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STEM in Transition: A Decade of Change in Brazilian and Subnational Higher Education

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Abstract

This article investigates a decade of transformations in STEM higher education in Brazil, with a focus on Minas Gerais. Drawing on longitudinal microdata from Brazilian higher education spanning 2010-2023, the study reveals an intense expansion of STEM graduates, largely propelled by private institutions and the rapid rise of distance learning. Despite this numerical growth, Brazil continues to lag behind OECD standards in the relative share of STEM graduates, and Minas Gerais shows signs of stagnation and regional concentration, with over 40% of STEM graduates concentrated in the Belo Horizonte metropolitan area. A critical mismatch is also observed between postgraduate training and its absorption by the productive sector: the study estimates only 2% of STEM master's and PhD holders in the state work in private Research and Development (R&D), indicating a structural disconnect between academic training and innovation systems. By integrating insights from innovation economics and higher education studies, the article contributes theoretically to the global debate on how STEM training intersects with territorial development. It also advances the Latin American perspective of *vinculación*, highlighting the need to align socially-oriented university missions with the demands of the knowledge economy. The findings suggest a bold policy agenda: fostering stronger academia-industry linkages, embedding regional innovation strategies in STEM curricula, and ensuring quality standards in the fast-growing distance education sector. Ultimately, the study calls for a reconfiguration of STEM education policies to ensure they fulfill their transformative potential — not just in expanding numbers, but in reshaping regional futures.

JEL Classification: I23; O33; R58

Keywords: *STEM Education; Third Mission; Regional Development; Brazil; Higher Education Policy.*

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1. Introduction

Contemporary universities are experiencing a fundamental redefinition of their missions and purposes. As observed by Kempton et al. (2021), universities have been established since the Middle Ages with the purpose of meeting the demands of their societies, demonstrating an extraordinary capacity for adaptation and reinvention throughout history. In the contemporary context, characterized by the rise of the knowledge economy, globalization, and financial and environmental crises, universities are called upon to go beyond their traditional missions of teaching and research, assuming a "third mission" of direct contribution to social and economic development.

The university’s third mission, defined by Compagnucci and Spigarelli (2020) as universities' contribution to society, represents a complex and evolving phenomenon that encompasses knowledge transfer activities to organizations and society in general, promotion of entrepreneurial skills, innovation, social welfare, and human capital formation. This multidimensional conceptualization is particularly relevant for the Latin American context, where there exists a rich tradition of university social function rooted in the Córdoba Reform of 1918 (CUESTA-DELGADO et al., 2024).

STEM fields (Science, Technology, Engineering, and Mathematics) occupy a strategic position in this scenario of redefinition of university missions. STEM education represents a crucial element for universities to effectively fulfill their third mission, as these areas are fundamental to the innovation and technological development processes that characterize the contemporary knowledge economy. However, the effectiveness of STEM education for regional development depends not merely on the quantitative expansion of educational programs, but critically on the capacity to create effective "bridges" between academia and the productive sector.

This article contributes to the debate on educational policies and regional development policies by analyzing the evolution of STEM education in Brazil, with a particular focus on Minas Gerais, given the state's significant economic importance within Brazil and its potential to lead knowledge-based development processes. The study seeks to fill a gap in the literature by empirically analyzing transformations in STEM higher education from a subnational perspective, offering important insights for the formulation of integrated public policies that articulate human resource formation with regional development strategies.

The article comprises four main sections: the first presents the theoretical framework on university third mission, regional development and the linkages with the economics of innovation; the second section discusses the methodology and presents the results of the empirical analysis; the third section offers an in-depth discussion of findings in light of literature; and the fourth section presents final considerations and implications for public policies.

2. Theoretical Framework: University Third Mission, STEM Education and ST&I Integrated policies

2.1. Evolution of University Missions: From Traditional Model to Third Mission

The contemporary understanding of university missions must be situated in a historical perspective that recognizes the extraordinary capacity of universities to adapt to the demands of their societies. Higher education plays a crucial role in the socioeconomic development of a nation or region, influencing multifaceted aspects such as forming qualified human resources equipped with skills to drive innovation, fostering increased productivity and competitiveness in various sectors of the economy; the generation of new scientific and technological knowledge through higher education institutions; the promotion of income inequality reduction, and the potential for university-business interaction to generate innovations (AGHION, et al., 2009; SUZIGAN;ALBUQUERQUE, 2011; BRITTO et al., 2015; HERMANNSSON et al., 2016; RUFFONI et al., 2021; HANUSHEK; WOESSMANN, 2010; MARGINSON, 2022).

Kempton et al. (2021) point out that, since the Middle Ages, universities were established with the purpose of meeting specific demands of their social, economic, and political contexts, varying from the Newman model of "community of thinkers" focused on learning for learning's sake, to the Humboldtian model that integrated research and teaching, and the Napoleonic model characterized by state regulation. The emergence of the third mission (TM) represents a natural evolution of this adaptive capacity, responding to transformations in the knowledge economy and growing social expectations about the role of universities. Compagnucci and Spigarelli (2025) identify that the third mission (TM) emerges as a response to pressures on universities to abandon their traditional "ivory tower" posture and address social needs and industrial objectives. This evolution is not merely incremental but represents a paradigmatic transformation in the conception of the role of higher education institutions. As the authors observe, "universities engaged in TM activities are becoming engines that contribute to the social, economic and cultural development of the regions in which they operate, by transferring knowledge and technologies to industry and to society at large" (COMPAGNUCCI; SPIGARELLI, 2020, p. 1).

