Revista Iberoamericana para la Investigación y el Desarrollo Educativo
ISSN 2007 - 7467

https://doi.org/10.23913/ride.v15i30.2357

Scientific articles

Progresiones del Aprendizaje y Mapas de Competencia en Educación Superior

Learning Progressions and Competency Maps in Higher Education

Progressões de aprendizagem e mapas de competências no ensino superior

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Resumen

Este trabajo describe una metodología para integrar progresiones del aprendizaje en la construcción de mapas de competencias en educación superior, con objeto de fortalecer el desarrollo de la formación del perfil de egreso en programas educativos de ingeniería. Las progresiones de aprendizaje se definen como secuencias didácticas planificadas para la adquisición gradual de conocimientos y habilidades, fundamentadas en la taxonomía de Bloom, revisada por Anderson y colaboradores. La construcción de competencias debe evitar una carga excesiva de contenidos académicos: se deben seleccionar aquellos que sean necesarios, suficientes y relevantes para el desarrollo integral del perfil de egreso. Esto asegura que los estudiantes adquieran las habilidades de manera efectiva, sin sobrecargar la carga académica de los planes de estudio con contenidos redundantes y que no estén asociados a desempeños específicos. Para la construcción de mapas de competencias se utilizó el análisis de contenido sobre las habilidades que los estudiantes deben adquirir en una disciplina académica, tal como las ciencias básicas y su relación transversal con asignaturas de ciencias de la ingeniería e ingeniería aplicada. Se presentan ejemplos transversales de progresiones de aprendizaje con el tema *"funciones"*, integrada en la materia *Cálculo diferencial*, vinculándolas con resultados de aprendizaje en las asignaturas de *Gestión de calidad*, *Balance de materia y energía* y asignaturas de *operaciones unitarias*. Este trabajo ofrece una perspectiva innovadora para fortalecer el diseño curricular en programas de ingeniería.

Palabras clave: Progresiones del aprendizaje, mapas de competencias, evaluación formativa, competencias profesionales, educación superior.

Abstract

This paper describes a methodology for integrating learning progressions into the construction of competency maps in higher education to strengthen the development of the graduate profile in engineering education programs. Learning progressions are defined as didactic sequences planned for the gradual acquisition of knowledge and skills, based on Bloom's taxonomy. The construction of competencies must avoid an excessive load of academic content: Only those that are necessary, sufficient and relevant for the integral development of the graduate profile must be selected. This ensures that students acquire skills effectively without overloading the academic load of curricula with redundant content that is not linked to specific performances.

To construct the competency maps, content analysis was used to analyze the skills that students should acquire in an academic discipline, such as basic sciences, and their cross-cutting relationship with engineering and applied engineering subjects. Transversal examples of learning progressions are presented with the topic of "functions", integrated in the subject of *Differential Calculus*, and linked to learning outcomes in the subjects of *Quality Management*, *Matter and Energy Balance*, and *Unit Operations*. This work offers an innovative perspective to strengthen curriculum design in engineering programs.

Keywords: Learning progressions, competency maps, formative evaluation, graduation attribute, higher education.

Resumo

Este artigo descreve uma metodologia para integrar progressões de aprendizagem no mapeamento de competências no ensino superior, com o objetivo de fortalecer o desenvolvimento de perfis de pós-graduação em programas de educação em engenharia. Progressões de aprendizagem são definidas como sequências de ensino planejadas para a aquisição gradual de conhecimento e habilidades, com base na taxonomia de Bloom, revisada por Anderson e colaboradores. O desenvolvimento de competências deve evitar uma carga excessiva de conteúdos acadêmicos: devem ser selecionados aqueles que sejam necessários, suficientes e relevantes para o desenvolvimento integral do perfil do egresso. Isso garante que os alunos adquiram habilidades de forma eficaz, sem sobrecarregar o currículo acadêmico com conteúdo redundante e não vinculado a desempenhos específicos. Para construir mapas de competências, a análise de conteúdo foi usada para identificar as habilidades que os alunos devem adquirir em uma disciplina acadêmica, como ciências básicas e sua relação interdisciplinar com ciências da engenharia e disciplinas de engenharia aplicada. São apresentados exemplos de progressões de aprendizagem interdisciplinares, com base no tópico "funções", integradas à disciplina de Cálculo Diferencial e vinculadas aos resultados de aprendizagem nas disciplinas de Gestão da Qualidade, Balanço de Materiais e Energia e Operações Unitárias. Este trabalho oferece uma perspectiva inovadora para fortalecer o design curricular em programas de engenharia.

Palavras-chave: Progressões de aprendizagem, mapas de competências, avaliação formativa, competências profissionais, ensino superior.

Reception Date: November 2024 **Acceptance Date:** March 2025

Introduction

The development of professional competencies during vocational training in a curriculum constitutes a fundamental reference point for employers and accrediting bodies when evaluating the quality and relevance of educational programs. For higher education institutions , this implies effectively meeting the demands of society. During the learning process, there is a need to gradually progress in the acquisition of knowledge and the development of skills, advancing from an initial cognitive level and attitudes to the development and formation of those increasingly significant and useful capacities, called graduation attributes, as the Engineering Education Accreditation Council (CACEI, 2021) calls them .

From an educational perspective, learning develops through an active verb that implies achieving specific goals and objectives, establishing a path to achieve them. A curriculum represents this academic journey: a bridge that connects subjects and their content to develop increasingly specific problem-solving skills or to define professional competencies. This process of progress is called academic advancement, through transversal learning paths. This paper explores various perspectives and proposals on the importance of *learning progressions and competency maps* and defines them as follows:

> The concept of learning progressions is a planned guide in didactic instruction to support the learning process and the development of professional competencies in higher education students.
>
> A competency map is a structured representation of the skills, knowledge and attitudes that students must acquire and develop throughout their academic training, which can be achieved through the design of learning progressions (Loría et al., 2025).

The competency map allows you to identify which transversal competencies are essential and how they interrelate to achieve optimal professional performance. It requires specifying the competency mastery levels to plan the learning progression and can be represented with figures or matrices to summarize competency profiles.

In this paper, the above definitions are considered a link between upper secondary and higher education educational models. The central premise is that learning is conceived as a continuous and progressive process in which students advance in their understanding of interrelated curriculum content, contributing to the development of increasingly comprehensive and meaningful competencies.

The relevance of both constructs lies in their ability to structure and guide the planning of the training process, ensuring a coherent and progressive acquisition of skills. To this end, the ideas presented by Heritage (2007), Paredes (2020) , and Talanquer (2013) , as well as the requirements of accrediting bodies, are taken as a basis. Barrera and Nieto (2021) point out that learning progressions are presented as a key approach to the development of professional competencies in higher education. It should be noted that, for the accrediting body, the *graduation attributes* correspond to the professional competencies or learning objectives declared by the educational program.

