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# Closing a Theoretical-Methodological Gap in the Internationalisation of Engineering Curricula*

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The internationalisation of the curricula is considered one of the principal factors for the improvement of teaching in engineering. Nonetheless, lack of a contextualized conceptual and methodological framework hinders the incorporation of an international dimension into the university education for future engineers. This article presents the steps of an investigation that seeks to address this problem. The principal objective of this study is the elaboration of a methodological guide for the internationalisation of the engineering curricula at the Instituto Tecnológico de Costa Rica [Costa Rica Institute of Technology—ITCR]. As a result of this study, a guide and scale for the implementation and assessment of curriculum internationalisation are developed. Additionally, the results of a diagnostic pilot study on the internationalisation of the undergraduate programs in agricultural and biotechnology engineering at ITCR are obtained. This article can be useful for faculty, school directors, program coordinators, advisors and members of curriculum committees, among others involved in the teaching, development and management of the curriculum and graduate program quality.

**Keywords:** internationalisation of the curriculum; undergraduate engineering programs; curriculum development; plan of study; ITCR

## 1. Introduction

Until just two or three decades ago, university education was mainly guided by the principle of local relevance. However, the acceleration of scientific and technological development, together with political, economic, social and cultural changes, at the beginning of the second half of the twentieth century made it evident that education solely based on local relevance no longer responds to the realities and perspectives of our context [1, 2]. Globalisation calls upon the central role of education, which not only has to teach how to live in this world, where local and global closely interact, but must also play a leading role in helping understand, manage and transform globalisation in the interest of attaining the greater wellbeing of nations [3, 4]. The United Nations Educational, Scientific and Cultural Organisation declared that higher education shall not only be guided by local and national criteria, but by regional and international criteria as well [5]. Thus, the incorporation of an international dimension into all academic work, better known as internationalisation or simply as the numeronym i18n, emerged as one of the factors that determine relevance and therefore, greatly affect the quality of university education.

Globalisation has revived internationalisation, inherent to university life since its origins, and turned it into the compass that points the way for academic and curricular reform [6]. The reasoning behind this situation is clear: if society's problems are no longer local and national and have become global, don't we need an internationalised curriculum[1] to deal with these imperatives and not trail behind? [7]. Emphasis is given to the fact that the adequate incorporation of the international, intercultural and global dimensions into curriculum design and management is a critical aspect and a task that must be undertaken responsibly by all universities worldwide [8–10]. In this manner, curriculum reform positions itself as higher education's response in order to build the capacities of individuals, professionals and citizens who want to become part of a globalised world, but without losing their local identity [11–16].

Programmes or programs that prepare graduates to become part of a profession, such as engineering that has a high level of social responsibility and transcends borders, face a task of great academic and human importance. The World Federation of Engineering Organisations has declared that in order to contribute to the solution of many regional problems, specialists must be trained in the required quantities, according to international quality standards and implementing curricular strategies that promote local and regional relevance of their knowledge [17]. International chairs and conferences on engineering education monitor the impact of globalisation on higher education in this area and emphasize aspects such as tailoring curricula to allow for the globalisation of professional

[1] In accordance with tradition and local practice, the word curriculum (plural: curricula) is used as a synonym for plan of study. Fig. 2 explains the composition of a plan of study or curriculum in engineering at ITCR.



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practice, incorporating foreign languages and cultures into the plans of study[2] (POS), international certification of programme quality, among other issues [12, 14, 18, 19]. Engineering students graduating in 2020 and beyond must be prepared to live and work as global citizens. This is an enormous challenge, but one that can be accomplished [12, 16, 20, 21].

Given that graduate qualities are highly dependent on the POS followed during their professional training, it should be underscored that teaching engineering requires curricula that are not just simple recipe books, but instead focus on how to learn, how to apply what has been learned in new international and intercultural contexts and how to respond to future changes in the profession resulting from the propagation of globalisation in all its dimensions [12, 20, 21]. In keeping with the omnipresence of mundialisation, it is clear that internationalisation must appropriately permeate all aspects and elements of the curricula, that is, i18n must be adopted as a curricular principle [22].

There are multiple approaches to the topic of POS design and i18n [8]. Although an engineering curriculum to a certain extent responds to a general scheme, derived from guidelines at different levels: from the institutional and national levels to the regional and global levels, it is to be expected that each institution, faculty and school must define its own agenda for study plan internationalisation [23]. The direction taken when internationalizing the curriculum varies depending on factors such as object of study, history, culture, profile, policies, interests, applicable regulations, opportunities, individual initiative, priorities, finances and the capabilities of each academic department. It can be said that the i18n of the curricula is not a series of clearly established good practices, but rather a construct under development that can be adapted to the particularities of each programme and institution [24, 25]. Consequently, the result of the i18n of a specific curriculum is always unique and unrepeatable. This means that the task of sustainably incorporating the international, intercultural and global dimensions into the curricula can pose a big conundrum for a university.

For example, according to a survey conducted in 2008 at the Instituto Tecnológico de Costa Rica (ITCR) amongst its academicians and officials, POS internationalisation should be assigned top priority [26]. This opinion concurs with those i18n concepts set forth in the National Plan for Higher Education, the academic model and the institution's current policies and plans. However, this same survey revealed a significant difference between awareness of the high importance of curriculum internationalisation and low level of implementation within the institution [26]. This inconsistency repeats itself in countless other universities, negatively affecting program quality [27–29].

This contradiction can largely be explained by the lack of a conceptual and methodological basis for internationalisation in general and for study plan i18n in particular. The following problems are noted: doubts as to the conceptualisation of this phenomenon; unawareness of its dimensions, manifestations and implementation trends; insufficiency of elements and mechanisms to enable the incorporation, monitoring, evaluation and enhancement of the processes and products related to the international dimension of university curricula. This conceptual vagueness and significant methodological gaps interrupt the process restricting the work of academicians in charge of curriculum development [12, 19, 30]. In many universities, internationalisation reforms are said to have failed because people underestimate the complexity of the issues involved [28].

Thus, it becomes apparent that the effective integration of the international dimension into university study programs very much depends on progress made in educational research in terms of closing the theoretical and methodological gaps in POS i18n. An initiative that paves the way in this regard is presented in the following paper. The most relevant aspects of a study contributing towards the conceptualisation, operationalisation and diagnosis of the i18n of engineering curricula are set out below [37].

## 2. Presentation

The study being presented to the reader was conducted under the auspices of the ITCR's Centre for Academic Development (CEDA) in the framework of a doctoral program in educational intervention offered by the University of Valencia and followed by the author. The study was prompted by the need to address a methodological deficiency faced by curriculum committees, directors, deans, academic advisors and other university faculty and staff members when internationalising an engineering plan of study.

The construct and research objectives were formulated accordingly. The construct was defined as the *internationalisation of engineering plans of study*.

[2] Plan of study (POS) is a curricular document that contains the detailed and methodic planning of the academic and administrative spheres of a university programme. It includes a series of components that are defined pursuant to the internal curricular regulations of each institution and those of the National Council of Deans. These components can be classified as either guiding elements or operative elements, as shown in Fig. 2. In Costa Rica, public universities are fully autonomous, which allows them to design their own plans of study.

The general objective was to prepare a methodological guide for the internationalisation of engineering plans of study at ITCR. This general objective was broken down into three specific objectives: (1) to develop a theoretical-conceptual framework for the engineering plan of study internationalisation construct; (2) to design a valid and reliable instrument to diagnose the i18n of engineering plans of study at ITCR; and (3) to pilot test the instrument by assessing the i18n of two of the institution's engineering POSs.

