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RISKS AND THE ENVIRONMENT IN NANOTECHNOLOGY HIGHER EDUCATION IN MEXICO[1]

Laura Liliana Villa
laura.villa@uaz.edu.mx

Abstract

The development of nanotechnologies has transformed the productive structure in the world; developed countries and those of the global south have had to incorporate public actions to accompany such technological deployment. In this context, education represents a key point to exploit the enormous technological potential that can be achieved without undermining the risks and environmental damage this may entail. In this sense, this chapter analyzes the results of the systematization of educational programs in Mexico to identify if the orientation in the curricular design of the academic offer provides a technical base training with the perspective of environmental care. The methodology deployed has been used to systematize the information on undergraduate and graduate programs specializing in nanotechnology. The market pressure to train nanotechnologists often causes aspects such as risks, environmental impact, or social

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implications to go unnoticed. The case of Mexico stands out because, after Brazil, it is the second leading country in nanotechnology development in Latin America.

***Keywords**: Nanotechnology, Higher Educational Programs, Risks, Environment, Mexico*

Introduction

This paper aims to organize information about higher education institutions in Mexico that offer undergraduate or graduate degrees in Nanotechnologies. Despite Mexico's position in the nanotechnological world of Latin America, the country does not have a public policy or program to promote these technologies. Their development has been indirectly organized by the National Council of Humanities, Science and Technology (CONAHCYT), through different programs such as basic science, mixed funds, frontier science, the Stimulus for Innovation program (PEI), public funding for specialized laboratories or research centers. Despite lacking a specific policy, several universities and educational institutions in Mexico have developed academic programs focusing on these technologies.

The training of human resources in NTs in Mexico has been present in Higher Education Institutions (HEIs) in the last two decades; the first program specialized in the subject was the degree in nanotechnology and molecular engineering offered by the University of the Americas in Puebla (UDLA) in 2006 (Takeuchi & Mora, 2014). Currently, there are multiple educational institutions, both public and private, that offer educational programs on the topic. However, there is no organized information on the programs and their characteristics. This paper focuses on systematizing the educational offer on NTs in Mexico.

The chapter is organized into five sections. The first section discusses the training of nanotechnologists worldwide. The second section focuses on the educational specialization in nanotechnology in Mexico, followed by an overview of the methodology used in the study. In the third section, the analysis of the curriculum takes place. The fourth section presents the results of the systematization of the curricula, emphasizing risks and the environment. Finally, the concluding ideas are presented.

1. Debate on the Formation of Nanotechnology Profiles in the World

The orientation of scientific research changed because of the nanotechnology boom at the beginning of the century. Since the 19th century, economic currents of thought have debated whether production leads to consumption or consumption leads to production. Obviously, both forces manifest themselves simultaneously with reciprocal effects, but for the purposes of economic public policy, taking one or the other perspective means favoring some sectors over others.

Since the ICT (Information and Communications Technology) revolution, historically coinciding with the establishment of neoliberal policies at the level of international organizations and in most countries, public policy in economic matters has been oriented towards a relative withdrawal of the role of the State in the economy and a certain boost to innovation as a strategic lever for development. Innovation is understood as the combination of two simultaneous characteristics. On the one hand, a novelty in the product's utility, which distinguishes it from traditional equivalents by being more efficient, meeting new or different requirements, or other utilitarian characteristics. On the other hand, the product in question must enter the market under economically advantageous conditions, i.e., implying a higher profit for the producing company. In short, innovation requires a novel commercial product.

When, at the beginning of the 21st century, the growth of NTs occurred, science suffered a shock. Known materials can be studied, manipulated, and applied at atomic and molecular sizes, unleashing little-known and previously unknown physicochemical and biological functionalities. Scientists race to discover new material behaviors to characterize nanoparticles and their potential functionalities. Scientists become a major economic and political force, or at least acquire such an appearance. This leads to a growing library of nanoparticles with their physicochemical and biological characterization without a clear application. It is a matter of identifying where to apply the new knowledge, to create previously unknown commercial needs, and to be able to leap into industrial production and consumption. Science and technology become the engine of productive processes, and their agents, academics, and researchers, a key piece with political bargaining power. Wilsdon's expression, "For now, these nanoparticles are a solution in search of a problem," is eloquent of the situation (Wilsdon, 2004, p. 16). This settles, in practice, the controversy, making it clear that it is production (in this case, the first stages of research and development - R&D) that creates and commands consumption.

