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ORIGINAL PAPER

The academia–industry relationship: igniting innovation in engineering schools

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Abstract

In several regions, but particularly in Latin-America, one of the greatest priorities not only for families but also for governments is the education of young generations. For any country in a knowledge-based economy, an educated youth and labor force backed by robust technological infrastructure could be the passageway to social and economic progress. We live today in a globalized and competitive world, where, for new generations of young people, popular skills such as reading, writing, and arithmetic won't be enough to succeed. Those will continue being critical skills, but they will not be sufficient. In this present century, new competencies are going to be vital factors that divide students between those who are ready to face more challenging environments in life from those who are not. At this point, the complex relationship between academia and industry is a social and institutional phenomenon guided by strategies. This relationship has evolved in diverse ways, where the industry sometimes collaborates with the academic communities in strategic efforts to support talent development for the good of both. One specific example, structured by the Intel® Guadalajara Design Center in Mexico, is the "Innovation Labs Network," which has the goal to ignite student creativity and innovation through the development of required competencies to impact the local ecosystems directly in the different states where those institutions and labs are located.

Keywords Academia · Educational innovation · Industry · Innovation · Innovation Labs · Intel · Mexico

1 Introduction

1.1 Background

Poverty is no longer measured only in economic or social terms. The world nowadays is also divided between those who control the new information and communication technologies (ICT) and those who do not. The growing, enormous inequality of access to modern technologies (computers, mobile telephony, and internet, for example) among countries or even among rich and poor regions is what we know as the digital divide [1]. Sellen et al. [2] affirm that we not only use technology but that we live with it.

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In our present society, knowledge is one of the pillars of strategic power. It is a society that is the result of massive social, economic and technological transformations, which materialized at the end of the last century. Controversially called the "Knowledge Society," it is a society that is subject to constant challenges, evolution, and changes due to the speed of the digital transformation. The Knowledge Society is one in which the conditions of the building of knowledge and the processing of information have been substantially altered by a technological revolution [3]. It is a society dependent upon the capacity of its citizens to apply knowledge dynamically and lead in creativity, innovation and entrepreneurship in the social and economic areas; a society that evolves and transforms at high speed; one in constant movement, and one that requires their individuals to be in a continuous learning process [4]. The Knowledge Society requires individuals to have a great capacity for learning, adaptability, and flexibility to respond to its needs.

Governments in many countries have been incorporating into their economic and political agendas the integration of various frameworks, including the ones for education. Implementing different strategies with the objectives of enhancing student learning through the development of new competencies and skills, they have been trying diverse technologies in the schools. These educational frameworks are essential for the development of critical competencies like innovation. Kairisto-Mertanen et al. [5] mention that innovation produces competencies and learning outcomes that are based on the knowledge, skills, and attitudes essential for innovative activities to be fruitful.

Young people need to understand that to succeed in their personal and professional lives, they must live in a globalized, changing and competitive world, which requires such new competencies and skills. The traditional skills of reading, writing and arithmetic won´t be enough to succeed. Those will continue being critical skills, but they will be insufficient on their own. There are new competencies that are going to be vital factors that divide students between those who are ready to face more challenging environments in life from those who are not. Various organizations and institutions around the world have been studying and analyzing this situation, where the students need new educational capabilities not only in school but beyond. For this new interrelated and digital world, they must develop the skills and knowledge necessary to succeed.

The end goal of applying the pedagogy of innovation is to close the gap between the educational context and working life, considering that the learning and teaching processes are developed to provide students with better skills that allow personal and professional growth [6]. Knowledge and thinking abilities are not enough in personal daily life nor work environments.

Students need to pay rigorous attention to develop skills and competencies suitable for life and their professional career. The interest in learning and the ability to acquire skills to solve emergent problems of the modern world are two of the most essential qualities that all students must develop within themselves these days. One key feature of successful innovators is that they have mastered the ability to learn on their own "at the moment" and then apply that knowledge in new ways [7]. Educational technology has a strong potential to induce the progress of the students in specific skills, such as carrying out independent investigations (research), developing critical thinking, solving problems, communicating and collaborating in more efficient ways [8]. These skills are based on profound knowledge, involving not only knowing what and how but also knowing how to be a person in a complex and changing competitive world [9].

Integrating knowledge, skills, attitudes, and patterns of personal abilities can be seen as a competency, especially when understanding that the final objective is knowing how these interact and work together [10]. In this twenty first century, society and industry (especially) are interested in new competencies, like creativity and innovation, and how these are applied in entrepreneurship. Several experts in this field who have a good understanding of various global trends have been emphasizing these competencies as strategic to lead the talent needed and demanded by society, industry, and government to confront the insufficiencies and the complex problems that are present in a constantly changing, uncertain world [11]. It should be noted that all these changes are currently generating new ways of working and new economic scenarios where the key to creating employment and improving the quality of life is based on innovative ideas applied to products, processes, and services in a global economy where risk, insecurity and constant change go from being an exception to being a reality [12].

Technology is an important factor that has been causing extraordinary changes in the economic and social aspects in many countries. The digital era is transforming human life. These changes in the technological area have produced a series of global environmental movements giving shape to promising new technological trends and cutting-edge products. There are some advisory and research companies that over the past years have been analyzing all these megatrends, detecting which ones would be viable or effective. They even examine the ones that could be exaggerations. One good example of these companies is the global consulting firm, Gartner, Inc. This company created a concept called, "Hype Cycles," which is a graphical representation of various technologies. It includes their possible application, maturity, adoption, etc., and the viable solutions that these might bring to solve important problems. [13]. The impact of technology is equally direct in the world of education. Schools and teachers are constantly facing the challenge of educating and guiding students through the advantages and disadvantages of the virtual world, but they do not always have the skills necessary to do so [14].

Here is the importance of academia: Academia plays different and critical roles in supporting talent development and preparing future professionals to be ready to face a twenty first century full of new challenges and transformations. For that reason, academia needs to be aware of all these digital transformations, all these *Hype Cycles,* and megatrends that will impact their students' academic curricula, so that the students are prepared to be the professionals needed by society and industry.