## 3. Methodology

### *3.1 Overview*

A brief description of the methodology is provided. This study falls within the domain of educational and evaluative research, specifically within the field of curriculum development for engineering education, whereas its scope is descriptive. This is a non-experimental study supported by a combination of quantitative and qualitative methods chosen according to the proposed objectives.

### *3.2 Stages*

The general objective of the study was progressively accomplished from 2007 to 2011. During this time, five research stages were completed. Each of these stages were easily distinguishable because of their specific objectives, methodological approaches, subjects and duration. Stages I and IV were predominantly qualitative, whereas stages II, III and V were markedly quantitative. The reasons for combining different approaches in a sequential design are similar to those pointed out by Ahn, Cox, London et al. [33, p. 118–119]. The stages of research are shown in the timeline in Fig. 1.

Stage I, labelled in Fig. 1 as "Conceptualisation", spanned from January 2007 to June 2008. During this period, work focused on three key aspects, namely preparing and validating the theoretical-conceptual framework pertaining to the curriculum i18n construct, proposing an initial set of POS i18n samples or items and creating the first supporting instrument to serve as a starting point for the design of the *Diagnostic Scale for the Internationalisation of Engineering Plan of Study Guiding Elements* (EDIPE, its Spanish acronym).

The first step in developing a theoretical-conceptual framework was to identify relevant literature available on the topic, which was subjected to a selection process and analysis. At the beginning of the search, a combination of descriptors was defined, which included terms such as *internationalisation, higher education, curriculum, plan of study and engineering education.* Different types of information sources were examined: books, articles, congress papers, Master's and PhD theses, reports, standards and other documents in Spanish, English and Russian. Approximately 2,500 bibliographic sources related to the topic were compiled.

A further selection was then conducted to include only 300 titles that focused on the topic of the i18n of higher education from the perspective of scientific-technological and engineering curricula. This process focused on the identification, deductive arrangement and description of elements and relationships pertaining to the engineering curriculum i18n construct within the contemporary context of a higher educational institution, such as ITCR.

The elements identified were then used to create a coherent semantic structure in the shape of a concept map and table of contents, which served as a guideline to write the theoretical-conceptual framework related to the object of study.

To end, the manuscript containing the theoretical-conceptual framework for the i18n of engineering program curricula was validated by a group of academic peers from Instituto Tecnológico de Costa Rica, Spanish National University of Distance Education, University of Valencia, University of the Basque Country, and Complutense University of Madrid.

Simultaneously, while preparing the theoretical framework, an initial set of i18n items or indicators was defined for the guiding and operational elements of the engineering POS following a procedure similar to the one described by Ball, Zaugg, Davies et al. [16, p. 157]. Both sets of curricular elements are presented in Fig. 2, which explains how to structure a plan of study at ITCR.

These items were used to create the first support-

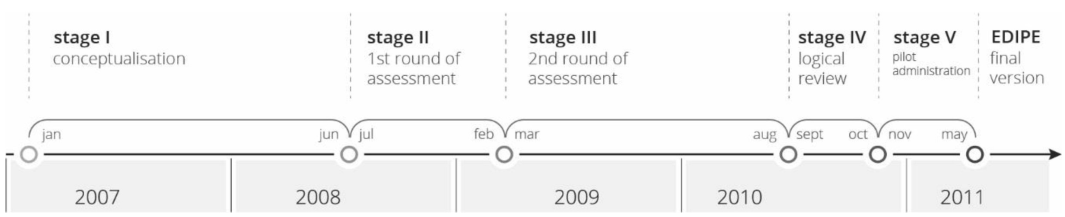


**Fig. 1.** Research Timeline. Notes: The dotted line indicates the beginning of each stage. The abbreviation EDIPE stands for *Diagnostic Scale for the Internationalisation of Engineering Plan of Study Guiding Elements.*

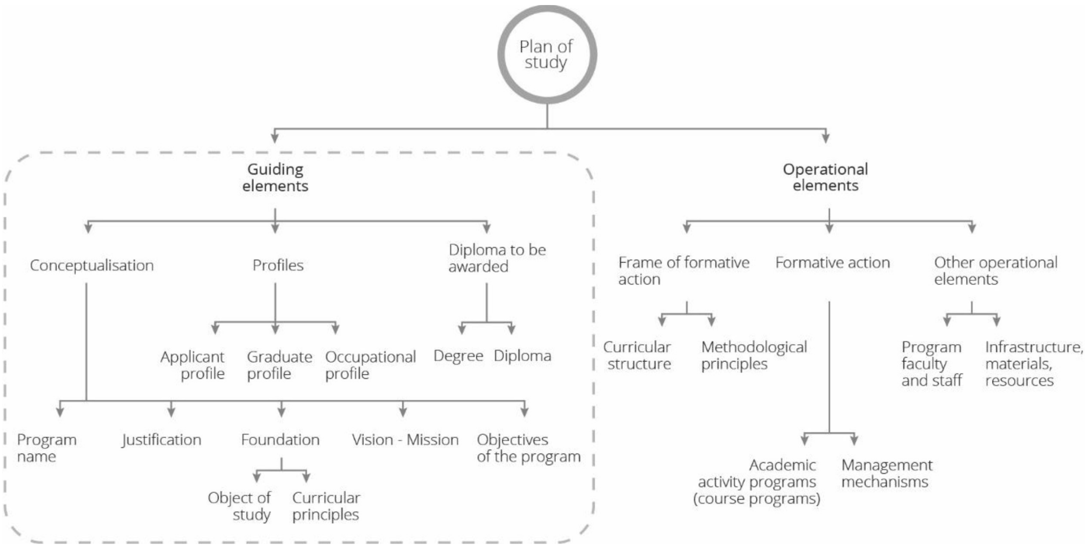


**Fig. 2.** Study Plan Structure for Engineering at ITCR. Notes: Dotted-line text frame contains POS guiding elements.

ing instrument at the end of stage I, which served as input to develop the Diagnostic Scale for the Internationalisation of Engineering Curricula. The work carried out during the following stages largely focused on filtering and refining this set of items in a manner similar to the one used by Lattuca, Knight and Bergom [34, p. 729]. Stage V resulted in the final version of these items.

Diagnostic scale design continued throughout stage II, from July 2008 to February 2009. The 1st round of assessment was carried out and the 1st supporting instrument was administered. This instrument was developed at the end of stage I and sent by email to the participant-raters together with a motivation letter and instructions for self-administering and returning. A total of 45 specialists in management, curriculum development and engineering education from 28 institutions in 14 American and European countries participated in stage II as raters. Using pre-established descriptors, this 1st supporting instrument allowed these specialists to give their opinion on the suitability of the proposed structure for the future diagnostic scale as well as on the relevance, sufficiency and clarity of each of the items proposed as indicators or samples for POS i18n. Expert scores were subjected to statistical analysis generating the necessary data to take decisions in terms of improving instrument structure and refining the initial set of internationalisation items or indicators.

The following statistical data was used to filter and refine subscales based on the detailed and integrated analysis of each i18n indicator: number of unfavourable scores, measure of relevance, coefficient of 1st cluster, communality, greater factor loading, corrected item-total correlation and Cronbach's Alpha if Item Deleted. Critical values used were those generally employed for item analysis [34, p. 729; 40, pp. 30–31]. Additionally, the raters' observations as well as the investigator's qualified opinion played an important part in indicator cleaning.

One of the following cleaning actions was applied for each i18n indicator: item remained the same or almost the same, item was substantially modified, item was eliminated (which also included the possibility of moving to another subscale or combining them with another item). New items could also be added.

As a result of this process, the original proposal was revised and reworked to obtain the 2nd supporting instrument, thus culminating stage II.