The illusion of scientists in the physical-natural and engineering areas having a leading role in guiding development has also reached social scientists and those in the humanities who, by drawing attention to the potential health, environmental, ethical, legal, safety, and other risks, contribute to the development of NTs with public acceptance. Several new terms emerge in the literature, such as "social construction of science," "co-production of knowledge," "insurance by design," and "life cycle," with the aim of imprinting a more socially friendly character away from the structural socioeconomic realities. Even assuming the success of these scientists in convincing the engineering and "hard" branches to introduce social and environmental concerns, they face an immeasurable challenge: to modify with voluntary, conscious, political actions, the involuntary and implacable spontaneous forces of the market by privileging economic benefit over any other criteria.

Nanotechnology education has been recognized as a critical element for global development, and numerous countries are implementing strategic initiatives to build a workforce equipped with the necessary knowledge and skills in this field. For instance, the National Nanotechnology Initiative (NNI) coordinates efforts among federal agencies to advance nanotechnology research and education in the United States. This initiative supports interdisciplinary research centers, graduate training programs, and educational initiatives for Kindergarten through to 12th-grade students to promote nanotechnology literacy from an early age (Friedersdorf, 2020).

Similarly, in Europe, countries are investing in collaborative research projects and educational initiatives to strengthen their position in nanotechnology through programs such as the European Union's Horizon 2020 framework. Institutions like the Joint Research Centre (JRC) provide expertise and resources to support nanotechnology education and training across member states (Malsch, 2014).

Countries like Japan, South Korea, and China are leading the way in nanotechnology education and research in Asia. Japan's Nanotechnology Platform Project aims to build infrastructure and human resources for nanotechnology research (Kishi, 2004). South Korea's National Nanotechnology

Initiative fosters interdisciplinary collaborations and trains the next generation of nanoscientists (Wieczorek, 2007). China has established multiple research centers and university programs dedicated to nanotechnology, with its "National Program for Nanoscience and Nanotechnology" aimed at positioning China as a global leader in nanotechnology research and innovation (Qiu, 2016).

However, despite the progress made in nanotechnology education, challenges persist. One significant challenge is the interdisciplinary nature of nanotechnology, which requires expertise spanning multiple disciplines, such as physics, chemistry, biology, and engineering, and integrating these diverse fields into cohesive educational programs. Developing a skill can be difficult, but it is necessary to promote growth and progress, especially innovation in nanotechnology. Moreover, ensuring access to quality education and training opportunities for students from diverse backgrounds and regions is critical for promoting inclusivity and diversity in nanotechnology. Efforts to address disparities in access to resources and opportunities, especially in developing countries, are essential for realizing the full potential of nanotechnology on a global scale.

As pointed out by Roco (2002), the growth of NTs required a policy of training nanotechnologists at the speed of the discoveries of the new properties of nanoparticles. In addition, education in nanotechnologies should begin in kindergarten and throughout education and incorporate two components: engineering and social (Roco, 2002; 2003). The development of the training of nanotechnologists has been very uneven among countries. Perhaps the least have opted to start teaching in kindergarten and primary school, such as in Taiwan and Greece (Jones *et al.*, 2013), others from secondary school, as some cases in Spain and the United States. In Mexico, there are no known incorporations of nanoscience and nanotechnology contents in the primary school curriculum (Takeuchi & Mora, 2014); nor at the secondary level of courses related to NTs (Flores-Camacho et al., 2024). The presence is noticeable from the modeling of higher-level academic programs that, from multiple perspectives such as physics, chemistry, biology, engineering, and converging technologies, address the formation of NTs.