2.2. The Third Mission in the Latin American Context: Vinculación and Mission-Oriented Innovation

The Latin American context offers a distinctive perspective for understanding university third mission, characterized by a rich tradition of social function that predates contemporary developments in the Global North. This regional specificity offers crucial insights for understanding how universities can effectively balance economic and social objectives in their third mission activities. Cuesta-Delgado et al. (2024) demonstrate that Latin American universities' commitment to social function originated with the Córdoba Reform movement in 1918 and consolidated throughout the 20th century, establishing a self-identity based on solving social problems. This historical foundation distinguishes Latin American universities from their counterparts in other regions, where third mission activities emerged primarily as responses to economic pressures and competitiveness demands.

The concept of vinculación (engagement) emerges as Latin America's specific contribution to third mission understanding. Unlike Global North models focused primarily on technology transfer and knowledge commercialization, vinculación encompasses "the usual teaching, research and diffusion but in interaction with non-academic communities" (CUESTA-DELGADO, 2024, p. 1423). This approach integrates internships in non-academic institutions, courses addressing non-academic demands, curricular alignment with community interests, and extension activities.

Empirical evidence from 1,304 mission statements across 19 Latin American countries reveals 82% orientation toward social issues and 55% toward economic issues, with significant cross-national variations reflecting each higher education system's particularities (CUESTA-DELGADO, 2024). This demonstrates that Latin American universities maintain strong social commitment even under growing pressure to adopt economic models, suggesting a distinctive pathway for third mission implementation that balances social responsibility with economic development.

Contemporary developments in Brazil[1] exemplify how vinculación principles can be operationalized through mission-oriented innovation policies. Recent initiatives have strategically combined university capabilities with private sector resources to address social and environmental challenges, positioning universities as crucial intermediaries in solving complex societal problems. This evolution represents a sophisticated integration of the traditional vinculación approach with contemporary innovation policy frameworks (MACULAN; MELLO, 2009).

This integration offers three fundamental theoretical contributions to understanding university third mission effectiveness: First, it demonstrates that economic and social objectives are not inherently contradictory when policies are systematically designed to align multiple stakeholder interests. Second, it evidences that innovation systems can be simultaneously territorially embedded and socially oriented. Third, it establishes the state's active role in directing technological demands and supplies to align social, environmental, and economic interests within coherent policy frameworks.

The vinculación framework thus provides a robust theoretical perspective, proposing a systemic approach that articulates economic development, social responsibility, and environmental sustainability through territorially embedded university action. This perspective proves particularly relevant for Brazil and its subnational units, where universities possess strong social engagement traditions and face specific challenges demanding integrated technological solutions that simultaneously consider economic viability, social benefit, and environmental sustainability.

For STEM education specifically, this framework suggests that effective third mission implementation requires curricula and research programs explicitly designed to address territorial challenges while maintaining scientific rigor and economic relevance. This approach moves beyond simple technology transfer to encompass comprehensive human capital formation oriented toward solving real-world problems within specific regional contexts.

2.3. STEM Education and Technological Paradigms: The Knowledge Economy Foundation

The centrality of STEM (Science, Technology, Engineering, and Mathematics) fields in contemporary development strategies can best be understood within the broader context of technological revolutions and evolving economic paradigms. While the STEM acronym gained prominence in the early 2000s through U.S. National Science Foundation reports emphasizing educational dynamics in computational technologies, natural sciences, engineering, and mathematics for economic development (Breinner et al., 2012), the foundational relevance of these fields traces back to Vannevar Bush's seminal 1945 report, "Science: The Endless Frontier." Bush's work underscored the critical importance of higher education in

[1] The calls for proposals from the Financiadora de Estudos e Projetos (Study and Project Financing Agency), a Brazilian public company linked to the Ministry of Science, Technology, and Innovation, whose mission is to promote the country's economic and social development by fostering science, technology, and innovation in companies, research institutions, and universities, demonstrate this trend. These calls for proposals can be accessed at< http://www.finep.gov.br/>.

science, technology, and engineering for national advancement (Bush, 1945).
The strategic importance of STEM fields directly aligns with theoretical elaborations by Dosi (1982), Perez (2002), and Freeman and Soete (1998) on waves of economic growth and technological revolutions. Each technological revolution generates new productive nuclei characterized by higher rates of technical change and a greater capacity to transform multiple sectors. These emerging sectors produce General Purpose Technologies (GPTs) —innovations with highly pervasive effects and high rates of technical change that can simultaneously influence diverse sectors.
An accurate analysis of Pavitt's (1984) seminal typology provides critical insights into the structural role of STEM fields within innovation systems. His analysis of 2,000 innovations in UK firms (1945-1979) demonstrated that science-based sectors—predominantly chemicals, electronics, and electrical engineering—generated innovations adopted almost universally across various sectoral groups: supplier-dominated (e.g., agriculture, traditional manufacturing), scale-intensive (e.g., automobiles, metals), and specialized suppliers (e.g., industrial machinery). Extending this framework through the lens of GPTs, we posit that during each technological revolution, science-based sectors function as primary generators of GPTs. These technologies exhibit heightened innovation-spillover potential, enabling transformative applications across diverse economic domains.
According to Perez (2024), we are currently experiencing the fifth technological revolution, the Information and Communication Technologies (ICT) revolution. Initiated in 1970 with the launch of the microprocessor, this revolution encompasses the emergence of the internet and artificial intelligence. This technological paradigm creates specific demands for professionals capable of managing complex information sets and generating technologies linked to software, hardware, algorithms, and life sciences, with practical applications across various knowledge areas.
The Yale Survey conducted by Levin et al. (1987) demonstrated that among the most effective learning methods for firms, in order of relevance, are: conducting Research and Development (R&D), technology licensing, reverse engineering of products, publications or technical meetings, hiring R&D professionals from other companies, patent disclosures, and conversations with professionals from innovative firms. More recent studies, such as Brazil's PINTEC survey, have further highlighted the relevance of research conducted in collaboration with universities or even startups as important sources of innovation, emphasizing the central role of in-house R&D in innovative firms (IBGE, 2017).
Perez's (2024) perspective, aligned with this evidence, underscores the critical role of highly skilled human capital in STEM fields for fostering innovation and technological development. Integrating Pavitt's typology with the General Purpose Technologies (GPTs) framework and empirical findings reveals that STEM professionals exhibit a heightened capacity to function as nuclei for diffusing technological knowledge throughout economic systems. This diffusion mechanism catalyzes economic growth and societal advancement