Next, during stage III, from March 2009 to August 2010, progress was made in the design of the diagnostic scale. Nonetheless, due to time limitations, as of this phase, work focused on the i18n of a specific portion of the POSs, which includes the guiding elements for engineering curriculum design. This can be seen in the dotted-line text frame in Fig. 2. Under these conditions, the 2nd round of assessment was carried out and the 2nd supporting instrument was administered. The procedures followed during this stage were similar to those of the previous stage. However, the number of participant-raters was increased in this round. A total of 108 experts were involved, representing 56 organisations from 19 countries in America and Europe. After administering the 2nd supporting instrument, gathering and processing data regarding relevance, sufficiency and clarity of the statements or items, work once again focused on the analysis and cleaning of these items. In this way, a set of indicators was defined that best represented the i18n of curriculum guiding elements. At the end of stage III, this set of items was used to prepare the draft *Diagnostic Scale for the Internationalisation of Engineering Plan of Study Guiding Elements* (EDIPE).

Subsequently, during stage IV, from September to October 2010, the draft EDIPE was submitted to a logic check.

Special attention was given to instrument clarity and match with the context of the institution where it will be used. Thus, thanks to the contribution of 15 specialists from the Instituto Tecnológico de Costa Rica, the pilot version of the diagnostic scale was obtained.

During stage V, from November 2010 to May 2011, the pilot version of the instrument was tested within its field of action. Eight academic advisors and eight faculty/members of ITCR curriculum committees administered this version of the EDIPE in order to diagnose the i18n of the guiding elements of the POSs for two programmes: *licenciatura* in agricultural engineering and bachelor in biotechnology engineering, both offered by the Instituto Tecnológico de Costa Rica. Data obtained was used both to verify and further enhance the instrument's technical performance parameters, as well as determine progress made in plan of study i18n. Variables related to the diagnostic performance of the instrument were used to conduct the last item cleaning and obtain the final EDIPE version. Meanwhile, data from the diagnosis of the curricula of both programmes has been validated and submitted before the Councils of the ITCR academic departments that took part in the study, with the objective that it be taken into consideration during their curriculum development processes.

### *3.3 Instruments*

The instrumental aspect was the main focus of the investigation, and this was because one of the principal goals of this study was to design an instrument called *Diagnostic Scale for the Internationalisation of Engineering Plans of Study* (EDIPE). Fulfilment of this goal was gradual occurring in five stages, described above. Each stage had an instrument that facilitated the development of this diagnostic scale until the final version was obtained. Therefore, during the successive stages of the study, two supporting instruments were used with formats based on the CEVEAPEU questionnaire developed by Gargallo, Suárez and Pérez [36, p. 20–24] as well as two anticipated and progressively more advanced versions of the EDIPE. Fig. 3 shows how the scale has evolved, specifying instrument name and number of valid administrations in each stage of the study.

The essential portions of the supporting instruments used in stages II, III and IV focused on two aspects: (a) the comprehensive assessment of the future EDIPE and (b) the assessment of each of the items proposed as i18n samples for the different portions of the plans of study. These portions have been fundamental to the design and validation process for the new diagnostic scale, because they enabled the compilation of expert opinion on the structure, reliability and validity of the subscales as well as relevance, sufficiency and clarity of each of the items included in the instruments that preceded the final version of the scale. On the other hand, in the pilot version of the EDIPE, administered in stage V, the essential portion was used to assess curriculum internationalisation.

It is also important to clarify what assessment options were used by the subjects to rate usefulness, relevance, sufficiency, clarity, conciseness, completeness or adequacy of item ordering and the future diagnostic scale. In the case of the 1st and 2nd supporting instruments, a Likert-type scale was used with the following response options: "1—None", "2—Little", "3—Some" y "4—Substantial". As far as the pilot version of the EDIPE, a nominal scale was used with the following response options: "1—Disagree, or indicator doesn't exist", "2—Partially agree, or partial manifestation of indicator" and "3—Completely agree, or full manifestation of indicator".

In addition to the assessment portion, all instruments presented in Fig. 3 contained several supplementary sections, such as cover sheet, presentation, motivation and instructions, identifying information for each rater and glossary. The complete versions of these instruments are available in the TESEO database [32, p. 581–639].

### *3.4 Methods of analysis*

A wide range of analytical methods were used in this study. Numerical data relating to the assessment

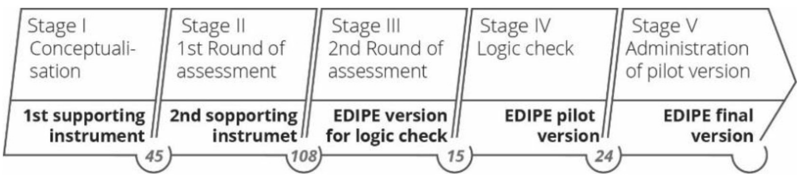


**Fig. 3.** Name of Instrument and Number of Times Administered in Different Stages of the Study.

and enhancement of relevance, sufficiency and clarity of the items proposed as i18n indicators, as well as those regarding the structure and organisation of the instruments used in stages II and III, has been subjected to a descriptive analysis (central tendency, variability and distribution), inter-rater concordance tests (Kendall's $\hat{W}$), data classification and reduction (hierarchical clustering and principal components analysis), and two-sample tests (including rank tests and the Kolmogorov-Smirnov and Mann-Whitney U tests, among others). Hierarchical cluster analysis and statistical analysis such as Cronbach's Alpha ($\alpha_{Cr}$), Alpha if Item Deleted, and the corrected item-total correlation coefficient (CI-TC coefficient or $r_{CETC}$) were utilized for the estimation and enhancement of internal consistency of instruments administered in stages II, III and V.

Central tendency, variability, and distribution were calculated for quantitative data obtained in stage V of the pilot diagnosis of the i18n of the plans of study for two ITCR programmes. The independent two-sample test was also applied.

Where appropriate, quantitative analysis was supplemented by qualitative analysis, based on the exploration and classification of the responses given by the raters to the open questions of the different instruments. Thus, for example, in stage IV, subject comments gathered through the administration of the logic check version of the EDIPE were recorded and classified accordingly into several tables. Subsequently, elements that needed some adjustment were modified.

It should also be pointed out that in the initial stage of the study, which focused on the development of a theoretical-conceptual framework for i18n, methods of bibliographic analysis were included, that is, identification, systematization and analytical reading of selected literature, extraction and deductive ordering of relevant aspects, and creation of coherent semantic structures to conceptualize and represent the phenomenon of the i18n of the plans of study for engineering.

In short, the methods of analysis applied were consistent with the general objective of the study, its approach, and the goals to be attained in each stage. Details of the procedures applied and all analytical data are contained in the complete report of this study available in the TESEO database [32].

## 4. Results and discussion

The results, together with their corresponding discussion, are presented in connection with the study objectives and reflect the different stages shown in Fig. 1.

### *4.1 Results and discussion pertaining to the development of the theoretical-conceptual framework*

The theoretical-conceptual portion of the methodological guide for curriculum internationalisation, which included the contextualized redefinition of the construct of interest to us, was essentially developed in stage I. This was the product evidencing fulfilment of the first specific objective of the study.

The theoretical-conceptual framework was divided into sections whose contents followed a general-to-specific order. The four main chapters of this research effort where devoted to the internationalisation of higher education, curriculum i18n in general, il8n of each of the components that make up of the POS, and il8n of engineering curricula. Aspects examined in greater depth in the conceptual framework were the origins, evolution, benefits, and risks of the internationalisation of higher education, trends in il8n in different parts of the world and in Costa Rica. The scope and implications of the phenomenon known as internationalisation at home (I@H) were also discussed, and the reasons, dimensions, manifestations, and elements of the i18n of university programme POSs, with emphasis on engineering curricula, were presented in the context of I@H. This conceptual framework constituted the theoretical portion of the methodological guide for the i18n of the plans of study for engineering at ITCR, which was made available through the Centre for Academic Development website [37].