NTs are, in themselves, interdisciplinary, both in their basic science aspect and in their applications. They are so because the characterization of nanoparticles includes physical and chemical forces almost without distinction, in addition to their effects on the metabolism and reproduction of living beings. They are also interdisciplinary because the parallel development of computation allows automatic processes to characterize nanoparticles by simply introducing a set of variables of interest, which places engineers in a position to participate in basic and, more clearly, applied science. The information banks on nanoparticle characterization and those corresponding to the human genome are an explicit material basis for interdisciplinary resources. This engineering component claimed by Roco for nanotechnology education envisioned a future of privileged applied science, prioritized for industrial applications, over what is traditionally known as basic science (Roco, 2002). The priority to the engineering aspect was made explicit in the funds granted by the National Science Foundation (NSF) from 2006 onwards in the United States. The engineering accent will have important humanistic implications because engineering is characterized by its practical approach and the consideration of science as something neutral, whose beneficial or harmful elements depend on who and what they are used for and not on the implications embedded in their own design and structure, which are reflected in the appropriation of knowledge, marketing, and consumption of nano products.

The second component, the social component, is not justified by the characteristics of nanotechnologies themselves but by the social context in which they arise. Mitcham (2003; 2009) has studied the evolution of engineering from an educational and philosophical perspective, showing that in their origin, at the beginning of the 19th century, they were intended to support industrial and commercial purposes because these were considered to coincide with the interests of society in a broad sense. But the experience gathered after more than a century, and the critical civil movement on the use of scientific knowledge after the Second World War and more accentuated around the end of the 20th century, have questioned the neutrality of scientific knowledge and its technological implementations (Mitcham, 2003; Mitcham *et al.*, 2009). More recently, some sectors of engineering have incorporated in their training the concern for responding to social needs, particularly those related to health and the environment; in this regard, Mitcham et al. cite the 2008 Code of Conduct for Civil Engineers in the United States: "All members shall give full consideration to the public interest, particularly in relation to health and safety issues, and to the welfare of future generations" (Mitcham *et al*., 2009, p. 185). However, in practice, ethical postulates are continually circumvented by market pressures.

Bensaude-Vincent is even more incisive in emphasizing the role of citizens in relation to the development of biotechnology and distant from blindly believing in scientific benefits. The pressures of civil society have been forcing science to make concessions, incorporating in the discourse and regulation key issues of safety to health and the environment, and it is in this area where social scientists and humanists find a space to integrate into the relevant role acquired by science since the late twentieth century (Bensaude-Vincent & Newman, 2007; Bensaude-Vincent, 2012; 2021).

The importance of education in advancing the fields of nanoscience and nanotechnology cannot be overstated. These fields are fundamental to securing innovation at the global scale, and educational programs are being developed and tested in various countries to increase awareness and provide advanced learning opportunities (Rocco, & Bainbridge, 2013; Jackman, *et al., 2016).*

These programs use diverse formal and informal educational techniques, such as group learning and peer assessment (Hersam & Light 2004). However, the interdisciplinary nature of nanoscience has made it difficult to develop standardized curriculum features, and the efficacy of integrating nanotechnology concepts into existing coursework versus creating new courses for nanotechnology still needs to be discussed (Jones, *et al*., 2013)

Nanotechnology is a rapidly evolving field that has raised concerns about its potential impact on human health and the environment. Due to their minuscule size, engineered nanoparticles can penetrate biological barriers and potentially induce toxic effects. Moreover, the long-term consequences of nanoparticle exposure remain largely unknown, raising questions about their safety in consumer products and industrial applications. Additionally, nanoparticles environmental persistence and potential bioaccumulation pose risks to ecosystems and biodiversity (Singh & Nalwa, 2007). Nanoparticles can interact with biological systems unpredictably, raising concerns about unintended consequences. These interactions may lead to cellular toxicity, immune responses, or genetic damage, necessitating thorough investigation into nano-bio interactions (Uddin, *et al.*, 2020). Understanding these complexities is crucial for developing and deploying nanotechnology-enabled products and therapies.

The regulatory landscape for nanotechnology is complex and constantly evolving. Current regulatory frameworks may need to adequately address nanomaterials' unique properties and risks. Furthermore, the rapid pace of nanotechnological innovation often outpaces regulatory agencies' capacity to assess safety and efficacy effectively (Allan, J., *et al.*, 2021). Bridging this regulatory gap requires robust collaboration among policymakers, scientists, and industry stakeholders to develop comprehensive oversight mechanisms.

