Analysis of gaps in the training of engineers in relation to international standards: The case of industrial engineering students in Chile.

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Abstract

Globalization has redefined engineering education. New engineers must use their knowledge to improve the quality of life and well-being of those communities impacted by their work, so their training must meet international standards to ensure success. The Washington Accord sets the criteria for competent and future-ready engineering graduates, emphasizing lifelong learning, problem-solving, research, engineering practices, and digital skills. However, studies reveal disparities between current engineering education and the evolving needs of the field. This study aims to identify perceptions held by industrial engineering students, graduates, and faculty members at a private university in Chile on the existing gaps in their training, compared to the competencies outlined in the Washington Accord. Aiming to reduce these through a transformation in the teaching practice of industrial engineering in an Engineering School that has the largest engineering enrollment nationwide. The objective being to transform teaching practices and reduce these gaps through curriculum redesign, pedagogical approaches, and evaluation methods. A questionnaire-based study with quantitative analysis was conducted, with descriptive statistics and SPSS software. Results highlight the strengths and weaknesses of the university's engineering training and provide a plan for incorporating the necessary skills to meet the standards set by the Washington Accord.

Keywords: International standards, Washington Accord, Training gaps, Industrial engineering.

Introduction

The insertion of Chile in today's large international markets requires the effective capacity to generate and add value in the service and knowledge industries [1]. The contribution that engineering science professionals are able to make in leading these processes is essential. Newly qualified engineers are expected to be able to apply knowledge in order to benefit the quality of life and well-being of communities, bearing a powerful impact on the development of the country, generating interactions with the environment or industry from a multidisciplinary perspective and producing new proposals. Within this context, and in rising up to these challenges, a comprehensive training of new professionals is essential and it is the task of current engineers as well as engineering schools to incorporate this new scenario in the training of new professionals. In this regard, accreditation standards, educational models, professional associations, industry needs, and globalization have influenced changes in engineering education around the world [2].

The goal of training is to equip students to handle new and changing problems, as noted by authors [3]. Today's engineers must have the skills to develop new technology products and play a role in starting technology-based companies, which society urgently needs [4. The progress of technology and its widespread adoption is dependent on bringing together specialists from various fields to form multidisciplinary teams [5].

Given the desired profile of 21st century engineers, it becomes crucial to define a set of engineering competencies that are comparable with international standards, to facilitate labor mobility, graduate title recognition, and international accreditation for industrial engineering students and graduates. Defining these competencies would allow us to evaluate the education received by future engineers, identify formative gaps, and suggest improvements.

Theoretical framework

The Accreditation Board for Engineering and Technology, (ABET) defines engineering as the application of knowledge in the mathematical and natural sciences, obtained through study, experience, and practice, to harness materials and forces of nature for the benefit of humanity. According to the International Engineering Alliance (IEA), engineering is a vital activity that satisfies societal needs, drives economic growth, and provides essential services. The IEA [6] defines engineering as the deliberate use of mathematics and natural sciences, along with engineering knowledge and the use of technologies and techniques. The definitions highlight that engineers have consistently been the driving force behind technological innovation and economic and social progress. Today's problems require engineers who are equipped to tackle the challenges posed by society, markets, the economy, and sustainable development, thus an engineering education capable of rising up to these challenges is essential.

Research in the field of engineering education took root in the mid-20th century. Since then, various international organizations have recognized the need to develop their own models for engineering education, moving away from focusing merely on the basic sciences, to a better alignment when dealing with economic and social changes [7]. Consequently, engineering education has evolved towards training engineers who can identify and solve increasingly complex and global problems, leading to a continuous need for educational adaptation. Engineers in today's world need training that not only equips them to solve technical problems, but also enables them to accurately identify and address non-technical aspects of problems, understand the connections between them, and find solutions to complex issues.

