The Strategic Curriculum Redesign of Ingeniería En Ciencia De Materiales (ICMA) at Universidad De Guadalajara

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Abstract
The Universidad de Guadalajara, Mexico, has restructured its *Licenciatura en Ciencia de Materiales* program, now known as *Ingeniería en Ciencia de Materiales* (ICMA), to align with the evolving demands of the materials science and engineering sectors. This overhaul aims to provide graduates with advanced technical skills and essential soft skills like adaptability, teamwork, and problem-solving, which are crucial for innovation and leadership in the modern world. The revised curriculum is supported by high-quality infrastructure, experienced faculty, exchange programs, and comprehensive student services to enhance employability and professional readiness. The redevelopment follows a holistic pedagogical approach structured around a Competency-Based Plan with a Mixed Modular Approach. This process encompassed nine stages: i) conducting a SWOT analysis of the existing program; ii) defining the objectives of the program; iii) creating a competencies map; iv) defining the graduate profile; v) drafting the curriculum structure; vi) designing the educational curriculum; vii) presenting the proposal for university endorsement and review; viii) organizing training for academic and administrative staff, and ix) implementing the plan. The curriculum integrates diverse physics, chemistry, and biology knowledge and methodologies and incorporates economic, ethical, and environmental aspects. It is designed to develop an in-depth understanding of materials at all levels, enabling graduates to apply their knowledge practically and effectively in a rapidly changing global context. This curricular redesign focuses on modernising education in key areas like Management and Society, and Emerging Technologies. It features five disciplinary areas and eight elective modules for specialisation and emphasises interpersonal and management skills competencies.

Keywords: Materials Science Engineering, Curricular Redesign, Competencies

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Introduction

Materials Science and Engineering is an interdisciplinary field that studies the relationship between the structure, properties, processing, and performance of materials. Its interdisciplinarity inherently arises from the interaction of various areas of knowledge to create materials with enhanced characteristics that meet the needs of a growing population. In this regard, Johanes P. (Johanes, 2018) establishes that the epistemology of Materials Science and Engineering is characterised by an integrative and pluralistic approach, recognising the need to combine and apply knowledge from various disciplines and areas of expertise to study complex phenomena. This approach, known as integrative pluralism, postulates that multiple theories and models can coexist compatibly and non-competitively to achieve a more complete and robust understanding of the phenomena studied at different levels of analysis. A relevant aspect of epistemology in this field is its emphasis on updating scientific practices through philosophical frameworks and vice versa to promote an inclusive and productive approach that accurately reflects scientific practice. This approach is crucial for teaching and research and preparing students to effectively navigate and collaborate in a multi- and interdisciplinary scientific environment. Thus, under the integrative pluralism approach, Materials Science and Engineering have evolved from traditional areas of knowledge like metallurgy, ceramics, and solid-state physics to a combination of several areas such as materials physics and chemistry, nanomaterials, biomaterials, polymers, and engineering, among others. Its evolution and impact on the vast aspects of human life and the environment demand that its research and application be carried out responsibly and sustainably. Therefore, in addition to the areas mentioned above, design principles, economics, ethics, environmental, and social aspects are also integrated, strengthening this discipline and ensuring a comprehensive education for Materials Science and Engineering graduates.

For the curricular redesign of this degree program, a mixed modular competency-based approach was considered (Vega-Maldonado, 2024). It is essential to describe the competency-based approach, characterised by a structure where learning is organised into sequential modules to develop specific competencies. This organisation promotes integrating skills, content, theory, and practice to ensure that learning is meaningful and applicable to real-life situations. This approach is flexible, allowing it to adapt to the needs of the environment, such as the demands of the labour market and the rapid pace of technological advancements. Regarding evaluation, this model prioritises learning based on demonstrable outcomes that reflect knowledge, skills, attitudes, and values, which constitute the foundation for ensuring that students can apply their knowledge and skills to both present contexts and future scenarios. Implementing this approach fosters comprehensive teaching and learning, where the way of learning, lifelong learning, flexibility in methods, and teamwork are priorities (Vargas, 2008).