To address these concerns, conducting thorough research and risk assessment of nanotechnology is essential. Researchers need to investigate the potential toxicological effects of nanoparticles on human health and the environment. Developing reliable methods for measuring nanoparticles' exposure and environmental impact is also essential. This will help to develop practical safety standards and regulations to protect human health and the environment. In this sense, the training of human resources, scientists, engineers, or specialists in nanotechnology should include technical and social notions about the risks of nanomaterials. One would expect that there would be some kind of courses or training at the undergraduate or graduate level on these issues. Nanotechnology holds immense promise for addressing pressing global challenges. However, its advancement must be accompanied by thoroughly examining its risks. Addressing health and environmental concerns, navigating regulatory challenges, and promoting ethical practices are imperative to harnessing nanotechnology's potential for the benefit of humanity while minimizing harm. By fostering interdisciplinary collaboration and ethical stewardship, we can pave the way for a future where nanotechnology is a force for positive transformation.

Ulrich Beck's work highlights the potential risks that come with technological advancements, but it falls short in addressing the fundamental systemic causes (Beck *et al.*, 2019). In contrast, Foladori's research delves into the structural roots of environmental issues in capitalist societies (Foladori, 1999). Despite this, the prevailing approach in both Mexico and globally tends to prioritize technical remedies, which aligns more closely with Beck's viewpoint.

Official documents on NTs from more developed countries and regions, mostly elaborated during the first decade and a half of the 21st century, are unanimous in establishing the need for research and training of nanotechnologists to include ethical and social aspects broadly. However, the productive and commercial reality has an independent movement and is often confronted with those of a social and humanistic nature. This contradiction is manifested in the curriculum and many undergraduate and graduate courses, something we will see in the case of Mexico. Thus, for example, a widespread and successful international NTs course funded by the European Union, with the participation of several countries, does not have in their curriculum disciplines on social, ethical, legal impacts, etc. (Cohen et al., 2016). Another eloquent example is the nanohub.org portal, which offers a wide variety of tools for learning NTs, including online simulation tools. However, it does not include information on risks or social implications, nor on the philosophy of the technology.

This reluctance to incorporate ethical, social, or environmental aspects and risks in the teaching of NTs even goes against the demands and requirements of some companies, for example, in the European Union, according to some research that illustrates this requirement (Malsch *et al.*, 2016). Due to increasing regulatory demands in this region, entrepreneurs demand nanotechnologists with regulatory and safety knowledge. This relationship between mandatory regulations by governments and concern for the training of nanotechnologists should attract the attention of science and technology policymakers in non-hegemonic countries as a suitable way to introduce humanistic and social issues into the engineering and natural-physical science education curriculum.

2. Educational Specialization in Nanotechnology in Mexico

The rapid development of NTs in the world has led Mexico to adopt them as a fundamental element to achieve the objectives of competitiveness. Nano components, nano-intermediates and nano-products are rapidly penetrating the country's productive development. In Latin America, many nations have incorporated NTs as priority development areas in their public policies (Foladori, 2016). In the case of Mexico there is no expressly national policy that articulates from the complex institutional architecture to such technologies; it has been the CONAHCYT that has tangentially accompanied its approach; providing public funding that resulted in support for research centers, laboratories, publications, patenting, companies with the "nano" component, as well as the training of human resources in the subject.

The emergence of the fourth industrial revolution, better known as industry 4.0, places the nanotechnological component at the center of all its expressions for its enablement; in this sense, the training of human capital that specializes in discovering new behaviors, uses of materials, characterizing nanoparticles and their potential functionalities is of capital importance for nations. The educational system in Mexico, specifically the Institutions of Higher Education, has attended to the growing presence of NTs by creating educational programs that train nanotechnologists. The precedent we have in Mexico on programs with specialization in the subject was the degree in nanotechnology and molecular engineering at the Universidad de las Americas in Puebla (UDLA), which began activities in 2006, highlighting its focus on molecular engineering and micro-electronics (Takeuchi & Mora, 2014). Over two decades, both Public and Private Higher Education Institutions have designed ad hoc programs to meet the needs of a market that requires professional profiles with knowledge and experience in manipulating matter at the nanoscale.

