38	6.43	9.00	6.75	9.29	5.50	8.33	7.33	6.78	7.65	8	7.50
D25—Possessing self-esteem, optimism and confidence	9.22	3.40	8.50	7.14	7.88	7.71	8.33	6.75	9.29	5.50	7.33	7.37	5.57	7.11	6.5	7.50
Motivation	9.17	3.34	9.17	8.34	9.16	7.18	9.16	6.68	9.16	5.58	9.16	7.83	6.67	8.50	6.80	7.91
Lifelong Learning	9.80	7.0	8.0	8.0	8.60	7.90	9.00	7.50	9.00	9.80	8.7	8.47	7.8	8.5	8.5	7.5
Self-Direction	9.60	6.4	8.0	8.1	8.6	7.10	8.30	5.30	8.0	8.80	8.5	7.88	7.2	7.8	7.5	6.50
Auxiliary Variable 2	9.17	6.81	9.03	9.10	9.17	8.92	9.17	6.78	9.17	9.17	9.17	8.69	8.76	9.17	9.166	7.88
Emotional Intelligence	9.16	5.100	9.16	8.98	9.16	7.85	9.16	6.81	9.16	7.47	9.16	8.29	8.52	8.88	6.83	7.67
Creativity	9.33	7.00	7.50	7.00	8.63	7.14	9.00	6.50	9.14	9.50	8.00	8.07	6.94	6.91	7.50	6.50
Innovation	9.44	5.80	8.50	8.43	8.00	6.86	9.00	5.25	9.43	8.00	7.67	7.85	6.42	6.51	7.50	6.50
Creative Thinking	9.16	6.80	9.16	9.16	9.16	7.07	9.16	6.64	9.16	9.16	9.02	8.52	6.75	6.73	8.33	6.64
RESULTS	9.16	6.67	9.16	9.16	9.16	6.87	9.18	6.66	9.16	7.83	9.16	8.38	9.16	9.16	9.16	6.77

5. Results and Conclusion

The proposed model was simulated in the present study, but also validated through its application in a case study involving students, teachers and graduates of the Federal Technological University of Paraná, in Brazil, as well as Engineers' employers. The targeted audience chosen for the validation was broad and representative with respect to the universe of the Engineering training. It involved 375 participants, who answered the questionnaires proposed in **Appendices 1-6**. The results of the application are detailed in the doctorate thesis from **Campos (2019)** and the model proved to provide consistent and coherent results.

The presented model is robust, as it allows the same guidelines to be applied in any Engineering courses, as long as it adapts to the expected time and space; in addition to covering a bibliographic review of the last 15 years of publications on the subject, in 4 databases and two journals with a high impact factor—which were essential to give the modeling reliability, equivalence, consistency, stability and shelf life.

The reliability of the data collection tool makes it possible to repeat a result in a solid manner (**Williamson & Piattoeva, 2019**). The equivalence of a research tool, on the other hand, relates to the level of agreement between at least two observers, with respect to the scores (**Ahn et al., 2019**). Both characteristics were explored in this work using the Delphi method, aiming to take the answers of the 40 organizational Psychologists, as well as for the calibration of the Fuzzy-TECH Software, in order to provide a collective consensus of ideas, demonstrating the most representative values, rather than isolated opinions.

The equivalence of a research tool refers to the agreement between at least 2 observers with respect to the data obtained with the tool (**Ahn et al., 2019**). Both points cited were addressed in this research using the Delphi method, starting from the integration of the responses of 40 Psychologists to the calibration of the FuzzyTECH Software, aiming the collective consensus of the data and preserving the subjective content of the collected data.

Regarding the stability of the tool, it concerns the similarity of the data obtained at different times, which can be evaluated by test-retest, applying the same measure in other times (**Souza, Alexandre, & Guirardello, 2017**). The test-retest was carried out in the modeling with several simulations in the FuzzyTECH Software for the analysis and interpretation of the data, which proved to be convergent and stable.

With respect to the validity of the research tool, **Fadzil and Saat (2019)** state that it is the capacity that the tool has to measure what it is proposed to measure. This characteristic is present in this model, by answering the research question “How to develop a fuzzy modeling to diagnose soft skills in Engineering training”. It has shown to be coherent and consolidated in concise manner.

For **Umanailo et al. (2019)**, the consistency of a tool has to do with its ability to measure the same characteristic, in the same field or domain. This research tool was consistent, since the questions asked about a particular soft skill were

kept under the same focus, homogeneity and coherence within the same perspective.

The comparison between the different profiles interviewed is another desirable characteristic that the model offers, in addition to allowing necessary adjustments to be made—the investment on people, resources and curricular adaptations to reach the index desired by the user. The relevance of these analyzes, as well as of the simulations, is supported by the orientation of improvements and improvements in the Engineering courses with regard to soft skills.

In addition, the proposed model presents a powerful structure for data collection, allowing its application in the comparison between the reality of the Engineering job market (Campos et al., 2020b) and the perception of graduates, students and teachers. The application of this model also includes intermediate results from all 6 thematic groups, that is, the soft skills listed as important for the training of Engineering professionals.

In a Nutshell, this is an easy-to-use model, in which only input data needs to be changed for each group (soft skills) or in isolation, and can be used for the investigation of the need for improvements in courses, curricular guidelines and training practices for Engineering professionals.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendices

Appendix 1. Questionnaire for Organizational Psychology professionals for FuzzyTECH Software calibration.

Consider that, to hire an Engineer in your organization, soft skills are evaluated using this query. Mark, for each of these skills, according to the corresponding scale, the minimum expected for a potential candidate to be able to be part of your organization.

How much "Find Solutions using multidisciplinary knowledge" using impacts "Problem Solving"	0	1	2	3	4	5	6	7	8	9	10
How much "Use knowledge, data and facts" impacts "Problem Solving"	0	1	2	3	4	5	6	7	8	9	10
How much "Problem Solving" impacts "Critical Thinking"	0	1	2	3	4	5	6	7	8	9	10
How much "Ability to solve problems in a pacific manner" impacts "Open Mind"	0	1	2	3	4	5	6	7	8	9	10
How much "Openness to suggestions, new ideas and contrary opinions" impacts "Open Mind"	0	1	2	3	4	5	6	7	8	9	10
How much "Open Mind" impacts "Critical Thinking"	0	1	2	3	4	5	6	7	8	9	10
How "Critical Thinking" impacts "Results"	0	1	2	3	4	5	6	7	8	9	10
How much "Ability to talk in public" impacts "Oral Communication"	0	1	2	3	4	5	6	7	8	9	10
How much "Ability to present ideas clearly during a conversation" impacts "Oral Communication"	0	1	2	3	4	5	6	7	8	9	10
How much "Oral Communication" impacts "Communication"	0	1	2	3	4	5	6	7	8	9	10
How much "Ability to write complex reports and documents with clarity" impacts "Written Communication"	0	1	2	3	4	5	6	7	8	9	10
How much "Having an understandable handwriting and good domain of grammar and rules of the native language grammar" impacts "Written Communication"	0	1	2	3	4	5	6	7	8	9	10
How much "Written Communication" impacts "Communication"	0	1	2	3	4	5	6	7	8	9	10
How much "Ability to listen to the interlocutor and wait to speak" impacts "Active Listening"	0	1	2	3	4	5	6	7	8	9	10
How much "Think in an articulate manner, with clear and efficient ideas" impacts "Active Listening"	0	1	2	3	4	5	6	7	8	9	10
How "Active Listening" impacts "Communication"	0	1	2	3	4	5	6	7	8	9	10
How much "Ability to interpret texts, using all the data within contained" impacts "Reading"	0	1	2	3	4	5	6	7	8	9	10
How much "Reading" impacts "Communication"	0	1	2	3	4	5	6	7	8	9	10

