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Knowledge based urban development: An approach to innovation districts based on education

Roberto Ponce-Lopez[1,2†], Gonzalo Peraza-Mues[1*†], Fernando Gómez-Zaldívar[3†], Jorge Membrillo-Hernández[1,4‡], Alejandro Acuña-López[1,5§] and Patricia Caratozzolo[1,5‡§]

[1]Tecnologico de Monterrey, Institute for the Future of Education, Monterrey, Mexico, [2]Tecnologico de Monterrey, School of Government and Public Transformation, Monterrey, Mexico, [3]Tecnologico de Monterrey, Institute of Advanced Materials for Sustainable Manufacturing, Monterrey, Mexico, [4]Tecnologico de Monterrey, School of Engineering and Sciences, Mexico City, Mexico, [5]Tecnologico de Monterrey, School of Architecture, Art and Design, Monterrey, Mexico

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University of Johannesburg,
South Africa

*CORRESPONDENCE
Gonzalo Peraza-Mues
✉ gonzalo.peraza@tec.mx

†These authors have contributed equally to this work and share first authorship

‡These authors have contributed equally to this work and share senior authorship

§These authors have contributed equally to this work and share last authorship

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Education is a concept that encompasses not only the teaching-learning process but also the conditions, environment, and facilities in which it takes place. Education is a precondition to development because it serves as a society's primary engine of innovation. Therefore, the concept of a space designated as an Innovation District is essential for the creation of Sustainable Cities since it is in such spaces that jobs are created and new markets specializing in products and high-added value services emerge. However, in the past, successful innovation districts have generally been found in developed countries, which have sufficient resources to invest in projects of this magnitude. Our methodology consists of a case study, the city of Querétaro, in central Mexico, to analyze the role of higher education within developing countries that seek to create innovation districts. We employ quantitative methods such as Geographic Information Systems (GIS) and locations quotients, along with qualitative documentary analysis, to conduct a spatial-urban analysis, characterize the industrial configuration, and to analyze the design of educational models adapted to the needs of specific industries. The results of our case study suggest that cities from developing countries that are fast industrializing can best maximize their chances of success by encouraging an explicit collaboration between industry and education through a Triple Helix Model. Such a collaboration would be based on matching educational competencies with opportunities for industrial reconfiguration to carefully select the location for the new district and decide over its area of specialization.

KEYWORDS
innovation districts, STEM education, educational innovation, socially oriented education, higher education

Introduction

In a competitive world, where the knowledge economy and information serve as the main sources of innovation and economic growth, governments seek strategies to transform and increase the sophistication of their current production capabilities. Regional studies and economic geography have recently been paying more attention to the concept of the *innovation district*. An innovation district is a nexus of knowledge-based development in cities, where public and private actors work to foster, attract, and retain investment and talent in order to revitalize urban areas and increase knowledge-economy activities and general innovation (Esmaeilpoorarabi et al., 2020). An innovation district is a geographic area where leading-edge anchor institutions and companies both cluster and connect with start-ups, business incubators, and accelerators. Notable examples are Silicon Valley, 22@Barcelona and One-North in Singapore (Bottero et al., 2020). At the country level, we find Finland, United States and Australia as leading countries with an established policy of promoting this kind of innovation precincts (Esmaeilpoorarabi et al., 2018).

Regions and countries seek to nurture and develop their own innovation districts to create jobs and insert themselves into new markets by specializing into high value-added products and services. A new global network and division of labor encourage cities and regions to find a niche market in the new economies associated with information technology (Znagui and Rahmouni, 2019). Knowledge and innovation are the two most important resources needed to build a successful innovation district. To the extent that cities and regions can insert themselves into such a dynamic of knowledge creation and innovation, their economies will generate high value-added products and services through research, technology, and intellectual capacity.

Although knowledge is a necessary component of success, it, alone, is not sufficient to create an innovation district's success. Innovation is a creative way of thinking and acting, based on new perspectives and applications that help industry and science gain a strong competitive position (Yigitcanlar and Inkinen, 2019). Unlike with an industrial policy of the past, generating both knowledge and innovation is a complex issue that requires the collaboration of multiple actors from academia, government, and the private sector operating through what is known as the Triple Helix Model (Cai and Amaral, 2021). Economic growth based on innovation and knowledge requires the transformation of education, research and development tasks into knowledge and viable economic results. While education as such is the foundation of innovative growth, it is important to distinguish between formal education and the operational skills of implementation and practice that are typically obtained through work rather than study. The challenge is to create an educational model that includes the development of these important skills as well. In this way, the collaboration between education and skills are connected within a pool of resources: universities, local companies, and other intermediaries then work together to produce a platform or innovation system. Then, the collaborative network requires an organizational and institutional effort to drive it.

In summary, innovation districts offer a "leapfrog opportunity" for regions to join the global economy and create high-paying jobs related to innovation, creativity, and digital transformation. Countries aspire to build their own Silicon Valleys. However, the successful cases found in the literature are concentrated in rich countries that have enough resources to invest in a project of this magnitude. Such countries can build first-class facilities for the district, have highly developed technological industries, have a strong public/private system of education, and have strong institutions to coordinate a Triple Helix Model with multiple stakeholders. Given this history, the research question for this paper is: *How can developing countries aspiring to build an innovation district increase their chances of success?* What steps should they follow to design a sufficiently robust strategy that rises the probability of the strategy's success? Working from the international literature on innovation districts, we propose a conceptual and methodological framework where quantitative methods are combined in the areas of industry analysis, spatial-urban analysis, and design of educational models adapted to the needs of industries, with the aim of designing a collaborative strategy based on the Triple Helix. We attempt to answer this question through a case study of the city of the Queretaro, in central Mexico.

The type of strategy referred in the research question is a framework for the development of innovation ecosystems through the identification and prioritization of productive capabilities that ensure a strategic collaboration of the three key actors under the Triple Helix Model, specifically highlighting the strategic participation of universities and other higher education institutions in the development of the productive knowledge necessary to achieve the proposed objectives. Legal, economic and financial incentives and an appropriate institutional framework must be put in place to make this collaboration most likely to happen.

Literature review

The literature on innovation districts can be divided into two groups. We find the first one in the field of economic geography, where the work of scholars such as Michael Storper and Allen J. Scott are amongst the most prominent (Kemeny and Storper, 2020; Scott, 2022). This group argues that institutions are the crucial element for the success of an innovation district (Martin et al., 2018). Institutions can be described as hard or soft. Hard ones have a defined organizational framework that facilitates communication and collaboration among government, industry, and universities. Soft institutions are the organizations that provide cultural and informal ties that foster creativity and provide the ability to recombine inputs and knowledge inputs in order to craft new ones. Soft institutions constitute the social and cultural elements that favor innovation and nurture new knowledge. One classic example that illustrates this theory is that of the emergence, at the beginning of the 20th century, of Detroit as an automotive innovation district (Drucker et al., 2019). In Detroit, there was a preexisting culture of entrepreneurship and access to capital based on the shipyards and boat production. The mixture of pre-existent institutions and cultural capital facilitated the transition from a nautical to an automotive industry; and skills and materials were reconfigured to generate new markets, products, and services. According to this school of thought, the emergence of an innovation district such as Silicon Valley or Bangalore is something organic and heavily influenced by the pre-existing soft institutions. Given this relationship, it is, thus, difficult to replicate through top-down planning design.

The second body of literature on innovation districts comes from the field of urban economics and authors such as Florida and Mellander (2020), Glaeser (2022), and others (Pratt, 2021). These authors argue that the attraction and retention of highly specialized human capital is the critical element for the success of an innovation district (Zhang et al., 2020). Florida calls this sector of the population the creative class, and to the extent that a city can attract and retain this creative class, new entrepreneurial ventures will begin to sprout (Mellander and Florida, 2018). He further adds that this class highly values a certain lifestyle and access to certain types of amenities such as cafes, art galleries, and restaurants. Therefore, cities should focus on fostering the creation of innovation districts that guarantee access to such amenities, including affordable housing. According to Florida, the creative class is nomadic and moves to where it finds the urban environments that best support its expression. His theory has been influential in the planning and design of innovation districts, most notably in Southeast Asia, where live-work-play-learning communities have become popular (Esmaeilpoorarabi et al., 2018). These communities consist of innovation districts that offer integrated housing, workplace amenities, and leisure offerings to attract and retain the creative class. Austin, TX is also seen as a success story for its cultural and musical offerings (Baily and Montalbano, 2018). As can be noted, the planning of these communities or districts has been careful and favored mixed uses that combine services, as well as interventions of urban space for the creation of cultural and leisure amenities. In summary, the two academic traditions offer two contrasting visions of the feasibility of attaining a successful innovation district by design that uses a top-down approach: centered on institutions and centered around the presence of the creative class. Tan Yigitcanlar (Yigitcanlar and Inkinen, 2019) and his group at the Queensland University of Technology in Australia propose a third approach based on the concept of *knowledge-based urban development* (Carrillo et al., 2018). This concept entails an array of factors that range from governance and education to urban development. The regions with the capability of tapping these varied encompassing elements increase the chances of success of the innovation district.