Analyzing the Mexican educational system as an example, over the past 50 years, it is possible to identify that the concept of innovation has been continuously a common element through different educational reforms. Unfortunately, most of the time its execution has been compulsive, which prevents its consolidation and evolution to a maturity that would bear the fruits expected by those reforms and innovations [15]. At the same time, the collaboration between academia and industry has been identified as a very strategic institutional and social phenomenon in Mexico. Conceptually speaking, this collaboration covers a substantial number of critical aspects of national progress, such as the country's competitiveness, quality of human resources, development of talent and innovation, among others. It is a very complex phenomenon complicated by the great diversity of universities and industries. Due to this factor, the possible forms of interaction vary, and there is not a single formula that would drive these potential collaborations. Although industry–university partnership and relationships are not new phenomena, it is clear that these have become more prevalent in recent decades. Innovation policies implemented by various governments around the world have been incorporating this collaboration as an essential component. Among the different actors in academia, government, industry, and society, there is an interest in promoting this kind of cooperation, highlighting its importance actors in the productive sectors and scientific agents who want to deliver a more significant impact to society and/or industry [16].

1.2 Reference frameworks for lifelong learning

In most all countries, the education of the new generations is considered one of the most important aspects for families and governments. At present, it is understood that, in a knowledge-based economy, it requires a highly educated workforce and a robust technological infrastructure for educated youth to have the means to achieve the social and economic progress desired in any country.

We live in a changing, competitive and globalized world, where, for new generations of young people to succeed, the traditional skills of reading, writing and arithmetic are insufficient. For decades, those have been considered to be the foundation and basis for education. Those will continue being critical skills, but there are new competencies that are going to be vital factors that distinguish students from those who are ready to face more difficult challenges in life from those who are not.

In this scenario, different institutions and organizations in various parts of the world have taken on the task of analyzing this problem that challenges young people in the twenty first century; therefore, various learning frameworks of reference have been consolidated.

Organizations such as UNESCO [17], Partnership for twenty first century Skills [8] and the European Union [18], among others, have developed new principles, practices, and frameworks that articulate skills, competencies, experience and the knowledge that students should master to be successful in the present century. Some of the competencies defined as in-demand and critical for the future are conducting independent investigations, developing critical thinking, solving problems and using technology to communicate and collaborate in more efficient ways [8].

The definition of the term, "competence," is not a simple exercise, because it involves notions about the mode of production and transmission of knowledge, the relationship of education and society, the mission and values of the educational system, teachers' practices and evaluations and the students' activities and performance [19]. A comprehensive definition of competence includes the capabilities that every human being needs to solve the challenges and situations of life, effectively and autonomously. The definition is based on knowing how to be a person in a complex and changing competitive world [9].

The organization, Partnership for twenty first Century Skills [8], conceived a framework for the segment known in the United States as K-12, a term describing preschool to high school in that country. However, this framework has functioned as a base in Higher Education Institutions in other countries to describe what should be the indispensable achievements for the students of the twenty first century, referring to the skills, knowledge, and competencies that students must master to succeed, both in personal life and at work [8].

The competencies defined on this framework are consolidated in the four points listed below:

- Basic curricular subjects and themes of the twenty first century.
- Competencies related to learning and innovation.
- Competency in the management of information, media and information and communication technologies (ICT).
- Skills for personal and professional life.

Concerning the competencies related to learning and innovation, an important, relevant point that should be emphasized to students is the fact that learning does not stop when their studies conclude; on the contrary, learning should become a life-long process.

Several competencies that are acknowledged as the ones that distinguish the students who are prepared for the twenty first century environments are demanding and increasingly complex. Among these, learning and innovation are critical ones. In addition, creativity, communication, critical thinking, and collaboration are being emphasized as essential skills in preparing students for the future [8].

A second framework that was born as a result of the objectives of the Bologna Declaration, an agreement signed in 1999 by the education ministers of various countries in Europe (including the European Union, Russia, and Turkey) is the Tuning Project, based on the context of the reforms of European higher education. The Tuning Project initiated articulation and debates among people and educational institutions about the changes in the structures and educational contents in higher education.

The Tuning-Latin America Project emerges from a context of intense reflection on higher education, both regionally and internationally. Until the end of 2004, Tuning had been an exclusive experience in Europe. More than 176 European universities since 2011 have been working hard to create the European Higher Education Area (EHEA). Tuning allowed the creation of a working environment so that European academics could reach points of reference, understanding, and confluence [19].

Therefore, the systematized effort to think and rethink together the academic and professional horizons has been one of the central themes of the Tuning Project. Keeping universities in constant dialogue with society is a pathway always open to the future; relevance to any reality requires sensitivity and adaptation to different contexts. These are naturally fundamental requirements that are present in the Tuning Project-Latin America [19].

If the two frameworks used as an example are considered, one can appreciate that the competencies that students have to develop, including those of innovation, are different than those before. A study carried out based on the PROFLEX Project (an alpha project partially financed by the European Union) provided information on approximately 10,000 graduates from 33 universities in nine Latin American countries [20]. The study was based on a wide range of surveys of the universities' graduates five years after graduation, in which they were asked numerous questions about their educational and current work experience.

The surveys provide information on the elements necessary to analyze the relationship between resources and results of university education in Latin America. The data revealed that the university curricula did not contribute equally to the development of the 19 competencies included in the questionnaire. The major competencies acknowledged by the university graduates corresponded to the following competencies: (a) analytical thinking; (b) working productively with others (teamwork); (c) rapid knowledge acquisition, and (d) education in one's particular domain. The lowest rated contributions were: (a) speaking and writing foreign languages; (b) negotiating effectively, and (c) leadership [20].

The potential of innovation as a competency for the graduates of higher education is that it is a fundamental determinant for success in professional careers and the integration into industries in many countries. The skills acquired by those who graduate each year from universities can be considered as multidimensional products that society derives from the resources that are allocated to the university systems [21].

In the current era, the different reforms of higher education refer to creativity and innovation. However, in practice, the reforms have been "more of the same". The research carried out by Mon [22] concludes that entrepreneurial spirit and initiative are the skills that are least promoted in professional training, skills that are generally associated with innovation, development, research and problem-solving. However, for Martínez and González [23], the conception of reform does not correspond to the results of their research either, because the teachers indicate that the university as an institution does not favor the development of creativity in its students. They also believe that it does not value creativity and innovation in the performance of teachers. Here lies the importance of developing the competency of innovation.