The mixed modular approach is characterised by integrating aspects of modular design with other approaches, such as traditional subject-based approaches. These approaches are used when it is necessary to maintain the internal structure of certain disciplines, particularly in areas requiring sequential and structured learning, as in the case of sciences and engineering (Rouvrais, 2006). It is possible to balance the teaching of fundamental knowledge and practical application through the mixed modular approach, thus facilitating the integration of learning with professional activity.

Given the characteristics of the Materials Science and Engineering degree program (here, ICMA) and the knowledge, attitudes, and values demanded by the professionals in this field, the mixed modular competency-based model meets the needs for developing a robust, flexible, and comprehensive curriculum. Moreover, this model aligns coherently with the institutional goals of our university (Universidad de Guadalajara, n.d.) and the university centre where this degree is offered (CUCEI, n.d.), and it fits well with the economic, social, and cultural characteristics of our university environment. At this point, it is relevant to mention some of these characteristics, which are common in developing countries and their public universities, and for which the structure of curricula under the mixed modular competency-based system is an alternative for comprehensively training professionals who can adapt to the contexts of an economic, social, and technological environment that experiences more pronounced changes compared to developed countries. It is important to recognise that, as a developing country, job opportunities may be scarce, competitiveness high, teaching-learning and practice resources limited, and there is a great need for innovation and entrepreneurship to create solutions to local problems.

Acknowledging these characteristics as a country and university, the qualities of the mixed modular model, and the requirements of the addressed discipline, it is possible to project the synergy between these factors to generate and achieve a successful curricular redesign.

Methodology

The curricular redesign of the bachelor's degree in Materials Science at the University of Guadalajara was based on a Competency-Based Plan with a Mixed Modular Approach, in which the key competencies for achieving the expected professional profile were identified and strengthened. The following constitute the phases in which this redesign was developed:

1. Review of the current program under a SWOT analysis framework. In this stage, areas needing reinforcement were identified, as well as opportunities to innovate and align the curriculum with current and future trends in materials science and engineering.
2. Definition of the object of study. Having identified the program's current state, the object of curricular study was focused on the need to train professionals with competencies that allow them to face and adapt to the challenges of the current and future economic, social, cultural, and technological environment.
3. Selection and development of a competency map. The key competencies that students must develop during their education were selected in this phase. For this, national and international universities and accrediting organisms were considered. These competencies were organised by their extent of complexity for each of the disciplinary areas and specialised modules.
4. Definition of the graduate profile. Based on the structured competency map, the graduate profile specifies the knowledge, skills, and attitudes that graduates must possess upon completing their education.
5. Curriculum proposal. Based on the graduate profile and competency map, a new curriculum structure was designed. The learning units were organised into training areas, allowing for a logical and coherent progression of knowledge and skills. The curriculum was also designed to be flexible so students could manage their education according to their interests.

6. Curricular proposal. The new curriculum proposal was consolidated into a formal document that included the academic structure, specific objectives, profiles, structure, implementation criteria of the study plan, teaching methodologies, mechanisms for curricular evaluation and follow-up, and the human and physical resources for its execution.
7. Submission to the University General Council for approval and evaluation. This process included presenting the proposal in Council sessions, where the merits and relevance of the redesign were evaluated in the context of current and future academic, social, and technological needs.
8. Training of teaching and administrative staff. During this phase, a training program was implemented for teaching and administrative staff to familiarise themselves with the new pedagogical approaches, teaching methodologies, and technological tools accompanying the new curriculum.
9. Implementation. This phase included adapting academic infrastructure, updating teaching materials, and creating a continuous monitoring plan to ensure that the objectives of the curricular redesign were fully met.

Results

The nine-phase process of the curricular redesign resulted in a holistic update of the study plan, covering key aspects such as incorporating competencies that respond to the demands of the productive sector and international standards of quality and competitiveness. A flexible curriculum was developed, oriented to the needs of the students, utilising national and international benchmarks and including a competency analysis conducted collaboratively through focal groups and committees. The curriculum was adapted to the latest scientific and technological advancements, considering emerging technologies that allow for the growth and integration of various areas of knowledge. Additionally, the curriculum integrates competencies in management and society and humanistic and social areas, strengthening interpersonal and management skills development and a graduate profile that is aligned with the demands of the current and future productive sector.