Despite the great deal of literature on innovation districts, we identify an important gap regarding the role of higher education in the success of innovation districts. The referred literature in innovation districts typically endorses the Triple Helix Model of governance described above (Etzkowitz and Zhou, 2017; Galvao et al., 2019; Cai and Amaral, 2021), which—again—focuses on the governance model and institutional arrangement among these three actors. The literature on Triple Helix Model also recognizes the need for universities to build the human capital that will grasp the opportunities that an innovation district generates. However, they do not delve into the identification of the necessary skills for the development of productive activities, nor the design of educational and pedagogical models that are more suitable in this Triple Helix Model to sustain the growth of an innovation district. Thus, the challenge for the current study is to create an educational framework to support students´ innovation and learning activities in the niche markets where regions seek to specialize. This is an opportunity for the field of education to contribute to this literature by claiming a more essential and active role for pedagogy in the design and planning of innovation districts that also take into consideration the specific industrial and urban context of the region. We explicitly address this role and these relationships in the framework described below.

Conceptual framework

Innovation districts are knowledge precincts that specialize in innovation and creativity. Within such districts, both information technologies (IT) and human capital are needed to recombine or create new products. Thus, the formation, attraction, and retention of human capital are critical for the success of a district. Our proposed framework focuses on the development of human capital, for which it is necessary to teach both so-called "hard" (technical) and "soft" (humanistic) knowledge and associated skills. The technical knowledge must be linked to the existing industrial or economic profile of the city, while the humanistic skills encourage the development of critical thinking and creativity in students.

The literature on innovation districts from economic geography focuses on the role played by institutions of higher education in the emergence of knowledge precincts, but it does not address the educational aspects of these precincts in enough detail. The creation of new or proposed industrial firms in the region creates a demand for new worker competencies that is generally not met by existing academic programs. Higher education institutions need to continually adapt and change to teach both the newly emergent required technical competencies and the additional necessary competencies that foster innovation and creativity in students. We consider that both aspects are critical to an innovation district's consolidation and success within a region. These competencies must be found within the industrial capabilities of the local region and linked to the urban context in the location of the proposed innovation district.

Fostering creativity and innovation in human capital to create a creative class is a daunting task that could benefit enormously from the recent advances in the field of education. The concept of Education 4.0 that offers students both technical competencies and experiential learning can provide the foundation for specific pedagogical models that allow innovation districts to attain their full potential. However, to adapt curricula and teaching practices, a feedback loop must be established between academia and industry both during the district planning stages and as the established district evolves.

Though an important consideration, the specific role each party takes in this interchange has not been discussed in enough detail in the current literature about either stage. This paper discusses ways such a feedback loop could be initiated and spells out the influence and importance of the university's role and teaching practices. We do so by investigating the triple helix model and proposing specific ways for government, business, and academia to partner and collaborate (Figure 1).

To determine the potential of a region based on its industrial configuration and to select specific industries with local potential for innovation and continued growth, an initial diagnosis of industrial capabilities is needed. To generate the capabilities identified in the industrial diagnosis and to propose an educational plan, an evaluation of the current educational system is needed. Finally, to retain and maintain the human capital that will be needed, features of the urban environment must be considered in determining the location where the proposed district should be placed. This is particularly useful for countries in the global south seeking to maximize resources and to increase the odds of success of an innovation district. The next section introduces our case study.

Methodology

Our methodology consisted of a Descriptive Case Study. To ensure the validity of the construct, the following three conditions were considered fulfilled (Rashid et al., 2019):

a. The form of the research question is how or why and requires an explanatory answer,
b. There is no investigative requirement to control behavioral events, and
c. The focus of the research is on contemporary events.

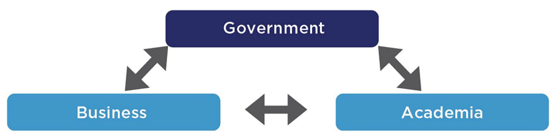

FIGURE 1
Triple Helix Model. Own elaboration.

The case study method implemented in this paper described and discussed a contemporary phenomenon in depth and related it to its real-life context, ensuring that the boundaries between phenomenon and context did not overlap (Yin, 2018). The research met these criteria and conditions: The research questions sought to investigate the impact of a more in-depth industry assessment and specially designed education policy in increasing the chances of success of a planned innovation district within the context of developing countries.

Case study selection: Queretaro, Mexico

The case study focused on the Metropolitan Area of Queretaro (MAQ), a 3-h drive from Mexico City, which has become an important industrial hub for the country. The city's international airport offers direct flights and connections to other regions of Mexico and the United States. MAQ was selected specifically in an attempt an answer to our research question about collaboration frameworks between academia, business and government to increase the chances of success for an innovation district at developing countries. MAQ is an urban region in a developing country, that has experienced accelerated industrial growth in the manufacturing sector. A similarly fast paced urbanization has accompanied this industrial growth, shaped by processes of urbanization that are common to fast-growing cities in Latin America, such as sprawl, informality and lack of infrastructure (Nieto and Niño-Amézquita, 2019).

In terms of innovation, the MAQ has the intention of planning and developing an innovation district. Different stakeholders have announced their ambitions to plan for one, including the two largest universities (a public and a private one), and both the state and local governments. These stakeholders have taken the initial steps in the planning process. Public officials interviewed for our research announced their ambition to have an innovation district specialized in gaming and the metaverse or a creative district specialized in design. However, again, the biggest challenge to leapfrog to such creation of new jobs might be the formation of human capital through very specialized higher education programs.

In this context, the local government, academia, and business work together to foster an innovation district for the region. The goal of such an innovation district is twofold: to leapfrog from manufacturing to more productive jobs, and to regenerate the urban space and create a district that can attract and retain the most productive human capital in the city. In the past, the problem has been that it is hard to combine these differing goals, especially for relatively poor regions. The case of MAQ can help to elucidate a pathway for regions to combine education and industrial policy to make precision shots that increase the likelihood of successfully establishing a thriving innovation district.

Case study description

MAQ's urban area has grown at a faster rate than its overall population. Between 1990 and 2020, the population of the metropolitan area increased from 579,597 inhabitants to 1.4 million, while its urban area increased from 60 square kilometers to 250. The population doubled while the urbanized area grew more than fourfold. This burgeoning growth resulted in a 42% reduction in population density over thirty years. In other words, the metropolitan area was forced to provide public services for an area that was 4.2 times bigger but had only 2.4 times more resources available (Elías and Cruz, 2018).

A comparison of the total population reported in census tracts from 2000, 2010, and 2020 shows that the highest rates of demographic growth occurred in the suburbs and outskirts of the city. The downtown area and the functional urban areas-- built in the 1960s and 1970s-- lose population and turn to commercial uses. The depopulating downtown area is a historic site with many cultural amenities that caused UNESCO to add it to its list of World Heritage Sites in 1996, in part because of its architecture that dates to the XVII and XVIII centuries. Today, city's downtown is a commercial and touristic area that houses boutique hotels, restaurants, and shops. In terms of employment, the city is experiencing a slow transition to a polycentric structure, as employment is slowly migrating to the suburbs, following an earlier the population shift. This change is creating new centralities located near the new suburbs. The city's changing morphology requires an expanded transportation infrastructure to connect new sub-centers of employment without using the already congested central area as a hub.

On the economic side, it is important to highlight the growth and industrial transformation that the Metropolitan Area of Querétaro (MAQ) had in 15 recent years (2004–2019). With regard to employment, in the 2004 Economic Censuses,[1] it can be seen that the number of employed in the MAQ totaled 177,493, while for 2019 the total was 506,960 (INEGI, 2019). This growth in employment was accompanied by a transformation in shared employment within the secondary sector (manufacturing industries, mainly), which increased from 31 to 35% of total employment in the region. Although the tertiary sector registered growth in absolute terms, its relative importance fell from 69 to 65% in the same period.

One of the most interesting results of the industrial transformation during this period was the appearance of new and more technical industries, which may, at first glance, seem to explain the strong economic growth that the MAQ has had in recent years (Geografía (INEGI), 2019). Figure 2 shows the 10 industries that did not exist in 2004 but that by 2019 already accounted for a significant amount of local employment. Over this 15-year period, the city both became a global hub for aerospace manufacturing and financial services, wholesale trade, and other manufacturing industries also experienced impressive growth.

To thrive in the global economy, innovation districts often focus on industries producing high added value within the areas of knowledge and technology. Mexico's 2019 Economic Census (INEGI, 2019), shows that the country's manufacturing industries generated around 52% of the total added value. In a disaggregated manner, the following industries were the leaders in terms of value creation: parts for motor vehicles (16%), plastic products (6%), pharmaceutical products (5%), aerospace equipment (2%), and electrical appliances (2%).