1.3 Creativity and innovation

To talk about innovation, it must be considered that creativity is the first step to achieve it [24]. The difference is that the ability of human beings to invent something is what we call creativity, while innovation, in addition to conceiving an abstract thought, is concrete and practical. The procedence of the word, "innovation," is from the Latin word, "*innovare*," having the meaning to renew or to do something new. Metaphorically, innovation reflects the metamorphosis of a present practice into something new, hoping it will be better [25].

To be innovative, it is necessary to take a creative idea and turn it into a product, service, method, strategy or technique that is useful. Therefore, the definition of creativity should not be assimilated only to a skill; it is more than that—it is the full use of intelligence [11].

In this century, the competencies of creativity and innovation in the training of professionals are points of remarkable interest in various sectors of society, a society that demands to find solutions to shortcomings, limitations and structural problems existing in a world that is in a permanent state of transformation. For this reason, experts in this area consider that the competencies of creativity and innovation are strategic to guide the professional development of students [11].

According to Ordóñez [26], the possibility of confronting the challenges of society and being successful lies in creativity (the ability of the human being to think new things) and in innovation (the ability to implement these ideas in a different mode).

Warner [7] poses creativity as a mental process that allows the generation of ideas. According to Hernández et al. [11], it is about generating ideas, while the focus of innovation is on the implementation of transformational ideas.

Creativity, known as inventiveness, refers to the ability to combine ideas uniquely. Álvarez [27], for example, considers that this relies on a kind of imagination that constructs and, therefore, requires both divergent thinking (which elaborates criteria of originality, inventiveness, and flexibility) and convergent thinking (which allows the act of inventing). Creativity also encompasses ingenuity (the ability to find novel solutions) and, above all, the will to change and transform the present reality. Creativity, then, is a mental attitude and a thinking technique, while innovation is recognized in the successful application of attitude and thought to novel ideas that become useful and increase productivity. Being creative has to do with the competence to make associations, establish relationships, make combinations and integrate ideas and concepts in unaccustomed, dissimilar, different or unique ways to produce revolutionary results [28].

We are currently living the Age of Innovation. Many times, the word, "innovation," looks as if it were synonymous with a variety of concepts, such as the improvement of living conditions, progress, job creation, technological development, and others. It is clear that today's world needs job creation, so the adoption and incorporation of a culture of innovation is a must in all the economic and social sectors [12].

According to the "Green Paper" of the European Commission, innovation is considered a synonym for producing, assimilating and successfully exploiting a novelty in economic and social spheres in such a way that it contributes unprecedented solutions to problems and, thus, responds to the needs of people and society [12].

The Oslo Manual from Eurostat and the OECD [29] have the following definition of innovation: the introduction of a new or significantly improved product, good or service; a fresh marketing method, and/or a new organizational method, that could be applied in the internal practices of a company, in the workplace's organization or even in its external relations.

There are many explanations and definitions of the term, "innovation," linked to economic and sociological areas, but, ultimately, all imply that to innovate means to introduce changes in the way things are done and to improve the final result. Thus, innovation might take the form of changing the price of an article to conquering a market based on a study or research, to improving an old product or discovering a new use for an existing one [30].

However, since 1934, the well-known economist, Schumpeter, rightly pointed out that innovation and technology play a key role as engines of economic growth. According to Schumpeter, the new economy is an economy based on innovation, which includes a continuous commitment to the renewal of products, processes, organizations, and people. Nowadays, innovation is widely accepted as an indispensable tool for survival and development not only for companies but also for economic growth, development and the welfare of nations [31].

1.3.1 Innovation's typology

Innovation can be seen from different points of view, and all can be successful. Given the complexity of this concept and the wide variety of possible interpretations of it, it is necessary to establish a common framework for interpreting it and related concepts. This need is even greater when, as in this case, we talk about innovation in the context of a study that seeks to know how to develop innovative competencies in the area of technology within universities.

To improve the measurement of innovation by establishing a coherent set of concepts and tools, the first edition of the Oslo Manual was published in 1992. It dealt fundamentally with the technological innovation of products and processes in the manufacturing sector. Since then, this manual has become a benchmark for surveys and analytical models that seek to deepen the nature and impact of innovation. Likewise, over the years, the Oslo Manual has also evolved in the precision of the concepts, the scope of applications and the methodologies used [31].

The Oslo Manual [29] defines the following types of innovations, which imply a wide range of changes to the activities of organizations:

(a) Product innovation: Corresponds to the introduction of a good, or a significantly improved product or service, concerning its characteristics or the use to which it is intended. This definition includes the significant improvement of technical characteristics, components, and materials, integrated computing, ease of use or other functional characteristics.
Product innovations can use new knowledge or technologies or be based on new uses or combinations of knowledge or existing technologies. It also encompasses new goods and services and significant improvements in the functional characteristics or the use of existing goods and services.
(b) Process innovation: Is the introduction of a new or significantly improved production or distribution process; this implies significant changes in techniques, materials and/or computer programs.
(c) Marketing innovation: Is the application of a new marketing method. Marketing innovations try to satisfy the needs of consumers, to open new markets or to position existing products or services of an organization in a novel way to increase sales.
(d) Organizational innovation: Is the introduction of a new organizational method in the practices, the organization of the workplace or the external relations of the company. These can have the objective of improving the results of a company by reducing administrative or transaction costs, improving simultaneously the level of employee work satisfaction, facilitating access to non-commercialized goods or reducing the costs of supplies [29].

Innovation typologies classify innovative results in generic categories according to different criteria. According to Guzmán and Martínez-Román [32], it is possible to establish a classification of innovation taxonomies using three basic criteria; namely, the object, the degree of novelty and the strategic purpose of the innovation. With respect to the degree of novelty, innovations are usually classified as radical or incremental. Radical innovations, also called disruptive innovations, refer to new products or processes because they present significant differences regarding their purpose, benefits, characteristics, theoretical properties, raw materials or components used in their manufacture [33]. On the other hand, incremental, partial, progressive or secondary innovations are improvements in existing products or processes and, consequently, provide less novelty [33].