Extending the analysis of learning progressions, in basic education learning progressions have the same purpose as in the Common Curriculum Framework for Upper Secondary Education, based on the New Mexican School model, which takes as a reference the idea of progressions in mathematical thinking, communication skills, and digital culture (SEP, 2022c) . In this sense, the learning progression routes presented in this study based on the concept of *mathematical function* constitute the result of collaborative work between teaching professionals from the basic sciences academy (CB) at an institute belonging to the National Technological Institute of Mexico, TecNM. In the same sense, the curricular design based on learning progressions (LP) is the opportunity to collaborate with teachers of the upper secondary level (NMS), since from 2025 the students graduating from high school will be trained with a graduation profile defined through progressions and the idea of transversality, based mainly on mathematical thinking, digital culture and oral and written communication skills (Sep, 2022).

This study is part of a series of quantitative and mixed research projects in the CB department, with the purpose of a didactic instrumentation under the *b-Learning methodology*. to support face-to-face education Rodríguez-Díaz et al. (2024), as well as studies aimed at improving effective communication in the classroom and establishing an institutional evaluation system to improve the educational process (Rodríguez-Díaz et al., 2023) . Furthermore, the results of this work are fundamental elements of a continuous improvement plan for the accreditation processes of engineering programs, in accordance with the CACEI quality indicators. The experience was developed through the action research method, from the perspective of Freire , who states that “there is no teaching without research and no research without teaching (Freire, 2004, p. 14).

Within the framework of the TecNM educational model (2013), the graduate profile is configured from a set of professional competencies that are developed as students take and complete courses in various academic areas, such as basic sciences , engineering sciences, applied engineering, and economic and administrative sciences. Thus, the graduate profile, defined in terms of performance skills, is based on the professional competencies that constitute the essential components of the curriculum.

The TecNM maintains that this integration is the way to guarantee the relevance of educational programs demanded by society, a quality ultimately determined by the CACEI (Center for Research and Development). This approach emphasizes that PAs play a fundamental role in the development of professional competencies. In this context, the following research objectives are established:

1. Develop a methodology to identify and build learning progressions that contribute to the development of professional competencies in an engineering academic program enrolled in the graduation profile.
2. Apply the Anderson and collaborators matrix in Bloom's taxonomy to generate learning outcomes with the topic of *mathematical functions* , with the purpose of operationalizing the construction of transversal competence maps in correlated subjects (Anderson et al., 2001).
3. Apply the topic *of functions* , from the subject *Differential Calculus* , to create the learning progression *"hypothesis testing"* in the subject *Statistics* , as an example of the competency map *"design and operate research projects for the analysis and interpretation of experimental data" and the "ability to solve problems".*

Theoretical Framework

Regardless of whether an educational program is defined by learning objectives, the development of professional competencies, or by learning progressions (LPs), which are the current trend in basic education levels, learning is determined by the verb that defines the teaching activity. To write a learning objective, the verb form used is the *infinitive* , because it indicates the action that must be performed to achieve it. In contrast, to write a competency, the recommended verb form is the *indicative,* since it not only indicates the action, but also infers the subject who will act to achieve the development of the competency, in addition to when, how, and why (Moliner, 2013; Pimienta, 2012) . Educational models based on the development of competencies *indicate* that the subject who assumes these actions is the student.

Following the idea of learning progressions, these aim to sequentially develop a competency or skill from a basic level to a more complex and meaningful performance, whether for solving a problem or designing a process or service. Learning these skills requires a sequence and transition (progressions) from lower cognitive levels to higher cognitive levels. Therefore, this paper builds on and substantiates the idea that PAs originate in Bloom's taxonomy.

In the 1950s, Bloom et al. (1956) pointed out that learning occurs when the nouns of an educational action are involved at different levels of cognitive objectives. Bloom and collaborators constructed their model (a classification system) with the noun of each verb in three aspects: *cognitive, affective and psychomotor* . This was done with the purpose of being able to evaluate learning in a more pertinent and objective manner. Using the cognitive taxonomy, they defined the following sequence of nouns that underlie educational actions to develop skills: knowledge, comprehension, application, analysis, synthesis and evaluation. This progression and cognitive ascent has been used in basic education curriculum designs, from the perspective of various learning theories.

Recently, based on the need to consider the scope of the digital age, Churches (2019) and Da Silva (2023) updated this sequence of cognitive levels, taking into account pedagogical and psychological advances in the act of learning. Additionally, they emphasized the role of the cognitive model in the development of critical thinking and the use of ICTs in teaching and learning. Marzano and Kendall (2007) published an update to Bloom's cognitive level classification system to generate specific strategies for teaching and assessing programmed skills; they included a system of beliefs and values that are currently very important in education.

For their part, Anderson et al. (2001) adapted Bloom's taxonomy to meet the requirements of contemporary educational psychology, modifying the noun with the use of active verbs. This allows for a better description of the dynamic nature of learning. By updating the taxonomy, the researchers integrated *"analysis-synthesis"* as a dual and dynamic process. They determined that, starting from the preceding level, the verbs *"evaluate"* and " *create"* define the highest cognitive level of the taxonomy. As an example, they refer to the following educational experiences:

- Students must learn to *outline* textbook lessons.
- Students must learn to *criticize* proposed solutions to social problems.
- Students must learn to *build* scenarios (Anderson, et al., 2001).

On this journey *delineate→ criticize →construct,* Anderson et al. indicate that the verb used is easily identifiable and, likewise, classifiable. In this example, " *delineate* " is an alternative term for organize (*analyze).* " *Criticize* " is associated with *"evaluate,"* while " *construct* " is an alternative term for " *produce* ," equivalent to " *create* ." Table 1 illustrates how learning moves from lower to higher cognitive levels. The authors of this update to Bloom's taxonomy created a list of verbs to make the learning activities in this sequence of knowledge construction more explicit and varied.

Table 1. Matrix for designing learning outcomes derived from teaching activities

Dimension of the Knowledge	Dimension of the process s cognitive					
	1 Remember r	2 Understand r	3 Apply	4 Ana li za r	5 Evaluate	6 Create
1 Factual						
2 Conceptual			X			
3 Procedural Knowledge			X			
4 Knowledge Me t acognitive						

Note: Source: Anderson et al. (2001). The table shows an example of interaction between the cognitive process dimension Applying and the conceptual and procedural knowledge dimensions to generate a learning activity.