With regard to higher education, in the State of Queretaro and based on information from the National Association of Universities and Institutions of Higher Education, ANUIES, (ANUIES, 2022), we can observe that from the period 2011–2012 to 2020–2021, the number students enrolled increased by 66%, from 49,627 to 82,341. Moreover, the enrollment of students in professional and technological careers related to STEM increased by 60% (from 18,134 to 28,994 students). Of

1 Economic Censuses are the most detailed and disaggregated source of economic and industrial information in Mexico. They are collected every 5years by the National Institute of Statistics and Geography (INEGI).

the total number of higher education students in the state, 86% were concentrated in the MAQ, which included the municipalities of Queretaro, Corregidora, and El Marquez.

Figure 3 below shows the total figures for enrollment in higher education from 2011 to 2022 and the corresponding figures for STEM careers. A drop in total enrollment due to the impact of the COVID-19 pandemic can be observed in the 2019–2020 period, with a slight recovery occurring in the following period. In terms of education, we observe an increase in the enrollment of students in STEM, but the numbers have been stagnant for the past decade. Also, the increase in STEM numbers for the region was lower than the population growth for the last ten years (relative to now).

In summary, the MAQ is a region with an impressive rate of growth with regard to its economy, population, and sprawl of the urbanized area. Economic development has attracted new industries and people seeking jobs from other regions of Mexico, creating an increased demand for housing and land zoned as industrial, all of which have shaped the process of urbanization. The city has favored a model of suburbanization and depopulation of the central area, although the old areas of Queretaro are rich in amenities and are neighborhoods that could be well suited to a project like an innovation district, which would, in turn, attract and retain a creative class. Despite all this potential, enrollment in STEM in higher education has increased but has remained stagnant for the last decade and this is a limitation to economic growth. Education policy must play a more active role in the planning and execution of economic plans for the region.

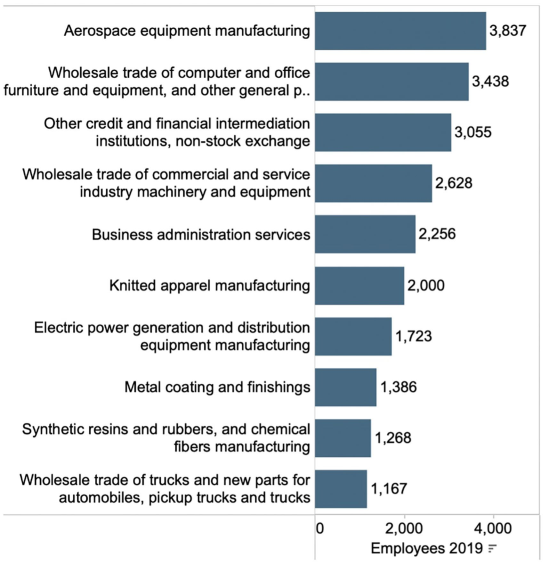

FIGURE 2
Top 10 industries that have emerged from 2004 to 2019. Own calculation based on Economic Censuses (INEGI) of 2004 and 2019.

A diagnosis to create specific recommendations for a triple helix model

Within our conceptual framework and the local context of the MAQ, it is understood that the probability of developing new industries and goods in innovation districts will be strongly linked to the availability of human capital able to innovate and recombine existing capacities in new products and services. Achieving a history of success in innovation districts requires specific education strategies to form the required capabilities in the short, medium, and long term. These strategies must include consideration of the urban component since it seeks not only to train but also to attract and retain specialized human capital by offering the appropriate amenities for their lifestyle. It must be noted that this is not a minor task for subnational governments (state and municipal) since it requires not only great technical, financial, and institutional capabilities, but also a shared

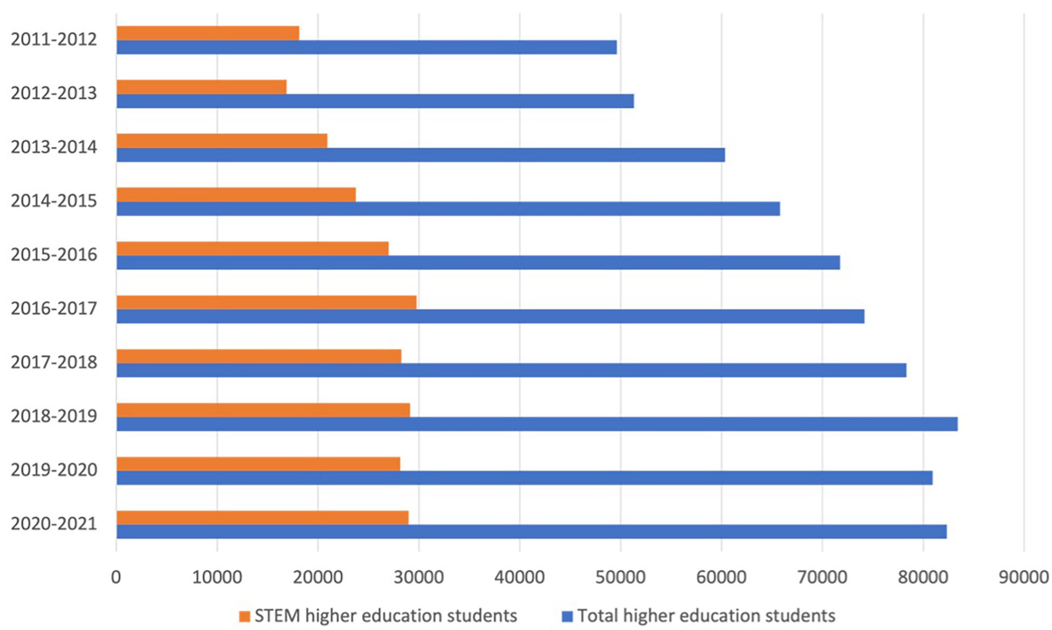

FIGURE 3
Enrollment of students in higher education and STEM degrees in the State of Queretaro by year. Own elaboration based on ANUIES, 2022.

long-term vision established jointly by government, companies, the community, and educational centers. Our proposed framework supports the goal of creating such an innovation ecosystem by providing the following three assessments in the planning stage: industrial, urban, and educational. The following sections discusses the three of these regarding the MAQ.

Assessment methods

Industrial assessment

A disaggregated diagnosis of the economic and industrial structure of the MAQ was developed to identify strategic industries for the specialization of the district, in terms of their:

1. Economic weight, added value, and employment generated in the area;
2. Potential for integration into local, national, and international supply chains;
3. Technological sophistication and potential to generate new productive capabilities within the region; and.
4. Potential to generate new productive capabilities in the region that would drive opportunities for innovation in products and services, and result in greater diversification leading towards more technologically sophisticated industries.

Our assessment identifies the industries or services with high economic weight, competitiveness, and technological level that could serve as a foundation for an innovation district in the MAQ, and its assessment is based on the methods from economic complexity (Hidalgo, 2021). Using the data from the 2019 Economic Census, we first prioritized industries that rank high for (1) economic weight for the MAQ in terms of employed personnel and added value; (2) competitiveness based on their level of specialization or the degree of relatedness to existing productive capabilities (distance); and (3) sophistication or technological level, based on the index of industrial complexity. Next, we used the Industrial Complexity Index (ICI)[2] to identify industries with greater sophistication and a higher technological level. See (Hidalgo, 2021) for the derivation of the mathematical specification of the ICI. Finally, we built a composite index to rank the industries by their economic impact (both value added and employment) and for their current proximity to the existing productive capabilities of the region. Refer to (Balland et al., 2022) for the methodology used to calculate the shortest distance between industries. Data to compute the indexes were processed in Excel and R. Visualization is performed in Tableau.

2 The ICI classifies the diversity and sophistication of the productive knowledge required by an industry. It is calculated based on how many other metropolitan areas can develop an industry and the economic complexity of those regions. The ICI captures the amount and sophistication of the knowledge required to develop an industry. More complex industries (which only highly complex regions can produce) include sophisticated machinery, electronics and chemicals, compared to less complex products (which almost all regions, including the least complex ones, can produce) which include raw materials and agricultural products.

Urban assessment

Our main method of analysis consisted of using Geographic Information Systems (GIS) in Python programming language and QGIS software to process spatial and census data for the MAQ. We calculated the build area of the city from the Global Impervious Surface Area (GISA) dataset to characterize urban growth and sprawl (Huang et al., 2021). GISA is a raster file that uses remote sensing data to classify 30×30-meter pixels into built and non-built categories for the surface areas. By adding up the area of built pixels inside the MAQ, it was possible for us to estimate the total impervious area for the region for the years since 1990.

Additionally, the decennial census information for 1990, 2000, 2010, and 2020 per unit area was processed, using census blocks and census tract, along with GIS. This profile enabled us to characterize the change in demographic and sociodemographic attributes over the decades by looking at the rate of change in the total population and the sociodemographic composition of neighborhoods.