There are different models that form the basis of a broad set of research and scientific models in the areas of innovation and the adoption of modern technologies. In a very general way, research on innovation focuses on two points of view: diffusion and adoption. Some authors use the diffusion perspective to try to understand how innovation spreads among the members of a community. This usually applies to new consumer goods in a potential market. Other authors use the perspective of adoption to assess receptivity and the changes an organization or society will adopt to accommodate innovation. The adoption process is complementary to the diffusion process, except that it refers to the psychological processes that an individual goes through, rather than global operations in specific social environments [34].

The Theory of the Dissemination of Innovation by Rogers [35] can be used as a reference to summarize the definitions of diffusion and adoption. Diffusion is defined as the procedure by which an innovation is communicated over time among a social system's members through certain channels, while adoption refers to the end-to-end process from the initial knowledge of an innovation by an individual or decision unit to a final attitude towards it. That could cover a range from a decision to adopt or reject it to the implementation and the confirmation of the possible new idea.

In summary, the dissemination perspective analyzes the innovation from the viewpoint of the producer of the innovation, and the adoption approach studies it from the viewpoint of its recipient [35].

The most relevant contribution of the Theory of the Diffusion of Innovation is the establishment of distinct categories of adopters. Rogers [35] mentioned that individuals do not accept an innovation all at the same time. He identified five different adopters' groups; namely, innovators, early adopters, early-majority adopters, late-majority adopters and, finally, the laggards.

In conclusion, although Roger's theory of Dissemination of Innovation is a good starting point for modeling the diffusion of the innovation process, it is based on the assumption that the members of the organization can choose freely and independently the adoption of an innovation.

With strategic management computer systems, there is usually little freedom of choice, and adoption becomes inevitable.

1.3.2 Innovative competency

Competencies can be defined in diverse ways, and they have been categorized over time in different classes [36–38]. While the concepts of knowledge and skill do not contain motivational aspects, the definition of competency does include them. Additionally, other aspects to be considered in this definition include: (a) characteristics of the individual; (b) level of performance and (c) context in which a competency is applied [39].

Various sectors of society have identified as a point of high interest the training of professionals who have competencies of creativity and innovation in this twenty first century. These competencies are expected to guide the talent development of future professionals who would be demanded by society and who would find solutions to shortcomings, limitations and the challenges that our changing world is bringing [11].

Innovation competency is the result of learning the requisite knowledge, skills, and attitudes to apply in this world. In the same way that there are different frameworks of reference for learning, there are appropriate frameworks for the competency of innovation. One example of these frameworks is the one headed by the Department of Applied Sciences at the University of Turku in Finland [6]. In this framework, three categories of innovation competencies were defined and presented by the European Qualifications Framework:

1. Individual innovation competencies:
   - Independent thinking and decision making.
   - Tenacious actions oriented towards objectives.
   - Creative problem solving and development of working methods.
   - Self-evaluation and development of own skills and learning methods.
2. Interpersonal innovation competencies:
   - Ability to cooperate in a multidisciplinary team.
   - Ability to take the initiative and work responsibly towards the objectives of the community.
   - Ability to work on research and development projects, to apply and to combine knowledge and methods from different fields.
   - Ability to work under the principles of ethics and social responsibility.
   - Ability to work in situations of interactive communication.
3. Networking innovation competencies:
   - Ability to create and maintain work connections.
   - Ability to work in networks; ability to collaborate in multi-cultural and multi-disciplinary environments.

- Ability to communicate effectively and interact in international environments [6].

Waychal et al. [40] have developed a framework with a specific axiom indicating that learning significantly increases if activities are done having intense reflections, active participation, and collaborative work. These would be based on case studies created from real-life projects designed for learning that is centered on the student. In this framework, creativity and innovation are understood by students through their ability to provide and apply innovative solutions to real-life problems while they consider their underlying dynamics. This framework does not intend to cover all the sub-competencies of innovation. However, it is a reasonable basis.

In the specific case of this framework, it should be noted that it is based on the following four principles:

1. It is possible to teach creativity and innovation.
2. Student-centered learning, team-based, and project-based learning, active learning, and case-based learning are the best methods to develop competencies of innovation.
3. Diversity increases the performance of innovation.
4. Innovators succeed when they work from a passion for challenges. [41].

These principles are elaborated below:

1. It is possible to teach creativity and innovation. Many thought leaders, researchers, and professors such as Robinson (cited by Amabile [24]), Smith [42] and Belski [41] believe that creativity and innovation can be taught. The first of these references take the position that pedagogy can be designed and intended to encourage other people to think creatively. He adds that participants can be asked to innovate and experiment without giving them all the answers but just by offering them the tools needed to find out possible answers or, even, to explore new ways. Smith [42] indicates that the generation of ideas was never intended to follow a scientific method until Altshuller [43] proposed the TRIZ process (Theory of the Solution of Inventive Problems), which is the antithesis of the psychological methods of trial and error, thought untrustworthy and contains repeatable, scientific, procedural and algorithmic processes. From the giant database of two million patents, but stripped of the technical components, Altshuller [43] discovered that only a small number of engineering abstractions and analogies were needed to explain the massive majority of inventions. Belski [41] designed and taught a distinct course on thinking and problem-solving based on TRIZ. He observed that students' perceptions of their problem-solving skills changed significantly as a result of the course. Chang [44] trusts that, by emphasizing consistently both the thinking strategies (outlined in the collaboration models) and the creative processes, companies and individuals can become creative and innovative long before they decide to use another method. Therefore, creativity and innovation are not inherent to the character; rather, they can be developed and taught using different frameworks, processes and appropriate pedagogies [40].
2. Student-centered learning helps to develop innovation competencies. Student-centered learning, such as team-based and project-based learning, active learning, and case-based learning, are the best methods to develop innovative competencies. Robinson (quoted by Azzam [45]) detected that when working with people who are invited to draw, think visually or even to move instead of just sitting and writing their points of view, something different happens. This creates a different dynamic that encourages innovation to happen, like having some schemes where people work with other associates with whom they would not normally work. Brown [46] and Waychal [47] have demonstrated that student-centered learning can help develop creativity. Two aspects of innovation; namely, fresh thinking and the delivery of values, require this method of learning.

It is very contributory when individuals get involved in real-life scenarios to understand problems and produce innovative ideas. The major value of this exercise is the implementation of ideas to solve real-life problems. Through the students' active participation in the sessions within the classroom and projects, the two above elements can be integrated [40].