Given the dynamic and continually changing nature of the world, the challenge for engineering education is to equip future engineers with skills in engineering thinking, allowing them to interact effectively with their environment, generate new knowledge, and continuously upgrade their skills and know-how. Having a changing environment, with various globalization scenarios playing out, with free trade and multilateral social and economic agreements, the curriculum of engineering has undergone significant changes. This evolution has led to the concept of Global Engineering, which was first introduced in the Industrial Engineering program at Northern Illinois University, which emphasizes the development of globally-focused engineering education [8].

Developing a global engineering practice entails addressing issues from a much wider perspective. In order to achieve this, it becomes crucial to integrate and cultivate into an engineer mindset elements such as language, communication proficiency, multiculturalism, among others. Thus, the goal of cultivating global engineering involves educating professionals who may operate effectively in complex, interdisciplinary, and multicultural settings.

In response to this shift in engineering education, top universities in various countries have taken concrete steps to address the key skills and qualities that the 21st century requires of such professionals.

Vega-Gonzalez [4] highlights that, based on international experience; the current focus in engineering education pertains to two areas:

- Development of Human Behavior Skills: areas that encompass communication skills, teamwork, interpersonal skills, emotional intelligence, ethics and moral autonomy.
- Continuous Development of Personal, Business, and Management Capacities and Competencies: including skills such as "Lifelong learning in engineering", "Creativity", "Leadership", "Management Skills", and "Development of New Products and Entrepreneurship".

Given international trends in program accreditation, it is imperative to establish quality standards aligned with areas of knowledge, particularly in regards to academic processes. Having specific standards such as these would allow for a more flexible and precise model in light of the diversity of programs [9]. Additionally, curriculum standards and academic credits that support student mobility both domestically and internationally must be taken into account, along with standardized guidelines that ensure the quality of programs in other countries and secure international recognition.

Given the intricacy of this scenario, international standards have been established and agreed upon to ensure the excellence of engineering education. These standards encompass the global level engineering competencies and skills required. The Washington Accord (WA) specifically sets standards for foundational guidelines on program evaluation criteria, outlining the attributes of the graduated professional and the necessary professional competency profiles. Thus, the Washington Accord ensures mutual recognition of engineering programs among signatory countries.

Graduate attributes

The International Engineering Alliance (IEA) aims to enhance engineering education and proficiency globally. It accomplishes this mission through educational agreements related to standards, best-practice accreditation processes, and mutual recognition of accredited engineering programs, as well as agreements that outline and acknowledge professional competence.

The IEA Agreements are founded on the principle of "substantial equivalence of academic programs." Substantial equivalence is understood as the general results achieved that, although not identical, are repeatable and effective against the same standard, even if the means by which the results are achieved or evaluated are not similar [10]. The Washington Accord, established in 1989, is the oldest component of the IEA. The Washington Accord addresses mutual recognition, among signatories, of accredited educational programs that form the basis for a professional engineering education.

The graduate attributes should be common to the education of professional engineers across all engineering disciplines. In 2013, graduate attributes were defined as a model or reference frame with which the substantial equivalence of programs are currently evaluated against. While graduate attributes serve as guidance for signatories and provisional members to develop outcome-based accreditation criteria and implement them in their respective territories [10].

A defining feature of professional engineering education as governed by the Washington Accord is the ability to work in complex and uncertain environments. Therefore, graduate attributes emphasize the centrality of understanding and solving complex engineering issues. These graduate attributes, as defined by the Washington Accord, are organized based on 12 distinctive characteristics, namely:

1. Engineering knowledge
2. Problem analysis
3. Design/ development of solutions
4. Investigation
5. Modern tool usage
6. The engineer and society
7. Environment and sustainability
8. Ethics
9. Individual and teamwork
10. Communication
11. Project management and finance
12. Life-long learning

The graduate attributes outlined by the Washington Accord are universal and apply to all engineering disciplines. According to the IEA they categorize what graduates should know, the skills they should demonstrate, and the attitudes they should possess. Some authors propose organizing them in different dimensions. An example of such a classification is that proposed by Hanrahan in [11], which organizes them in three dimensions. The first bring the enablers which allow for analyzing problems and proposing solutions (WA1 to WA4); the responsibilities that an engineering practice has in relation to social, economic, cultural, health and safety issues, etc. (WA5 to WA8); and essential workplace attributes an engineer must have (WA9 to WA12).