Educational assessment

The model of Education, Competencies, and Learning that was designed in this study to assess for the educational programs of an Innovation District in the MAQ was based on the dynamic Strategic Intelligence platform of the 2022 WEF (World Economic Forum, 2022). The platform's information draws on the collective intelligence of the WEF network to explore key trends, interconnections, and interdependencies between industry and regional or global issues. The visual representation of this topic, *Transformation Map*, is an interactive version available online at,[3] where an overview of issues and key trends affecting them can be found, along with summaries and links to the latest research and analyses on each of the trends. The summaries for the countries also include data from the WEF benchmarking indices.

To search for key occupations by industrial branch and the skills associated with these occupations, the National Occupation and Employment Survey, ENOE, of Mexico (INEGI, 2022) and the O*Net database of the United States of America (O*NET Program, 2022) were used. Subsequently, two main variables were selected from these databases: namely, the number of employed persons by branch of economic activity, as well as the list of their occupations. Finally, the branch of economic activity, which is identified with a 4-digit code from the North American Industrial Classification System, NAICS (INEGI, 2018), was associated with the occupations related to each of the branches.

From the number of employed persons by type of occupation and branch, the Location Quotient (LQ) indicator was estimated to determine the level of specialization or concentration for each occupation considered within the economic branches, using the National Occupational Classification System, SINCO (INEGI, 2019), of the ENOE. The higher the LQ indicator, the greater the presumed importance of a given occupation within the branch of economic activity, described with the equation:

$$LQ_{z,i} = \frac{\frac{e_{z,i}}{e_i}}{\frac{E_z}{E}}$$

3 https://intelligence.weforum.org

where $e_{z,i}$ is the level of employment in occupation z in industry i; e_i is employment of all occupations in industry i; E_z is the employment of that occupation z in all industries and, E is the total employment in all occupations and all industries. The quotient was computed in Excel software.

From the previous analysis, relevant skills for the key occupations are identified from the data bases. An analysis on educational models to foster these skills is performed.

Results

Industrial assessment

The criteria of economic complexity were used to determine the comparative advantage of industries in the region. Figure 4 ranks the industries by comparative advantage for the MAQ from highest to lowest.

The greatest comparative advantage of the region can be seen in personal services, insurance, and aerospace equipment manufacturing.

The ICI of 276 industrial branches registered at the national level in the 2019 Economic Censuses was estimated. At a national level, the most complex industries in Mexico are those within the area of Financial Services. In this way, it was possible to identify the most sophisticated industries for which the MAQ has a high level of competitiveness as compared to most of the country's metropolitan areas. As can be seen in Figure 5, the most complex industries with the greatest comparative advantage are found in the manufacturing sector.

The industries in which the MAQ currently specializes were prioritized, and the manufacturing of automotive vehicle parts stands out as one of the most important industries in economic, technological, and competitive terms for the region.

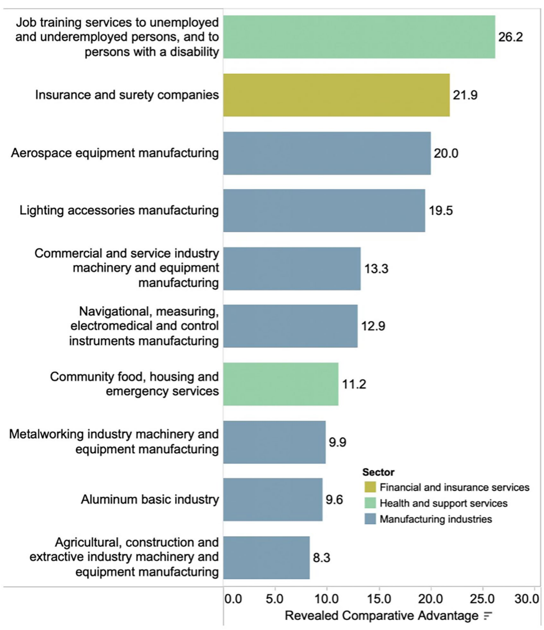

FIGURE 4
Industrial specialization of the MAQ. Own elaboration based on Economic Censuses 2019 (INEGI).

Next, the composite index of economic impact was estimated (Balland et al., 2022). Figure 6 illustrates the results and ranks the industries based on such composite index. Although the industries in the manufacturing sector once again show up in the highest ranks, new industries also appear possible to develop in the MAQ within the sectors of technical and professional services and amass media information. Specifically, the design of computer systems and the development and edition of the system software, programming, application, or mass or packaged entertainment, industries based on the knowledge and capabilities of the creative economy are presented as viable options for the specialization of the innovation district. The following three industries were selected for the educational assessment found later in this paper: 1. software publishing and integrated software publishing and reproduction; 2. electronic data processing, hosting, and other related services; and 3. computer systems design and related services.

In summary, there were two important findings from the industrial assessment: First, the MAQ already showed a high degree of specialization in manufacturing, and the region is known nationally for this. Second, activities related to IT grew quickly between 2004 and 2019. The next obvious question was: which industry selection is most important for an innovation district to specialize in? This is where the Triple Helix model matters because it is not only a technical question. The industrial assessment sheds light on the patterns of industrial growth and shortlists several activities. However, stakeholders and the academia must discuss these shortlisted alternatives to build a collective vision and educational policy to form such human capital that can grasp these new opportunities and these industries ripe. For instance, in the case of the MAQ, it seems plausible to promote IT-related activities, but also to foster the conversion of manufacturing into Industry 4.0 capabilities with Artificial Intelligence (AI) and the Internet of Things (IoT).

Urban assessment

The construction of a district involves the investment of capital and the provision of infrastructure within one or more specific locations in the city. A project of this nature has a regional and metropolitan impact that reshapes urban form, transportation demand, and housing prices in the city. Thus, an innovation district is large enough that it can regenerate and/or socially transform an area of a city, improving or worsening its access to employment, transport, and leisure for the region. In addition to its potential for transforming a center of development the innovation district must also recreate an urban environment that is attractive to the creative class that will join the new labor market that will develop.

The most important trait of the model of urbanization for the Queretaro area is suburban sprawl. Over the last three decades, new, low-density neighborhoods sprouted in the city's outskirts, pushing the urban boundaries further from its center. Moreover, the industrial development of the last 15 years that we referred to in the previous section was one of the drivers of sprawl. Figure 7 compares the urbanized areas in 1991 and 2019, by which they had increased by a factor of 4.

The urban sprawl has reconfigured spatial patterns with regard for the location of people and jobs. Understanding these patterns and spatial-demographic dynamics is very important when choosing the location of an innovation district. We analyzed the changes in the location of people and jobs for the last 2 decades. Figure 8 traces concentric circles every 1 kilometer starting downtown. We used the census blocks from 2000 and 2020 to compare the population change

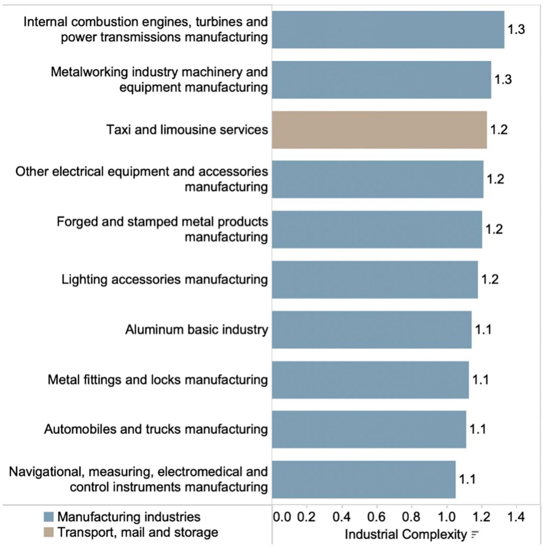

FIGURE 5
Top 10 industries with greater complexity and specialization of the MAQ. Own elaboration based on Economic Censuses 2019 (INEGI).

represented by a concentric circle, and we did the same for the number of jobs between 2000 and 2010. These years were selected because information on employment units was only available after 2010, and because the census data by block were available only after 2000. The concentric circles are useful to trace demographic patterns of internal migration from the center of the city to the suburbs. After this analysis, we repeated this exercise for the elderly and youth as well.

The red circles in Figure 8 show a declining population and a negative balance between 2000 and 2020. The blue circles illustrate the areas with a net growth in total population. The demographic implication of urban sprawl can be seen in the rearrangement of spatial population patterns within the metropolitan area. In terms of population, we observe a loss in the central zone and migration towards the urban periphery. The lack of affordable land and of an adequate housing supply in the central zone are the main causes of this sprawl: young families move to areas with a generous housing supply where their economic hopes and lifestyle aspirations can be met; this mainly happens mainly in the suburbs. The paradox is that the city, which has the best transportation infrastructure and services, is losing population and this is a factor that those selecting the site for an innovation district should consider.