3. Diversity increases the performance of innovation. Robinson (quoted by Azzam [45]) comments that we have to promote and teach collaboration to benefit from diversity, instead of promoting homogeneity. Amabile and Kurtzberg [48] highlight that diversity increases creativity due to heterogeneous sets of viewpoints, but they also warn that it could hold back the group's process.

Hargadon [49] mentions that many past innovations are the result of joining or synthesizing ideas from different fields. He argues that innovation is the result of simultaneous thinking in multiple boxes and not the suggested "thinking outside the box".

4. Innovators succeed as they work on the challenges that emanate from their passions. Robinson (quoted by Azzam [45]), points out that if you combine a personal aptitude with a passion for the same objective, there are no limits to innovation. Munshi [50] feels that innova-

tors require an attitude of "creating history" to accept impossible challenges that encompass the heart instead of appealing to reason. If the possible innovation starts with an idea, it might end with its failure, but, on the other hand, if you start with a challenge about which you feel passionate, the failure of an idea would prompt you to think about possible new solutions and ideas. Therefore, it is possible that work on the innovation would continue in spite of everything until the challenge or problem is overcome.

The principal idea behind the application of the pedagogy of innovation is to close the gap between the educational context and working life, taking into account that the learning and teaching processes are developed to provide better skills to students and to nurture personal and professional growth [7].

1.4 Impact of industry–university collaboration on innovation

Innovation is a complex phenomenon and requires skills in multiple areas; there is not a single way to define innovation. Rogers [35] proposes that innovation can be defined as an idea or a way of doing things that could be considered new. According to him, in absolute terms, innovation does not have to be something new, but the individuals involved must experience it and consider it as such. The use of knowledge, as well as the innovation, play a vital role in the new and changing economic scenario in which we find ourselves, both factors being very interconnected. Growth and productivity are mainly based on the accumulation of knowledge and technical processes. The transformation of the labor market requires an evolutionary and educational transformation, which allows finding a point of convergence between the sectors of academia and industry [51–53] so that higher education must re-evaluate and accept the role that industry plays in learning. The changes in the conception of the economy will require new indicators to appraise the economic condition in time and space, including the complexity of measuring a variable with as much current weight as knowledge. The latest report of the OCDE [14] indicates that developed countries are moving faster and earlier towards the new society of knowledge. In emerging economies, such as many countries in the Latin-American region, often the possible transition to the society of knowledge would be more gradual. That is why universities must remain alert to detect technological mega-trends and the cycles of over-exposure to analyze how their educational systems would need to be transformed to offer their students knowledge in these new areas. The purpose is to allow students to integrate themselves not only to a constantly changing world but also to industry specifically and, in general, to a society that in many cases evolves with the pace of technology.

Different initiatives at the state and federal level in Mexico are being implemented to support local economies in the constant and challenging global environment. In this competitive environment, it is pretty clear that to attract new talent, investment and business, governments and organizations must keep pace with digital transformation, or they will be relegated irrevocably to the losing positions. For this reason, new initiatives, incentives, and resources are being distributed with the aim to ignite collaboration among the different members of the ecosystem, which includes industry, academia, government and society [16].

New ways of partnering and collaborating are yielding the fruits of innovation, and a good example of the collaboration between academia and industry is the "innovation laboratory". Innovation laboratories can be seen as a possible space and sets of protocols that involve individuals, technologies and several other actors, such as academia, society, the public, and industry coming together to resolve different situations and to solve problems. It is a physical space used by those actors [54]. In this arrangement, academia can take advantage of the ideas, knowledge, and practices from industry [55].

1.4.1 Innovation laboratories network in Latino America

Over the previous past decades, the rapid growth of knowledge added to the digital technical transformation happening in several industries, forcing companies to renew themselves faster than ever to be competitive. Many times, talent-development initiatives are not going hand in hand with these transformations inside universities.

The Intel® Guadalajara Design Center (GDC) is the largest center of engineering in the Latin-American region of Intel®, which focuses on delivering advanced technology in different areas, from small devices for the internet of things to highly innovative solutions for datacenters and artificial intelligence [56].

Among differente activities that the Intel® GDC has been driving in collaboration with the academia, several Mexican states and universities were visited in May of 2016 to analyze three factors needed to develop innovation competencies. The first one was the talent-development activities carry on by the institutions. The second was the level of innovation shown by the students' projects (Both of these two factors were in the engineering area). Lastly, the third was the collaboration of these universities with some of the local players at the state, which include the industry and the government. In several cases, a lot of flaws were encountered.

As a result of the problems noted in the universities examined, Intel® GDC decided to implement a conceptual strategy in Mexico of a network of laboratories that would fulfill the following goals:

- To promote the students' and teachers' development of talent in the technical areas in the engineering schools.
- To incentivize innovation competencies within the academia.
- To increase the collaboration among the actors of the local ecosystems and the academia.

Consequently, Intel® GDC made the initial decision to select ten different Mexican universities in various states to create an innovation-laboratories network which includes public and private institutions. But, after knowing about this effort some other universities in the Latin American region, there were several requests to be included as part of this list. For that reason, to start a broader collaboration among different countries, a university from Colombia was incorporated as part of this network.

Considering the feedback from the studies and the megatrends that might have significant repercussions in Latino America´s technological area, the analysts used the Gartner Hype Cycle method [13] that led to the report that revealed that the "internet of things" and cloud-and-datacenter technologies are the two areas with the most significant growth and potential. Therefore, the main focus of this innovation network was on these technological areas, and Intel provided equipment and training to establish each one of these labs.

2 Methodology

2.1 Objective

The end goal was to describe the critical factors required to develop creativity and innovation competencies in the technological areas in 15 universities in Mexico.

2.2 Type of research

The design of the current research is based on the classification done by Creswell and Plano-Crack [57], a mixed method of an exploratory type. This design was constituted by two phases, where the findings of the method used in the first phase of the study, in this case, the quantitative, contributes to the development of the second qualitative phase. This type of design proposes explorations as a requirement for the second phase of the study, and it is especially useful to identify the important variables buried in its data or the unknown variables [57].