This matrix has two components. The four types of knowledge *are* located on the horizontal axis : the *Factual* , *Conceptual* , *and Procedural* dimensions . *and Meta - cognitive* that they represent , respectively :

- *Knowledge factual :* this bound to the knowledge the elemental , necessary for that he student solves problems in particular situations .
- *Knowledge conceptual :* HE refer i er e to the interrelation of concepts basics , applied in a scenery that requires the knowledge of a basic structure that is defined and linked to solve a given problem .
- *Knowledge procedural :* describes the way in which HE resolve to a problem certain , using or techniques , methods , criteria and at a rhythm appropriate .

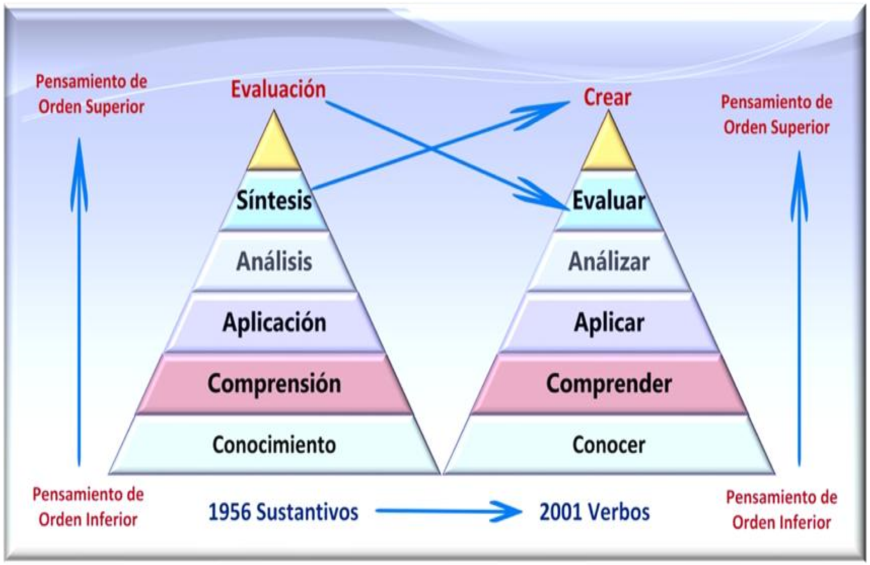
- *Knowledge m e t acognitive :* i mp li c a the awareness and reflect on how we learn , besides d and recognizes r how broad and deep is the acquisition of knowledge of a specific content . At this stage , interdisciplinary and transdisciplinary collaboration is expected to be applied in the development of solutions . to problems . It is also required that the student maintains a self -regulated awareness to manage his or her learning (Anderson, et al., 2001) .

Those of us who participated in this educational experience consider that the learning No only is a progression of see r bo s that deno t a n he process of the level cognitive used to generate learning . It requires also relate them to the dimensions of that knowledge . In this context , Ander son 's matrix et al. (2001) represented by Table 1, is used to generate r the inter action between the dimensions clue of the learning : the gradual dimension of cognitive processes represented by the verbs and the gradual process of the knowledge dimension .

Following the description of the matrix in Table 1 , in the vertical axis and in transverse sequence it is arranged of the six cognitive processes updated , represented by verbs in their infinitive form, which denotes the action : these processes correspond to the and stages by r t a s that a student advance in my path learn , from and the simple memorization until the creation of an idea , the design and creation of a process or service , based on what was learned progressively . The Table 1 offers the teacher 2 4 alternatives for using associated verbs to a action pedagogical expressed as *learning outcomes* , in different dimensions of knowledge and with different cognitive processes, selected according to the expected learning goal . For example, the combination of the *cognitive dimension* of evaluation, with the intersection of the *dimensions of conceptual and procedural knowledge,* allows for the planning of a teaching activity to *apply the hypothesis testing* procedure in the statistical evaluation of a process or service.

Similarly, Figure 1 graphically shows the updating of the taxonomy and how knowledge construction progresses. From the cognitive action of *"remembering,"* students move on to " *understanding."* This means that They transform what they hear or read into knowledge with personal meaning. The next step is to *"apply":* At this level, learners put what they have learned into practice, both in familiar situations and in new challenges. As in Table 1, Figure 1 also describes how the *"know" level* progressively moves to the higher-order *"create" level* , because knowledge is constructed by synthesizing "constituent parts" to explore how knowledge fits into a larger framework (Anderson et al., 2001).

Figure 1. Development of knowledge through cognitive processes



Note: Adapted from Anderson et al. (2001)

At the "evaluate" level , near the top of the pyramid, students become critics, evaluating and judging information. At the top, with " *create,"* they reach creativity, combining elements to generate new ideas and projects, thus demonstrating the maximum level of their learning (Anderson et al., 2001) . This foundation of learning progressions arises from the idea that the updated Bloom's taxonomy should be used for the design of teaching instruments, through which the teacher plans teaching, learning, and assessment activities, always considering the gradual construction of *learning outcomes* , according to the constructivist paradigm. From this perspective, for the construction of learning progressions as the fundamental objective of this work, a base concept is used: the subject of *mathematical function* and its progressive relationship with performance profiles in subjects such as *Differential Equations* , *Statistics*, *Quality Management* , and other subjects in the engineering sciences and applied engineering. In this study, the theory and design of learning progressions are applied in a Biochemical and Chemical Engineering educational program at TecNM.

As a final part of this section, it is important to emphasize that the Anderson matrix is not intended to classify educational actions, but rather to program them to determine how students will respond behaviorally during learning. This matrix is used to plan students' activities in their learning process, ensuring that they progressively acquire the necessary skills and knowledge. This is consistent with what Bloom et al. stated in their taxonomy:

> It should be noted that we are not attempting to classify the instructional methods used, the ways in which teachers relate to students, or the different types of instructional materials they use. We are not attempting to classify the particular subject matter or content. What we are classifying is the intended behavior of students—the ways in which individuals should act, think, or feel as a result of participating in some unit of instruction (Bloom et al., 1956, p. 12).

Progressions, Feedback and Formative Assessment in Higher Education

The relevance of Bloom's taxonomy, updated by Anderson et al. (2021) applied to learning progressions, has special application in teaching strategies and their assessment processes. In this context, Heritage (2007) states that learning progressions are used to plan educational action and especially formative assessment. She points out that by its very nature, learning implies progression, that is, a didactic sequence of how learning is constructed. She calls them progress maps since they provide a description of the development of skills and acquisition of knowledge, in the sequence in which they normally develop. In her work on how elementary-level students construct learning, the author agrees with Stevens et al. (2013) in considering that progressions *"represent not only how knowledge and understanding develop, but also predict how knowledge is constructed over time"* (p. 2). With Popham (2007), she agrees that PAs are building blocks of knowledge based on skills that improve performance. Based on the above, when developing progressions, it is necessary to consider feedback during the learning process using the principles of formative assessment. This type of assessment is useful because:

- Teachers make adjustments to teaching and learning in response to assessment evidence;
- Students receive feedback on their learning with tips on what they can do to improve and
- is promoted through self-assessment (Heritage (2007, p. 2).