In terms of employment growth, the comparison between 2020 and 2010 shows that the highest density of economic units and

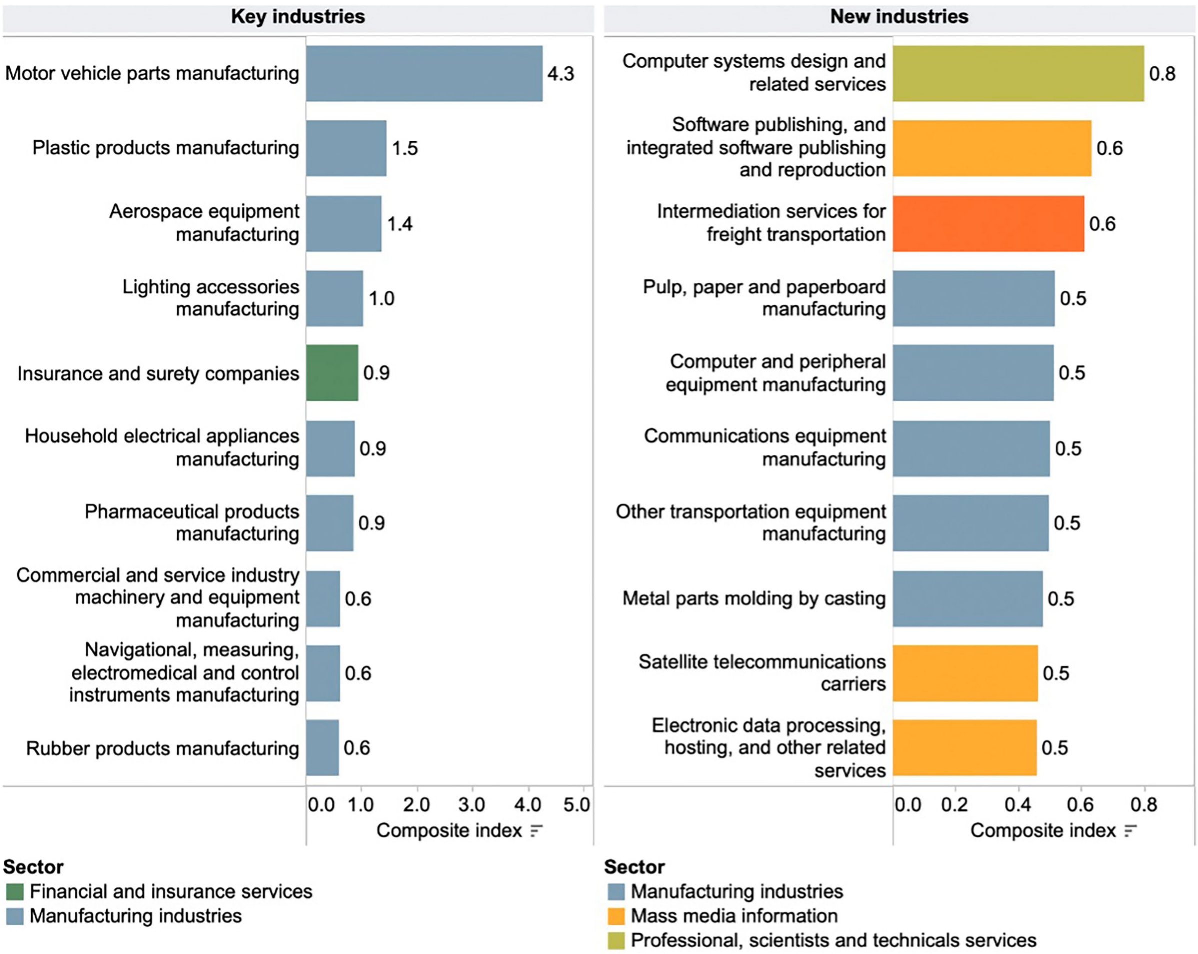

FIGURE 6
Top 10 key new industries of the MAQ. Own elaboration.

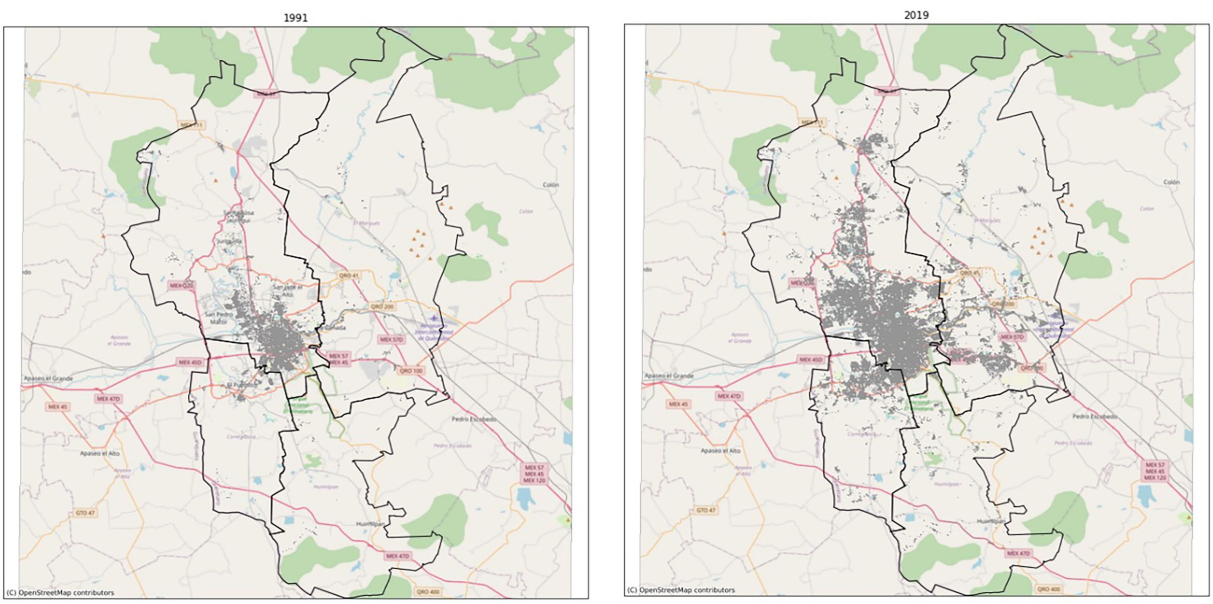

FIGURE 7
Urbanized area in the MAQ. Own elaboration.

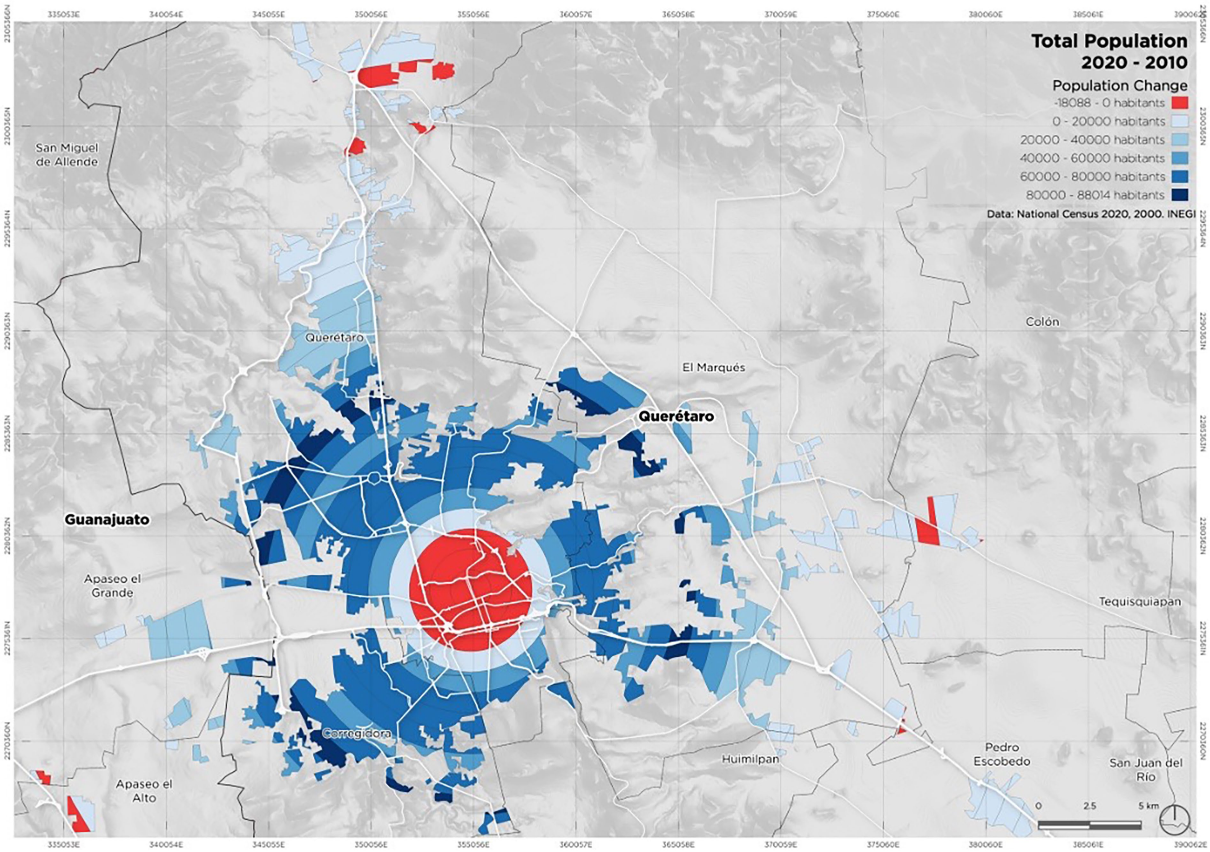

FIGURE 8
Population changes indicated by concentric circles (1-kilometer betweenness) from 2000 to 2020. Own elaboration based on the decennial censuses from iNEGI for 2000, 2010 and 2020 by block.

employment was still in the central zone of Queretaro, that is, in the area located less than 6 kilometers from the historic center. This area coincides with the one that has lost population in the last 20 years. However, job creation in the MAQ has been also gradually deconcentrated from the central zone, generating new urban centralities located in the suburbs. In urban terms, the city is said to be going through a transition from a monocentric to a polycentric city.