Moreover, it may be acknowledged that these attributes cannot be honed only through training in the so-called hard skills. The lack of development of soft skills leaves graduates with a deficient skillset, necessary for lifelong learning and effective communication [12], having a negative impact on their employability and their ability to contribute to wider society. According to the authors, interpersonal skills such as ethical responsibility should be incorporated into engineer training, in order to ensure that engineers are able to continuously evolve, keeping pace with the growth of technical knowledge and effectively contributing to their own well-being and that of society.

According to several studies, engineering graduates may not possess the necessary qualities and persistence to compete and drive the growth of the industry for the benefit of the nation [13], [14]. Authors point out that for some students acquiring technical skills is a central part of achieving their socially relevant future goals. However, there is much more at stake than mere problem solving [15]. Faced with this situation, engineering teachers must be aware of the urgent need to equip graduates for the 21st century. It is paramount that both engineering teachers and graduates understand the public interest that engineering should serve. It is necessary to have a more reflexive and engaged worldview with the social and political dimensions of technological challenges and not just problem-solving isolated from reality [16].

Studies have shown that there are discrepancies between students' perception of their abilities and the perceptions that their teachers may have on the issue. The teachers underestimate motivations and expectations that students may have in relation to their learning [17].

This study aims to bridge the gap between student expectations and teacher perception, by identifying key discrepancy areas when training industrial engineers at a private university in Chile in regards to the competencies outlined by international standards. The aim being to provide guidelines in engineer training that may lead to professionals who can then be inserted in a globalized and changing labor market.

Methodology

Participants

An online survey on perceptions was used for this study. The perception survey was applied in 2022 to three groups of participants at a private university in Chile. Undergraduate students, consisting of a group of senior students in their last semester working on their degree projects, alumni who are currently working in the labor market and a third group made up of academics who teach in the industrial engineering program at the university. Regarding the study sample, out of 155 responses obtained, 54.2% were senior students, while 32.3% were alumni and 13.5% were university academics. Table I shows the gender distribution in the sample per each group.

Table 1. Sample distribution according to gender

Group	*Male*		*Feminine*		*Prefer not to say*	
	Frequency	*Percent (%)*	*Frequency*	*Percent (%)*	*Frequency*	*Percent (%)*
Undergraduate	65	77.4%	18	21.4%	1	1.2%
Alumni	40	80%	9	18%	1	2%
Academics	14	67%	7	33%	0	0%
Total	119		34		2	

Survey

The instrument was built based on the graduate attributes defined by the Washington Accord (Appendix). The reliability of the survey presents a Cronbach's Alpha of 0.833.
The study used convenience sampling, a non-probabilistic and non-random sampling method that selects participants based on ease of access or their availability within a specific period or based on other practical criteria. The scale is of the Likert type that goes from 1, “Strongly disagree” up to 5, “Strongly agree”. Regarding the statement for the items, for group 1, undergraduate students in their last semester, it was as follows: After careful reading, please indicate how you perceive the current situation per each of the following attributes in your formation. For group 2, the former students (alumni), the statement used was: After careful reading, please indicate how you perceive the current situation per each of the following

attributes in your job performance as a graduate. For group 3, academics, the statement used was the following: After careful reading, please indicate how you perceive the situation per each of these attributes regarding industrial engineering graduates.

Results Analysis

The data analysis was done using descriptive statistics, to have sample characterization. Having analyzed the samples using the Kolmogorov - Smirnov test, results showed that the sample corresponding to academics had a non-normal distribution, thus non-parametric statistics were used for result analysis, such as Kruskal Wallis test, Mann Whitney test and the Spearman correlations. All tests used the SPSS statistical software.