The author also highlights that one of the most important functions of formative assessment is that it helps students identify the strengths and weaknesses of their learning. By providing them with specific and relevant feedback, they can better understand what they are learning, what they need to improve, and how they can advance their learning.

Learning Progressions in Upper Secondary and Higher Education

Once the relevance of progressions in the learning process has been analyzed, we address how they are applied at various educational levels. In 2019, an update of the curricula at the basic level began, integrating revisions at the primary, secondary, and high school levels (SEP, 2019) . The changes in this curricular update transcend the training of high school graduates as input to higher education. Learning progressions are used in the New Curriculum Framework for Upper Secondary Education (NMCNMS) to establish a logical and coherent sequence of learning achieved in professional training. This facilitates curricular planning, the design of teaching activities, and the assessment of learning. Furthermore, PAs constructed from sociocognitive resources established in Chapter 9 of the DOF agreement 17/08/22 allow teachers and students to create a shared commitment in how they interpret learning objectives and performance standards. Sociocognitive resources are defined as follows:

> These are articulating learning processes common to all levels of upper secondary education and are comprised of the essential elements of language and communication, mathematical thinking, historical awareness, and digital culture, for the construction of knowledge and experience in the social sciences, natural sciences, experimental sciences and technology, and the humanities. They play a transversal role in the curriculum to achieve trajectory learning (DOF, 2022) .

In this context, since the concept of *mathematical function* is associated with problem-solving, mathematical thinking requires analysis and synthesis, logical reasoning, communication, and collaboration to generate problem-solving strategies that involve the use of arithmetic, algebraic, trigonometric, or geometric processes. When all of this is integrated into a successful solution to the problem at hand, students develop a self-regulated awareness of their learning process, which gives them confidence in their ability to apply the knowledge they have acquired.

In the MCCNMS, the progression of mathematical thinking is based on the idea of transversality, which denotes the " *high interaction approach between areas of knowledge, socio-cognitive resources and socio-emotional resources of the MCCEMS"* (SEP, 2022b, p. 30) . It implicitly includes the idea of intradiscipline, interdiscipline, and transdiscipline. *Intradiscipline* refers to the congruence between the understanding and coherent application of mathematical processes to solve a specific problem, which contributes to the development of abstract-mathematical thinking. For its part, *interdiscipline* integrates mathematical thinking with other areas of knowledge. It is very useful for the approach to STEAM education, in its English acronym, which means strengthening science , technology , engineering , art, *and* mathematics . On the other hand, *transdiscipline* does not refer exclusively to the integration of various disciplines, but the grouping and interaction between disciplines aims to solve problems in the social, cultural, and environmental spheres, fostering the capacity to build contextualized and adaptive learning (SEP, 2022a) .

On the other hand, in the field of higher education, the National Autonomous University of Mexico frequently publishes research articles on learning progressions to address the teaching of various topics in inorganic chemistry, organic chemistry, and biology, among others (Gallardo and Merino, 2022 ; Hernández et al., 2024 ; Stevens et al., 2013 ; Talanquer, 2013) . When addressing the theoretical perspectives of their studies in BS subjects, Mexican and Latin American authors agree that it is important to value the interconnected relationship of theoretical topics with practical experience, such as the conception of substance, Marzábal et al. (2024) or the idea developed by Candela and Cataño (2019) that integrates the nature of matter and its relationship with stoichiometry. In the same context of chemistry teaching, Hernández et al. (2024) use a didactic sequence in the chemical determination of the quantity of starch present in a food, which allows students to demonstrate adequate performance standards, such as *knowing and knowing how to do* . For their part, Stevens et al. (2013) refer that learning progressions constitute a framework to enhance *"old ideas",* such as Ausubel's meaningful learning, which considers prior knowledge and the student's ability to actively relate new knowledge (Ausubel et al., 2001) .

It is necessary to affirm that learning progressions are being widely used in basic sciences, both in Mexico and Latin America, which questions the effectiveness of a curricular design focused on the fragmentation of knowledge and based on subjects grouped by semester, which, if not integrated into progressive, transversal and interdependent learning maps, fractionate and limit the acquisition of comprehensive knowledge and skills. There are previous research reports in CB using progressions. In *Chemistry* , Candela and Cataño (2019) work with the topic of stoichiometry. In *Physics* , Giordano (2021) uses them to develop basic concepts and their relationship with astronomy. In *Mathematics* , Cárcamo et al. (2023) apply them to teach systems of linear equations with infinite solutions. These authors agree that progressions offer a gradual construction of knowledge and that they can be extended to other subjects, fostering a positive attitude towards basic sciences.

In this abbreviated review on the study of learning progressions in higher education, the application of progressions in the educational institution belonging to the TecNM is highlighted, to link them to the development of competency maps, as a way of demonstrating compliance with a quality indicator. In this context, Galicia et al. (2022) indicate how this framework or competency maps should be evidenced, using schedules 3.3.2, 4.2.1a, and 4.2.1b for each subject in the curriculum. In the self-assessment process, Barrera and Nieto (2021) state that the performance levels for each graduation attribute are subject to indicator verification, as an external evaluation process for accreditation purposes. For their part, in updating the evaluation process, Loría et al. state that "the graduation attributes must cover all the components of knowledge, skills, and attitudes necessary to achieve the educational objectives of the educational program." Loría et al. (2025, p. 22).

The application of Anderson et al.'s matrix in the development of learning progressions planned in objective two of this work, allows us to affirm that the gradual construction of knowledge schemes facilitates the personalization of teaching and learning strategies, which are centered on students, with feedback based *on learning outcomes* , rather than on the development of the content, while favoring formative assessment and feedback. Furthermore, the progressions allow the integration of theoretical and practical knowledge related to the graduation profile and not based on the subject topics. This benefits a coherent alignment between the competence to be developed and teaching activities, promoting student participation in learning activities (Marzábal, et al., 2024).