Territorial expansion and the loss of residential density in the central zone are the main traits of urban growth in the MAQ. The central zone retains its commercial attraction because it is the most accessible zone in the metropolitan area. This territorial pattern of sprawl is not sustainable in the long run. Thus, it is desirable to re-densify the central area and promote a community of mixed uses. The central area of the city has the best access to existing services and urban infrastructure such as hospitals, schools, and amenities are already built.

In this context, a critical choice suggested by use of the Triple Helix Model is the selection of the most suitable location for an innovation district, a decision in which the three actors and the community as a whole must be involved. This assessment of urban growth shows that the central area of the city, which has been depopulated but still has amenities, has enormous potential to host an innovation district. This area comprises downtown, but it also includes other neighborhoods that were built in the 1950s and 1960s. It has neighborhoods, amenities, and proximity to institutions of higher education, and is, thus, suitable to host an innovation district and accommodate a creative class that might live in proximity to the district. Other factors, such as available land, the relative location of the site to universities, and the participation of the community, should be considered when making a final choice for the location of the innovation district. This participatory process that involves the urban context in the selection of the site for the innovation district embodies the principles of Knowledge-Based Urban Development.

Up to this point, the industrial assessment has been useful to shortlist a selection of industries with special potential to establish and develop in the innovation district, conditional on the strengths of the region in human capital and industrial profile. Then, the urban assessment analyzed the process of urbanization of the city and discussed the convenience of locating the district into an area having the potential for re-densification and amenity creation in order to grow the human capital for the district. Once the new strategic industries with the greatest potential to thrive in the region were identified, and anchored in the urban context, an educational assessment was done to complete the plan. The objective was to meet the potential demand for specialized workers in new industries, which will require not only the training of new professionals and technicians, but also the possible retraining of current workers from related industries. In the Triple Helix Model, it is important to link these two assessments, industrial and educational, so that they can work together in the reconfiguration or creation of educational programs, professional careers, and continuous training courses. In a city such as MAQ in a developing country, this step is not automatic and requires the active engagement of all the stakeholders.

Educational assessment

The model of Education, Competencies, and Learning for the educational programs of an Innovation District in the MAQ is supported by 4 pillars:

1. Educational Innovation.
2. Skills Development.
3. Digital Transformation.
4. Lifelong Learning.

Figure 9 below shows the fundamental elements of the model from the perspective of the development of basic and transversal competences. The model must meet the requirements of the Fourth Industrial Revolution (4IR), but it must also meet the following 3 criteria: focus on the training of specialized labor and for occupations that are a priority in the technology sector; respect public finances and educational programs for emerging industries; and include STEM skills.

In the ENOE survey, the INEGI (2022) collects quarterly information on the characteristics of the workforce, occupations, labor informality, underemployment, and unemployment. This survey is carried out in 39 representative cities of the 32 states of the country. The ENOE classifies occupations based on the National Occupational Classification System, SINCO (INEGI, 2019).

We computed the Location Quotient (LQ), or the significance of a particular occupation within a branch of economic activity, and now present the results. Three new industries with the greatest growth potential in the MAQ were selected for study based on the outcome of the industrial assessment (see Figure 6). These were: software publishing and integrated software publishing and reproduction; electronic data processing, hosting, and other related services; and computer systems design and related services. For these industries, the most important occupations by economic branch were considered, the equivalence was made with the NAICS of the Economic Censuses to assign the occupations to the strategic industries that resulted from the first stage of the project analysis and the most suitable industries to consider as part of the educational programs of the District of Innovation those indicated in Figure 10, where the corresponding NAICS code is indicated in parentheses. In addition to their importance with regard to specialization, the occupations most related to the video game industries, such as technicians or software developers, were determined as cases of interest in the Queretaro KBUD Innovation District study.

The second source consulted was the O*NET Program (2022), a database that describes the characteristics of occupations and required skills, knowledge, and other features for the types of occupations-codified using the Standard Occupational Classification (SOC) and economic activities noted within NAICS. This information has become a basic tool for both workers and employers because it describes the characteristics of almost 1,000 occupations that cover all economic sectors in the United States in a way that reveals both the skills companies are looking for in various occupations and the skills that will allow them to be competitive in the market. Using this list of occupations and skills, the equivalences were sought, especially for the occupations with the SINCO in order to be able to relate the skills to each occupation. Table 1 includes the possible jobs activities according to the SINCO classification for the three NAICS branches of Figure 10.

To determine the skills required for each of the jobs chosen according to the SINCO classification, an analysis of the databases was carried out and the required skills were determined. Figure 11 shows, as an example, the skills identified for the SINCO #2271.

High-value-added industries and services depend on local human capital with the skills required to enter new labor markets and aspirations for entrepreneurship and innovation. These technical/critical-thinking and entrepreneurial skills can be taught and learned through the educational system and are necessary for the success of an innovation precinct.

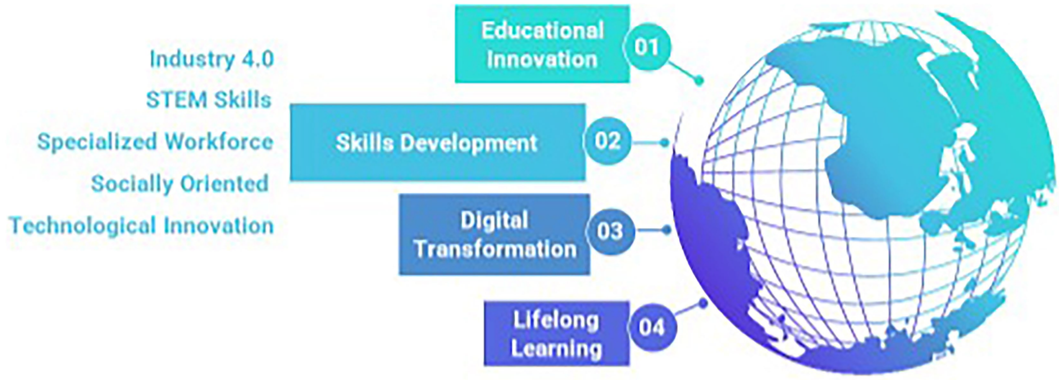

FIGURE 9
Education, Skills, and Learning Model for a KBUD Innovation District. Own elaboration based on the Education 2030 Report (OECD).

FIGURE 10
Examples of branches of the videogames sector according the NAICS. Own elaboration based on NAICS codes of the Economic Censuses.

Innovation district and education 4.0: Framework, characteristics, and technologies

In innovation districts, the training of human capital in skills and abilities associated with Industry 4.0 is essential to meet the hiring requirements of high-value industries and to become competitive entrepreneurs in the new technological markets. Industry 4.0 is defined as digital production having real-time reaction and optimized artificial intelligence systems, which works in a highly self-managed network (Koizumi, 2019). Industry 4.0 is characterized by the consolidated use of emerging technologies, including artificial intelligence, the Internet of Things (IoT), advanced data analytics, cloud computing, virtual and augmented reality, robotic process automation, blockchain, drones, and other digital technologies that can transform work (Martinelli et al., 2021). With the concept of Industry 4.0 advancing rapidly within all aspects of production, jobs and occupations in this sector are constantly changing and will keep changing in the future. Therefore, there is a need for ongoing training to help workers improve those skills and competencies that allow them to continuously learn and use new knowledge to both ensure their own employability and contribute to the development of a sustainable world. It is especially important that Industry 4.0 workers develop a lifelong learning mindset that allows them to easily adapt to changes and transformation, always acquiring and updating the knowledge and skills necessary to perform well in constantly evolving work situations (UNESCO & Institute for Lifelong Learning, 2020).

Traditionally, professionals and technicians working in the technology sector have followed a structured and often rigid path to advance in their professions, so continuing education for these workers has also been associated with structured curricula. The current era of Industry 4.0 requires that upskilling and reskilling ongoing training programs to include the preparation of professionals with regard to such specific topics as: process digitization, 3D printing, artificial intelligence, data analysis, robotics, additive manufacturing and blockchain (World Economic Forum, 2018). A completely new educational model, called Education 4.0, embraces this new form of training. Education 4.0 involves Continuing Education (CE) and Lifelong Learning (LLL) and represents a scenario in which workers must consider continuous training carry out functions based on constantly changing technologies, and improve their skills and competencies to avoid job obsolescence (Chakrabarti et al., 2021).