Continued

How much “Ability to read, speak and write in a language other than the native language” impacts “Foreign Language”	0	1	2	3	4	5	6	7	8	9	10
How much “Foreign Language” impacts “Communication”	0	1	2	3	4	5	6	7	8	9	10
How much “Communication” impacts “Results”	0	1	2	3	4	5	6	7	8	9	10
How much “Ability to work in collaboration with individuals from different cultures, genders, religions and lifestyles” impacts “Multiculturalism”	0	1	2	3	4	5	6	7	8	9	10
How much “Multiculturalism” impacts “Team Work”	0	1	2	3	4	5	6	7	8	9	10
How much “Creation of collaborative relationships with colleagues and clients” impacts “Networking”	0	1	2	3	4	5	6	7	8	9	10
How much “Networking” impacts “Team Work”	0	1	2	3	4	5	6	7	8	9	10
How much “Ability to negotiate and manage conflicts with diverse teams” impacts “Leadership”	0	1	2	3	4	5	6	7	8	9	10
How much “Encourage others to develop their strengths to achieve a common goal” impacts “Leadership”	0	1	2	3	4	5	6	7	8	9	10
How much “Ability to use interpersonal skills to train and develop others” impacts “Leadership”	0	1	2	3	4	5	6	7	8	9	10
How much “Leadership” impacts “Team Work”	0	1	2	3	4	5	6	7	8	9	10
How much “Team Work” impacts “Results”	0	1	2	3	4	5	6	7	8	9	10
How much “Demonstrate Integrity and ethical behavior” impacts “Ethics”	0	1	2	3	4	5	6	7	8	9	10
How much “Commitment with work” impacts “Professionalism”	0	1	2	3	4	5	6	7	8	9	10
How much “Professionalism” impacts “Ethic Perspective”	0	1	2	3	4	5	6	7	8	9	10
How much “Act responsibly according to the society’s needs” impacts “Ethic Perspective”	0	1	2	3	4	5	6	7	8	9	10
How much que “Social Responsibility” impacts “Ethic Perspective”	0	1	2	3	4	5	6	7	8	9	10
How much “Ethic Perspective” impacts “Results”	0	1	2	3	4	5	6	7	8	9	10
How much “Ability to Learn with the own mistakes” impacts “Control of emotions”	0	1	2	3	4	5	6	7	8	9	10
How much “Possessing self-control” impacts “Control of emotions”	0	1	2	3	4	5	6	7	8	9	10

Continued

How much “Control of Emotions” impacts “Emotional Intelligence”	0	1	2	3	4	5	6	7	8	9	10
How much “Being persistent” impacts “Motivation”	0	1	2	3	4	5	6	7	8	9	10
How much “Having passion for the goals” impacts “Motivation”	0	1	2	3	4	5	6	7	8	9	10
How much “Possess self-esteem, optimism and confidence” impacts “Motivation”	0	1	2	3	4	5	6	7	8	9	10
How much “Motivation” impacts “Emotional Intelligence”	0	1	2	3	4	5	6	7	8	9	10
How much “Ability to continuously acquire new knowledge and skills” impacts “Lifelong learning”	0	1	2	3	4	5	6	7	8	9	10
How much “Lifelong Learning” impacts “Emotional Intelligence”	0	1	2	3	4	5	6	7	8	9	10
How much “Ability to evaluate the own needs for improvement” impacts “Self-Direction”	0	1	2	3	4	5	6	7	8	9	10
How much “Self-Direction” impacts “Emotional Intelligence”	0	1	2	3	4	5	6	7	8	9	10
How much “Emotional Intelligence” impacts “Results”	0	1	2	3	4	5	6	7	8	9	10
How much “Ability to bring new ideas” impact “Creativity”	0	1	2	3	4	5	6	7	8	9	10
How much “Creativity” impacts “Creative Thinking”	0	1	2	3	4	5	6	7	8	9	10
How much “Ability to put new ideas into practice” impacts “Innovation”	0	1	2	3	4	5	6	7	8	9	10
How much “Innovation” impacts “Creative Thinking”	0	1	2	3	4	5	6	7	8	9	10
How much “Creative Thinking” impacts “Results”	0	1	2	3	4	5	6	7	8	9	10

Appendix 2. Questionnaire about the students’ perception on the soft skills development at their attended courses.

Check the scale corresponding to your perception of the development of soft skills in the courses you attended.

Questions about Problem Solving

D1—Find solutions using multidisciplinary knowledge 0 1 2 3 4 5 6 7 8 9 10

D2—Use knowledge, data and facts to solve problems at work 0 1 2 3 4 5 6 7 8 9 10

Questions about Open Mind

D3—Ability to solve problems in a pacific manner 0 1 2 3 4 5 6 7 8 9 10

D4—Openness to suggestions, new ideas and contrary opinions 0 1 2 3 4 5 6 7 8 9 10

Questions about Verbal Communication

D5—Ability to talk in public 0 1 2 3 4 5 6 7 8 9 10

Continued

D6—Ability to present ideas clearly during a conversation	0	1	2	3	4	5	6	7	8	9	10
Questions about Written Communication											
D7—Ability to write complex reports and documents with clarity	0	1	2	3	4	5	6	7	8	9	10
D8—Having an understandable handwriting and good domain of grammar and rules of the native language	0	1	2	3	4	5	6	7	8	9	10
Questions about Active Listening											
D9—Ability to listen the interlocutor and wait to speak	0	1	2	3	4	5	6	7	8	9	10
D10—Think in an articulate manner, with clear and efficient ideas	0	1	2	3	4	5	6	7	8	9	10
Question about Reading											
D11—Ability to interpret complex texts, being able to utilize all the data contained in them	0	1	2	3	4	5	6	7	8	9	10
Question about Foreign Language											
D12—Ability to read, speak and write in a language other than the native language	0	1	2	3	4	5	6	7	8	9	10
Question about Multiculturalism											
D13—Ability to work in collaboration with individuals from different cultures, genders, religions and lifestyles	0	1	2	3	4	5	6	7	8	9	10
Question about Networking											
D14—Creation of collaborative relationships with colleagues and clients	0	1	2	3	4	5	6	7	8	9	10
Questions about Leadership											
D15—Ability to negotiate and manage conflicts with diverse teams	0	1	2	3	4	5	6	7	8	9	10
D16—Encourage others to develop their strengths to achieve a common goal	0	1	2	3	4	5	6	7	8	9	10
D17—Ability to use interpersonal skills to train and develop others	0	1	2	3	4	5	6	7	8	9	10
Question about Ethics											
D18—Demonstrate Integrity and ethical behavior	0	1	2	3	4	5	6	7	8	9	10
Question about Professionalism											
D19—Commitment with work	0	1	2	3	4	5	6	7	8	9	10
Question about Social Responsibility											