Competency Maps

Regarding learning progressions, the design of competency maps constitutes a collaborative strategy among subject-specific teachers to design teaching tools that promote the achievement of specific aspects of the graduate profile. For CACEI, professional competencies contribute to developing the graduate's professional profile. Learning progressions *"refer to the levels of achievement of indicators expressed in stages necessary to achieve complex attributes and learning."* (Barrera and Nieto, 2021, p. 25) . This is associated with formative assessment and not just summative. The TecNM educational model considers feedback, which teachers and students must consider, as a kind of gap that defines academic performance at a particular moment in the teaching-learning process and the final result. This leads the teacher, based on formative assessment, to carry out an action plan to evaluate the learning outcomes, with respect to what was initially planned. When this process within a subject is extended to several transversal subjects, a *"competency map" is generated* , which contributes to the analysis of the curricular mapping required by the CACEI to substantiate and demonstrate learning progressions. Based on the information presented in this section, it can be concluded that, based on the PAs, there is a correspondence between the demands of accrediting bodies, between the training at the upper secondary and higher education levels, due to the way in which the development of professional competencies is conceived, and the didactic structure in which learning activities are programmed, taking into account formative assessment and feedback. These two elements are important in the creation of PAs oriented towards training students according to desirable performances and not primarily based on content.

Materials and methods

The main objective of this study was to develop a methodology to identify and construct learning progressions that contribute to the development of professional competencies in an engineering academic program, which constitute the graduate profile. To effectively implement the learning progressions, a methodology was developed in four interdependent phases: content analysis, design, construction, and implementation.

1. Content Analysis: A comprehensive analysis was conducted of the content and skills students must acquire in specific disciplines, including the topic *"mathematical functions"* in the basic sciences and their cross-disciplinary relationship with engineering science and applied engineering subjects. This analysis identified the essential knowledge and skills for the comprehensive development of professional competencies.
2. Design of learning progressions: Learning progressions were designed based on Bloom's taxonomy, revised by Anderson and colleagues. These were structured into planned sequences that allow for the gradual acquisition of knowledge and skills, from lower cognitive levels to higher levels. Active verbs were used to describe the learning actions at each level, facilitating the understanding and application of Anderson's matrix.
3. Competency mapping: Competency maps were constructed that integrate learning progressions with the professional competencies of the educational program. These maps were used to design teaching strategies to guide students through their learning process, ensuring they progressively acquire the necessary skills and knowledge.

4. Practical application: Transversal examples of learning progressions were presented with the topic " *functions* " of the *Differential Calculus subject* , linking them with subjects such as *Statistics* , *Quality Management* , and in topics of material balance and some unit operations.

These stages are interconnected because the content analysis of a curriculum's subjects guides the design of progressions to construct competency maps to enrich teaching practice. Furthermore, this methodology is based on the idea that learning is conceived as a continuous process in which students advance in their understanding of interrelated content in the curriculum. Here, the Anderson et al. (2001) matrix is used to design various teaching strategies that guide students in their learning process, ensuring that they progressively acquire the necessary skills and knowledge.

Results

The contents of the basic sciences are the conceptual and operational basis for many processes in the engineering sciences and applied engineering. Regardless of the development of the graduate profile, whether based on educational objectives, through the development of professional competencies, or through the design of learning progressions, the three perspectives are structural building blocks for building professional competencies. The results of this educational experience are presented below, based on the objectives set forth in the research, both in developing PA within a subject and in interaction with other subjects in the curriculum. Furthermore, with the application of the described methodology, a competency map for the *"hypothesis testing" content is shown* , which demonstrates the progression of these learning processes.

Objective one: Methodology for building learning progressions

The methodology developed to achieve the first objective, which aims to build learning progressions that contribute to the achievement of professional competencies, is as follows:

1. Content analysis by subject: This activity establishes the relationship between the contents of the subjects of the educational program with the professional competencies referenced in the graduation profile of an educational program, following a classification of categories and subcategories, as textual units without establishing coding, given that the topics and subtopics in the subjects of a study plan are already predefined (Riba, 2017) . With this information, forms 4.2.1, 4.2.1b and

4.2.1c can be completed, which are essentially maps of professional competencies to support the graduation profile. It should be noted that when filling out the forms, the assessment of the achievement of the learning outcomes, the justification and the goal to be obtained in each subject or learning unit must be specified (Loría, et al., 2025).

2. Drafting the competency. This is done within a subject, considering that it involves a specific competency as a graduation attribute. Its drafting uses Pimienta's (2012) methodology , which presents a verb in its *indicative form* , then an *object* (idea, process, or service), followed by a *purpose* , and finally, its context, or *level of performance* at which the competency is developed.
3. Building progression with an integrative concept. This process is carried out within a subject and its relationship to other subjects in the curriculum, through content analysis in specialized literature. The concept of *"mathematical function" was selected as an example* . It is worth mentioning that the content analysis of subject topics must consider that the integrative concept meets the idea of *being essential, sufficient, and relevant* to theoretically ground the development of professional competence. This helps teachers and students focus their attention on the development of competence and not on the conceptual development of content, which is generally excessive and mostly disconnected from the graduate profile.
4. Design of the Anderson matrix. Here, it is necessary to determine the interaction between the dimensions of knowledge and the dimension of cognitive processes (Anderson et al., 2001). The selection of the Anderson matrix responds to its ability to clearly describe the transition between cognitive levels in the sequential learning of concepts and technical procedures. This stage is important because it determines the pedagogical action of the intention and its didactic implementation. It is the means to specify the development of the learning progression within a subject, and then relate it to other subjects in the curriculum. This makes it possible to construct competency maps.
5. Create a competency map: Establish strategies and recommendations for teachers in different academic areas to create competency maps and inform students about how their academic training is conducted and the assessment strategies used, ensuring the acquisition of the competencies and skills described in the graduate profile. An example using hypothesis testing is presented in the section on achieving the third objective.

6. Evaluate the level of academic performance achievement. This requires operationalizing this study variable associated with the achievement of self-regulated learning. While developing the previous stage fulfilled the first requirement, which is defining what we want to measure (the achievement of the competency map), it is also necessary to specify how the variable "competency achievement" will be assessed (Creswell, 2012) . That is, to consider whether there is a relationship between the development of professional competency maps and adequate learning performance and the achievement of the competency of the graduate profile.
7. Design assessment instruments to measure satisfaction. These are assessed with students through psychometric indices, primarily the internal consistency index (Cronbach's alpha), content validity, construct validity, and criterion validity using confirmatory factor analysis. These indices allow valid inferences to be made about student performance.