2.3 Socio-demographical context

The study was executed in public and private institutions and universities across the Mexican Republic, particularly in eight different states, in complete association with the departments of Engineering and Exact Sciences in each institute. Innovation, Programming, Mechatronic, Mechanic, Electronic, Industrial and Cybernetics were the selected engineering areas for this research. The names of the majors listed above might vary within the institutions, but similar careers (curriculum disciplines) could be chosen.

Table 1 Students and teachers in the areas of engineering focused on technological careers and the selected universities and states of the Mexican Republic

Name of the University	State	Students	Teachers
Universidad Tecnológica de Tijuana	Baja California	280	18
CETYS Universidad	Baja California	300	25
Instituto Tecnológico de Chihuahua	Chihuahua	400	27
Instituto Tecnológico de Chihuahua II	Chihuahua	400	20
Tecnologico de Monterrey, Guadalajara	Jalisco	220	20
Tecnologico de Monterrey, Monterrey	Nuevo León	300	20
Universidad Tecnológica de Querétaro	Querétaro	500	30
Instituto Tecnológico de Sonora (ITSON)	Sonora	300	20
Universidad Autónoma de Zacatecas	Zacatecas	200	30
Instituto Tecnológico Superior Zacatecas Occidente	Zacatecas	300	15
Instituto Tecnológico Superior de Fresnillo	Zacatecas	100	10
Instituto Tecnológico Superior de Loreto	Zacatecas	200	30
Universidad Politécnica de Zacatecas	Zacatecas	200	30
Instituto Tecnológico Superior de Jerez	Zacatecas	200	30
Universidad Politécnica de Yucatán	Yucatán	150	5

Source: Adapted by the author based on the instrument applied in 2017

2.4 Population and sample

From the total of universities and technological institutions in Mexico, eight institutions were included to have an innovation laboratory donated by Intel®. After that, with an aleatory number list of universities without this kind of laboratory, seven universities were selected (Table 1).

The participants of the study were classified into three categories:

a) Students: Students from the engineering and science areas, especially those focused on the areas of innovation, mechatronics, electronics, systems or related careers, in which there would be a sample of more than 500 participants. The students' ages ranged from 18 to 24 years, having the sample considering both sexes.
b) Teachers: Teachers who took part in the research comprised a sample of more than 100 participants. Their ages ranged from 30 to 50 years on average. The majority were married men. Their education is postgraduate level (at least masters), and, on average, they had taught between 10 and 15 years.
c) Head of the Engineering Area: Even though several institutions have a director level position, the work was directly done by the head who coordinates (in each institution) the careers in engineering. The sample size was 15 participants.

2.5 Instruments

For the quantitative phase, three surveys were designed, one for each participant in the research. Those surveys are detailed in the below tables.

The Institution Survey as shown in Table 2 is divided into six large categories, the first one collecting the general data of the institution. In this, it is identified whether it is a public or private institution, the type of focus it has (teaching, research or innovation), some careers, teachers, and students in the area of engineering focused on technology, and, finally, the average number of students graduated in each locality. Next, general details of the students are collected, covering assorted topics such as the theme of diversity. The next area covers general aspects of the infrastructure of the institution, such as the number and type of laboratories and specific efforts in the area of entrepreneurship. A following section of the survey covers the curricular area focused on innovation competency, requiring information about the types of teaching strategies used, the efforts to promote said competencies and the teaching training offered to support innovation activities in the institution. Next, information is required on the relationship of the institution with the local ecosystem, focusing on innovation activities and internal efforts by the institution and its impact in this area (Tables 3, 4).

The Teacher survey has four areas, the first one collecting general data, then continuing with the curricular activity that they do in the area of innovation. Information is collected about the teaching strategies that they use to encourage competencies in creativity and innovation. The survey concludes with questions about their training in these areas.

Regarding the student survey, this is divided into five areas. The first phase collects general information about the student and continues with the collection of data relating to

Table 2 Instruments in the quantitative phase—institution

Name	Survey for the institution
Information collected	General data of the Higher Education Institution, specifically in the areas of Engineering and Exact Sciences. General information about the students of the institution. The infrastructure of the Institution. Ecosystem focused on Innovation. Efforts in the area of Innovation The internal impact on the institution
Number of items	Thirty-five items whose answers were placed in ranges, and some of them with a Likert scale
Created by	The researcher responsible for this investigation
Form of application	In some institutions, the survey was applied in person with the directors of the Engineering area. In some other cases, it was through digital means, using the Google Forms platform, granting them the direct web link
Codification	Some of the queries had more than two options so that the coding was done option by option. With this information, it was proposed to configure the database with the information of each institution

Source: Adapted by the author for the actual research

Table 3 Instruments in the quantitative phase—teacher

Name	Survey for the teacher
Information collected	General data, curricular activity, teaching strategies in the area of innovation, training in innovation
Number of items	Twenty-nine items whose answers were placed in ranges, and some of them with a Likert scale
Created by	The researcher responsible for this investigation
Form of application	Digital through the Google Forms platform, granting them the direct web link. In some institutions, the survey was applied in person, and in other cases, the teachers answered digitally in a period no longer than a week
Codification	Some of the queries had more than two options so that the coding was done option by option. With this information, it was proposed to configure the database with the teacher

Source: Adapted by the author for the actual research

Table 4 Instruments in the quantitative phase—students

Name	Survey for the student
Information collected	General data, XXI century competencies, curricular activities in the area of innovation, learning strategies in the area of innovation, training in innovation
Number of items	Thirty items whose answers were placed in ranges, and some of them with a Likert scale
Created by	The researcher responsible for this investigation
Form of application	Digital through the Google Forms platform, granting them the direct web link. In some institutions, teachers applied surveys during class time. In other cases, the students were free to answer it in a period no longer than a week
Codification	Some of the queries had more than two options so that the coding was made option by option. With this information, it was proposed to configure the database with the information of the students

Source: Adapted by the author for the actual research

the competencies of the twenty first century that they possess. Next, the survey focuses on specifying the curricular activities in the area of innovation and the learning strategies that are used. Finally, it covers the training that students have in innovation (Fig. 1).

In some cases, universities or technological institutes hold innovation competitions in the technical area, where the projects presented by the students are documented. In order to standardize the evaluation criterion of the projects that were taken into consideration, as a record of the innovation carried out by the institution, different evaluation criteria were analyzed. One of the most relevant to this research was the General Criteria for the Evaluation of Innovative Product (Tecnos Award) where the criteria to be evaluated and the definition of each of them is defined.