Continued

20—Act responsibly according to the society's needs	0	1	2	3	4	5	6	7	8	9	10
Questions about Control of Emotions											
D21—Ability to Learn with the own mistakes.	0	1	2	3	4	5	6	7	8	9	10
D22—Possessing self-control	0	1	2	3	4	5	6	7	8	9	10
Questions about Motivation											
D23—Being persistent	0	1	2	3	4	5	6	7	8	9	10
D24—Having passion for the goals	0	1	2	3	4	5	6	7	8	9	10
D25—Possessing self-esteem, optimism and confidence	0	1	2	3	4	5	6	7	8	9	10
Question about Lifelong Learning											
D26—Ability to continuously acquire new knowledge and skills	0	1	2	3	4	5	6	7	8	9	10
Question about Self-Direction											
D27—Ability to evaluate the own needs for improvement	0	1	2	3	4	5	6	7	8	9	10
Question about Creativity											
D28—Ability to bring new ideas	0	1	2	3	4	5	6	7	8	9	10
Question about Innovation											
D29—Ability to put new ideas into practice	0	1	2	3	4	5	6	7	8	9	10

Source: Campos, 2019.

Appendix 3. Questionnaire about the graduate students' perception about the soft skills learned at university.

Check the scale corresponding to your perception regarding the soft skills you learned during university

Questions about Problem Solving											
D1—Find solutions using multidisciplinary knowledge	0	1	2	3	4	5	6	7	8	9	10
D2—Use knowledge, data and facts to solve problems at work	0	1	2	3	4	5	6	7	8	9	10
Questions about Open Mind											
D3—Ability to solve problems in a pacific manner	0	1	2	3	4	5	6	7	8	9	10
D4—Openness to suggestions, new ideas and contrary opinions	0	1	2	3	4	5	6	7	8	9	10
Questions about Verbal Communication											
D5—Ability to talk in public	0	1	2	3	4	5	6	7	8	9	10
D6—Ability to present ideas clearly during a conversation	0	1	2	3	4	5	6	7	8	9	10
Questions about Written Communication											
D7—Ability to write complex reports and documents with clarity	0	1	2	3	4	5	6	7	8	9	10

Continued

D8—Having an understandable handwriting and good domain of grammar and rules of the native language	0	1	2	3	4	5	6	7	8	9	10
Questions about Active Listening											
D9—Ability to listen the interlocutor and wait to speak	0	1	2	3	4	5	6	7	8	9	10
D10—Think in an articulate manner, with clear and efficient ideas	0	1	2	3	4	5	6	7	8	9	10
Question about Reading											
D11—Ability to interpret complex texts, being able to utilize all the data contained in them	0	1	2	3	4	5	6	7	8	9	10
Question about Foreign Language											
D12—Ability to read, speak and write in a language other than the native language	0	1	2	3	4	5	6	7	8	9	10
Question about Multiculturalism											
D13—Ability to work in collaboration with individuals from different cultures, genders, religions and lifestyles	0	1	2	3	4	5	6	7	8	9	10
Question about Networking											
D14—Creation of collaborative relationships with colleagues and clients	0	1	2	3	4	5	6	7	8	9	10
Questions about Leadership											
D15—Ability to negotiate and manage conflicts with diverse teams	0	1	2	3	4	5	6	7	8	9	10
D16—Encourage others to develop their strengths to achieve a common goal	0	1	2	3	4	5	6	7	8	9	10
D17—Ability to use interpersonal skills to train and develop others	0	1	2	3	4	5	6	7	8	9	10
Question about Ethics											
D18—Demonstrate Integrity and ethical behavior	0	1	2	3	4	5	6	7	8	9	10
Question about Professionalism											
D19—Commitment with work	0	1	2	3	4	5	6	7	8	9	10
Question about Social Responsibility											
D20—Act responsibly according to the society's needs	0	1	2	3	4	5	6	7	8	9	10
Questions about Control of Emotions											
D21—Ability to Learn with the own mistakes.	0	1	2	3	4	5	6	7	8	9	10
D22—Possessing self-control	0	1	2	3	4	5	6	7	8	9	10

Continued

Questions about Motivation

D23—Being persistent	0	1	2	3	4	5	6	7	8	9	10
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D24—Having passion for the goals	0	1	2	3	4	5	6	7	8	9	10
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D25—Possessing self-esteem, optimism and confidence	0	1	2	3	4	5	6	7	8	9	10
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Question about Lifelong Learning

D26—Ability to continuously acquire new knowledge and skills	0	1	2	3	4	5	6	7	8	9	10
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Question about Self-Direction

D27—Ability to evaluate the own needs for improvement	0	1	2	3	4	5	6	7	8	9	10
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Question about Creativity

D28—Ability to bring new ideas	0	1	2	3	4	5	6	7	8	9	10
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Question about Innovation

D29—Ability to put new ideas into practice	0	1	2	3	4	5	6	7	8	9	10
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Source: Campos, 2019.

Appendix 4. Questionnaire about the professor's perception about the development of soft skills in their courses.

Mark on the corresponding scale your perception of how much the _____ (your course's name) contributes to the development of the students' soft skills

Questions about Problem Solving

D1—Find solutions using multidisciplinary knowledge	0	1	2	3	4	5	6	7	8	9	10
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D2—Use knowledge, data and facts to solve problems at work	0	1	2	3	4	5	6	7	8	9	10
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Questions about Open Mind

D3—Ability to solve problems in a pacific manner	0	1	2	3	4	5	6	7	8	9	10
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D4—Openness to suggestions, new ideas and contrary opinions	0	1	2	3	4	5	6	7	8	9	10
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Questions about Verbal Communication

D5—Ability to talk in public	0	1	2	3	4	5	6	7	8	9	10
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D6—Ability to present ideas clearly during a conversation	0	1	2	3	4	5	6	7	8	9	10
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Questions about Written Communication

D7—Ability to write complex reports and documents with clarity	0	1	2	3	4	5	6	7	8	9	10
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D8—Having an understandable handwriting and good domain of grammar and rules of the native language	0	1	2	3	4	5	6	7	8	9	10
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Questions about Active Listening