Objective two: Application of the Anderson Matrix

Once the application of the Anderson matrix has been described, its specific implementation with the subject *of functions is detailed.* The subject of *functions* from the subject of *Differential Calculus was selected* to carry out the content analysis on the relationship that this subject has with other subjects in the curriculum of the Chemical and Biochemical Engineering degree, to evaluate the competencies *"design and operate research projects" and "problem-solving capacity".* Due to space limitations, only the case developed for the subject of *hypothesis testing is presented* , where the *Fisher F function* connects to the statistical evaluation of a process or service through the analysis of variance. This competency was defined as follows:

> Interprets and formulates the strategy for solving complex engineering problems to improve and innovate manufacturing and/or service delivery processes, applying capabilities developed in basic sciences, engineering sciences, applied engineering, and quality management systems.

Table 2 shows several learning progressions to illustrate how to solve an analysis of variance and the hypothesis testing process, following different learning progressions in a teaching sequence using the Anderson et al. (2001) matrix.

Table 2. Learning progressions with the variable anthropometric measurements

Dimension of the Knowledge	Dimension of the process s cognitive for he The variance and its test of h i pótes is					
	Remember	Grasp	Apply	Analyze	Assess	Create
Factual	Understand descriptive measures and their graphic representation	I n t e r p r e ta the measures anthropometric	Use the measures anthropometric	Compare the measures anthropometric	Valuable the analysis of variance in measures	D i s e n new s techniques of measurement to avoid mistakes
Conceptual	Define the Probability Distribution Function and the types of errors	Explain the role of the distribution function	Use the probability distribution Normal and Fisher	Ana li z a the probabilities and calculates the “p-value” in the distribution	Eva l ú a the consequences of errors in the measurement of the variable	C r e a strategies for avoid errors in measurement
P r o c e d i m e n t a l	Describe he procedure from one to another proof of hypotheses	I n t e r p r e ta he methodological p r ocesses to carry out a proof of hypotheses	Applied a proof of hypotheses	Structure and difference step s of a proof of hypotheses	Eva l u a the e f f e c t i v i t y of a proof of hypotheses	C r e a a recommendation to base of the conclusion of the proof
I am welcoming	Conceptualization the interpretation of errors Type I and Type II	Understand the i mpo rt anc ia of the interpretation of errors Guy I and Guy II	Use T h e r r o r s T i p e I and T i p o II to describe a process	Ana li z a the effects of errors Guy I and Guy II and their consequences	Eva l u a the simplifications of the errors Guy I and Guy II	Create the conclusion and interpretation of the analysis of variance Design strategies of self - regulation of the process for avoid errors

Note: Own elaboration

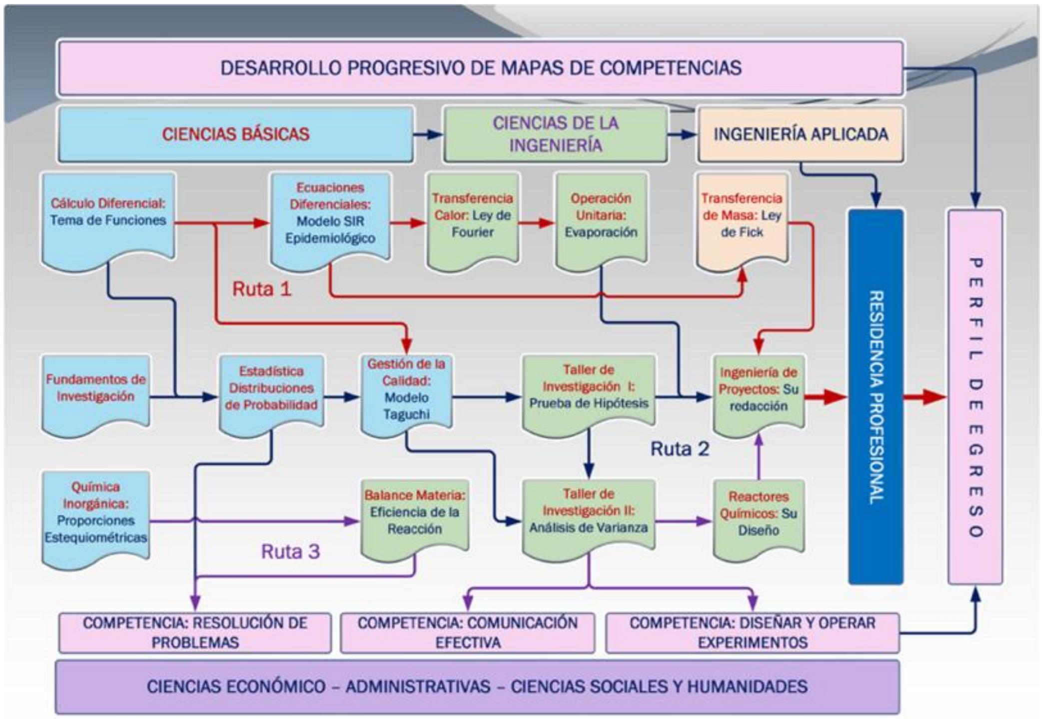
The six teaching interventions highlighted in the table for constructing progressions based on learning outcomes collectively provide several series of learning progressions within the subjects of *Statistics* and *Experimental Data Analysis,* ranging from understanding concepts of descriptive statistics, Fisher's probability distribution function, analysis of variance, hypothesis testing, and types of errors, to writing conclusions and interpreting results. The intersection in Table 2 between the *Metacognitive* and *Creating dimensions* allows for improving the measurement process for the variable "anthropometric measurements," which is used as an example, although this methodology is useful for any measurement process involving another variable. This overall progression *is a way of approaching the learning of analysis of variance and hypothesis testing* . Instructors can use different combinations of cognitive processes and knowledge dimensions to construct their teaching strategy and guide student behavior toward achieving competency. Furthermore, it should be noted that this process is not a linear sequence but rather a systemic one. For example, learning activities can be designed by taking into account another interaction between the dimensions of the table: the cognitive process of *Analyzing* and its relationship with the *Procedural and Metacognitive dimensions,* constructing different educational actions to achieve more comprehensive learning in analysis of variance and hypothesis testing. These results demonstrate the relevance of the concept of mathematical functions as a central axis of cross-curricular learning in basic and applied science subjects.

Objective three: Learning Progressions and Competency Map Construction

When applying the *mathematical function topic* and performing the content analysis within other CB subjects, several mathematical functions were found that describe and explain engineering, health sciences, and economic and administrative sciences processes. Let's analyze just two examples: the exponential function and the rational function. In differential equations, when applied in epidemiology, the teacher manages these functions so that students acquire a precise understanding of their properties, which allows them to interpret the graphical representation and its elements of the *exponential model* . Subsequently, with the susceptible population rate of change model, in the *epidemiological SIR model,* the interaction between the susceptible and infected populations is analyzed to describe the rate of change of the susceptible population (Rodríguez-Villamar, 2017) .