Results and data analysis

The dimensions addressed by the instrument were in relation to the 12 graduate attributes as defined by the Washington Accord (WA). Descriptions of collected data are presented first. Followed by inferential analyzes. Table 2 below shows results obtained per each dimension. In addition, it can be seen from Table 2 that the lowest averages are in WA4 (Investigation), for the three groups. While the highest averages occur in dimension WA9 (Individual and teamwork), in groups 1 and 2, but not in group 3, where the highest average is seen in dimension WA8 – (Ethics). Inferential comparisons between groups are shown later in this analysis.

Table 3 shows results from the Kruskal Wallis test, where statistically significant differences between groups in the WA9 dimensions (Individual and team work), and WA12 (On-going learning) are apparent.

In order to further the analysis of statistically significant differences among groups, the Mann Whitney U Test was performed for two independent samples. The results showed that there is a significant difference between the undergraduate and alumni groups for item WA12 (Life-long learning), (WA12: $M1=4.19$, $M2=4.50$, $Z=-2.327$, $p=0.020$). Likewise, for items WA9 (Individual and teamwork) and WA12 (Life-long learning), there is a significant difference between the alumni and academic groups (WA9: $M2=4.62$, $M3=4.05$, $Z=-3.079$, $p=0.002$; WA12: $M2=4.50$, $M3=3.81$, $Z=-2.861$, $p=0.004$). Finally, there are significant differences between the undergraduate and alumni groups for item WA4 (Investigation), and for the item WA9 (Individual and teamwork), (WA4: $M1=3.75$, $M3=3.33$, $Z=-1.946$, $p=0.052$; WA9: $M1=4.35$, $M3=4.05$, $Z=-1.966$, $p=0.049$).

Additionally, in order to perform Exploratory Factor Analysis for this study, it was necessary to apply the KMO and Bartlett test. The recommended minimum value of the KMO statistic is 0.5, to use exploratory factor analysis effectively. For the study sample data, the KMO test gives a significant value (Kaiser-Meyer-Olkin measure of sampling adequacy = 0.787). The Exploratory Factor Analysis performed in this study was Principal Component Analysis with Varimax rotation. Using Principal Components Analysis as the extraction method, from eigenvalues greater than 1, four principal components were drawn.

Regarding total variance (Table 4), the total eigenvalues and the sum must be considered. The total variance represents how much variability the model can explain. In this case, as can be seen, 65% of the variability is explained by the 4 components as created by the principal component extraction method.

Table 2. Descriptive analysis results per each survey dimension by group.

Dimensions	*By group*	*N*	*Min*	*Max*	*Mean*	*Std. Dev.*
WA1	Undergraduate	84	1	5	4,11	0,695
	Alumni	50	1	5	3,86	0,857
	Academics	21	1	5	3,95	0,921
WA2	Undergraduate	84	2	5	4,05	0,82
	Alumni	50	1	5	3,72	1,031
	Academics	21	3	5	4,00	0,775
WA3	Undergraduate	84	1	5	3,81	0,885
	Alumni	50	1	5	3,58	1,052
	Academics	21	2	5	4,05	0,805
WA4	Undergraduate	84	1	5	3,75	0,943
	Alumni	50	1	5	3,46	1,147
	Academics	21	2	5	3,33	1,111
WA5	Undergraduate	84	1	5	3,77	1,144
	Alumni	50	2	5	3,96	1,068
	Academics	21	2	5	4,00	0,894
WA6	Undergraduate	84	1	5	3,88	0,884
	Alumni	50	1	5	3,66	1,042
	Academics	21	2	5	4,14	0,793
WA7	Undergraduate	84	1	5	3,87	1,05
	Alumni	50	1	5	3,56	1,181
	Academics	21	2	5	4,10	0,768
WA8	Undergraduate	84	2	5	4,26	0,762
	Alumni	50	1	5	4,34	0,848
	Academics	21	2	5	4,24	0,831
WA9	Undergraduate	84	1	5	4,35	0,885
	Alumni	50	3	5	4,62	0,567
	Academics	21	2	5	4,05	0,805
WA10	Undergraduate	84	1	5	4,23	0,75
	Alumni	50	2	5	4,18	0,941
	Academics	21	2	5	3,86	1,062
WA11	Undergraduate	84	1	5	3,82	1,055
	Alumni	50	1	5	4,12	0,799
	Academics	21	2	5	3,86	0,727
WA12	Undergraduate	84	1	5	4,19	0,871
	Alumni	50	2	5	4,50	0,735
	Academics	21	1	5	3,81	1,078