Continued

D9—Ability to listen the interlocutor and wait to speak	0	1	2	3	4	5	6	7	8	9	10
D10—Think in an articulate manner, with clear and efficient ideas	0	1	2	3	4	5	6	7	8	9	10
Question about Reading											
D11—Ability to interpret complex texts, being able to utilize all the data contained in them	0	1	2	3	4	5	6	7	8	9	10
Question about Foreign Language											
D12—Ability to read, speak and write in a language other than the native language	0	1	2	3	4	5	6	7	8	9	10
Question about Multiculturalism											
D13—Ability to work in collaboration with individuals from different cultures, genders, religions and lifestyles	0	1	2	3	4	5	6	7	8	9	10
Question about Networking											
D14—Creation of collaborative relationships with colleagues and clients	0	1	2	3	4	5	6	7	8	9	10
Questions about Leadership											
D15—Ability to negotiate and manage conflicts with diverse teams	0	1	2	3	4	5	6	7	8	9	10
D16—Encourage others to develop their strengths to achieve a common goal	0	1	2	3	4	5	6	7	8	9	10
D17—Ability to use interpersonal skills to train and develop others	0	1	2	3	4	5	6	7	8	9	10
Question about Ethics											
D18—Demonstrate Integrity and ethical behavior	0	1	2	3	4	5	6	7	8	9	10
Question about Professionalism											
D19—Commitment with work	0	1	2	3	4	5	6	7	8	9	10
Question about Social Responsibility											
20—Act responsibly according to the society's needs	0	1	2	3	4	5	6	7	8	9	10
Questions about Control of Emotions											
D21—Ability to Learn with the own mistakes.	0	1	2	3	4	5	6	7	8	9	10
D22—Possessing self-control	0	1	2	3	4	5	6	7	8	9	10
Questions about Motivation											
D23—Being persistent	0	1	2	3	4	5	6	7	8	9	10
D24—Having passion for the goals	0	1	2	3	4	5	6	7	8	9	10

Continued

D25—Possessing self-esteem, optimism and confidence	0	1	2	3	4	5	6	7	8	9	10
Question about Lifelong Learning											
D26—Ability to continuously acquire new knowledge and skills	0	1	2	3	4	5	6	7	8	9	10
Question about Self-Direction											
D27—Ability to evaluate the own needs for improvement	0	1	2	3	4	5	6	7	8	9	10
Question about Creativity											
D28—Ability to bring new ideas	0	1	2	3	4	5	6	7	8	9	10
Question about Innovation											
D29—Ability to put new ideas into practice	0	1	2	3	4	5	6	7	8	9	10

Source: Campos, 2019.

Appendix 5. Questionnaire about the minimum requirement of soft skills from Engineering employers for Engineer's hiring.

Consider that, to hire an Engineer in your organization, soft skills are evaluated using this query. Mark, for each of these skills, according to the corresponding scale, the minimum expected for a potential candidate to be able to be part of your organization.

Questions about Problem Solving											
D1—Find solutions using multidisciplinary knowledge	0	1	2	3	4	5	6	7	8	9	10
D2—Use knowledge, data and facts to solve problems at work	0	1	2	3	4	5	6	7	8	9	10
Questions about Open Mind											
D3—Ability to solve problems in a pacific manner	0	1	2	3	4	5	6	7	8	9	10
D4—Openness to suggestions, new ideas and contrary opinions	0	1	2	3	4	5	6	7	8	9	10
Questions about Verbal Communication											
D5—Ability to talk in public	0	1	2	3	4	5	6	7	8	9	10
D6—Ability to present ideas clearly during a conversation	0	1	2	3	4	5	6	7	8	9	10
Questions about Written Communication											
D7—Ability to write complex reports and documents with clarity	0	1	2	3	4	5	6	7	8	9	10
D8—Having an understandable handwriting and good domain of grammar and rules of the native language	0	1	2	3	4	5	6	7	8	9	10
Questions about Active Listening											
D9—Ability to listen the interlocutor and wait to speak	0	1	2	3	4	5	6	7	8	9	10
D10—Think in an articulate manner, with clear and efficient ideas	0	1	2	3	4	5	6	7	8	9	10

Continued

Question about Reading

D11—Ability to interpret complex texts, being able to utilize all the data contained in them 0 1 2 3 4 5 6 7 8 9 10

Question about Foreign Language

D12—Ability to read, speak and write in a language other than the native language 0 1 2 3 4 5 6 7 8 9 10

Question about Multiculturalism

D13—Ability to work in collaboration with individuals from different cultures, genders, religions and lifestyles 0 1 2 3 4 5 6 7 8 9 10

Question about Networking

D14—Creation of collaborative relationships with colleagues and clients 0 1 2 3 4 5 6 7 8 9 10

Questions about Leadership

D15—Ability to negotiate and manage conflicts with diverse teams 0 1 2 3 4 5 6 7 8 9 10

D16—Encourage others to develop their strengths to achieve a common goal 0 1 2 3 4 5 6 7 8 9 10

D17—Ability to use interpersonal skills to train and develop others 0 1 2 3 4 5 6 7 8 9 10

Question about Ethics

D18—Demonstrate Integrity and ethical behavior 0 1 2 3 4 5 6 7 8 9 10

Question about Professionalism

D19—Commitment with work 0 1 2 3 4 5 6 7 8 9 10

Question about Social Responsibility

D20—Act responsibly according to the society's needs 0 1 2 3 4 5 6 7 8 9 10

Questions about Control of Emotions

D21—Ability to Learn with the own mistakes. 0 1 2 3 4 5 6 7 8 9 10

D22—Possessing self-control 0 1 2 3 4 5 6 7 8 9 10

Questions about Motivation

D23—Being persistent 0 1 2 3 4 5 6 7 8 9 10

D24—Having passion for the goals 0 1 2 3 4 5 6 7 8 9 10

D25—Possessing self-esteem, optimism and confidence 0 1 2 3 4 5 6 7 8 9 10

Question about Lifelong Learning

Continued

D26—Ability to continuously acquire new knowledge and skills	0	1	2	3	4	5	6	7	8	9	10
Question about Self-Direction											
D27—Ability to evaluate the own needs for improvement	0	1	2	3	4	5	6	7	8	9	10
Question about Creativity											
D28—Ability to bring new ideas	0	1	2	3	4	5	6	7	8	9	10
Question about Innovation											
D29—Ability to put new ideas into practice	0	1	2	3	4	5	6	7	8	9	10

Source: Campos, 2019.

Appendix 6. Questionnaire about the employers' perception about their recently-hired collaborators' soft skills.

Check the scale corresponding to your perception regarding the soft skills of the recently-hired Engineers in your organization (up to 1 year experience)

Questions about Problem Solving											
D1—Find solutions using multidisciplinary knowledge	0	1	2	3	4	5	6	7	8	9	10
D2—Use knowledge, data and facts to solve problems at work	0	1	2	3	4	5	6	7	8	9	10
Questions about Open Mind											
D3—Ability to solve problems in a pacific manner	0	1	2	3	4	5	6	7	8	9	10
D4—Openness to suggestions, new ideas and contrary opinions	0	1	2	3	4	5	6	7	8	9	10
Questions about Verbal Communication											
D5—Ability to talk in public	0	1	2	3	4	5	6	7	8	9	10
D6—Ability to present ideas clearly during a conversation	0	1	2	3	4	5	6	7	8	9	10
Questions about Written Communication											
D7—Ability to write complex reports and documents with clarity	0	1	2	3	4	5	6	7	8	9	10
D8—Having an understandable handwriting and good domain of grammar and rules of the native language	0	1	2	3	4	5	6	7	8	9	10
Questions about Active Listening											
D9—Ability to listen the interlocutor and wait to speak	0	1	2	3	4	5	6	7	8	9	10
D10—Think in an articulate manner, with clear and efficient ideas	0	1	2	3	4	5	6	7	8	9	10
Question about Reading											
D11—Ability to interpret complex texts, being able to utilize all the data contained in them	0	1	2	3	4	5	6	7	8	9	10