The conceptualisation of the POS i18n phenomenon was evidently also part of the theoretical framework. As a result of this stage, the study concluded that internationalisation, from the perspective of plan of study design, is a curricular principle. In other words, it is one of the basic ideas behind the conception of a POS and underlies the structure and functioning of a programme in its scientific-technological, economic, and socio-political contexts. These basic ideas serve as connectors between the epistemic basis, curricular structure, and teaching-learning process of a university program [32, p. 503].

Thus, the construct of curriculum internationalisation, initially perceived as a phenomenon relating to the incorporation of an international dimension into the formal and operational aspects of the POS [22], was finally redefined as a system of guidelines that lay the foundations for the academic-administrative organisation of a programme, and must be addressed at the curriculum design stage in order to promote international relevance and establish the necessary conditions for students to develop competencies they need to be successful people, citizens, and professionals in settings where local and national intensely interact with regional and global.

It is clear that curriculum internationalisation is a complex and systemic phenomenon made up of heterogeneous elements and processes related to quality enhancement through the search for greater relevance, projection, impact, equity, and inclusion of engineering education and training in an institution and country immersed in globalisation. Evidently, it is a strategy meshed with curriculum design, execution, evaluation, and enhancement policies and processes at a university. Furthermore, its status as a construct under development and a system of ideas capable of being adapted to the circumstances of each programme or institution was emphasized [24, 38]. Fig. 4 provides a concept map summarizing the principal ideas underlying the conceptualisation of the curricular principle of study plan internationalisation.

Furthermore, as a result of stage I, the il8n of plans of study for engineering was also operationally defined. From this perspective and in accordance with ITCR curriculum standards and practices, the construct was defined using two subconstructs and six categorical dimensions. These dimensions, in turn, were operationalised through a series of simpler variables known as statements or items. The items were essentially conceived as indicators of the inclusion of the international

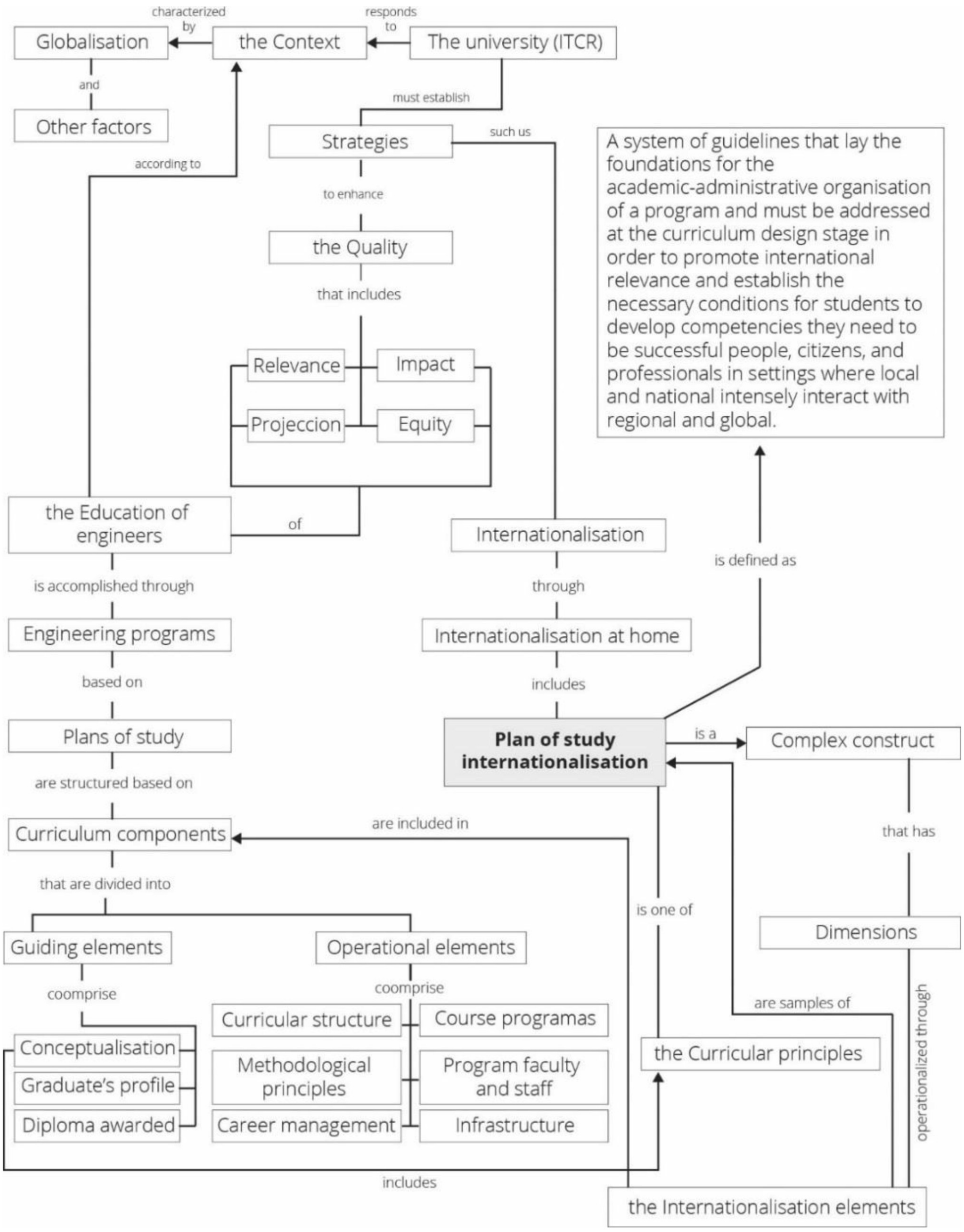


**Fig. 4.** Principal ideas related to the conceptualisation of il8n of ITCR engineering study plans.

dimension in each of the plan of study components, shown in Fig. 2. The correspondence between variables, dimensions and the construct identified as the object of study of the investigation is shown in Fig. 5.

The initial set of engineering curriculum i18n samples, produced in stage I, included 122 items or variables. Of those items, 49 belonged to the three dimensions pertaining to the sub-construct of POS guiding element il8n (programme conceptualisation: mission, vision, organisational objectives, justification, foundation, APP or academic-professional profile, and diploma to be awarded) and the remaining 73 referred to the operational elements (programme structure, methodological principles, course programs, management, infrastructure, and faculty/staff). Each item was presented as an affirmative statement on the existence of specific evidence for the il8n of a certain portion of the plan of study. These statements constituted an essential part of the 1st supporting instrument, which served as starting point for the design of the diagnostic scale on curriculum il8n, which is discussed further on considering the second specific objective of the study.

### *4.2 Results and discussion pertaining to the design of the instrument for the diagnosis of il8n*

The second specific objective was committed to designing an instrument to diagnose the il8n of engineering plans of study at ITCR. This instrument, abbreviated as EDIPE, was obtained in stage V. However, all stages of this study, from the first to the last, contributed important elements that enabled progress towards achieving this goal. Representative examples of intermediate and final results related to the design of a valid and reliable diagnostic scale are presented and discussed below.

EDIPE validity was reflected in two aspects. On the one hand, in the quantitative and qualitative assessments relating to the appropriateness of instrument structure; and on the other hand, in the relevance, clarity, sufficiency and applicability to the institutional context of items chosen as indicators of curriculum il8n. Diagnostic scale reliability, was demonstrated through internal consistency indicators, such as Cronbach's Alpha and CI-TC coefficient.