2.4. Integrative Framework: STEM Education as a Vehicle for University Third Mission

The integration of the concepts presented above reveals how STEM education serves as a crucial vehicle for universities to fulfill their third mission while contributing to regional development and innovation systems. This integrative framework synthesizes several key relationships that inform our empirical analysis.
First, STEM education assumes strategic relevance when analyzed from the perspective of university third mission, as these areas constitute the nucleus of competencies necessary to participate in the current technological revolution of information and communication technologies. As pointed out by Compagnucci and Spigarelli (2020), the materialization of university third mission occurs through "knowledge and technology transfer to industry and society in general," which depends fundamentally on

the availability of professionals capable of acting as "bridges" between academic knowledge and its practical application. And, since technical progress is the fruit of human creativity (FURTADO, 2000, p. 43), this creativity is enhanced when a society is equipped with knowledge, as a more educated population has a greater capacity to generate innovations.

Second, Pavitt's (1984) typology fortifies this articulation by demonstrating that "science-based sectors—where STEM professionals predominate—function as pivotal innovation diffusion hubs for the entire economy. This underscores how education in these areas not only meets specific labor market demands but also constitutes a fundamental mechanism through which universities can fulfill their function of relevant knowledge dissemination impacting multiple sectors.

Third, considering the National Innovation Systems approach (NELSON; WINTER, 2005), economic systems grow and flourish through processes of technological capacity acquisition by economic agents. In this process, the presence of qualified labor is indispensable, both for generating innovations in the productive fabric and for absorbing and adapting technologies from other regions. STEM education plays a central role in forming these capabilities, particularly when complemented by training and experimentation activities in productive contexts (LALL, 2005). In this regard, Suzigan and Albuquerque (2011) provide a critical perspective on the Brazilian context, emphasizing that the development of qualified human capital by universities and research institutes constitutes an essential pillar for the construction and maturation of a robust national innovation system. They further contend that the persistent absence or underutilization of this human capital acts as a substantial bottleneck for Brazil's technological and economic advancement.

Finally, the Latin American perspective of *vinculación* adds a crucial dimension to this framework by emphasizing that STEM education should not only serve economic objectives but also contribute to social development and community engagement. This perspective suggests that effective STEM education policies must balance technical competency development with social responsibility and territorial engagement. Thus, STEM education represents simultaneously a product of university third mission and an instrument for its realization, creating a virtuous cycle where technical competencies articulate with innovation capacities and territorial engagement to promote sustainable regional development. This framework guides our empirical analysis of STEM education transformations in Brazil and Minas Gerais, allowing us to assess not only quantitative changes but also their implications for regional development and innovation systems.

It is necessary to note that the need for professionals in STEM does not diminish the importance of professionals from other fields. On the contrary, having trained professionals in various scientific domains — such as arts and humanities, management, and law — is also essential. However, the absence or low participation of professionals in STEM may hinder significant catch-up processes, as these professionals can be understood as key actors enabling economies to engage with the profound changes brought about by successive technological revolutions.

3. STEM Graduate Trends in Brazil, Minas Gerais and Selected Countries

3.1. Methodology and Data Sources

This study employs a descriptive quantitative methodology based on secondary data analysis to examine STEM graduate patterns in Brazil and Minas Gerais. Microdata from the Higher Education Census provided by the National Institute of Educational Studies and Research Anísio Teixeira (INEP) were used for the undergraduate level and microdata from the Coordination for the Improvement of Higher

Education Personnel (CAPES) for the graduate level. Due to differences in temporal availability of databases, the research uses Higher Education Census microdata for the period from 2010 to 2023, complemented by CAPES data on graduate studies for the period between 2004 and 2022.

To enable valid cross-national comparisons, STEM field definitions follow OECD and UNESCO (2015) guidelines, adapted to the Brazilian classification of knowledge areas. Given slight differences between INEP and CAPES classifications and the absence of Brazilian consensus on STEM field definitions (CHIARINI et al., 2025), we adapted international STEM typologies to national contexts as follows: a) for undergraduate data (INEP) the areas considered were Natural Sciences, Mathematics and Statistics; Computing and Information and Communication Technologies (ICT); and Engineering, production and construction; b) for graduate data (CAPES) the areas considered were Exact and Earth Sciences; Biological Sciences and Engineering.

Data extraction and analysis utilized R statistical software, while tables and visualizations were prepared using Excel. The data and R programming of the analyses performed can be accessed at: https://zenodo.org/records/15553229.

3.2. Results and Discussion

Brazil graduated 214,171 new STEM professionals at the undergraduate level in 2023, nearly double the 118,709 graduates in 2010. During this period, STEM graduates increased from 12% to 16% of total new graduates (Table 1).