Continued

Question about Foreign Language											
D12—Ability to read, speak and write in a language other than the native language	0	1	2	3	4	5	6	7	8	9	10
Question about Multiculturalism											
D13—Ability to work in collaboration with individuals from different cultures, genders, religions and lifestyles	0	1	2	3	4	5	6	7	8	9	10
Question about Networking											
D14—Creation of collaborative relationships with colleagues and clients	0	1	2	3	4	5	6	7	8	9	10
Questions about Leadership											
D15—Ability to negotiate and manage conflicts with diverse teams	0	1	2	3	4	5	6	7	8	9	10
D16—Encourage others to develop their strengths to achieve a common goal	0	1	2	3	4	5	6	7	8	9	10
D17—Ability to use interpersonal skills to train and develop others	0	1	2	3	4	5	6	7	8	9	10
Question about Ethics											
D18—Demonstrate Integrity and ethical behavior	0	1	2	3	4	5	6	7	8	9	10
Question about Professionalism											
D19—Commitment with work	0	1	2	3	4	5	6	7	8	9	10
Question about Social Responsibility											
20—Act responsibly according to the society's needs	0	1	2	3	4	5	6	7	8	9	10
Questions about Control of Emotions											
D21—Ability to Learn with the own mistakes.	0	1	2	3	4	5	6	7	8	9	10
D22—Possessing self-control	0	1	2	3	4	5	6	7	8	9	10
Questions about Motivation											
D23—Being persistent	0	1	2	3	4	5	6	7	8	9	10
D24—Having passion for the goals	0	1	2	3	4	5	6	7	8	9	10
D25—Possessing self-esteem, optimism and confidence	0	1	2	3	4	5	6	7	8	9	10
Question about Lifelong Learning											
D26—Ability to continuously acquire new knowledge and skills	0	1	2	3	4	5	6	7	8	9	10
Question about Self-Direction											
D27—Ability to evaluate the own needs for improvement	0	1	2	3	4	5	6	7	8	9	10

Continued

Question about Creativity

D28—Ability to bring new ideas 0 1 2 3 4 5 6 7 8 9 10

Question about Innovation

D29—Ability to put new ideas into practice 0 1 2 3 4 5 6 7 8 9 10

Source: Campos, 2019.

Appendix 7. 335 articles related to the research scope. The articles in bold are the ones ordered by the Index Ordinato. The JEE articles are also shown in bold at the end of the table.

Article	Journal	Year
“Liberal Education Has Failed”: Reading Like an Engineer in 1960s America.	Technology & Culture	2009
Rounding-up the industrial engineering educational profile with adaptive soft skills framed by a cultural competency approach in an industry-university partnership	Proceedings of the ASEE Annual Conference & Exposition	2014
“Continue The Story” A Simple Game, Profound Implications For Knowledge Management	Conference proceedings of eLearning and Software for Education	2013
“Ningen Ryoku”: the Japanese Way in Inculcating Human Skill into Engineering Education	International Conference On Teaching And Learning In Higher Education In Conjunction With Regional Conference on Engineering Education And Research In Higher Education	2012
“Necessary to engineers of the new generation”: what is important for engineers to know?	Engineering Studies	2015
“The best and the brightest”?	TIDSSKRIFT FOR SAMFUNNSFORSKNING	2003
A blended approach to course design and pedagogy to impart soft skills: An IT company’s experiences from software engineering course	Students’ Technology Symposium	2011
A case study on project led education in engineering: students’ and teachers’ perceptions.	European Journal of Engineering Education	2007
“Liberal Education Has Failed”: Reading Like an Engineer in 1960s America.	Technology & Culture	2009
A Competence-Based Approach to Sustainable Innovation Teaching: Experiences Within a New Engineering Program.	Journal of Mechanical Design	2007
A differential evolution algorithm to solve multi-skilled project portfolio scheduling problems	International Journal of Advanced Manufacturing Technology	2013
A Global Human Potential Movement and a Rebirth of Humanistic Psychology.	Humanistic Psychologist	2016
A good answer to (perhaps) not such very good questions.	Engineering Studies	2015
A method for designing automatic assessment systems based on teachers reasoning for evaluating subjective engineering student’s competences	2014 9th Iberian Conference on Information Systems and Technologies	2014
A new engineering education model for Malaysia	International Journal of Engineering Education	2002
A Notional Model of Creation, Maintenance, and Enrichment of Human Capital	Procedia Manufacturing	2015
A pressure cooker—Coaching framework for teaching soft skills in an engineering master’s programme	2015 IEEE Global Engineering Education Conference	2015
A Problem Based Learning Framework to Assess and Develop Soft Skills in a Linear Programming Course.	Proceedings of the ASEE Annual Conference & Exposition	2015
A Skills Audit.	Training & Development Journal	1980

Continued

A Study of Alumni Feedback on Outcome based Education in the Faculty of Engineering & Built Environment, Universiti Kebangsaan Malaysia	Procedia-Social and Behavioral Sciences	2012
A Systematic Approach to Engineering Ethics Education	Science and Engineering Ethics	2012
A world first in collaborative cross-discipline agriculture and engineering education project	International Journal of Mechanical Engineering Education	2015
ABET 2000: what are the most important criteria to the supervisors of new engineering undergraduates?	age	1998
AC 2011-1117: Liberal Learning Revisited: A Historical Examination Of The Underlying Reasons, Frustrations, And Continued Prospects For Engineering And Liberal Arts Integration	American Society for Engineering Education	2011
Acclimating International Graduate Students to Professional Engineering Ethics	Science and Engineering Ethics	2009
Active learning strategies: An illustrative approach to bring out better learning outcomes from Science, Technology, Engineering and Mathematics (STEM) students	Journal of Emerging Technologies in Learning	2014
Adapting Teaching Strategies to Global and Analytic Learning Styles by Real World Engineering Projects	2014 IEEE Global Engineering Education Conference (EDUCON)	2014
Adoption of new subjects to improve the formation of future engineer	29th Annual Frontiers in Education Conference: "Designing the Future of Science and Engineering Education"	1999
Advancing global capacity for engineering education research: relating research to practice, policy and industry.	European Journal of Engineering Education	2010
ADVEISOR– Learning By Doing– The Experience Of Soft Skills In An Engineering Project Created And Accomplished By Students.	EDULEARN13 Proceedings	2013
An analysis of the curriculum for water supply and drainage, science and engineering, based on CCDIO	Applied Mechanics and Materials	2013
An approach for harmonizing engineering and science education with humaneness	Science and Engineering Ethics	2004
An approach to assess knowledge and skills in risk management through project-based learning	Journal of Biomechanical Engineering	2016
An approach to developing independent learning and non-technical skills amongst final year mining engineering students.	European Journal of Engineering Education	2012
An evaluation of the use of computer supported peer review for developing higher-level skills	Computers & Education	1998
Analysis of Non Technical Skills for ICT Profiles	5th Iberian Conference on Information Systems and Technologies (CISTI), Santiago de Compostela	2010
Answers Are Not Written At The End Of The Book: Non-Technical Content Of Engineering Education	Fire Engineering	2012
Applied System and Control Sciences to Social Systems: Globalization Age Paradigms	IFAC Proceedings Volumes	2008
Assessing oral presentations and writing skills	Proceedings—2004 International Professional Communication Conference	2004
Assessing soft and higher order thinking skills among Students using a rubric and Progressive Reflection	MOOC Innovation and Technology in Education	2013
Assessing technology incubator programs in the science park: the good, the bad and the ugly	Technovation	2005
Assessment of soft-skills for student outcomes using engineering courses	American Society for Engineering Education	2011