#### *4.2.1 Results and discussion pertaining to instrument structure*

The proposed structure of the instrument, made up of scales, subscales, and items—according to curriculum layout guidelines at ITCR and the object of study (Figs. 2 and 5)—was well rated by the experts who revised it in stage II. When asked about the suitability of this structure, almost 35% of the raters responded that it is "completely" suitable, whereas 57% indicated that it is "fairly" suitable. A mere 7% considered it "little" suitable and 1% "not at all" suitable. This assessment was considered positive and the decision was made to maintain the order of the instrument in further versions. Additional comments by the raters reinforced this decision, pointing out that the arrangement of the diagnostic scale into subscales consistent with the configuration of a plan of study, is appropriate.

#### *4.2.2 Results and discussion pertaining to instrument validity and reliability*

In the interest of ensuring the diagnostic applicability of the EDIPE, a large part of the work carried out in stages II, III, IV, and V focused on enhancing instrument reliability and validity, which was confirmed by the relevance, clarity, sufficiency, and applicability to the ITCR context of the sub-

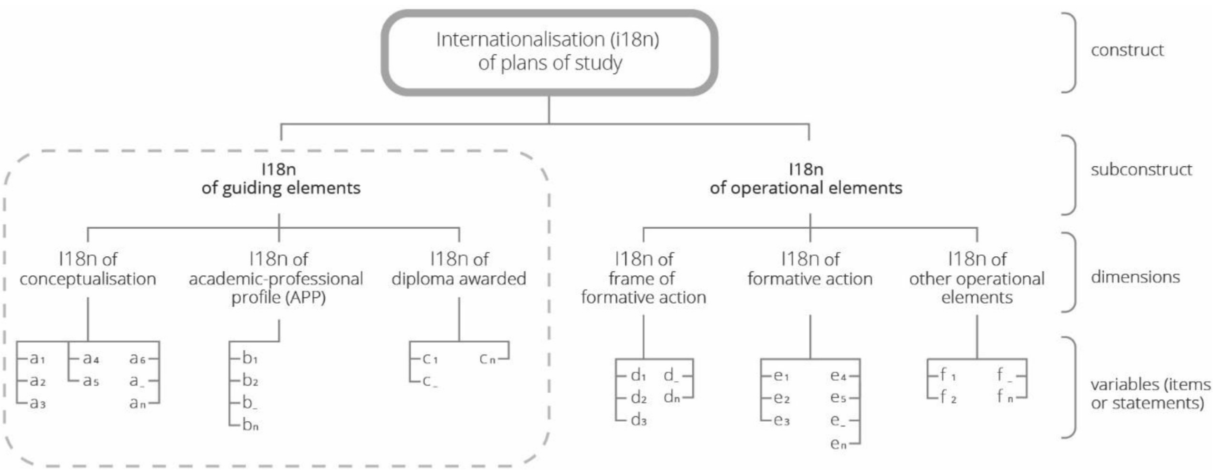


**Fig. 5.** Object of Study Structure. Note: Letters of the alphabet in the lower portion of the figure represent specific statements or items.

**Table 1.** Indicators of Subscale Validity and Reliability in Stages II and III

| | | | Averages | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Items | | Relevance/ Standard Deviation | | Sufficiency | | Clarity | | Cronbach's Alpha | | CI-TC Coefficient | |
| **Subscales** / **Stages** | **II*** | **III*** | **II** | **III** | **II** | **III** | **II** | **III** | **II** | **III** | **II** | **III** |
| Subscale-1 (Conceptualisation) | 11 | 10 | 3.25 / 0.722 | 3.40 / 0.705 | 3.09 | 3.30 | 3.07 | 3.11 | 0.854 | 0.818 | 0.605 | 0.505 |
| Subscale-2 (APP) | 29 | 14 | 3.26 / 0.733 | 3.54 / 0.664 | 3.28 | 3.38 | 2.93 | 3.33 | 0.939 | 0.895 | 0.581 | 0.579 |
| Subscale-3 (Degree) | 9 | 9 | 3.23 / 0.851 | 3.39 / 0.773 | 3.17 | 3.31 | 3.17 | 3.33 | 0.731 | 0.753 | 0.430 | 0.435 |
| Three subscales together | 49 | 33 | 3.25 / 0.769 | 3.44 / 0.714 | 3.18 | 3.33 | 3.06 | 3.26 | 0.836 | 0.823 | 0.539 | 0.506 |

*Roman numbers II and III refer to stages II and III, or 1st and 2nd assessment-cleaning, respectively.

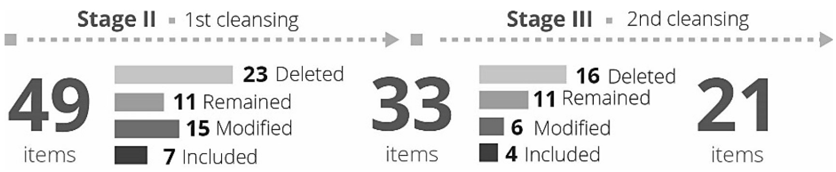


**Fig. 6.** Results of Scale Cleansing in Stages II and III.

scales and engineering curriculum internationalisation items or indicators.

The results of the 1st round of assessment, conducted in stage II, demonstrated that the subscales and items evaluated by the experts had admissible levels of validity and reliability. Therefore, as summarized in the corresponding columns in Table 1, the values corresponding to subscale averages of relevance[3] (from 3.23 to 3.26), average standard deviations (from 0.722 to 0.851), averages of sufficiency and clarity (higher than 3.09 and 2.93, respectively), Cronbach's Alpha results (higher than 0.731) and CI-TC coefficient averages (from 0.430 to 0.605) were indicative of a positive general panorama in terms of item and subscale diagnostic capacity. This was interpreted as an initial success of the study's exploratory phase.

However, a more detailed analysis of item behaviour revealed that, despite a positive general panorama, there was little expert agreement on the relevance of some statements. This was noticeable because in some cases Kendall's $\hat{W}$ values between raters in this stage were relatively low (from 0.049 to 0.188, with a 0.01 level of significance). Furthermore, several items in all subscales of the 1st supporting instrument had a level of relevance that was less than the corresponding critical value established at 3.0, which is equivalent to *moderately significant.*

Thus, in order to clean the subscales and enhance instrument validity and reliability, an integrated analysis of each of the items was conducted (refer to section 3.2, stage II). In fact, with the purpose of achieving greater validity and reliability of the scales, the analysis and cleansing process was carried out in two consecutive rounds: at the end of stages II and III, and was alternated with expert ratings. Fig. 6 shows the data resulting from these two cleansing rounds.

As is apparent in Fig. 6, this cleansing, conducted twice consecutively (stages II and II), enabled item number optimisation—which had been pointed out as a necessity by several raters—reducing these by 57%, from 49 to 21. This contributed towards greater ease of instrument administration and consequently, towards overall scale validity. At the same time, the number of items remained showed that core features relevant to the characterisation of the POS il8n construct were outlined during the early stages of the investigation.

Data cleansings conducted in these stages also had a positive effect on aspects such as relevance, clarity and sufficiency. This data is included in Table 1. When comparing columns with data from stage II with columns presenting data from stage III, it is evident that relevance, sufficiency and clarity

[3] Relevance, sufficiency, and clarity values can range between 1.00 or not at all relevant, sufficient or clear and 4.00 or completely relevant, sufficient or clear.

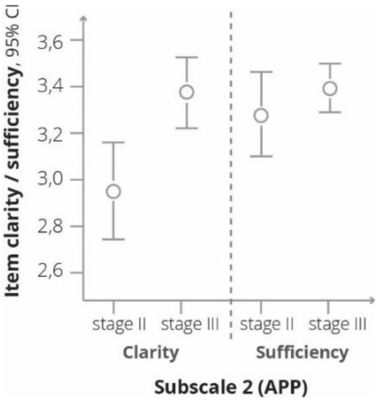


**Fig. 7.** Error Bars for Subscale-2 Clarity and Sufficiency Assessments (APP il8n), in Two Consecutive Stages. Note: CI—confidence interval.

increased in the instrument's three subscales as a result of these procedures. Despite the fact that the increase in these parameters was not necessarily statistically significant in all cases, it always showed a positive trend. This is illustrated by the example in Fig. 7, where the improvement in subscale-2 clarity was significant (95% confidence level), whereas the improvement in sufficiency did not attain this level of significance, despite experiencing an evident increase.