In the second example, learning progressions constructed with the rational function, which involves *a fraction* in the mathematical model, contribute to the development of competencies in the graduation profile, specifically for the design of chemical and biochemical reactors. At the beginning of this progression, students understand the properties of this function and its graphical representation. Subsequently, they describe and understand its application in the Michaelis-Menten equation. Finally, they apply the nonlinear function of the Michaelis-Menten model to the design of reactors with enzymatic catalysis, integrating theory and practice. Figure 2 generally shows three competency map paths constructed with the *mathematical function theme* . This has applications in various subjects and can be replicated through content analysis in other curricula. The same can be done with other integrative content.

Figure 2. Competence maps with the topic mathematical functions



Note: Source: Prepared by the authors based on the results obtained in the study.

The learning progressions shown in Figure 2, and their integration into competency maps included in the graduation profile of the Chemical and Biochemical Engineering programs, are essential for the development of professional competencies. In Route 2 shown in the image, starting from the quadratic function, this gradual sequence of knowledge acquisition is applied to the Taguchi *quality loss function* , as indicated by Gutiérrez and De la Vara (2008): *as a content associated with quality management and assurance processes* . In the Chemical Engineering curriculum, *Differential Calculus* is taught in the first semester and *Quality Management is taught* in the third semester.

Table 3 provides a more detailed and specific synthesis to describe and explain the learning paths shown in Figure 2, the product of the content analysis of the *functions topic* in various subjects of CB, engineering sciences and applied engineering.

Table 3. Learning progressions for building competency maps

Content Analysis of the Function Type	Description of learning progressions	Application of progressions in the design of competency maps in various academic areas
Exponential function and the microbial growth model	Understand the properties of the exponential function. Analyze the graph of the exponential function. Describe and interpret the model of microbial growth and decay Develop solutions to simple differential equations with the exponential function. Analyze the Normal and Standard Normal probability distribution functions. Applies to the initial phase of the epidemiological SIR model.	In Pathway 2, this progression is based on an understanding of the properties of the exponential function in *differential calculus* , in differential equations, and their application to applied engineering problems. Understanding the mathematical properties of this function enables students to interpret models of microbial growth and decay, developing skills in solving simple differential equations. It also applies to the Normal and Standard Normal probability distributions, and to thermal decomposition in continuous reactors, with a specific case study on nitrogen dioxide, integrating theory and practice.
Linear function: Fick's and Fourier's laws	Understand the properties of linear functions. Perform graphical representation and calculation of the linear model. Characterizes the simple and multiple linear correlation and regression models. Application of Fick's diffusion law for mass transport and Fourier's law for heat transfer.	Route 1 begins with an understanding and interpretation of linear functions to calculate linear models that describe engineering processes. *Differential calculus* focuses on the characterization of simple and multiple linear correlation and regression models, applying this knowledge to Fick's Law of Diffusion for mass transport and Fourier's Law for heat transfer.
Nonlinear function	Understand the properties of a nonlinear function. Interpret the graph of a nonlinear function. Analyzes the interaction between susceptible and infected populations to describe the rate of change of the susceptible population.	In Path 1, using the epidemiological SIR model and differential equations, students analyze the interaction between susceptible *and infected populations* to describe the rate of change of the susceptible population. They also compare exponential and nonlinear function models to visualize the rate of change of the susceptible population, integrating theory and practice.
Rational functions	Understand the properties of rational functions. Analyze the graph of rational functions and describe and understand the application of a rational function in the Michaellis-Menten equation to evaluate	In Pathway 3, this PA connects the courses *on Differential Calculus* and Chemical Reactor Contents and the professional residency. They then describe and understand the application of a rational function in the Michaelis-Menten equation

Content Analysis of the Function Type	Description of learning progressions	Application of progressions in the design of competency maps in various academic areas
	enzyme catalysis and reactor design.	, which is useful for evaluating enzymatic catalysis.
Probability density functions	Differentiate between the types of functions described by probability distributions for discrete and continuous variables. Understand the usefulness of the probability distribution model and its method for calculating probabilities. *t* and Fisher's *F* probability distributions .	Also in Route 2, learning begins by differentiating the types of functions described by probability distributions for discrete and continuous variables. They then calculate interval estimates to draw inferences about the behavior of the random variable, learning that is key to making decisions based on empirical experience. An example is the Student's *t -test* and Fisher's *F* -test, which are used to evaluate the behavior of an experimental design associated with these distributions.

Note: Prepared by the author, derived from the content analysis of the subject bibliographies.

There are undoubtedly more learning progressions that can be built and integrated into learning paths for the topic of *mathematical functions* . The results presented here reflect the experience of instructors who teach *Differential Calculus* , *Statistics, Quality Management, and Research Workshops.* Expanding the collaborative work of instructors who teach other subjects, such as *Linear Algebra, Differential Equations, Programming, and Numerical Methods* , among others, can expand the examples of learning progression maps, thereby providing a better focus on the development of professional competencies.

Discussion

The methodology developed in this study to construct learning progressions for competency mapping can serve as a reference for curriculum design and competency assessment using standardized instruments. Furthermore, the examples of progressions presented can improve teaching performance and demonstrate that these progressions positively exceed the CACEI requirement, which requires verification of how the completion competencies are achieved in the curricular development of a study plan. In reality, what the accrediting body requires is simply to record in an Excel spreadsheet the contribution that each subject or learning unit makes to the minimum completion attributes, as well as a matrix of relationships between them and their achievement indicators.

By developing learning progressions within a subject using the proposed methodology, using an integrative concept, and then using the competency map to show the sequential manner in which several subjects interrelate around a competency of the graduation profile, not only is the indicator required by the accrediting body met, but by communicating it to the student, a holistic understanding of how their graduation profile is constructed as they progress through their professional training is established, with relevant and significant learning. By performing a content analysis of the subject topics to select those that are sufficient and pertinent, the teaching function can be structured based on the student's future performance, as defined in the graduation profile, rather than programming it based on content. This represents the challenge of a radical change in curricular design based on content-heavy subjects. Regarding this aspect, Einstein stated in 1980:

> For a valid education to exist, it is necessary to develop critical and independent thinking in young people, a development continually endangered by an excess of subjects (the punctual system). This excess necessarily leads to superficiality and a lack of true culture. Teaching must be such that it can be received as the greatest gift and not as a bitter obligation (Einstein, 1980, p. 26).