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Between general culture and challenges of engineering businesses: the diversity of teaching in the humanities and social sciences at the Ecole Centrale de Lyon	Shst 2013-Upec: Sciences Humaines En Sciences Et Techniques—Les Sciences Humaines Dans Les Parcours Scientifiques Et Techniques Professionalisants: Quelles Finalites Et Quelles Modalites Pratiques?	2014
Booknotes.	European Journal of Engineering Education	1999
Brains of Steel: Mind Melding with Materials	International Journal of Engineering Education	2001
Bringing the Human Factor to Software Engineering.	IEEE Software	2014
Broadening Engineering Education: Bringing the Community In Commentary on “Social Responsibility in French Engineering Education: A Historical and Sociological Analysis”	Science and Engineering Ethics	2013
Building a Bridge Between Engineering and the Humanities.	Chronicle of Higher Education	2016
Building ethics and project management into engineering technology programs	age	2004
Building Excellence In Engineering Education In India	Proceedings Of 2015 IEEE Global Engineering Education Conference (EDUCON)	2015
Can disciplinary integration promote students’ lifelong learning attitudes and skills in project-based engineering courses?	The International Journal of Engineering Education	2015
Capabilities for a cosmopolitan citizenship in higher education The experience of the Technical University of Valencia	Procedia-Social and Behavioral Sciences	2010
Capstone engineering design experience: Opportunities to develop and implement skills that work for real people doing real jobs	SPE Annual Technical Conference and Exhibition	2010
Care Ethics in Engineering Education Undergraduate Student Perceptions of Responsibility	2012 Frontiers In Education Conference (FIE)	2012
Challenges before engineering education—Role of humanities and social sciences	Pertanika Journal of Social Science and Humanities	2012
Chemical Engineering students soft-skills in Integrated Project (IP) Part 4	2015 IEEE 7th International Conference on Engineering Education	2016
Closing the Gap Between College Entry and Employment.	About Campus	2013
Coaches safety orientation and training skills program	ASTM Special Technical Publication	1997
Co-creating liberal studies in engineering program(s)—a perspective from Ethnic Studies, Women’s & Gender Studies, and Science & Technology Studies.	Engineering Studies	2015
Cognitive And Emotional Variables In University Students	Studia Psychologica	2010
Cognitive Readiness and the Challenge of Institutionalizing the “New” Versus “News”;	Journal of Cognitive Engineering and Decision Making	2012
College Chinese and humanities education	2011 International Conference on Computer Science and Education, CSE 2011	2012
Comments on “On ‘Bettering Humanity’ in Science and Engineering Education”.	Science and Engineering Ethics	2008
Communication skills to develop trusting relationships on global virtual engineering capstone teams.	European Journal of Engineering Education	2013
Comparison of the impact of two research experiences for undergraduate programs on preparing students for global workforces	2014 IEEE Frontiers in Education Conference (FIE) Proceedings	2015
Competencies And Innovations Labs: Humanities In Engineers’ High-Education	INTED2012 Proceedings	2012
Competency-based on-the-job training for aviation maintenance and inspection - A human factors approach	International Journal of Industrial Ergonomics	2000

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Computational and soft skills development through the project based learning	International Conference on Computational Science	2003
Concept For An Interdisciplinary Seminar Added Value By Multiformity And Bridging The Gap Of Engineering And Humanities At The Rwth Aachen University	EDULEARN13 Proceedings	2013
Contribution of Shell Eco-Marathon engineering design experience to soft skills development: A qualitative analysis in the Asian context	Interactive Collaborative Learning	2015
Control System Approaches For Sustainable Development And Instability Management In The Globalization Age	IFAC Proceedings Volumes	2006
Controlled experiments as means to teach soft skills in software engineering	Overcoming Challenges in Software Engineering Education: Delivering Non-Technical Knowledge and Skills: Delivering Non-Technical Knowledge and Skills	2014
Converging technologies in higher education—Paradigm for the “new” liberal arts?	Annals of the New York Academy of Sciences	2006
Cooperative learning and soft skills training in an IT course	Journal of Information Technology Education	2012
Course on engineering leadership	Journal of Professional Issues in Engineering Education and Practice	1999
Cultivating engineers’ humanity: Fostering cosmopolitanism in a Technical University	International Journal of Educational Development	2012
Curriculum development for project-based engineering education: How to include soft skills	Proceedings SEFI and IGIP Joint Annual Conference	2007
Curriculum for an Engineering Renaissance	IEEE Transactions on Education	2003
Degrees failing to boost students’ “soft skills”.	Times Higher Education	2015
Demystifying Engineering.	Diverse: Issues in Higher Education	2008
Derive Hard Numbers From Soft Skills.	TD: Talent Development	2015
Designing the Liberally Educated Engineer.	Peer Review	2012
Designing the module “methods for activating engineering creativity” on basis of competence approach	Recent Patents on Computer Science	2016
Determinants of Cognitive Skills and Competencies: Preliminary Statistical Analysis of PIAAC Data	VOPROSY OBRAZOVANIYA-EDUCATIONAL STUDIES	2015
Developing Competences in Engineering Students. The Case of Project Management Course	Procedia-Social and Behavioral Sciences	2014
Developing construction professionals of the 21st century: Renewed vision for leadership	Journal Of Professional Issues In Engineering Education And Practice	2008
Developing students’ collaborative skills in interdisciplinary learning environments	International Journal of Engineering Education	2015
Developing technical competency and enhancing the soft skills of undergraduate mechanical engineering students through service-learning	age	2004
Developing well-rounded graduates through integration of soft skills in the teaching of engineering courses	2014 IEEE Frontiers in Education Conference (FIE) Proceedings.	2015
Development of the Novel e-Learning System, “SPES NOVA” (Scalable Personality-Adapted Education System With Networking of Views and Activities)	Proceedings Of The 9th Conference On Man-Machine-Environment System Engineering	2009
Don’t Drunk-Dial HR: Creating Soft-Skills Workshops for College Interns.	NACE Journal	2010
Don’t Overlook Middle-Skill Jobs.	Educational Leadership	2012