Below you will find the criteria's categories based on the Tecnos award for the evaluation of student´s projects (Table 5).

2.6 Investigation procedures

- The research problem was defined based on the Innovation Labs Network´s project, implemented in several universities and different states, by a collaboration agreement with Intel®, whose objective is to develop Mexican talent and promote competencies of creativity, innovation, and entrepreneurship. The experience of the first participating universities showed that each institution develops these competencies in a non-systematic way, where some cases are not part of the curricular plan because they are done empirically by the teachers and, sometimes, even by the students. Based on this experience, it was decided first to investigate in an exploratory phase the use of educational strategies for the promotion of innovation competency—but in a broader range of 15 institutions in eight states of the Republic.
- The theoretical framework was prepared that would document the main models of the development of innovation competency, some of the teaching strategies used for this purpose, as well as the relevance of collaboration among the different members of the ecosystem. Finally, the importance of understanding the megatrends in the technological area was highlighted, based on different studies carried out by international consulting firms.
- A mixed methodology was designed to gather the necessary information in the institutions. The research instruments were submitted to the scrutiny of experts in the field to verify the validity of their construction.

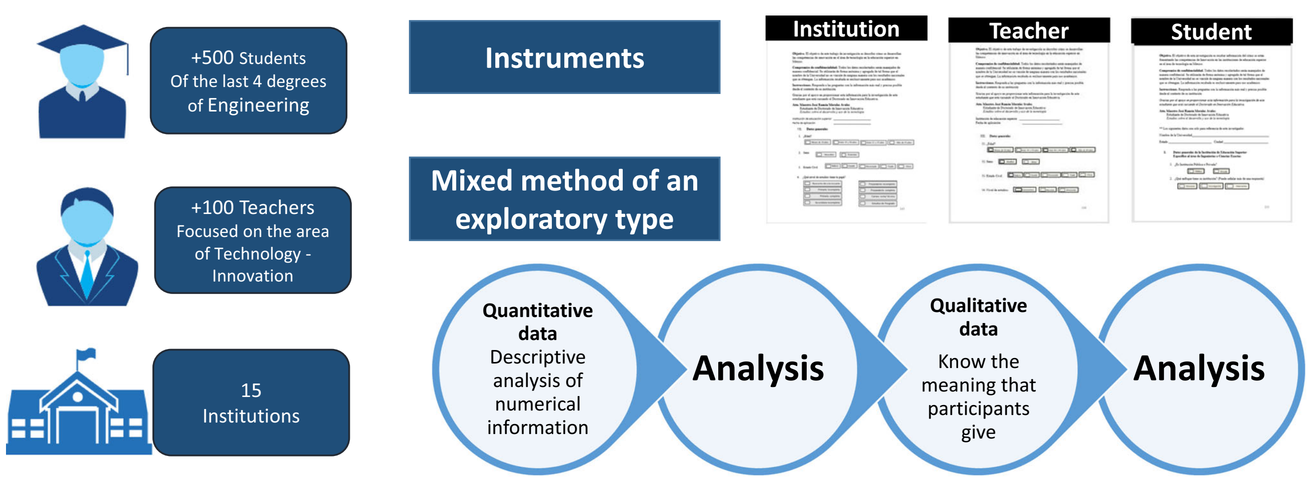

Fig. 1 Overall illustration on the process and method being used *Source*: Adapted by the author

Table 5 Innovative product's general evaluation criteria

Criteria	Definition
1. Technological level	First Level: Standard. Good solutions brought by known methods are not new but still elementary in the field. They are contributions, not real-life inventions. Support to others in some need (in medical or psychological counseling; in education, in problem-solving: some have fixed a short circuit in a pipe, have given gifts, have transported people: "give a ride" or "turn into a taxi") Second Level: Improvement. This level consists of improving a system that already exists with a higher degree of progress and greater complexity in the same industry or a related one Third Level: Major improvements in systems that already exist by importing methods from other areas. Inventions within the paradigm Fourth Level: Inventions not related to the paradigm of conceiving a brand new generation of existing systems; changing the behavior basis of the essential function: "Non-technological, but scientific solutions" Fifth Level: Discovery process. Creators in the making of a brand new system. This usually consists of a big discovery, such as a new science
2. Cleverness in technological contributions	How many related existing jobs are there? It is the outcome of all technological research, based on patents and works found online—also, the optimization rate—the most favorable qualities that can be gathered
3. Added value	The relevance of the range of solutions for the market's problems or needs. Not only the promotion of productive activities and their development but also the big technological advantages, productivity, and competitiveness generated
4. Monetary factors	Are you able to multiply jobs? Does it help to reduce the operating costs? Are any other monetary benefits obtained from this?
5. Impact and relevance	The additional value to the communities, companies and society. The environmental impact and the rise in quality of life
6. Quality of the memo	Quality in the way the information is presented. This includes the integration, structure, logical arrangement of ideas and, consequently, writing and spelling. References are especially important. Show technological research, bibliography, graphics, and reasoning; information that will support the conclusions. Appendices and citations

Source: Premio Tecnos [58]

- Piloting of the instruments was carried out in three higher-education institutions, with a combination of public and private institutions similar to the real sample.
- Adjustments were made to the original instruments and digitized in the Google Forms platform, which was used for the collection of information.
- Communication was done with those responsible for the engineering areas in each institution to request their authorization to carry out this study, defining the possible logistics for the collection of answers by students and teachers and taking the opportunity to apply the survey focused on collecting the data of the institution.
- The instruments were given to teachers and students in digital form over a total space of six weeks.
- The databases for the descriptive statistical analyses were developed, initially using the Microsoft Excel platform and then migrating to the IBM SPSS platform. Initially, the analysis was carried out in a general way and then continued with a more detailed analysis.
- Randomly, a project was selected by each institution, which was evaluated following the rubric defined for the Premio Tecnos [58].
- With this analysis, specific interviews covering an array of topics were determined for certain outstanding institutions (see results and conclusions below).
- The results and conclusions were elaborated.

3 Results and conclusions

This work contains the results obtained from the application of the instruments in the institutions and the relevant points that stood out in the students' results.

3.1 Results of the quantitative phase

The results of the quantitative phase are presented and categorized in the two major areas on which this document focuses, the institutions and students.