Works have been published that count educational programs related to nanotechnologies. An example of this is the Diagnosis and Prospective of Nanotechnology in Mexico, carried out by the Center for Research in Advanced Materials (CIMAV) in 2008, which reported a total of 99 programs in which subjects related to nanotechnologies are taught (p. 118). Mundo Nano 2016 conducted an important classification work of Institutions that develop research lines in Nanosciences and Nanotechnology (N&N), that possess infrastructure, that have intellectual property protection instruments requested and granted, that provide teaching and training of human resources (including undergraduate and postgraduate degrees in N&N) (Zanella, *et al*., 2016). The findings report 29 educational programs, distributed as follows: 8 in CONAHCYT Public Research Centers, 7 in public Universities, 2 in private, 4 in technological institutions, and 3 in decentralized organizations (Zanella *et al*., 2017, p. 6). The above background shows the growing interest in integrating research and teaching topics related to NTs. However, information on technical careers and undergraduate and postgraduate degrees explicitly recognized by the suffix "nano" is not systematized. In this sense, the present work aims to identify the geographic location, as well as the integration of topics such as risks and environmental monitoring aspects in their curricula.

3. Methodology

The methodology was updated based on an exercise carried out in the year 2022, in which a web-based review of higher education programs in NTs in Mexico was established (Villa Vázquez, 2022). The list of educational programs involved a process of systematization and organization of the information to identify the different universities, laboratories and public and private research centers that offer programs in the subject. The reference criterion was the prefix "nano" content in the program title. It is important to note that the methodology used could leave out several educational programs since many careers or postgraduate programs may have some emphasis on NTs without necessarily specifying it in the degrees awarded. Nevertheless, this work is an organized approximation of the available information that shows the diversity of programs and their location in the Mexican Republic. The statistical yearbooks of the National Association of Universities and Institutions of Higher Education of Mexico (ANUIES, 2023) and the database of higher education institutions of the SEP (2023) were used as references.

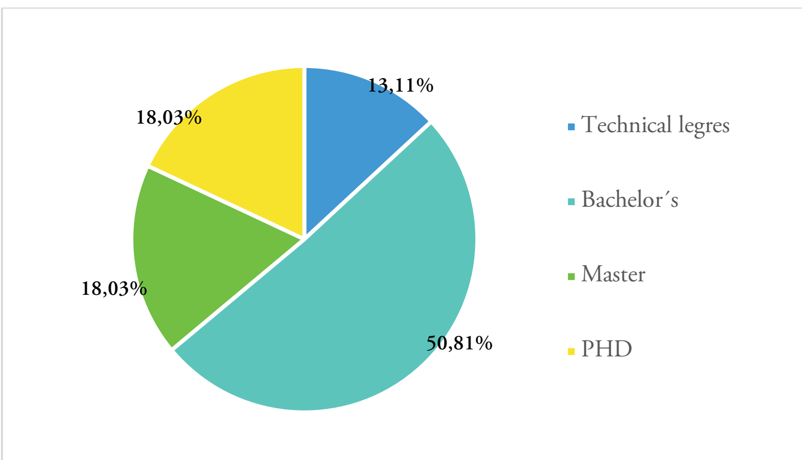
The systematization of the information made it possible to have data related to the subjects, a significant element in identifying if the curricular designs integrate subjects related to risks and damage to the environment in the training. It is recognized that risks in their generic form involve damage to health, the environment, social impacts, adverse effects on employment, and some other situations, but in order to broaden the search in the subjects, the subjects that integrate the concept of risks and the environment in their denomination were taken separately. It should also be added that the public information of the educational programs in a very small proportion provides detailed syllabi, i.e., in all cases, versions were not found that would allow knowing the exact contents of each subject.

4. Results

In Mexico, higher education is divided into three fields according to their profile and level of specialization: higher university technician (TSU), which consists of short careers that generally take 2 or 3 years and whose emphasis is on training of a technical-practical nature; the bachelor's degree itself, which includes engineering programs, which by definition focus their study on applied technologies; and finally, the postgraduate program, which consists of master's and doctoral degrees.

A total of 61 educational programs in NTs were identified (see graphic 1), of which 31 educational options correspond to the undergraduate level, 11 to master's degrees and 11 to doctorates, and 8 to university technical degree programs in the subject. The 8 programs corresponding to University Technicians are offered in their entirety by the network of Technological Universities (UTs) throughout the country. The UTs model contemplates an "intensive training that allows them to join the productive market in a short time (after 2 years)" (Ministry of Public Education [MPE], n.d.). It is important to point out that the programs offer the option of a second period of studies to obtain a degree in Nanotechnology Engineering, taking a little less than two years after completing their TSU studies.