Table 3. Kruskal Wallis test results per attribute.

	WA1	*WA2*	*WA3*	*WA4*	*WA5*	*WA6*	*WA7*	*WA8*	*WA9*	*WA10*	*WA11*	*WA12*
Chi-Square	3	2,882	3	4,229	1	3,881	3	0,821	10	2,048	3	10,09
Df	2	2	2	2	2	2	2	2	2	2	2	2
Asymp. Sig.	0,271	0,237	0,193	0,121	0,577	0,144	0,177	0,663	**0,007**	0,359	0,245	**0,006**

a Kruskal Wallis Test
b Grouping Variable: Group

Results from the Principal Component Analysis shows that it is possible to obtain four dimensions (as seen in Table 5), namely:

- *Dimension 1:* Problem analysis and solution synthesis, items WA1 (Engineering knowledge), WA2 (Problem analysis), and WA3 (Design / development of solutions).
- *Dimension 2*: Professional responsibilities, items WA6 (Engineering and society), WA7 (Environment and sustainability) and WA8 (Ethics).
- *Dimension 3*: Critical thinking and problem solving, items WA4 (Investigation), WA9 (Individual and teamwork), and WA10 (Communication).
- *Dimension 4:* Management skills and professional development, items WA5 – (Modern tool usage), WA11 (Project management and finances), and WA12 (Life-long learning).

Table 4. Total variance explained.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4,321	36,009	36,009	4,321	36,009	36,009	2,079	17,326	17,326
2	1,364	11,365	47,375	1,364	11,365	47,375	2,047	17,056	34,382
3	1,112	9,263	56,638	1,112	9,263	56,638	1,939	16,160	50,542
4	1,022	8,519	65,157	1,022	8,519	65,157	1,754	14,614	65,157
5	,824	6,863	72,019						
6	,641	5,345	77,365						
7	,604	5,035	82,400						
8	,559	4,656	87,056						
9	,482	4,020	91,076						
10	,446	3,714	94,790						
11	,369	3,079	97,870						
12	,256	2,130	100,000						

Extraction Method: Principal Component Analysis.

Table 5. Dimensions and reliability.

Dimension	*items*	*Crombach's Alpha*
	All	0.833
DIM_1: Analysis of problems and synthesis of solutions	WA1 WA2 WA3	0.649
DIM_2: Professional responsibilities	WA6 WA7 WA8	0.726
DIM_3: Critical thinking and problem solving	WA4 WA9 WA10	0.708
DIM_4: Management skills and professional development	WA5 WA11 WA12	0.633

The following table, Table 6, shows Spearman correlation test results among the four dimensions for group 1, the undergraduate group. It can be seen that within it there are statistically significant correlations among all dimensions. At a moderate level among dimension 1 and the others, with the highest correlation being that between dimensions 1 and 3, while a lower correlation is seen between dimensions 2 and 4 and between 3 and 4.