Table 1 also shows that the reduction in the number of items by almost a third that occurred between stages II and III, did not result in an unsustainable decrease in Cronbach's Alpha (which has a positive correlation with the number of variables). The level of alpha obtained was adequate for this type of scales (close to 0.8), which was accepted as a positive indicator of instrument reliability. A similar situation occurred with the corrected item-total correlation coefficient.

In this manner, double item cleansing in stages II and III enabled improvement of il8n indicators for engineering POS guiding elements as well as preparation of a draft version of the EDIPE, ready to undergo logic check. The following instrument validity and reliability parameters (Table 1) clearly showed improvement: decrease in item number (from 49 to 21); increase in relevance rating (from 3.25 to 3.44) accompanied by a decrease in the standard deviation (from 0.769 to 0.714); increase in sufficiency and clarity scores (from 3.18 to 3.33 and from 3.06 to 3.26, respectively); and adequate level of alpha (over 0.8). Fig. 9 illustrates instrument improvement.

### *4.2.3 Results and discussion pertaining to instrument adaptation to ITCR context*

Next, in stage IV, the shortest of them all, the necessary results to adapt the draft version of the EDIPE to the context of ITCR were obtained. Format and content clarity and applicability were examined. This was done both to ensure users' correct understanding of instrument components as well as verify that all information requested during diagnostic scale administration is contained in programme POS at ITCR. This was achieved by means of a logic check conducted by 15 experts from ITCR, which enabled the compilation and analysis of 158 comments and recommendations. Almost 75% of these comments were consistent with the objectives of this stage and pointed to certain errors in terms of clarity, conciseness, and adaptation of the instrument to the context of the institution. Overall, observations made were related to content format, grammar, lexicon, and semantics. In total, 118 comments contained relevant inputs for diagnostic scale improvement.

After careful analysis of annotations made, one of the items in Subscale-1 was eliminated, instrument layout was perfected, and the EDIPE pilot version was prepared. This version included 20 statements rated as suitable indicators of the il8n of engineering POS guiding elements at ITCR. Therefore, the resulting instrument was more compact, clear, simple, precise and, at the same time, more valid and reliable. In this manner, throughout stages II, III, and IV, the overall structure of the diagnostic scale was defined, scale validity and reliability were increased, the instrument was adapted to the context, and the EDIPE pilot version was finalised.

### *4.2.4 Results and discussion pertaining to instrument enhancement based on pilot version administration*

In stage V, along with the administration of the EDIPE pilot version to diagnose plan of study il8n, actions were taken to verify and improve scale parameters in terms of technical performance in the field. This allowed for the design of the final version of the instrument, whose structure is shown in Fig. 8.

The EDIPE, which completed the instrumental portion of the methodological guide for plan of study il8n, is made up of 15 pages and administration time is approximately one hour. As shown in Fig. 8, the diagnostic portion of the instrument contains the assessment section, which in turn is made up of three diagnostic subscales. The first of these refers to il8n of programme conceptualisation and consists of seven indicators regarding mission, vision, values, justification, and object of study. The second subscale pertains to the il8n of the APP or academic-professional profile and includes eight indicators in connection with an engineer's specific work-related attributes, use of resources on a global

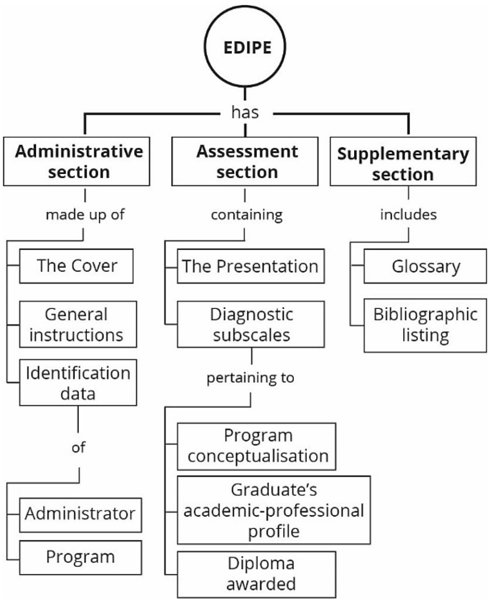


**Fig. 8.** Structure of the EDIPE final version.

scale, and soft intercultural competencies. Finally, the third subscale is related to the diploma awarded and is composed of two indicators that address diploma and academic degree il8n.

The internationalisation items or indicators of the EDIPE final version are shown in Table 3. Relevant data on instrument reliability is summarized in Table 2 and Fig. 9.

Table 2 shows that despite having a reduced number of items, all three subscales of the EDIPE pilot version showed acceptable values of Cronbach's Alpha ($0.7 < \alpha_{Cr} < 0.8$) and average CI-TC coefficient ($0.4 < r_{CETC} < 0.6$). This data demonstrates reasonable instrument consistency. Additionally, several opportunities to further improve certain items and subscales were identified in this stage. For example, three items with a relatively low CI-TC coefficient ($r_{CETC} < 0.2$) were detected in Subscale-2, and Cronbach's Alpha if Item Deleted also highlighted the need for careful adjustment in this regard. Furthermore, three items were identified in Subscale-3 that did not correspond to ITCR's true context and consequently were removed from the final version of the instrument.

Starting with the administration of the 1st supporting instrument and ending with the final version of the diagnostic scale, Fig. 9 shows the evolution of two of the EDIPE's technical properties, reliability and validity.

The vertical bars in Fig. 9 represent the number of il8n items or indicators contained in the instruments used in each stage. Throughout the course of the instrument design process, the original number of items was reduced by almost a third. Table 3 shows the 17 items or statements that make up the final version of the EDIPE.

The data in Fig. 9 also reveals that the values of the principal indicator of instrument reliability (Cronbach's Alpha) remained at a satisfactory level ($0.7 < \alpha_{Cr} < 0.8$). Additionally, an improvement in relevance, sufficiency and clarity indexes is observed throughout the corresponding stages, which attests to the fact that the final version of the scale had adequate levels of validity and reliability. Therefore, this version of the EDIPE was included in the methodological guide for the il8n of ITCR plans of study. In this manner, the second specific objective of the study was fulfilled.

### *4.3 Results and discussion pertaining to the diagnosis of the il8n of two ITCR engineering plans of study*

The study's third and last specific objective, which entailed administering an EDIPE pilot version to assess the il8n of two ITCR engineering careers, was addressed in stage V. Eight academic advisors and eight faculty/members of the ITCR curriculum committees for *licenciatura* in agricultural engineering (AE) and bachelor's in biotechnology engineering (BE) participated here. In this regard, the administration of Subscale-1, made up of seven items, revealed statistical similarity between both programmes in terms of the il8n of POS conceptualisation elements ($\alpha = 0.05$) as can be seen in Fig. 10. At the same time, however, this similarity was partial and heterogeneous given that some aspects showed greater progress than others. For example, the incorporation of the international dimension is notorious in elements identified in Table 3 as "Justification", "Values" and "Object". On the other hand, progress was much less in connection with components such as "Vision", "Mission", "Entities" and "Policies".