The most relevant findings are:

3.1.1 Institution

- More than 53% of the universities do not contemplate the development of innovation competencies in their students explicitly as a part of the curriculum.
- Female enrollment in these careers ranges from 11 to 25% in the institutions sampled.
- The three main strategies used by the institutions to promote innovation are (a) through student events and courses, 27%; (b) through teachers' training, 39%, and (c) construction of an environment dedicated to innovation and entrepreneurship, 19%.
- 33% of the technology careers in sampled institutions use projects in class to promote innovation among students.
- Of the universities that were a part of this study, 26% of their teachers do not meet internally or externally to discuss themes of innovation.
- 85% of teachers receive training to encourage innovation in their students. However, inside this percentage, 35% receive this training external to the institution. Note that 15% of teachers do not receive any training in innovation.
- Concerning collaboration between the industrial sector and the academia, 47% of institutions accept that there is little collaboration between these entities.
- More than 53% of universities are not generating patents.
- 73% of the universities show that the incorporation of high-technology laboratories has a big positive impact on the institution.
- The majority of the institutions (93%) could generate projects hatched in high technology or innovation laboratories with commercial feasibility.
- 47% of the institutions have not been able to collaborate with other universities in innovation projects.

3.1.2 Students

- The vast majority of the universities have a student body consisting mainly of men (71%), while only two institutions report having more than half of students who are female.
- Regarding the level of study of the parents, the reports show that 25% concluded secondary education. From this point, the percentages decrease as the level of studies increases.
- Mostly all the students at the general sample and the institutions are prepared to learn new techniques, skills and procedures to study.
- From the students' perspective, innovation activities are part of the curriculum. It should be noted that students have also devoted time to self-taught exercises with the same purpose.
- Results show that there are a few internal research groups linked to technology in which students can strengthen their creativity and innovation competencies through institutional projects.
- A way to encourage innovation that has had high acceptance on an international scale is through the implementation of events highlighting innovations, where young talented people internally show their different projects. 88% of the students have not had the chance to win a prize or a competition.
- 40% of students have attended at least one internal innovation event. A similar scenario is present in the case of events held outside the institution, where more than 44% of students have had the opportunity to attend at least one.
- 58% of the students confirm that the problems, projects or challenges assigned by the teachers are real-life challenges. This gives students experience to face everyday situations and, as a result, the learning outcomes are improved.
- Brainstorming and mind maps are the most known creativity techniques recognized by students.
- More than half of students (56%) commonly do not use innovation methodologies, either because they do not need them at the time or because they do not know of their existence.
- Most students consider that Information and Communication Technologies (ICT) are truly relevant and important in their learning process.
- 63% of the students are familiarized with the concepts of creativity and innovation.
- The majority of the students agree that the teacher acts as a consultant in the assigned projects.
- In the majority of the projects in the innovation area assigned by the teachers, students from other areas or careers are not involved (business administration area, industrial design, etc.).
- About a third of the students say they have not used technology or innovation laboratories over the past months.

3.2 Results of the qualitative phase

After the quantitative phase, there were some important results documented in the qualitative phase, the most important being:

- Several students share their motivation to obtain a university degree and to get a better job, and a lot of them expect to help their families after achieving these objectives.
- The fact they can count on a high technology or innovation laboratory in the university does not mean that is the determining factor for the development of the competency

of innovation. Other factors as well affect the development of these competencies.

- The organization of innovation events by the universities represents the most prominent activity of the institution to encourage the innovation competency.
- The majority of the institutions develop innovation competencies in a non-systematic way, where in some cases, they are not formal parts of the curriculum. They are carried out empirically by the teachers and even, in some instances, by the students.
- The lack of communication and utilization of collaborative skills have sometimes limited the efforts that could promote the development of innovation competency in the universities.
- Few universities genuinely have a strategy to encourage creativity and innovation with their students. The majority of the activities are carried out in an empirical, unstructured manner that limits the different efforts to promote creativity and innovation.
- In some institutions, the teachers, who average more than 14 years in the institution, receive their updates in new technological trends thanks to the contacts they have with their graduates, who are invited to participate and collaborate with their alma mater.

4 Recommendations

In the course of the investigation and to accomplish its objectives, several proposals were documented and are presented below.

4.1 Institution

- Efforts should continue to strengthen programs to promote diversity, specifically for women in engineering areas.
- Encourage an innovation culture in the institution, not only with teachers but also with students through different activities such as events, workshops, conferences, and others that the institution offers. The creativity of young people in Mexico is unique.
- Implement a strategy as part of the institution to promote creativity and innovation skills, understanding that our young people are growing in a world that is increasingly dominated by technology.
- Implement a strategy as part of the institution to promote the creation of intellectual property and patents.
- Continue analyzing the technological megatrends to identify which ones should be considered by the institution.
- Encourage collaborative work with local ecosystems, which includes a closer relationship with the industrial sector, government, and even other universities.

4.2 Students

- Continue fostering specific competencies like critical thinking.
- Encourage self-learning in their free time. Many students can develop their creativity and innovation skills through self-learning.
- Projects proposed to students in the courses should be based on real situations so that the students might be able to offer innovative solutions to the potential problems in their local ecosystems.
- Attend and participate in internal events of the institution and external ones as well, to strengthen personal and academic development.
- Take advantage of the programs, events, and facilities offered by the university for professional development.
- Learn to work in multidisciplinary groups to communicate and collaborate.

One of the areas where the educational and scientific community would benefit is the exploration, especially, of collaboration as a competency not only for students but also for teachers Working with multi-disciplinary groups in and among institutions can strengthen the professional development of all the actors of the university.

Currently, there is a big concern from the high technology industry that the number of engineers that Mexico would require shortly would not be covered in the short run by the Mexican academies and, consequently, having to open the door to recent graduates from other countries. In addition to this, the issue of diversity is relevant, because the presence of the female gender in engineering areas is limited. These points open the possibility of conducting a more in-depth study to detect the root problems that cause this situation. The development of creativity and innovation competencies in academic institutions has a high dependence upon numerous factors, but, unfortunately, in Mexico, strategies that allow the development of these skills for our future generations have not been formally incorporated. The industry might be able to help through different efforts, but collaboration between academia and industry often is limited, depending on the institution and state.

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