Graphic 1. Educational programs un nanotechnology in Mexico



Source: own research, 2023

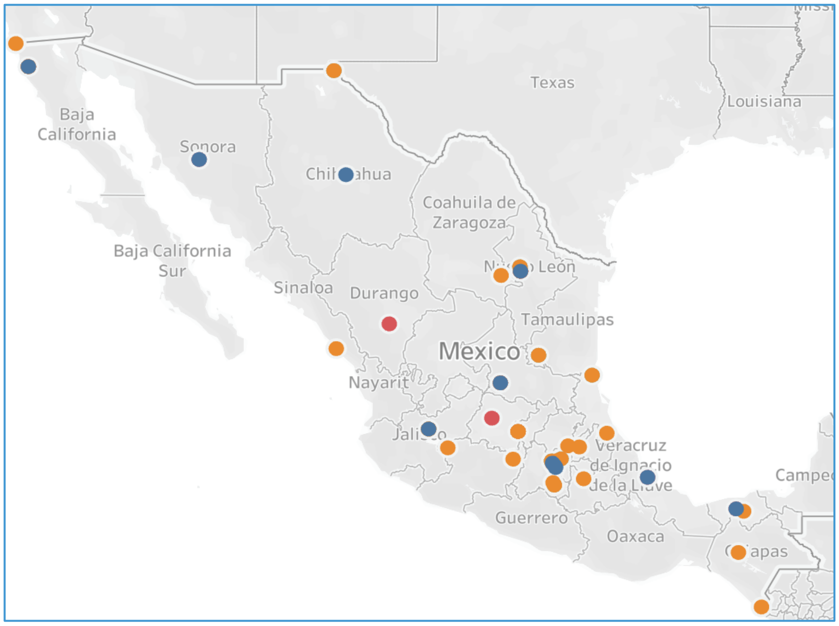
On the other hand, of the 31 educational programs referred to at the bachelor's degree level, 24 correspond to careers that are called engineering, and 7 are bachelor's degrees. This coincides with the trajectory followed by training policies in some countries, integrated into their National Nanotechnology Initiatives, which have been designed to meet productive and commercial expectations. In this sense, the data provided by the systematization of the programs in Mexico show that 77.5% of the educational offers integrated at the undergraduate level in this subject correspond to engineering, assuming a deepening in the applied technological orientation from its conception.

In relation to the nature of the institutions that have educational offerings in the subject, we find a wide presence of public institutions. The interest in accompanying the training of human resources specialized in nanotechnologies has echoed in the broad public educational structure; the need to incorporate these technologies has been growing in the global market and has been met by public HEIs. Of the 61 programs identified in Mexico, 86.89% are part of this system. Public higher education in the country comprises 12 types of subsystems, of which 9 have integrated into their academic options curricular designs to train nanotechnologists. State Public Universities, with 31.14%, and Technological Universities, with 29.5% of the programs, stand out as trainers of professional profiles in nanotechnological areas.

Regarding the academic options promoted by private HEIs in Mexico, three private institutions were found, the University of the Americas (Puebla), the Monterrey Institute of Technology and Higher Education and the ITESO Jesuit University of Guadalajara, which make up 13.11% of the educational alternatives in nanotechnology.

The presence of educational options specializing in the technologies of the tiny has space in 21 of the 32 states (see map 1). Those with the greatest academic offerings coincide with states with a large contribution to the Gross Domestic Product, characterized by an important industrial and economic dynamic. This suggests that industrial activity is echoed in educational institutions at the professional level, which designs educational programs that form professional profiles in accordance with the demands of a local or regional market that increasingly demands the integration of technological innovations. NTs do not escape this structural logic.

Map 1. Educational programs in nanotechnology in Mexico



Source: Villa & Arteaga, 2023.