The diagnosis obtained using Subscale-2, which included eight items related to the academic-profes-

**Table 2.** Reliability of EDIPE Pilot Version Subscales

| | **Instrument Subscales** | | |
|---|---|---|---|
| | **Subscale-1 (Conceptualisation)** | **Subscale-2 (APP)** | **Subscale-3 (Diploma)** |
| Number of Items | 7 | 8 | 5 |
| Cronbach's Alpha | 0.719 | 0.720 | 0.758 |
| Average CI-TC Coefficient | 0.438 | 0.486 | 0.561 |

sional profile (APP), revealed an acceptable level of il8n of both programmes. In general, agricultural engineering showed slightly greater progress in terms of APP internationalisation (with the exception of the ''English'' and ''Standards'' indicators). This can also be seen in Fig. 10. However, in this regard, only two significant differences ($\alpha$ = 0.05) were recorded between AE and BE and these had to do with the ''Implications'' and ''Agencies'' items.

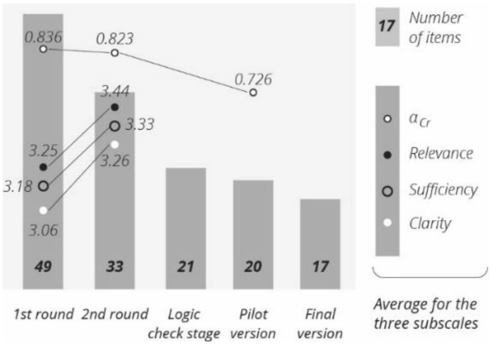


**Fig. 9.** Evolution of the Technical Properties of the Diagnostic Scale for the Internationalisation of Engineering Plan of Study Guiding Elements.

Meanwhile, the diagnosis that resulted from the administration of Subscale-3, which was made up of only two indicators related to the diploma to be awarded, confirmed the existence of an acceptable level of internationalisation in terms of the diploma and academic degree of AE and BE, revealing no differences between them.

In summary, the pilot test of the EDIPE revealed a perceptible degree of il8n of those more important curriculum elements of both programmes evaluated (such as conceptualisation, academic-professional profile and diploma). On a scale from 1 to 3, the degree of il8n fell between 1.96 and 2.69. Additionally, the graduate's academic-professional profile

**Table 3.** Items or Indicators Contained in EDIPE Final Version

| Abbreviated Identification | Item Statement |
|---|---|
| Subscale-1 Internationalisation of programme conceptualisation | |
| Mission | 1.1 The mission incorporates an international dimension that enriches programme identity. |
| Vision | 1.2 The vision captures the connection between programme and international context. |
| Values | 1.3 The plan of study enunciates a series of universal values (for example: peace, freedom, respect for human dignity, solidarity, tolerance, democracy) that the programme adopts as its academic and administrative code of ethics. |
| Justification | 1.4 The justification presents specific practical arguments that situate the programme in a context where local and global interact. |
| Policies | 1.5 The justification includes the description of institutional benchmarks (policies, plans or others) that underpin programme internationalisation. |
| Entities | 1.6 The justification lists relevant international entities* devoted to engineering education that support the programme's connection with a context where global and local interact. |
| Object | 1.7 The programme's object of study is defined in line with the internationally accepted conceptualisation of engineering* (and specific branch). |
| Subscale-2 Internationalisation of the graduate's academic-professional profile (APP) | |
| Implications | 2.1 The APP indicates that graduates are aware of the implications of greater local-global interaction for their field of work. |
| ICT | 2.2 The APP sets forth that graduates use information and communication technologies (ICT) to broaden their field of work globally. |
| English | 2.3 The APP indicates that graduates use English (verbal and written) where necessary in their professional activity. |
| Groups | 2.4 The APP enables engineering graduates to work for international groups or corporations characterised by cultural diversity. |
| Standards | 2.5 The APP states that engineering graduates are skilled at using international standards (for example: environmental, safety and quality standards) in their field of specialisation. |
| Tasks | 2.6 The APP points out that graduates are capable of performing the principal engineer tasks* according to their area of specialisation in situations where local and global interact. |
| Resources | 2.7 The APP stipulates that in order to perform their professional tasks, graduates select the most appropriate resources taking internationally available options into consideration. |
| Agencies | 2.8 The APP for engineering graduates is designed according to criteria* used by Washington Accord signatory accreditation agencies. |
| Subscale-3 Internationalisation of the diploma to be awarded | |
| Diploma | 3.1 The engineering specialty area* appears on the diploma and is understandable internationally. |
| Degree | 3.2 The academic degree awarded at the end of the programme, which is specified on the diploma; it is consistent with degree classifications used internationally (bachelor's or *licenciatura*). |

* The terms included in this table and identified with an asterisk (*) are explained in the glossary at the end of the article.

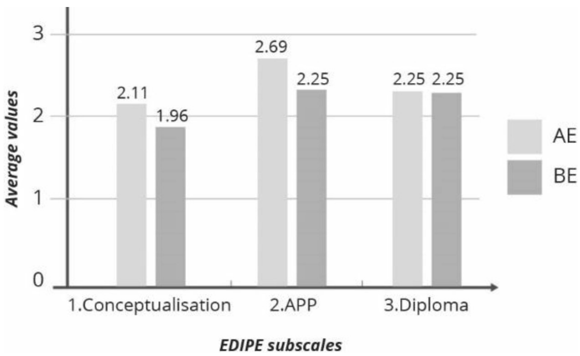


**Fig. 10.** Average il8n Values per Subscale for Both Programmes.

was the POS component that showed greatest progress in terms of the incorporation of the international dimension, whereas programme conceptualisation displayed the least amount of progress in this regard. The general situation with regard to the diagnosis of AE and BE plan of study il8n is shown in Fig. 10.

It was confirmed in stage V that ITCR has begun to internationalise its agricultural engineering and biotechnology engineering curricula. Tangible progress has been made (Fig. 10); however, it is still partial and heterogeneous.

Thus, the results of the diagnosis of the il8n of the plans of study for two of the institution's programmes were obtained upon finalising the last stage of the study. These results enabled the assessment of the actual status of curriculum internationalisation for these two programmes and highlighted the need to continue with POS il8n in order to enhance relevance and impact, and further improve the quality of engineering education and training at ITCR.

In order to facilitate the incorporation of the international dimension into the curricula, the methodological guide [37] for the il8n of engineering POSs was obtained and put at the disposal of the Spanish-speaking academic community. This methodological guide contains both the conceptual basis for curriculum il8n, generated in stage I, as well as a valid and reliable instrument for the diagnosis of the il8n of POS guiding elements for this type of programmes at ITCR.

## 5. Conclusions

The first specific objective was to develop a theoretical-conceptual framework for the construct known as the il8n of ITCR engineering plans of study. This objective was met in stage I, after having obtained the theoretical section of the methodological guide for POS il8n, available online [37, p. 70]. This guide, which contained an extensive description of engineering curriculum internationalisation, explained that this il8n is a phenomenon considered a curricular principle. It was also defined as a system of guidelines that lay the foundations for the academic and administrative organisation of a programme. Emphasis was made on the fact that this system of guidelines must be addressed at the curriculum design stage in order to promote international relevance and establish the necessary conditions for students to develop competencies they need to be successful people, citizens and professionals in settings where local and national intensely interact with regional and global. It was also pointed out that the i18n of the curricula is not a series of clearly established good practices, but rather an open and dynamic construct that can be adapted to the needs and particularities of each institution and program.

The second specific objective was to design a valid and reliable instrument to diagnose the i18n of ITCR's engineering POSs. This objective was gradually met throughout all five stages of the study and fulfilled in its entirety at the end of stage V with the final version of the EDIPE.