Table 6. Results of the correlation analysis by dimensions for Group 1- undergraduates

		DIM_1	DIM_2	DIM_3	DIM_4
DIM_1	Correlation Coefficient	1,000	,473(**)	,591(**)	,485(**)
	Sig. (2-tailed)	.	,000	,000	,000
	N	84	84	84	84
DIM_2	Correlation Coefficient	,473(**)	1,000	,424(**)	,348(**)
	Sig. (2-tailed)	,000	.	,000	,001
	N	84	84	84	84
DIM_3	Correlation Coefficient	,591(**)	,424(**)	1,000	,399(**)
	Sig. (2-tailed)	,000	,000	.	,000
	N	84	84	84	84
DIM_4	Correlation Coefficient	,485(**)	,348(**)	,399(**)	1,000
	Sig. (2-tailed)	,000	,001	,000	.
	N	84	84	84	84

Regarding group 2, the alumni group, Table 7 also shows statistically significant correlations between the four dimensions. The highest correlation occurs among dimensions 3 and 4, while the lower correlations occur among dimensions 1 and 2 and among dimensions 1 and 4. Finally, in relation to group 3, the academics group, as in previous groups, it is possible to see, in Table 8, significant correlations among dimensions; high level correlations occur among dimensions 2 and 3, and among dimensions 3 and 4; and moderate correlations among dimensions 1 and 3, 1 and 4, and 2 and 4. Furthermore, results analysis show that dimension 1 does not significantly correlate with dimension 2. It is also possible to highlight the fact that dimension 3 is the one that correlates most strongly with dimensions 2 and 4.

Table 7. Results of the correlation analysis by dimension for Group 2 – alumni

		DIM_1	DIM_2	DIM_3	DIM_4
DIM_1	Correlation Coefficient	1,000	,320(*)	,435(**)	,323(*)
	Sig. (2-tailed)	.	,023	,002	,022
	N	50	50	50	50
DIM_2	Correlation Coefficient	,320(*)	1,000	,430(**)	,474(**)
	Sig. (2-tailed)	,023	.	,002	,001
	N	50	50	50	50
DIM_3	Correlation Coefficient	,435(**)	,430(**)	1,000	,488(**)
	Sig. (2-tailed)	,002	,002	.	,000
	N	50	50	50	50
DIM_4	Correlation Coefficient	,323(*)	,474(**)	,488(**)	1,000
	Sig. (2-tailed)	,022	,001	,000	.
	N	50	50	50	50

Table 8. Results of the correlation analysis by dimension for Group 3 – academics.

		DIM_1	DIM_2	DIM_3	DIM_4
DIM_1	Correlation Coefficient	1,000	,400	,557(**)	,532(*)
	Sig. (2-tailed)	.	,072	,009	,013
	N	21	21	21	21
DIM_2	Correlation Coefficient	,400	1,000	,786(**)	,499(*)
	Sig. (2-tailed)	,072	.	,000	,021
	N	21	21	21	21
DIM_3	Correlation Coefficient	,557(**)	,786(**)	1,000	,793(**)
	Sig. (2-tailed)	,009	,000	.	,000
	N	21	21	21	21
DIM_4	Correlation Coefficient	,532(*)	,499(*)	,793(**)	1,000
	Sig. (2-tailed)	,013	,021	,000	.
	N	21	21	21	21

Discussion and analysis of results

The research collected field information, which enabled measuring perceptions on current development of each graduate attribute among senior students close to graduating, among alumni present in the workforce, and academics. This information was used to measure the current development of each attribute.

Given the descriptive analysis, considering results obtained with respect to the WA4 dimension (Investigation), it is possible to see that the perception regarding how this attribute has developed is the lowest for the three groups in relation to the rest of the items. It is therefore possible to put forward the notion that there is insufficient research present among the three groups, which would imply under performance in this item for future graduate training, eventually impacting on other related ones such as WA2 (Problem analysis) and

WA3 (Design/development of solutions). Given a curricular training perspective, it is necessary to rethink how to approach research development in future graduates.