As a result of the review conducted on trends and innovation in Materials Science and Engineering, a set of mandatory disciplinary areas was established for all students in this degree program. Additionally, specialisation modules were identified, from which students can choose and complete two. For each of the areas and modules, a set of competencies was assigned, which were selected, strengthened, and organised by their level of complexity through work with different focal groups formed by entrepreneurs, researchers, professors, students, and graduates. Table 1 shows the areas, modules, and respective competencies with the highest level of complexity (exit competencies).

	Areas	Competencies of greater complexity
Disciplinary areas	Structure and processing of materials	Applies, designs, develops, and evaluates synthesis and processing methodologies to obtain new materials, allowing innovation with sustainable and efficient procedures (PLCMAIB/SM GAT EYP.120).
	Properties and performance of materials	Predicts the performance of materials by understanding deterioration processes. Applies methods for evaluating material performance.
	Design and integration of materials	Designs and creates new materials of all types based on the process-structure-properties-performance paradigm to achieve positive economic and social impacts across the field and society.
	Quality and sustainability of materials	Manages materials and processes for their proper operation by applying current environmental legislation and good operating practices
	Management and society	Ability to understand and apply the principles and techniques of quality management and technological innovation in organisations
Modules	Nanomaterials and nanotechnology	Designs chemical and physical methods in the production of a nanomaterial substance or nanostructure with the most suitable properties for a specific application.
	Biomaterials	Applies knowledge of biomaterials in devices and technological systems for use in the health sector.
	Metallic materials and alloys	Analyses, evaluates, and improves metallurgical processes.
	Polymeric materials	Creates high-value, sustainable, and high-quality polymeric products. Selects the necessary materials for the optimal development of a polymeric product
	Materials simulation	Uses design tools to predict mechanical properties such as strength, toughness, deformability, and elasticity as well as optical, thermal, and electronic properties, and learns to predict the failure of material in 3D printed designs.
	Additive manufacturing	Applies technology to design in a concurrent engineering context as an activity that meets customer needs and leads to profitable manufacturing.
	Renewable and biodegradable materials	Evaluates and analyses the environmental impact, biodegradability, and lifecycle of renewable materials, specifying key aspects such as production, use, and final disposal to make informed decisions in the selection and design of new materials.
	Emerging Technologies	*The competencies and their learning units will be adapted according to the needs of the modules offered in the educational program.*

Table 1: List of exit competencies by disciplinary area and module.

Similarly, collegial groups established the relationships between competencies and their integration into the curriculum. As illustrated in Figure 1, these relationships were organised into a map that distinguishes the different competencies, each labelled with a unique code, and the simple and complex relationships between them. The simple competencies, represented horizontally, show how competencies are developed from the beginning to the end of each area of knowledge. The initial competencies are represented in yellow, the intermediate in blue, and the final in green. Vertical connections represent the complex relationships between competencies, indicating how they are interrelated with their content and applied in more advanced and multidisciplinary contexts, in essence, among the different areas of knowledge or specialisation.

This approach provides the curriculum with great flexibility, allowing students to design their academic path beyond the traditional structures suggested by a curricular map (simple or horizontal relationships). This flexibility represents a paradigm shift in higher education and an appreciation for the diversity of skills and perspectives that students can bring to the discipline. The opportunity for students to design their academic journey grants them autonomy, fostering their self-management and adaptability, essential qualities in a constantly evolving professional environment.