This growth partially reflects student expectations of high future demand in these fields. The World Economic Forum (2023) reports that STEM competencies are globally the most sought-after by companies, with persistent professional shortages across many regions. In Brazil, a study by the Association of Information and Communication Technology (ICT) and Digital Technologies Companies - BRASSCOM (2023) on the technology sector reveals that between 2021 and 2025, the country would need approximately 797 thousand professionals in information and communication technology (ICT), but faces an annual deficit of about 106 thousand qualified talents, indicating that current training capacity cannot meet growing demand.

Furthermore, specific policies and initiatives promoted these fields, the most significant policy being the creation and expansion of the Federal Network of Professional, Scientific and Technological Education (CEFETs). Established by Law No. 11,892, of December 29, 2008, which integrated the former Federal Centers for Technological Education (CEFETs), federal agrotechnical schools and technical schools linked to federal universities, creating the Federal Institutes of Education, Science and Technology (IFs). The structure of Federal Institutes was designed on the principle of verticalization, allowing the offering of courses from basic education (technical high school) to graduate studies, articulating teaching, research and extension with explicit focus on science and technology. This public policy prioritized expansion into interior regions and expansion of access to quality professional and technological education, with strong emphasis on STEM areas, aiming at local and regional development and the formation of qualified labor for strategic sectors of the economy (NEUHOLD, R. R.; POZZER, 2023).

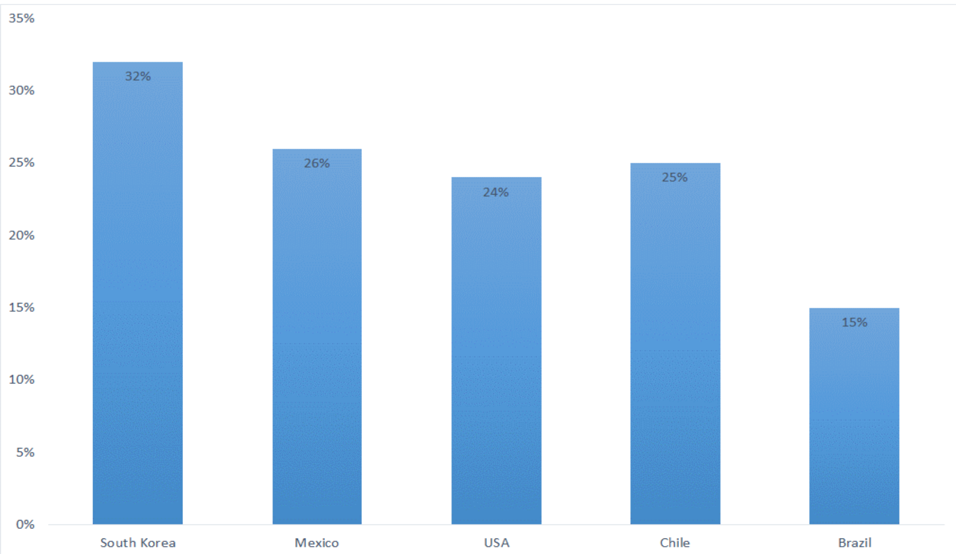
Among the total new STEM graduates in Brazil, the state of Minas Gerais was responsible for between 10% and 14% of these graduates in the same period, with the number of new graduates in the area increasing 1.6-fold from 13,954 to 22,131. Considering the percentage of STEM graduates in relation to the total new graduates in 2023, Minas Gerais had 16% of the total amount, a value higher than 2010 (12%), but declined compared to the period from 2014 to 2020, where this percentage oscillated between 20% and 23% (Table 1). Table 1 - Percentage of new graduates in STEM areas in relation to the total number of graduates in all areas of knowledge and total number of new graduates in STEM areas: Minas Gerais and Brazil - 2010 to 2023.

Anos	MG		Brasil		MG STEM/Brasil STEM
	%	Total	%	Total	10%
2010	12	13.534	12	118.709	11%
2011	14	15.311	12	125.199	12%
2012	15	16.335	13	137.823	12%
2013	17	17.715	14	140.745	13%
2014	19	19.808	15	150.488	13%
2015	20	22.509	15	172.867	13%
2016	21	26.018	16	190.071	14%
2017	22	27.719	17	203.740	14%
2018	23	30.380	18	222.773	14%
2019	20	28.322	18	219.797	13%
2020	20	26.490	17	215.594	12%
2021	17	24.393	15,2	202.576	12%
2022	16	21.638	15,5	200.575	11%
2023	16	22.131	15,5	214.171	10%

***Source:** INEP, Higher Education Census Microdata, 2010 to 2023. Author's elaboration*

However, international comparisons reveal Brazil's relatively modest performance in STEM graduate production. Based on the most recent available data (2021), Brazil generated only 15% of its new graduates in STEM fields, substantially below OECD benchmarks. This contrasts markedly with leading economies: Germany achieved 35% STEM graduate share, South Korea 32%, Mexico 26%, Chile 25%, and the United States 24% (OECD, 2023). This performance gap suggests significant untapped potential for Brazil's participation in the global knowledge economy, as illustrated in Figure 1.