It is possible to state that there are some differences between reported perceptions, meaning statistically significant differences among the averages for the three groups (students, alumni, and academics) for WA9 (Individual and Team Work) and WA12 (Lifelong Learning). When comparing differences among the groups, with respect to groups 1, undergraduate, and 2, alumni, these occur in WA12 (Life-long learning). (WA12: M1=4.19, M2=4.50, Z=-2.327, p=0.020), which may be interpreted by the need graduates have for life-long learning, which becomes increasingly relevant as they insert themselves in the world of work as a characteristic element of a discipline under constant evolution and development.

Regarding groups 1 and 3, the undergraduate and academic groups, respectively, there are significant differences in item WA4 (Investigation) (WA4: M1=3.75, M3=3.33, Z=-1.946, p=0.052), which shows that undergraduate students perceive themselves to be more developed or competent in this aspect than what academics perceive regarding this attribute in graduate students, perhaps given the depth of area knowledge that the latter have versus the concept or preparation that students have in this regard. Also in these two groups there are differences regarding item WA9 (Individual and teamwork) (WA9: M1=4.35, M3=4.05, Z=-1.966, p=0.049). It is likely that, given the teaching methodologies used throughout the training program applied, the academic group perceives that the training provided regarding this attribute does not reach the level of development perceived by undergraduate students.

Finally, among groups 2 and 3, alumni and academics, respectively, there are significant differences for WA9 (Individual and teamwork) (WA9: M2=4.62, M3=4.05, Z=-3.079, p=0.002). Thus, perceptions held by the alumni group regarding how this attribute develops is also higher than the perception held by academics. The same situation occurs with respect to WA12 – Lifelong learning (WA12: M2=4.50, M3=3.81, Z=-2.861, p=0.004), where there is a significant difference. The alumni group may eventually face the fact that developing this attribute influences the development of other attributes. It may be possible to ascertain that the perception that the alumni group is developing both these attributes may account for their ability to learn in an independent and sustained manner, and being able to adapt to their work context and market needs. The academic group could well use such characteristics to address pedagogical effects and challenges during the training process. On this point, the referenced findings coincide with what was stated by [17] regarding teachers underestimating students and/or graduates.

Unlike the three-dimensional classification of graduate attributes proposed by Hanrahan in [11], this research proposes a classification of them in four dimensions. In this regard, we believe that dimension 3, Critical thinking and problem solving (consisting of WA4 - Investigation, WA9 - Individual and teamwork, and WA10 - Communication), provides an interesting perspective for engineering education. Indeed, the combination of individual work, teamwork, communication and research can be seen as a way of approaching and solving problems. Solving a problem often requires working independently to gather information to fully understand the problem, collaborating with others to brainstorm solutions and discuss different approaches, communicating effectively to share ideas and information, and researching and gathering additional information as needed to document any troubleshooting processes.

Considering the profile required of an engineer, dimension number 3 under reference may be used to accounts for the complexity of problems on a global scale, particularly in a post covid-19 scenario. In this sense, it is relevant to appreciate how the attributes WA9 (Individual and teamwork) and WA10 (Communication), traditionally associated to soft skills, are interlinked with research, favoring the deployment of technical skills. The former is consistent with the approach seen in [15], in the sense that solving problems involves much more than merely applying technical skills.

The results corroborate the above given that, for the three groups involved, dimension three correlates highly. While dimension 1 correlates with group 1 (undergraduate), dimension 4 correlates with group 2 (alumni) and dimensions 2 and 4 correlates with group 3 (academics).

Conclusions

Globalization has consistently redefined engineering education. Newly graduated engineers must be able to apply their knowledge to benefit communities in terms of their quality of life and well-being, so their training must meet certain criteria as established in international standards. This research involved surveying senior students in their last semester, recent graduates at their new work and faculty academics, to determine to what degree graduate's attributes have been developed in senior students in their last semester and graduates who have recently started working in their field.