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Educating Engineers in the art, science and practice of Project Management: A New Course	2008 IEEE International Conference On Management Of Innovation And Technology, Vols 1-3	2008
Educating the Humanitarian Engineer	Science and Engineering Ethics	2009
Education or Creativity: What Matters Most for Economic Performance?	Economic Geography	2012
Effective Teaching.	Journal of Engineering Education	2006
El impacto del desarrollo de habilidades para la competitividad: Evidencia empírica de una comparación entre países	El internacionalismo moderno	2010
E-Learnings For Soft Skills In Technical Universities	Conference proceedings of» eLearning and Software for Education	2013
Emotional and affective temperament in 23 professional areas	Journal of Affective Disorders	2010
Emotions and interpersonal skills for IT professionals: An exploratory study	International Journal of Technology Enhanced Learning	2010
Employer Perspectives on the Role of Soft Skills in Subsidized Employment Relationships.	Families in Society	2014
Enabling and characterizing twenty-first century skills in new product development teams	International Journal of Engineering Education	2008
Engineering and Technology Board appoints new Chief Executive.	Insight: Non-Destructive Testing & Condition Monitoring	2005
Engineering and the Liberal Arts: Strangers No Longer.	The Chronicle of Higher Education	2008
Engineering as a liberal education for the 21st century	Technical Paper—Society of Manufacturing Engineers. AD	1996
Engineering education in the Middle East and North Africa: An industry perspective	Advances in Engineering Education in the Middle East and North Africa	2015
Engineering education the future is sharpening up, not dumbing down.	Engineers Journal	2010
Engineering ethics—A collaboration between engineering and philosophy	ASEE 2004 Annual Conference and Exposition, “Engineering Researchs New Heights”	2004
Engineering Ethics Beyond Engineers’ Ethics	Science and Engineering Ethics	2013
Engineering Ethics Education and Moral Education Reform in Universities of Science and Engineering	Proceedings Of The 2015 3d International Conference On Advanced Information And Communication Technology For Education	2015
Engineering ethics education on the basis of continuous education to improve communication ability	Electrical Engineering in Japan	2011
Engineering soft skills development to avoid hard knocks	2011 IEEE Global Engineering Education Conference	2011
Engineering student learning and emotional competencies	2010 IEEE Transforming Engineering Education: Creating Interdisciplinary Skills for Complex Global Environments	2010
Engineering Students’ Perceptions of Soft Skills, Industry Expectations, and Career Aspirations.	Journal of Professional Issues in Engineering Education and Practice	2016
Engineering teaching behaviors in PK-3 classrooms.	Proceedings of the ASEE Annual Conference & Exposition	2014
Engineering Undergraduates’ Perceptions of Soft Skills: Relations with Self-Efficacy and Learning Styles	Procedia-Social and Behavioral Sciences	2012
Engineering with liberal and technical education (ELITE)	Frontiers in Education Conference	1996
Engineers as Problem-Solving Leaders: Embracing the Humanities.	IEEE Technology & Society Magazine	2007

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Engineers learn “soft skills the hard way”: Planting a seed of leadership in engineering classes	Leadership and Management in Engineering	2007
Engineers of tomorrow and beyond knowledge, insight and skills needed to work across borders	age	2002
Engineers take hard look at soft skills.	Electronic Engineering Times	2000
Enhancement and assessment of engineering soft skills in a game-based learning environment	ECGBL2015-9th European Conference on Games Based Learning: ECGBL2015	2015
Enhancing individual employability: The perspective of engineering graduates	Education + Training	2010
Enhancing Your Soft Skills.	Journal of Management in Engineering	1999
Ergonomics service learning project: Implementing an alternative educational method in an industrial engineering undergraduate ergonomics course	Human Factors and Ergonomics in Manufacturing & Service Industries	2014
Ethical Decision Making in the Conduct of Research: Role of Individual, Contextual and Organizational Factors: Commentary on “Science, Human Nature, and a New Paradigm for Ethics Education”	Science and Engineering Ethics	2012
Ethical learning in higher education: The experience of the Technical University of Valencia	European Journal of Engineering Education	2009
Ethics and IT: Module suggestion for a future degree qualification in Computing Engineering	5th Iberian Conference on Information Systems and Technologies.	2010
Ethics as Philosophical History for Engineers	Ethics in Science, Technology and Engineering	2014
Ethics, engineers and drama	Science and Engineering Ethics	2009
Ethics, social capital and development in engineering education: A pedagogical proposal	Revista de la Facultad de Ingenieria	2012
Evaluating the Soft Skills Performed by Applicants of Malaysian Engineers	Procedia-Social and Behavioral Sciences	2012
Expectations and deficiencies in soft skills	Global Engineering Education Conference	2012
Exploration on Infiltrating Human Education in the Basic Chemistry Courses of Science and Engineering	Mechanical Engineering And Green Manufacturing Ii, Pts 1 And 1	2012
Extended student quality improvement programs of Xiamen University	Annual International Conference of the IEEE Engineering in Medicine and Biology Society	2014
Faculty development in engineering colleges in mainland China: The humanities perspective	1st IEEE International Conference on Teaching, Assessment, and Learning for Engineering, TALE 2012	2012
Feedback on professional skills as enculturation into communities of practice	Journal of Engineering Education	2015
Flexible firms, skills and employment	MPT Metallurgical Plant and Technology International	1996
For Better or Worse? The Marriage of Key Skills Development and On-line Learning.	Journal of Vocational Education & Training	2002
For Illinois superintendent, the soft skills count.	American School Board Journal	2011
Global and Competition-based Model for Fostering Technical and Soft Skills in Software Engineering Education	2009 22nd Conference on Software Engineering Education and Training	2009
Global Engineers: Creating Needed Solutions Through Intercultural Competence	International Journal of Engineering Education	2009
Global talent, local careers: Circular migration of top Indian engineers and professionals	Research Policy	2015
Globalization, curricula reform and the consequences for engineers working in an international company.	European Journal of Engineering Education	2006
Going Soft.	Mechanical Engineering	2004