The World Economic Forum estimates that by 2023, 75 million jobs will be eliminated by the shift from human to machine work--but that a further 133 million new jobs will be created to accommodate ever-expanding digital workplaces (Ratcheva et al., 2020). Even before the pandemic, a strong sense of uncertainty among workers regarding how the workforce would be affected as Industry 4.0 unfolded. Skills gaps continue to be a challenge to success; the biggest impact of this skills shortage in business has been the inability to innovate effectively. Such gaps and the potential limitations they impose will be very relevant for innovation districts. Industry 4.0 not only generates demand for new skills related to new technologies, but also demands new attitudes and temperaments associated with new concepts of work, workforces, and workplaces.

Regarding the concept of *work*, it can be said that Industry 4.0 represents a cognitive revolution, in the sense of changing our understanding of performing tasks and solving problems. This change is eliminating more than 14%, and disrupting 32% of current jobs (Nayak et al., 2022). Roles are being redefined, combining technology with human skills, and incorporating new kinds of skills, abilities, activities, and practices. One of the roles of an Innovation District's continuing education and LLL programs will be to change the way work is handled and to develop the training that a workforce needs in the short term to take on these new roles and assignments.

Industry 4.0 redefines the concept of the *workforce*, and its changing demographics (it has become older and more diverse in recent years) must be taken into account. However, with this approach, the social contract between employees and employers has also been transformed: from the ways to find workers, to the percent of full-time vs. part-time employees, to managed services, to outsourcing, crowdsourcing; the

TABLE 1 SINCO codes and workforce activities for NAICS branches.

SINCO	Workforce activities
2271	Software and multimedia developers and analysts
2651	Technicians in the installation and repair of computer networks, equipment and computer system
2653	Aides and technicians of video recording and reproduction equipment
2654	Audio, sound and lighting engineering assistants and technicians

Own elaboration based on SINCO classification (O*Net).

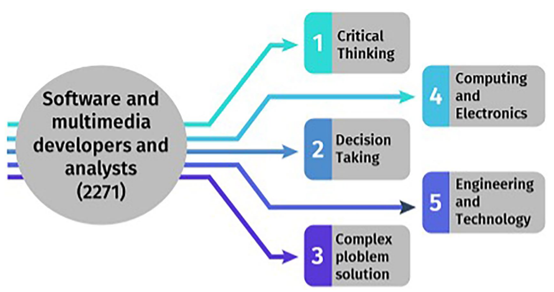

FIGURE 11
Some skills and competencies related with SINCO#2271. Own elaboration based on SINCO classification (O*Net).

presence of alternative workers (currently 35% of the US workforce is in supplemental, temporary, project or contract positions) and finally the novelty that the freelance workforce is growing faster (up to 8.1%) than the total workforce (Schwartz et al., 2019).

Regarding the concept of *workplace*, it should be noted that this concept started changing drastically in March 2020 with the COVID-19 crisis, moving from the requirement that employees work in *physical proximity* to instead working using digital communication, collaboration platforms and/or even with digital reality technologies (World Economic Forum, 2020). These changes were accompanied by the creation of distributed teams and had social consequences: organizations were able to organize different workplace options, from the traditional single workplace to the new, distributed workplace with 100% virtual interaction. As teams became more highly distributed, organizations needed to rethink how to promote workplace culture, maintain efficiency and sustain team connections. In post-COVID times, the Innovation District must work intensely on the design of upskilling and reskilling programs that include the social–emotional and networking skills necessary to continue carrying out this ongoing transformation (World Economic Forum, 2020).

Considering the transformations generated by the substantial changes in the model of the labor force that were mentioned above and taking into account the reports of international organizations such as the Organization for Economic Cooperation and Development (OECD) and the World Economic Forum (WEF), the global challenge is to meet the demands of Industry 4.0 regarding the nature of future work and the skills of the workforce to adequately meet those demands (World Economic Forum, 2020).

One way to ensure that workers are satisfactorily trained with regard to Industry 4.0 requirements is to ensure that the education model of Innovation Districts uses an Outcome-Based Education (OBE) approach (Rao, 2020). For adult education, OBE is an approach since decisions about the curriculum are driven by the learning outcomes that students are required to show at the end of the course: in this way, the final product defines the process (Macayan, 2017). The implementation of OBE requires complementarity between the desired educational outcomes, teaching and learning activities, and assessment methods and practices. The three most significant aspects of OBE are: first, the focus on results; secondly, the curriculum design process that starts from exit-level result and works its way backward; and finally, the responsibility of the institution and the teacher/coach to provide appropriate learning experiences to enable the success of all students (Premalatha, 2019).

With regard to curricular design and implementation, there are several conditions that must be met. These include: where instructional focus is placed; how much, how often, and when time is provided for learning; what learning is expected from whom and how it is rewarded; and how the curriculum is designed and organized. The theoretical framework for the education model for Industry 4.0, Education 4.0, can be identified with two competencies with four learning characteristics that ensure high quality:

Transversal Competencies: Global Citizenship, Use of Technology, Innovation and Creativity, and Interpersonal Awareness.

Learning Characteristics: Personalized and self-paced, Accessible, Inclusive, Collaborative, and Student-driven.

This framework was used throughout the study to propose different implementation schemes of a viable educational model for an Innovation District. Various international organizations such as the Organization for Economic Cooperation and Development (OECD) (Howells, 2018; Hughson and Wood, 2020) and the World Economic Forum (WEF) (World Economic Forum, 2018; Ratcheva et al., 2020) have in the last 5 years published reports related to the emerging technologies of the 4IR, the jobs, and occupations required by the Industry 4.0 labor market, and, finally, the best active learning practices for the development of:

Technical skills, also called STEM skills (Science, Technology, Engineering, and Mathematics). STEM skills are those technical skills that complement higher-order thinking skills and social–emotional skills. The objective of incorporating STEM approaches into the educational programs of an Innovation District is to close the gap between the skills acquired prior to entering the program and the skills needed for the future workplace, as confirmed by professionals from the human resources (HR) departments of major international companies (Nguyen et al., 2020). In the near future, to thrive in their jobs, workers will need to develop a high level of digital fluency and STEM skills. The ability to find innovative solutions to global challenges, including climate change, resource management, agricultural production, health, biodiversity, and declining energy and water sources, requires an interdisciplinary STEM educational approach (Millar, 2020; Deák et al., 2021).

Soft skills: Critical Thinking, Decision Making, etc. In 2012, the Organization for Economic Cooperation and Development (OECD) carried out an important study, which is still widely read, on the analysis of cognitive skills (both basic and higher) to measure possible mismatches between supply and demand in international labor markets (OECD, 2017). In the Program's Adult Skills Assessment Survey, a potential but growing mismatch in needed vs. available cognitive skills becomes apparent: the demand for higher cognitive skills, such as critical thinking, decision-making, and complex information processing, will grow at double-digit cumulative rates through 2030. Demand for these skill categories is estimated to increase by 19% in the United States and 14% in Europe, according to the forecast carried out (Caratozzolo et al., 2021; Supena et al., 2021); however the supply for these skills is/will be missing because our educational programs need to adapt to teach such new competencies.

Transversal Competencies: Use of Technologies, since technological advances can support in teaching techniques; and innovation and creativity, since these digital skills are the basis for the digital transformation required in upskilling and reskilling (Caratozzolo et al., 2019, 2020; Hiğde and Aktamış, 2022).

Digital skills: Interpretation of images, Management of Multimedia Platforms, Network Management, etc. (CEDEFOP, 2022; Ostmeier and Strobel, 2022).

When designing educational programs for an Innovation District, it is important to offer students an interdisciplinary, personalized, inclusive, flexible, collaborative, student-centered, attractive, and, above all, motivating learning environment. In order to provide quality education in a globally competitive environment, all Innovation District programs must be structured towards the development of 21st-century skills, that is, designed within the Education 4.0 Framework, which explicitly includes increasing the skills, knowledge, and abilities that students/professionals bring from their previous training. In the report *Skill Shift: Automation and the Future of the Workforce*, the McKinsey Global Institute stressed that in the future technology professionals' demand for cognitive skills would shift from basic to higher skills, due to the ongoing consolidation encouraged by Industry 4.0 (McKinsey, 2018). Specifically, the study predicted that the needed transformation of skills with a view to 2030 will mean that the jobs and occupations of the future will require, above all, higher cognitive skills.