Regarding perceptions on the further development of attributes seen in undergraduate students and recent graduates of an industrial engineering program, it is possible for the head of the undergraduate program and its academic body to take advantage of the high value attributable to the "Individual and team work" and "Lifelong learning" criteria. This would allow to redesign learning methodologies used, both inside and outside the classroom, considering these not merely from a knowledge sharing standpoint, but also from the perspective of training future engineers in knowledge generation.

We consider that the dimensions generated in a factorial analysis may account for current scenario regarding industry needs and the constant development seen in engineering education, seen as an indicator regarding where curricular and methodological strategies should be updated to improve student-training processes. Consequently, to demonstrate learning results that apply not only to when the undergraduate course requires accreditation under a results-based international accreditation system, but also to fulfill the wider role engineering has in society.

In relation to action guidelines that enable the incorporation of competencies to reduce training gaps as identified, the conclusion was that, when examining what a graduate should be able to do as a result of the training program, main action lines seen that need to be addressed is the constant evaluation of the curricular design of the study program. Including the graduation profile sought; the use of active teaching methodologies such as collaborative learning or problem-based learning (PBL) and its application based on Kolb's experiential learning theory (1984). Also the formalization of alumni linkages through a system that institutionalizes periodic feedback regarding key attributes, in order to contribute in a timely manner to undergraduate formation in consideration to current and future industry needs.

It must be pointed out, however, that research conclusions are subject to certain limitations not only in relation to the type of sample used, but also in relation to the instrument used. The skills referenced by the criteria of the Washington Accord were not directly measured, but the perception of said skills.

Research findings also invite other engineering programs to re-examine the quality monitoring system of their educational process cycle to address any deficiencies in their current engineering education system.

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Appendix 1

Elements of the Washington Accord Graduate Attribute Profile

Dimensions	*Items*
Engineering knowledge	WA1: Apply knowledge of mathematics, natural science, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to the solution of complex engineering problems.
Problem analysis	WA2: Identify, formulate, research literature and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences (WK1 to WK4).
Design/ development of solutions	WA3: Design solutions for complex engineering problems and design systems, components or processes that meet specified needs with appropriate consideration for public health, and safety, cultural, societal and environmental considerations (WK5).
Investigation	WA4: Conduct investigations of complex problems using research-based knowledge (WK8) and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.
Modern tool usage	WA5: Create, select and apply appropriate techniques, resources and modern engineering and IT tools, including prediction and modelling, to complex engineering problems, with an understanding of the limitations (WK6).

The engineer and society	WA6: Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex engineering problems (WK7).
Environment and sustainability	WA7: Understand and evaluate the sustainability and impact of professional engineering work in the solution of complex engineering problems in societal and environmental contexts (WK7).
Ethics	WA8: Apply ethical principles and commit to professional ethics, responsibilities, and norms of engineering practice (WK7).
Individual and teamwork	WA9: Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.
Communication	WA10: Communicate effectively on complex engineering activities with the engineering community and society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations and give and receive clear instructions.
Project management and finance	WA11: Demonstrate knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work as a member and leader in a team, to manage projects and in multi-disciplinary environments.
Life-long learning	WA12: Recognise the need for, and have the preparation and ability to engage in, independent and life-long learning in the broadest context of technological change.

Appendix 2

Elements of the Washington Accord Knowledge Profile:

- WK1: A systematic, theory-based understanding of the natural sciences applicable to the discipline.
- WK2: Conceptually-based mathematics, numerical analysis, statistics and formal aspects of computer and information science to support analysis and modelling applicable to the discipline.
- WK3: A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline.
- WK4: Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.
- WK5: Knowledge that supports engineering design in a practice area.
- WK6: Knowledge of engineering practice (technology) in the practice areas in the engineering discipline.
- WK7: Comprehension of the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the professional responsibility of an

engineer to public safety; and the impacts of engineering activity – economic, social, cultural, environmental and sustainability.

- WK8; Engagement with selected knowledge in the research literature of the discipline.