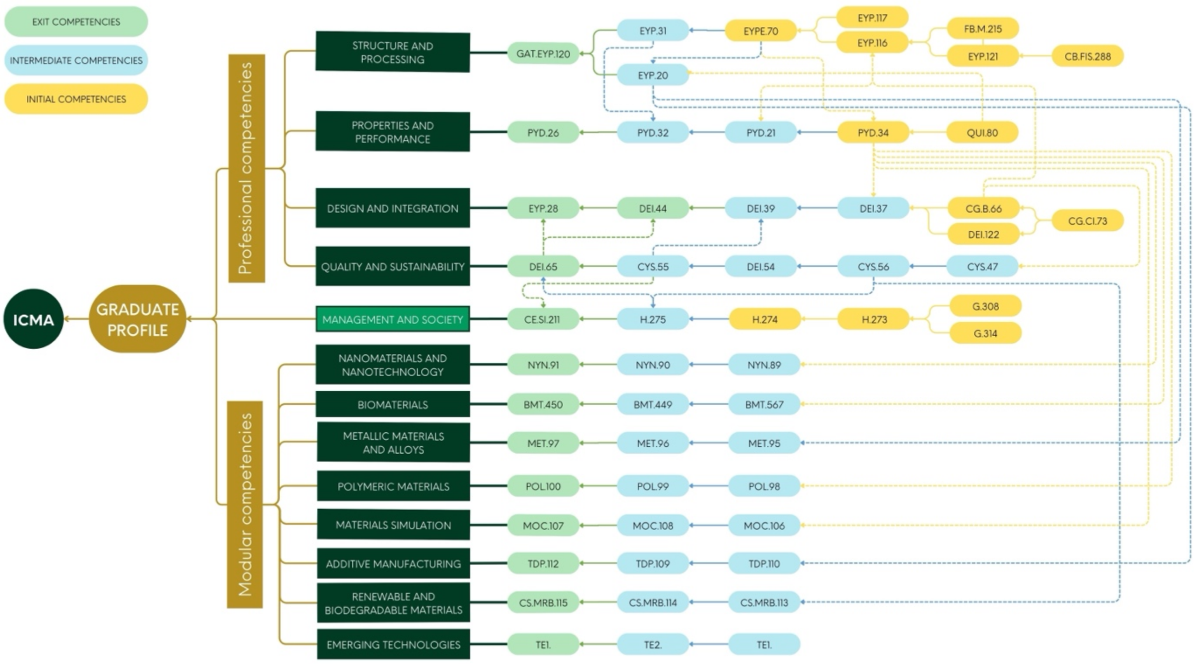

Figure 1: Integration and relationship scheme of competencies for initial, intermediate, and graduate profile.

Based on the most complex competencies for each of the disciplinary areas, the following graduate profile was defined, describing the technical and transversal competencies that students must have upon completing their education:

> *The Materials Science Engineering program graduate will be capable of proposing, developing, and evaluating synthesis and processing methodologies to design and obtain new materials, predict their performance, and apply specialised evaluation methods with an innovative approach oriented towards sustainable and efficient procedures. They will demonstrate management skills by handling materials and processes, ensuring their operation agrees with current regulations. They will promote technological innovation within organisations, consolidating a comprehensive and humanistic professional profile oriented towards sustainable development in national and global contexts, contributing to technological advancement and societal well-being.*

The new curricular proposal was approved by the University General Council, which formally recognises the relevance and quality of the redesign work. Implementing the new curriculum is expected to improve key academic indicators, such as retention rates, academic performance, time to graduation, and graduation rates. A high employment rate for our graduates is anticipated, further enhancing the University of Guadalajara's reputation as a leading institution in the education of professionals in Materials Science Engineering.

Conclusions

- The Materials Science and Engineering (ICMA) program at the University of Guadalajara has been redesigned to meet the current demands of the labour market and society, aiming to adapt education to these needs.

- A flexible curriculum has been created through a strategic process that utilises a mixed modular competency-based approach that enhances students' technical and transversal skills, which are fundamental for achieving success in the globalised professional sphere.

- The new *Ingeniería en Ciencia de Materiales* (ICMA) designation, replacing *Licenciatura en Ciencia de Materiales* (LCMA), represents an educational approach that aligns with current needs, promoting integration and adaptability. This new methodology provides students with advanced technical knowledge and cultivates the social skills and flexibility required to thrive in an ever-changing environment.

- The resulting curriculum integrates interdisciplinary knowledge in materials science and engineering, fostering innovation and sustainable development.

- With training that enables them to adapt and lead in a dynamic environment, students will be better equipped to overcome current technological and social challenges.

- The General University Council has confirmed the relevance and quality of this redesign, which is expected to impact academic indicators and graduate employability positively.

This new curriculum modernises training in key areas such as emerging technologies and management and offers students the opportunity to personalise their academic path, thus fostering their autonomy, self-management, and adaptability. In this way, the University of Guadalajara seeks to position itself as a leading institution in training professionals in materials science and engineering to make outstanding contributions to technological progress and social well-being nationally and internationally.

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