Teaching tools (which are not the focus of this study) can be developed with this methodology using the Anderson et al. (2001) matrix and prioritizing formative over summative assessment. This complies with the TecNM educational model regarding the professional competency assessment system. Furthermore, we agree with Heritage (2010) on the usefulness of formative assessment. This author states that this type of assessment is not conceived as the application of several assessments per year, but rather is addressed *as a process,* and not as an instrument to carry out the comprehensive evaluation of the educational process.

The learning progressions developed are a sample from an integrative concept, built on professional performance, and not based on the accumulation of content in subjects per academic period. This agrees with the statement by Meckes and Pogré (2018) that progressions are built with learning outcomes in mind, rather than activities based on specific content. When conducting content analysis in the curricula, we become aware of the importance of the idea of *essential, sufficient, and relevant content* . This is because, in general, the curricula have very extensive content broken down by topics, subtopics, and sub-subtopics. When examining the case of the *Chemical Kinetics subject* of the Biochemical Engineering degree (TecNM, 2016), it is found that it contains 42 subtopics and sub-

subtopics, included in six thematic units. It is worth noting that it also contains the topic of *electrochemistry* , which is unrelated to the content to be developed for chemical or biochemical kinetics. This excess of content exceeds the possibility of scheduling learning activities to cover this content in an 80-hour semester of training. Implementing progressions allows for reducing the burden of unnecessary content by focusing on key concepts for developing professional competencies. In this way, a learning progression can be developed for the following specific competency:

> Identify the relationship between biomolecules and their function in biological systems, analyzing biochemical phenomena and their metabolism, to apply them to the use of biotic resources and the design of reactors that produce metabolites of interest or in the treatment of effluents and polluting waste.

Although this study only reports PAs for the competencies *“design and operate research projects” and “capacity to solve problems”* were also developed for the *effective communication competency* , since solving a problem requires writing conclusions and recommendations to improve processes and services, evaluated from the variable(s) of interest in the problem analyzed. These three competencies must be linked by transversality since it is a didactic strategy that links the NMS graduation profiles with the higher one (SEP, 2022c). The progressions for these competencies allow students to progressively advance in their academic training in fundamental skills for future professional development. This common link is the learning progressions.

Conclusions

Once the objectives set forth in this research project have been achieved, the following conclusions are derived, which underscore the importance of integrating a described methodology to create learning progressions in the teaching role and in academic agreements, in addition to ensuring the development of competencies aligned with the graduation profile of an educational program.

Regarding the first objective, the methodology allows for the construction and sequencing of learning outcomes and skills that contribute to the development of professional competencies. This progressive structure facilitates the gradual acquisition of specific and general competencies by students, directly impacting the coherence of engineering graduate profiles. Regarding the second objective, which generated the application of Bloom's taxonomy, updated by Anderson et al. in a matrix that crosses the dimension of cognitive levels and the dimensions of knowledge *to generate learning outcomes* , it also contributed to accurately verifying the achievement of professional competencies. The application of the matrix in Table 1 allows for the breakdown of 24 didactic training alternatives to plan the learning of achievable and assessable competencies, which is essential for the development of key competencies in students. The third objective proposed interdisciplinarity in the construction of learning progressions. The application of the topic of *functions* in the subject of *differential calculus* , as an example of how to progress towards learning the topic *of hypothesis testing* in *statistics* , demonstrates how mathematical concepts can serve as a basis for understanding and developing skills in statistics and research. This interconnection facilitates the integration of competencies such as the design and operation of research projects and the ability to solve problems, essential graduation skills in the training of engineers, which is a fundamental quality requirement for accrediting bodies.

Together, these three objectives outline the design of a competency map, as shown in Table 3, since learning progressions are also progressions of specific professional competencies. Based on the design and operation of experiments and the interpretation of results, as well as the ability to solve problems, it provides students with critical thinking skills and contextualization, given that society demands social responsibility from them when applying research and problem-solving.

Furthermore, the results also lead to the conclusion that there must be consistency between the sequential content of the upper secondary and higher education levels, as well as the level of depth with which it is developed at both educational levels. To achieve this, it is useful to promote collaboration and the exchange of experiences between teachers at both levels: Teachers at the secondary and higher education levels must collaborate and share experiences to ensure that students have a smooth and effective transition between the two educational levels. This also allows for the identification of areas for improvement and the implementation of effective pedagogical strategies.

On the other hand, the information obtained from formative assessment feedback allows for a comprehensive and appropriate institutional evaluation, since measuring satisfaction with the implementation of learning progressions provides elements for improvement not only in the classroom but also throughout the entire educational process. This requires the design and statistical standardization of assessment instruments that allow for valid inferences through psychometric indexes of content, construct, and criterion validity.

Finally, content analysis in curricula and programs is an excellent opportunity for curricular updating and/or redesign based on PA. For example, in the fourth semester of Biochemical Engineering, the excess of content that students face during their professional training in a particular semester is evident. In the *Biochemistry* and *Quality Assurance courses alone,* there are more than 100 subtopics and sub-subtopics, which combine to require attention in learning activities by students in the four remaining courses that complement the academic load of that semester: *Programming* and *Numerical Methods* , and topics on electromagnetism, matter and energy balance, and instrumental analysis. Undoubtedly, this situation exceeds the capacities of teachers and students to manage the teaching and learning processes. This excess of content can be mitigated through the application of learning progressions, as they allow essential concepts to be prioritized over the accumulation of information. Based on the above conclusions, some future lines of research are proposed below.

Future Lines of Research

The assessment of learning and the impact of learning progressions on the development of professional competency maps and the achievement of the graduate profile is a very important process. Therefore, this work is considered to impact various lines of research addressing the design, validation, and statistical standardization of formative and summative assessment instruments. These instruments must have content, construct, and criterion-referenced validity to ensure the accuracy and relevance of the assessments at each level of the progression. Research on these topics generates assessment instruments with psychometric indicators that allow for valid inferences. For example, construct validity with measurement indicators establishes congruence with professional competencies and the theory that underpins them. Meanwhile, criterion-referenced validity determines the degree to which the results of competency assessment tools correlate with external indicators, such as good performance in the competencies developed to support the professional profile.

The above opens the possibility of generating longitudinal research projects, applying the exploratory and confirmatory factor analysis method under the structural equation systems model. The objectives of these projects would seek to explore the relationship between learning progressions and the development of professional competencies, measuring their effectiveness through standardized assessment indicators. This also allows for monitoring student learning progress throughout their training and provides data to support continuous improvement programs for engineering programs.

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Ride Revista Iberoamericana para la Investigación y el Desarrollo Educativo
ISSN 2007 - 7467

https://st03.tepic.tecnm.mx/files/asignaturas/BQF1005_Cinetica_Qumica_y_Biologica.pdf

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