Figure 1 - STEM graduates as percentage of total new graduates across all fields of knowledge: selected countries, 2021

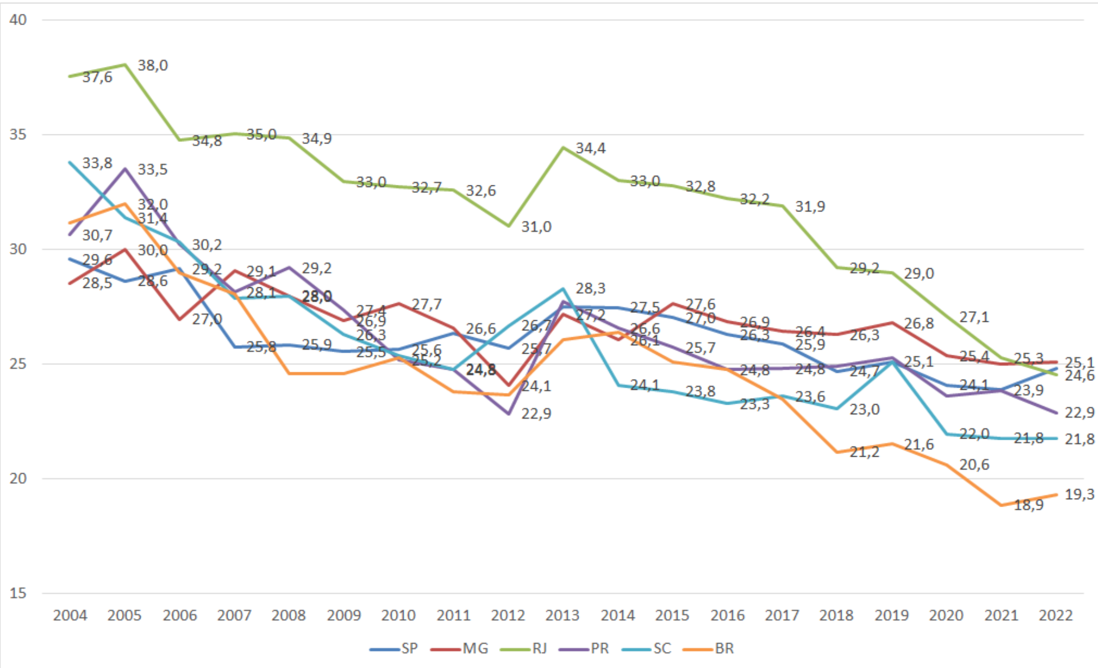


***Source**: OECD. Author's elaboration. https://goingdigital.oecd.org/en/indicator/43*

Conversely, postgraduate STEM education demonstrates marginally superior performance relative to undergraduate levels. In 2022, Brazil achieved 19% STEM representation among new postgraduate degrees, while Minas Gerais reached 25.1%, positioning it as the leading state in STEM postgraduate production. São Paulo ranked second with 24.8%, followed by Rio de Janeiro at 24.6%. Nevertheless, this apparent strength conceals concerning downward trends across major Southern and Southeastern states, with Brazil experiencing a particularly steep decline, as demonstrated in Figure 2.

STEM postgraduates, particularly master's and doctoral degree holders, typically possess the specialized competencies essential for Research and Development (R&D) activities, including complex problem-solving capabilities, logical reasoning, critical thinking, and the capacity to apply scientific and technological knowledge for innovation and technological advancement. However, Brazil's private sector has demonstrated limited capacity for absorb these highly qualified professionals. Innovation Survey (PINTEC)[2] data reveal that postgraduates have consistently failed to secure positions in private R&D laboratories over time. Between 2004 and 2017, Minas Gerais produced 21,063 STEM masters and doctoral graduates, yet PINTEC indicates that private sector R&D employment for postgraduates increased from merely 261 to 406 positions—representing only 2% of the trained workforce. Nationally, this absorption rate reached 4%. This structural mismatch, combined with the academic sector's limited capacity to absorb all trained professionals, may contribute to the declining proportion of STEM postgraduate degrees observed in both Brazil and Minas Gerais (IBGE, 2019).

Figure 2 - Percentage of new STEM master's and doctoral graduates: Brazil and selected states, 2004-2022



***Source**: CAPES, microdata. Author's elaboration. <dadosabertos.capes.gov.br>*

In absolute terms, postgraduate STEM production represents a substantially smaller fraction of total STEM human capital formation. While Minas Gerais generated 21,638 new STEM graduates in 2022, master's and doctoral degrees accounted for merely 2,232 individuals—approximately 10% of

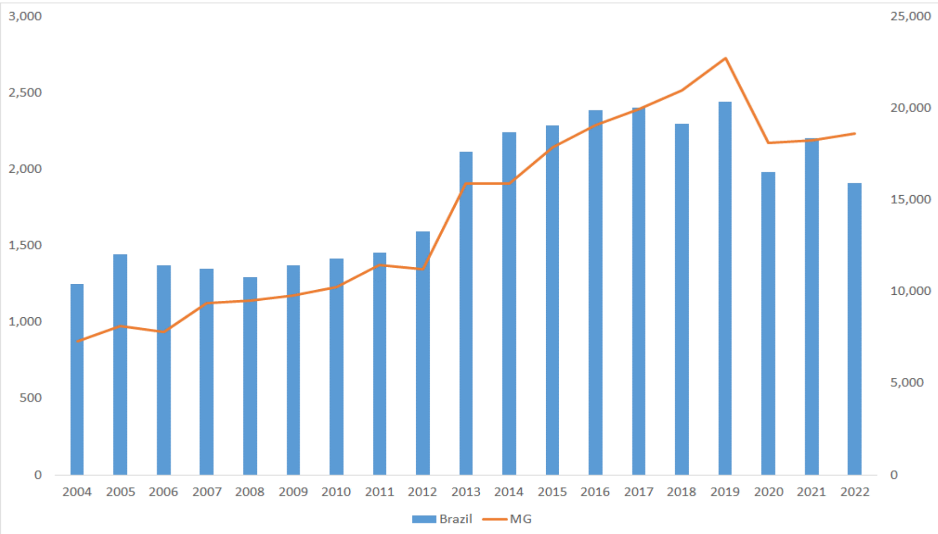
[2] The most recent PINTEC data available is from 2017. Since then, the semiannual PINTEC was introduced, but it no longer includes this indicator. PINTEC (Pesquisa de Inovação) is Brazil's official survey on innovation activities in enterprises, conducted by IBGE (Brazilian Institute of Geography and Statistics).

undergraduate output. This ratio underscores the pyramidal structure of Brazil's STEM education system, with postgraduate education serving as a specialized apex rather than a broad foundation for advanced technical competencies.