The third specific objective called for the pilot test of the instrument to assess the il8n of the guiding elements of both the *licenciatura* degree in agricultural engineering (AE) and bachelor's degree in biotechnology engineering (BE) curricula. The pilot test revealed that the il8n of the POS for both programmes has already begun and tangible progress is being made. However, progress made is partial, heterogeneous (with regard to the 17 indicators detailed in Table 3), and sometimes barely palpable. Progress was evident in terms of the definition of the programmes' object of study, values adopted by each programme, and certain characteristics of their academic-professional profiles (for example, use of English and international environmental, safety, and quality standards). On the other hand, the level of il8n was much lower in terms of these programmes' mission and vision statements as well as regarding some aspects of the justification. Additionally, there was little disparity in relation to curriculum il8n between AE and BE. Only two indicators, identified in Table 3 as "Implications" and "Agencies", showed a significant difference in terms of il8n. These results allowed for the assessment of the current status of curriculum internationalisation and appropriate actions were taken regarding the academic development of these programmes.

The general objective of the study, that is, the need to close the theoretical-methodological gap in the internationalisation of ITCR's engineering plans of study, was attained. The concrete expression of the fulfilment of this objective is the generation of the document entitled *Plan of Study*

*Internationalisation: A Methodological Guide* [37]. This 237-page guide contains a theoretical framework relating to the curricular principle of engineering programme il8n and diagnostic scales for the incorporation of the international dimension into ITCR programme POSs. The most advanced version of the EDIPE was also included in the study report published in the TESEO database [32].

Both the guide and EDIPE diagnostic scale, developed in the course of this study, are deemed to have immediate and specific value given that they are now part of the methodological pool of those academicians involved in programme design, delivery and management at ITCR. At the same time, the study is believed to have value as a starting point for new lines of research, while operationally addressing a phenomenon as abstract as internationalisation.

After finalising the study, the empirical determination of engineering POS il8n at Instituto Tecnológico de Costa Rica is no longer an illusion, but a real possibility. The detection of advances and deficiencies in internationalisation constitutes valuable input for ITCR programme self-regulation. Furthermore, considering that this was one of the first studies in this field conducted in Latin America, the results of this investigation may be of use for curriculum internationalisation in other universities prior adaptation to the context of each institution and educational system. Therefore, this study is deemed to contribute to the enhancement of relevance and in consequence to the quality of engineering education and training not only at ITCR, but throughout the entire region.

The innovative result of this study is a valid and reliable theoretical-methodological guide for internationalising the curriculum. This guide enables the enhancement of relevance and quality teaching in engineering in a context where local never ceases to be important and interacts with international and global.

Nonetheless, it is important not to lose sight of the limitations of a study, which are only inevitable and derive from its objectives and scope. In relation to the limitations of this study, its object of study focuses on the curriculum guiding elements and leaves out the operative elements (as shown in Fig. 5). Another limitation is that the study only covers undergraduate engineering programs and does not include other types of careers and undergraduate programmes available at ITCR. Furthermore, there are limitations in terms of research methodology: final validation and pilot test were based on a small number of test administrators and careers (24 and 2, respectively).

However, these limitations are seen as inputs for subsequent research. Possible lines of research deriving from this study include the il8n of POS operational components; il8n of other types of programs (other than engineering and undergraduate level); il8n of the entire curriculum management cycle, which includes university programme inputs, processes, products, and context; and il8n of educational systems at other levels (institutional, national and supranational), just to name a few.

This would be an important factor in the consolidation of a body of theoretical and practical knowledge on the internationalisation phenomenon in all its manifestations and at all levels, contributing towards the task of improving higher education in the context of an increasingly interdependent world.

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## Appendix: Glossary

***Criteria pertaining to APP design used by accreditation agencies.*** An example of these criteria are those prepared in 2013 by the International Engineering Alliance (IEA) and titled "Graduate Attributes and Professional Competencies". This text sets forth a series of criteria regarding graduate competencies or academic-professional profiles (APP), which agencies for the accreditation of engineering education that are signatories to the Washington Accord can use in programme quality evaluation processes.

Therefore, the following two aspects should be considered when assessing the internationalisation of the APP design of an engineering programme. Firstly, the academic-professional profile design format must focus on graduate competencies or attributes. Secondly, the APP must include attributes related to: (1) engineering knowledge; (2) complex problem analysis; (3) design and development of solutions; (4) investigation; (5) modern tool usage; (6) the engineer and society; (7) environment and sustainability; (8) ethics; (9) individual and team work; (10) communication; (11) project management; and (12) lifelong learning [39].

***Engineering specialty area.*** The name of a programme's specialty area usually coincides with the name of the branch of engineering defined as the object of study. This name is also known as the degree and is specified on the diploma and other documents awarded to the graduate. In relation to the degree, which describes the diploma holder's field of knowledge and action, mention is made of the fact that some institutions are extremely creative when it comes to engineering programme names [40].

However, the name of the specialty area of an internationalised programme must allow graduates to fulfil their role as professional engineers at global level. For this reason, it is important to consider factors such as international recognition and homogenisation of education received and professional practice.

In some Latin American countries, there are over 100 specialty areas in engineering, of which more than half are offered by a single university such as perforation engineering or cinema and TV engineering. Nonetheless, Latin America's most popular engineering programmes are: environmental, civil, electrical, electronic, industrial, computer, mechanical, production, systems, telecommunications, and chemical [41].

Consequently, there is a need to adequately distinguish the different types of engineering by encouraging curriculum innovation; however, excessive proliferation of programme names should be avoided as this does not contribute to international comparability and acceptance of degrees.

***Competent international entities in engineering education.*** The following are the names, acronyms and website addresses of the principal international entities in the field of engineering education: World Federation of Engineering Organizations (WFEO: www.wfeo.org), International Federation of Engineering Education Societies (IFEES: http://www.ifees.net), International Engineering Alliance (IEA: http://www.washingtonaccord.org), International Council of Academies of Engineering and Technological Sciences (CAETS: http://www.caets.org), Academia Panamericana de Ingeniería (API: http://www.apingenieria.org), Engineering for the Americas (EFTA: http://www.efta.oas.org/english/cpo_sobre.asp), Latin American and Caribbean Consortium of Engineering Institutions (LACCEI: http://www.laccei.org), Asociación Iberoamericana de Instituciones de Enseñanza de la Ingeniería (ASIBEI: http://www.asibei.org), European Council of Applied Sciences and Engineering (Euro-CASE: http://www.euro-case.org/index.html), among others.

***Engineering.*** With regard to the conceptualisation of engineering, the Asociación Iberoamericana de Instituciones de Enseñanza de la Ingeniería (ASIBEI) considers the need to "establish several boundaries within which concept use shall be valid," but taking into consideration the natural evolution of this professional activity [41]. ASIBEI recommends paying close attention to the following four factors when defining the concept: 1) knowledge bases (mathematics, natural sciences, and engineering sciences); 2) work methods (scientific modelling and design); 3) objects or areas of application (infrastructure, industries, services companies, environment protection, health, education, and information); and 4) purposes (create value, create goods, provide effective solutions to social issues). The superposition of these four factors is what determines the existence of an engineering activity as such [41].

Different competent bodies in this area agree that engineering is the profession where knowledge of mathematics, natural sciences, engineering sciences, and design and execution processes and methods - obtained through research, experience and practice - is used creatively and with sound judgement to make optimum use of materials, resources, and the forces of nature to fulfil the needs of humans and enhance their quality of life respecting ethical, economic, legal, environmental, social, technological, and quality demands and limitations [40, 41].

In terms of this curriculum component, the international dimension requires congruence between the definition of the object of study of the programme and the internationally accepted concept of engineering.

***Engineer tasks.*** The phrase "principal engineer tasks" refers to project design, development, and administration as well as production, inspection, and consultancy services, among other possible functions assumed by a specialist depending on each branch of engineering.

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