With regard to the selection of pedagogical techniques, the instructors who are in charge of the training and updating courses for an Innovation District must consider that the use of a single technique is insufficient to obtain the desired results. For this reason, the role of the District of Innovation instructors will be highly relevant as they will facilitate instruction within student-centered communities of practice, addressing individual concerns and questions, and providing support to maintain focus on complex problems. Education programs designed in an Innovation District have the challenge of preparing professionals to prosper in a world mediated by rapid technological advance, and discerning and then filling gaps between what students need to learn to perform in more demanding competitive and globalized work environments, and what the training and updating programs of the Innovation District offer. According to recent academic reports by Hughson and Wood (2020) and Sgambi et al. (2019). Instructors must choose which among the many cutting-edge teaching techniques available to them will be most appropriate for a given Innovation District. Available teaching techniques/activities include the following three:

Gamification. Gamification is a technique that has gained popularity in the era of digital transformation and is defined as the use of game mechanics in non-game environments. In such environments, participants play and develop needed skills through action-reward (Raju et al., 2021; Hayes, 2022).

Flipped classroom. The flipped classroom technique allows students to learn about the learning material before having contact with the instructors or the systematic information, which allows classroom time to be used for interaction, discussion, and problem-solving with classmates. The model for a flipped classroom can be enriched with materials provided by the digital environment (Strelan et al., 2020; Senali et al., 2022).

Challenge-Based Learning. The Challenge-Based Learning technique is based on experiential learning, which allows students to actively face, and help solve, real-world business situations and industry problems. This "learn-by-doing" approach involves students' interaction with instructors and business partners to solve challenges that allow the students to develop their teamwork skills and deliver products of different complexities (Caratozzolo and Membrillo-Hernández, 2021; Membrillo-Hernández et al., 2021).

To ensure the success of the educational programs in an Innovation District, it is essential to use various cutting-edge educational technologies including the use, design, and implementation of media, web portals, and technological platforms in the service of the educational learning processes (Hernandez-de-Menendez et al., 2020). It is important that the Innovation District have specific spaces earmarked for the development of skills and acquisition of knowledge using cutting-edge technologies and the assistance [OR "guidance" or "support"-?] of instructors with expertise in pedagogy and evaluation, who can implement learning dynamics that motivate the learner and trains them to better meet the requirements of Industry 4.0.

The additional educational technologies described below were originally designed to address the needs and concerns of users and employers within the Education 4.0 Framework and focus on Information and Communication Technologies (ICTs), which are essential for training professionals in specific skills required for the jobs that are targeted (Okoye et al., 2021):

Virtual Environments. The virtual environment technique allows courses to be redesigned based on their use of new communication channels (videoblogs, open classes, e-books, etc.) that are used with activities, laboratory practices (e.g., virtual and augmented reality), simulators, and immersive haptics, which allow students to understand and develop cutting-edge technical skills (Huang et al., 2019; Halabi, 2020).

Podcast and Video Recording. Second-generation podcast recording (audio and video) and screencasting videos are an excellent educational technology option for Generation Z learners. Because these types of platforms are used by young people in their interactions with social networks and for entertainment, they are familiar to students and manage to keep their attention (Hess et al., 2021; Priyadharshini et al., 2022).

Internet-based platforms. The use of internet platforms and other online networks as educational technology allows courses and training to be delivered to a large number of students, without the physical limitation of classrooms. One example of these technologies are the platforms used for teaching MOOCs (Massive Online Open Courses) at no cost to an unlimited number of students. These types of educational technologies also produce options for students to earn micro-credentials and alternative credentials (Sheikh et al., 2021; Liapis et al., 2022).

To ensure the quality of technical education worldwide, there are three international agreements known within the field as *Washington* (for engineers), *Dublin* (for technologists) and *Sidney* (for technicians) These agreements guarantee the mutual recognition among participating countries (Jadhav et al., 2020). Many countries have adopted the OBE approach for their undergraduate engineering programs after signing the *Washington Accord*. Currently 21 countries are signatories to the *Washington Accord* and another 7 countries (Mexico among them) that have provisional status. These countries offer many programs producing graduates with highly similar and related skills and competencies (Wilson and Marnewick, 2018). Although the *Washington Accord* covers only undergraduate engineering degrees, and graduate engineering programs are not included in the agreement, it is a stand-alone agreement between national organizations that grants external accreditation to higher education programs and signified that graduates have met the criteria for access to the practice for professional engineers. Signatories agree to grant the graduates of each other's accredited programs rights and privileges similar to those available to their own graduates. Through this arrangement, the agreement increases the movement of graduates between signatory jurisdictions and grants them a greater understanding and recognition of their engineering education and accreditation systems.

Educational programs that are implemented within an Innovation District must consider the adequacy of the professional and career preparation of the students, specifying not only the results or skills that the local market demands, but also the possibility of incorporating the worker into the wider global labor market. From this point of view, it would also be important for the educational model to ensure assessment and accreditation of skills and competencies in a framework similar to those of the *Washington*, *Dublin*, and *Sydney Agreements*.

Conclusion and future work

This paper draws from the Knowledge Based Urban Development (KBUD) framework of innovation districts to emphasize the importance of the community and of education policy in the construction of an innovation district. The KBUD is important in our approach to innovation districts because it assumes the importance of the Triple Helix Model for the planning and governance of such innovation precincts, in which targeted education is seen as essential to the success of a project like this. However, the KBUD and triple helix model have one major limitation since it takes for granted the connection between educational institutions and industry that is needed to grow human capital with the soft skills needed to innovate and thrive in an innovation district. The lack of connection might be more relevant for countries with institutional weakness, limited financial resources and a less diversified economy, where connections between education, industry and the urban context for the district might simply not exist. This is where the design and implementation of specific collaboration strategies, and public policies that give them support and legitimacy becomes especially relevant.

Queretaro is one of the industrial hubs in Mexico that served as an example of thriving manufacturing regions that long to plan for and host a thriving innovation district. Our case study demonstrated that the triple helix model can be better sustained by a detailed analysis of the industry sector in the planning process of an innovation district to highlight specific areas of economic opportunity based on special strengths of the region. For instance, Queretaro is already a hub of aeronautical and automobile manufacturing, but the hiring and productivity of the software and ICTs industries have increased largely only in the last 15 years. Our analysis of economic complexity shortlisted the industries with the greatest chance of success. Then an urban assessment helped better understand the challenges needed to generate a potentially productive urban environment --in the context of a sprawling city shaped by processes of informality and inequality--to attract and retain the called creative class.

Finally, Education 4.0 was crafted as a response, within the educational sector, to the needs for new skill sets that the Industry 4.0 demanded. The same concept of Education 4.0 has vast applications in innovation districts to generate the transversal competencies and learning characteristics that are also needed to develop the full potential of the industries that were tagged as critical in the industrial assessment, such as the ICTs in Queretaro. Moreover, the educational literature can contribute enormously to the physical and urban design of innovation districts through its findings and demonstrable experience in implementing educational technologies. It can also suggest designs and configurations the physical for learning spaces that promote student-centered communities that foster soft skills needed for creativity and innovation. For instance, gamification, flipped classrooms, challenge-based learning, virtual environments, podcast and video recording and internet-based platforms can be important instruments, already tested in educational settings, that can contribute enormously to the success of an innovation district. Our case study exemplifies our view regarding the necessity of a deeper collaboration between education, industry, and government within a KBUD framework that is customized for specific spaces and pedagogies. The classic Triple Helix Model proposed in the literature of innovation districts do not reach to this level of detail when addressing the relevance of education for regional economies. However, this is the level of specificity that we believe is essential, and the fields of education, pedagogy and educational technology area all important in any discussion of innovation districts. The main contribution of our research through this case study has been to demonstrate that such a three-pronged approach this is feasible and requires institutions and academia to both play primary roles.

An innovation district makes a society more sustainable--if it is based on a recognition of the interplay of education and technology. Education must be the fundamental engine of a transformation towards innovation and competitive production systems. Educational models using cutting-edge technological tools should complement innovation districts in order to enable the districts to function as extracurricular spaces where, following a specific pedagogical design, technologies that may not be available in other settings can be made accessible or more affordable to students. In this way, an innovation district serves as an incomparable space to deploy the potential and knowledge that a region possesses and apply them to the production of goods and the generation of new knowledge. The case study of Queretaro Innovation District in Mexico provides an example of how human resources can be used for greater transversal and the development of specific skills.

Two are the main limitations of our research. First, to include other case studies of cities from other developing countries than Mexico, that also have a strong industrial base in manufacturing. Second, to translate the mapping of competencies and skills needed for the innovation district into a pedagogical curriculum for higher education. The Triple Helix stakeholders would take part into this definition. We defer these two tasks to future work.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: https://github.com/gperaza/paper_frontiers_kbud.

Author contributions

RP-L organized the project and assembled the team, proposed the structure of the paper, carried out the literature review of innovation districts and triple helix models, worked in the urban assessment of the case study. GP-M put together the different pieces, structured the conceptual framework, and prepared the first manuscript of the paper. FG-Z carried out the industrial assessment and the location quotient methodology. JM-H participated in developing the theoretical linkage between innovation districts and education. AA-L contributed with the description of educational attainment statistics in Queretaro and reviewing the first draft of the paper. PC provided guidance throughout execution of the project and was the driving force behind the concept of the importance of Education 4.0 in for the success of innovation districts. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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