From an alternative perspective, absolute numbers reveal more nuanced dynamics. STEM postgraduate production in Minas Gerais nearly doubled between 2010 and 2022 (from 1,230 to 2,236), a trend observed nationally. This suggests that declining STEM percentages in postgraduate education reflect the expansion of non-STEM fields rather than absolute contraction of STEM programs. However, since 2020, both Minas Gerais and Brazil have experienced genuine declines in STEM postgraduate completions compared to the 2013-2019 period (Figure 3), largely attributable to COVID-19 pandemic disruptions that extended dissertation/thesis defense timelines for postgraduate students.

Brazil's STEM workforce composition reflects a broad-based educational pyramid, with technical (35%) and undergraduate (59%) levels comprising over 90% of STEM professionals in 2021. This distribution pattern aligns with international trends and demonstrates consistency across temporal periods, as illustrated in Table 2. Such concentration in foundational and intermediate levels suggests Brazil's STEM education system prioritizes broad access over specialized advanced training.

Figure 3 - Total STEM master's and doctoral completions: Minas Gerais and Brazil, 2004-2022



Source: *CAPES, microdata. Own elaboration. <dadosabertos.capes.gov.br>*

Table 2 - Percentage of graduates in STEM fields by degree level: selected countries – 2021

	Technical *	Bachelor's degree	**Master's degree**	**Doctoral degree**	Total
França	48%	20%	30%	2%	100%
Japão	38%	44%	17%	2%	100%
Coreia	22%	64%	10%	4%	100%
EUA	27%	52%	18%	3%	100%
Brasil	35%	59%	4%	2%	100%

Source: *OECD. OECD Data Explorer. Own elaboration. Available at: https://data-explorer.oecd.org/.*
**This includes graduates from upper secondary vocational education and post-secondary non-tertiary vocational education, referred to here as technical courses for clarity.*

Given the strategic importance of this professional cohort and the availability of comprehensive data at both national and state levels, the following section provides an in-depth analysis of STEM undergraduate professionals in Minas Gerais, contextualized within Brazil's broader higher education landscape and national comparative framework.

3.2.1. Higher Education STEM Graduates in Minas Gerais and Brazil: Analysis of the 2010-2023 Period

Examining the general panorama of higher education provision in Brazil and Minas Gerais, in 2023, Minas Gerais possessed 22 public higher education institutions (HEIs), including 18 federal and 4 state institutions. These institutions maintain campuses offering face-to-face courses across all state regions. Brazil had 316 public HEIs total, with 121 federal institutions, 18 of which are located in Minas Gerais, encompassing 15% of the country's federal universities. Regarding private institutions, there were 288 institutions, representing 13% of the national total. Therefore, although experiencing some growth during the period, this growth was just over half that observed nationally (Table 3).

Table 3 – Number of higher education institutions: Minas Gerais and Brazil – 2023

Region	Public			Private
	Federal	State	Municipal	
Minas Gerais	18	4	-	288
Brasil	121	138	57	2.264
(%) MG	15%	3%	-	13%

***Source**: INEP, Higher Education Census microdata, 2023. Own elaboration.*

Considering total undergraduate completions in Minas Gerais, a 22% increase occurred (from 112,319 to 137,596) between 2010 and 2023. Brazil experienced a 40% total increase in undergraduate completion volume: from 980,662 to 1,374,789 completions. Figures 5 and 6 present this information. Therefore, although experiencing certain growth during the period, this growth was slightly more than half that observed nationally. A notable similarity between Brazil and Minas Gerais was distance learning's contribution to this increase. In Brazil, distance higher education completions between 2010 and 2023 jumped from 15% to 43% of total completions (from 144,856 to 591,834), while in Minas Gerais it increased from 17.5% to 41.4% during the same period (from 19,617 to 56,978) (Figures 4 and 5).

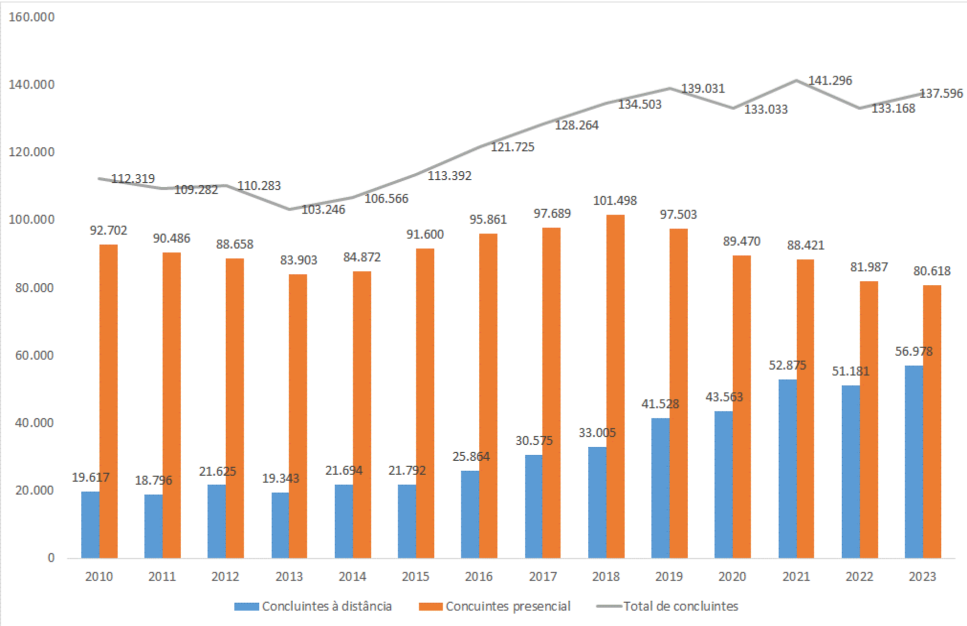
This increase in distance undergraduate completions is related to various factors, including the convenience of these courses that can be completed at more flexible hours to accommodate work schedules, as well as legal measures facilitating new distance course openings. Among these legal measures, Decree No. 9,057/2017 stands out, which, among other aspects, permits new distance courses to open without requiring institutions to offer face-to-face courses, and also allows new distance courses to open without MEC authorization in HEIs already authorized for distance education (DE).