The Map 1 reveals that 21 out of 32 states offer educational opportunities for those looking to specialize in tiny technologies. Interestingly, the states with the most robust academic offerings contribute significantly to the Gross Domestic Product and have a thriving industrial landscape. This correlation suggests that professional-level educational institutions are attuned to the market's needs, which increasingly demands skilled professionals who can integrate technological innovations like nanotechnology. States like Morelos, Veracruz, Michoacán, Tamaulipas, Chiapas, Sinaloa, and Durango have developed options, outpacing regions traditionally focused on secondary activities. It is worth noting that despite being the capital and home to top universities and research institutions, Mexico City does not host a significant number of programs specializing in tiny technologies.

Experts have expressed concern about the potential toxicity and harm to health caused by nanotechnology. To address this, proposals have been made to include subjects in nanotechnology studies that would provide nanotechnologists with the knowledge and tools to analyze and respond to any adverse effects these technologies may have on health and the environment (Saldivar, 2019; Saldivar 2022). However, the educational programs in Mexico show a different trajectory from the specialists' recommendations.

The current state of educational curricula reveals a clear need for more integration of risk, environmental, and social topics. This issue is particularly pronounced in Higher Education Institutions, where only a few options include these crucial topics. Specifically, there is only one option that addresses risks, four options that touch on social topics, and a mere 18 options that delve into environmental issues (refer to Tables 1, 2, and 3). This lack of emphasis presents a significant challenge for students who seek interdisciplinary training with a socio-environmental approach. It is worth noting that even postgraduate programs are not immune to this problem, as there are only two master's degrees and one doctorate in risk management that include these crucial topics.

5. Conclusions

Higher education specializing in nanotechnology has been developing in Mexico for twenty years. The interest in training nanotechnologists according to market demands has permeated the different subsystems that make up higher education in the country. The systematization of the information made it possible to compile 61 educational programs integrated into Higher University Technician, Undergraduate, and Postgraduate degrees. The bachelor's degrees occupy a little more than 50% of the academic proposals, with engineering programs accounting for the largest number. The above has a particular significance since the approach of the educational programs focuses its theoretical-practical batteries on technical issues, responding to the objectives outlined from the operational functions (of objectification - operational), which prioritize the manufacturing execution. When geo-referencing the programs that train nanotechnologists, it was found that the presence of nanotechnology as a higher education proposal is throughout the Mexican Republic, with a total of 21 states where profiles in the subject are trained. It is noteworthy how federal entities that are involved in an important industrial activity have consistently added within their academic options the training of nanotechnologists.

The organization of the information allowed us to identify that there is a significant absence of risk and environmental topics in the educational programs. Although the count was made separately for the two concepts, a limited number of programs include at least one subject on the mentioned topics; the characteristics of the curricular designs show a clear omission of these topics. Such a characteristic in the academic configuration of NTs replicates the tendency of global markets to exploit technical potentialities to ensure profits, obviating or subordinating other subjects to this systemic purpose. To ensure that students have a comprehensive understanding, it is recommended that additional content be incorporated in these areas.

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Appendix

Table 1: Higher education programs with risk subjects

Program	*Institution*	*Subject*
Nanotechnology Engineering	University of the Ciénega de Michoacán de Ocampo	Nanotoxicology
Nanotechnology Engineering	Polytechnic University of Chiapas	Nanoprevention
Bachelor's Degree in Nanotechnology Engineering	Juarez Autonomous University of Tabasco	Nanotechnology and health
Master in Nanosciences	Ensenada Center for Scientific Research and Higher Education, Ensenada, Baja California/ National Autonomous University of Mexico	Nanotoxicology (elective)
Master's Degree in Nanomaterials Science and Technology	University of Guanajuato	Nanotoxicology (elective)
PhD in Nanosciences	Ensenada Center for Scientific Research and Higher Education, Ensenada, Baja California/ National Autonomous University of Mexico	Nanotoxicology (elective)

Source: own research, 2023

Table 2: Higher level educational programs with subjects in social issues

Program	*Institution*	*Subject*
Bachelor's Degree in Molecular Design and Nanochemistry	Autonomous University of the State of Morelos	Chemistry and Society
Degree in Nanotechnology and Molecular Engineering	University of the Americas Puebla	Nanotechnology and Society
Nanotechnology Engineering	Autonomous University of Baja California	Nanotechnology and Society
Nanotechnology Engineering	Jesuit University of Guadalajara	Historical and Social Context

Source: own research, 2023