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Group Work: A Humanistic and Skills Building Approach.	Social Work Education	2011
Guidance for the Model Developer on Representing Human Behavior in Egress Models	Fire Technology	2016
Hard Core vs. Soft Core: A Debate	American Society for Engineering Education	2012
Help Wanted: “T-Shaped” Skills to Meet 21st Century Needs.	T+D	2009
Higher education hones in on the skills gap.	T+D	2012
How experiential service-learning affects student perceptions of education in their careers and as a wildlife management activity.	Wildlife Society Bulletin	2015
Human performance data in a high workload environment during the simulated Mars expedition “AustroMars”	Acta Astronautica	2010
Human skills are always needed.	Farmers Weekly	2004
Human-centred design in engineering curricula	International Journal of Engineering Education	2012
Humanistic Quality Education in Engineering Undergraduate Education	ASIA-PACIFIC MANAGEMENT AND ENGINEERING CONFERENCE (APME 2014)	2014
Humanities and social sciences in engineering education—Postwar to postmodern and beyond	Technology and Society	2001
Humanities and social sciences on the outer in Australian engineering curricula	age	2005
Humanities and social sciences within Civil Engineering curriculum	118th ASEE Annual Conference and Exposition	2011
Humanities for Undergraduate Engineers: A Rich Paradox	Journal of Engineering Education	1993
Hutchinson Technology revamps employee training	Journal Of Applied Manufacturing Systems	1998
ICCSE Invited Lecture: Importance of Development of Soft Skills in Engineering Education.	World Congress on Engineering 2009 (Volume 1)	2009
ICChemE recruits soft skills course directors.	TCE: The Chemical Engineer	2011
Ideas for adding soft skills education to service learning and capstone courses for computer science students	Proceedings of the 42nd ACM technical symposium on Computer science education	2011
IDEAS: Interdisciplinary Design Engineering and Service.	International Journal for Service Learning in Engineering	2014
Identification of non-technical skills from the resilience engineering perspective: A case study of an electricity distributor	Safety Science	2013
Impact of a multimedia laboratory manual: Investigating the influence of student learning styles on laboratory preparation and performance over one semester	Education for Chemical Engineers	2011
Implementing technology education in Finnish general education schools: studying the cross-curricular theme “Human being and technology”	International Journal of Technology and Design Education	2014
Importance of Soft skills development in 21st century Curriculum.	International Journal of Education & Allied Sciences	2010
Improving engineering students’ communication competence: Designing innovative learning strategies	International Journal of Engineering Education	2015
Improving Students’ Soft Skills through a NSF-Supported.	Proceedings of the ASEE Annual Conference & Exposition	2014
Improving undergraduate soft skills using m-learning and serious games	Teaching, Assessment, and Learning for Engineering	2015
Incorporating ABET “soft skills” into energy conversion courses	age	2004
Incorporating and assessing ABET “soft skills” in the technical curriculum	ASEE Annual Conference and Exposition, Conference Proceedings	2008
Incorporating Global Components into Ethics Education	Science and Engineering Ethics	2013

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Incorporating social issues of computing in a small, liberal arts college: A case study	42nd ACM Technical Symposium on Computer Science Education, SIGCSE 2011	2011
Increasing Student Engagement Through the Development of Interdisciplinary Courses: Linking Engineering and Technology, the Sciences, and the Humanities	Frontiers in Education Conference	2015
Innovation and skills from a sectoral perspective: A linked employer-employee analysis	Economics of Innovation and New Technology	2010
Innovative Recruiting-Targeting Passive Professionals.	Power Engineering	2009
Inspire, Connect, Persuade: Mix Technology And Art In Teaching Presentation Skills	Quality And Efficiency In E-Learning, Vol 1	2013
Inspiring creativity for the Engineer of 2020	Interdisciplinary Engineering Design Education Conference	2012
Integrated project: An innovative way to reduce students' burden and enhance soft skills and integration elements	Proceedings of the 8th WSEAS International Conference on Engineering Education	2011
Integrating Communication and Engineering Education: A Look at Curricula, Courses, and Support Systems.	Journal of Engineering Education	2003
Integrating engineering design with humanities, sciences and social sciences using integrative learning blocks	2001 ASEE Annual Conference and Exposition: Peppers, Papers, Pueblos and Professors	2001
Integrating ethics into engineering education	Contemporary Ethical Issues in Engineering	2015
Integrating humanities and liberal arts in engineering curriculum: Need, experiences and new directions	Pertanika Journal of Social Science and Humanities	2013
Integrating Service, Learning, and Professional Practice: Toward the Vision for Civil Engineering in 2025	Journal of Professional Issues in Engineering Education and Practice	2013
Integrating soft skills in a BME curriculum	ASEE 2004 Annual Conference & Exposition	2004
Integrating soft skills in the teaching of hard sciences at a private university: A preliminary study	Pertanika Journal of Social Sciences & Humanities	2014
Integration of green soft skills in Malaysian technical education	Advanced Science Letters	2013
Integration Of Humanities And Social Sciences Into Civil Engineering Education	2010 ASEE Annual Conference & Exposition	2011
Integration Of Science, Technology, And Society (Sts) Courses Into The Engineering Curriculum	American Society for Engineering Education	2012
Integrative Learning: Integrating a Course on Human Values with Technology Education	2010 IEEE International Conference On Technology Enhanced Education (ICTEE 2012)	2012
Introducing professionalism and ethics in engineering curriculum	Journal of Professional Issues in Engineering Education and Practice	1991
Introducing Survival Ethics into Engineering Education and Practice	Science and Engineering Ethics	2013
Is there a case for a "liberal education"?	On the Horizon	2014
It ain't what you do, it's the way that you do it.	Professional Engineering	1998
It's just so darn hard ...	IEEE Control Systems	2012
Just another Title? MSc. Human Factors Engineering Versus Sports Engineering	Procedia Engineering	2016
Keep development skills current.	Electronic Engineering Times	1998
Learning leadership skills in a simulated business environment	Computers & Education	2012
Learning professional competence and confidence: the link between instructional practices and learning gains for female and male students	Frontiers in Education Conference	1999

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Liberal education for the engineer of 2020: Are administrators on board?	2010 ASEE Annual Conference and Exposition	2010
Liberal studies in engineering—a design plan	Engineering Studies	2015
Liberal Studies in Engineering Programs—Creating Space for Emergent & Individualized Pathways to Success for Women in Computing Disciplines.	Proceedings of the ASEE Annual Conference & Exposition	2015
Linking engineering and medicine: Fostering collaboration skills in interdisciplinary teams	IEEE Pulse	2012
Making Best Use of Alumni Associations for Holistic Development of Engineering Institutes	2012 IEEE International Conference On Engineering Education: Innovative Practices And Future Trends (AICERA)	2012
Making Choices: Ethical Decisions in a Global Context	Science and Engineering Ethics	2016
Managing technical people: Creatively teaching the skills of human interaction in today's diverse classrooms	Software Engineering Education and Training	2008
Manufacturing education and research at Texas A&M University: Responding to global trends	Journal of Manufacturing Systems	2005
Mapping competencies	Mechanical Engineering	2010
Meyerhoff scholars program: A strengths-based, institution-wide approach to increasing diversity in science, technology, engineering, and mathematics	Mount Sinai Journal of Medicine: A Journal of Translational and Personalized Medicine	2012
Mind the gap: school leaver aspirations and delayed pathways to further and higher education.	Journal of Education & Work	2010
Mine of the year 2020: technology and human resources	CIM bulletin	1998
Mobile learning in art museum-the immersive teaching on arts and humanities	2013 IEEE 13th International Conference on Advanced Learning Technologies, ICALT 2013	2013
More Education and Employment Trends.	Power	2014
Moshe Barak, Michael Hacker (eds.): Fostering human development through engineering and technology education: ishers, Rotterdam, 2011, ISBN: 978-94-6091-547-5 (paperback)	International Journal of Technology and Design Education	2012
Motivating an engineer to be a leader.	Engineering Studies	2015
NASA's educational programs	Government Information Quarterly	1990
Next generation science standards: Preparing students for careers in energy-related fields	The Leading Edge	2015
Nontechnical Subjects In The German Engineering Curriculum—A Historical Overview	Technology in Society	1993
Nontechnical subjects in the German engineering curriculum: A historical overview	Technology in Society	1993
Note to Self: Save Humanity (A Social and Cultural History of the “Grand Challenges”)	American Society for Engineering Education	2011
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