Scudeler and Tassoni (2023) also point out that reduced DE course tuition fees were among strategies adopted by private HEIs to maintain student numbers despite reduced Student Financing Fund (FIES)3 resources from 2015 onward, contributing to distance undergraduate course expansion. According to the authors, average DE course monthly fees fell nearly by half from R$ 405.22 to R$248.67 or US$ 73.37 to

[3] **The Student Financing Fund (FIES)** is a program administered by Brazil's Ministry of Education (MEC) that provides financial assistance to low-income students pursuing higher education at private institutions. The program aims to improve access to tertiary education by enabling financially disadvantaged students to afford tuition fees at non-free, in-person undergraduate programs. FIES offers different financing modalities, with interest rates that may vary according to the student's family income.

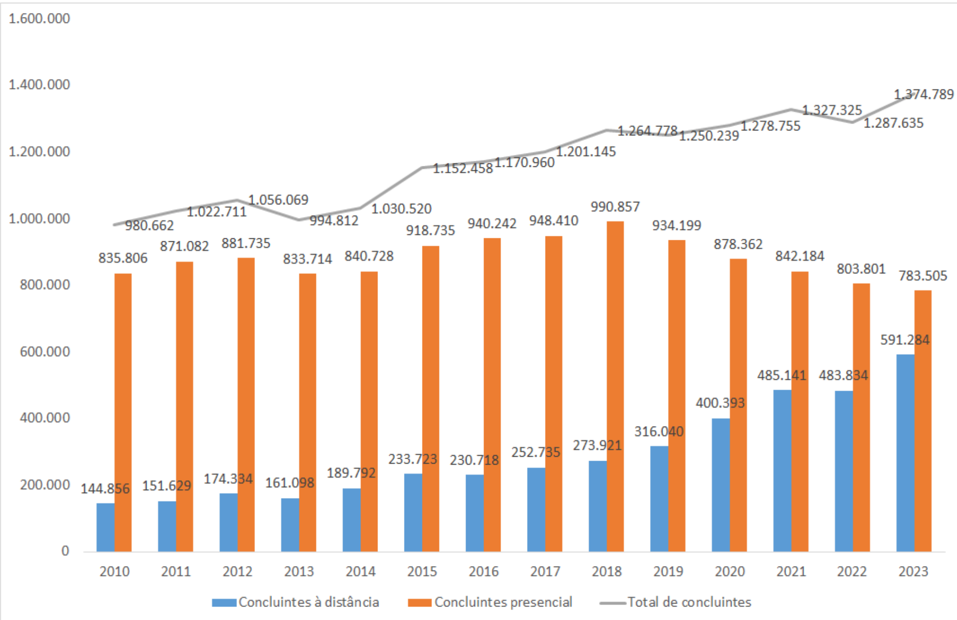
US$ 44.90 over the last decade.

Figure 4 - Undergraduate completions in Minas Gerais: Total, face-to-face and distance – 2010 to 2023



Source: *INEP, Higher Education Census microdata, 2010 to 2023. Own elaboration.*

Figure 5 - Undergraduate completions in Brazil: Total, face-to-face and distance - 2010-2023



Source: *INEP, Higher Education Census microdata, 2010 to 2023. Own elaboration.*

It should be noted that private universities primarily drove these changes in completion volumes in both Brazil and Minas Gerais, despite public universities expanding completion volumes by over 50% between 2010 and 2023 (from 17,998 to 27,544) in Minas Gerais and over 30% nationally (from 190,809 to 250,358). Private universities in 2023 accounted for approximately 80% of total completions with significant participation in distance education in both Minas Gerais and Brazil (Table 4).

Table 4 - Private and public HEI undergraduate completions, between face-to-face and distance course modalities: Minas Gerais and Brazil - 2010 and 2023

Regions	Completions		**2010**		**2023**	
			Total	**%**	**Total**	**%**
MG	Private HEIs	Face-to-face	76,422	68	54,011	39
		Distance	17,899	16	56,041	41
		Total	94,321	84	110,052	80
	Public HEIs	Face-to-face	16,280	14	26,607	19
		Distance	1,718	2	937	1
		Total	17,998	16	27,544	20
	Total		**112,319**	100	**137,596**	100
Brasil	Private HEIs	Face-to-face	657.187	67	553.263	40
		Distance	132.666	14	571.168	42
		Total	789.853	81	1.124.431	82
	Public HEIs	Face-to-face	178.619	18	230.242	17
		Distance	12.190	1	20.116	1
		Total	190.809	19	250.358	18
	Total		**980.662**	100	**1.374.789**	100

***Source**: INEP, Higher Education Census microdata, 2010 and 2023. Own elaboration.*

Considering STEM areas, private universities likewise accounted for the majority of STEM professionals trained in both Brazil and Minas Gerais. During 2010-2023, 70-73% of higher education STEM completions came from the private sector, a trend partly attributable to these institutions' territorial reach. In absolute terms, both public and private sectors grew at similar rates, with increases of 1.72 and 1.84-fold respectively, corresponding to absolute increases from 35,865 to 61,943 in the public sector and from 82,701 to 152,228 new completions in the private sector (Table 5 and Figure 6). Minas Gerais, conversely, although experiencing STEM completion expansion until 2019—driven mainly by the private sector—has shown a decline since that period, reaching 2014 levels by 2023 (Figure 6).

Regarding face-to-face and distance modalities, face-to-face education prevails in STEM areas throughout the analyzed period. Nevertheless, the almost exponential increase in distance education's participation in total STEM completions deserves highlighting: between 2010 and 2023, the share of professionals trained in this modality increased from 7% to 34% of total STEM graduates in Brazil. In absolute terms, this represented an increase from 8,987 to 73,016, an eight-fold increase during the period. In Minas Gerais, this increase was relatively smaller: from 7% to 28%, a six-fold increase (Figure 7 and Table 5).

This aspect seems to reflect a structural shift toward distance education also in areas with greater technological content. While this expansion has significantly contributed to professional training in strategic fields for the country's technological development, quality concerns emerge regarding these graduates, since these areas generally demand more practical training hours and/or greater infrastructure investment. This raises concerns about potential deficiencies in these professionals in practical skills, since these courses require laboratory experimentation and face-to-face interaction to develop technical competencies. Santos et al. (2016), for example, analyzed distance education centers in Minas Gerais, pointing to great fragility and heterogeneity in center quality. Many do not meet the minimum requirements established in legislation and MEC quality standards.

The most recent National Student Performance Examination (ENADE) 2023 data, conducted by the Ministry of Education (MEC) to assess graduating undergraduate student performance in Brazil, shows that only 1.3% of DE graduations achieved maximum scores, while 42% of face-to-face programs had good or excellent scores. Public face-to-face and DE courses continue performing better than private ones, with most private institutions demonstrating poor performance, reinforcing quality disparities between sectors (BARBOSA, 2025; INEP, 2023). This scenario underscores the imperative to evaluate and enhance educational quality in Brazil and emphasizes that STEM distance education expansion, if not accompanied by rigorous quality assurance mechanisms and practical opportunities, may compromise the capacity to train professionals with adequate characteristics.

Conversely, DE enabled STEM program expansion to regions with limited face-to-face offerings, promoting access democratization (ALVES, 2023). DE also diversified access, making it possible for students from more vulnerable families to enroll, due to reduced costs combined with policies like FIES and PROUNI (SCUDELER; TASSONI, 2023).

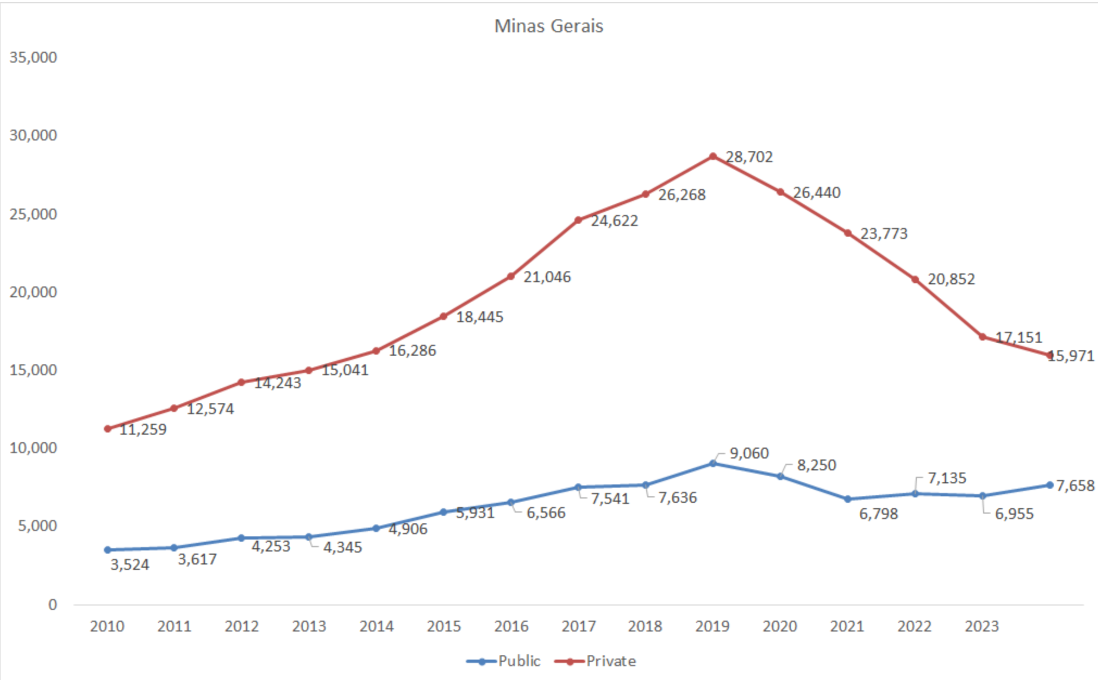
Table 5 - Graduates in STEM fields from private and public higher education institutions, in both in-person and distance learning modalities: 2010 and 2023 (Brazil and Minas Gerais)

Years		Brazil			Minas Gerais		
		Face-to-face	DE	Total	Face-to-face	DE	Total
2010	Public	33.930	2.078	36.008	3.617	0	3.617
	Private	75.882	6.819	82.701	8.957	960	9.917
	Total	**109.812**	**8.897**	**118.709**	**12.574**	**960**	**13.534**
2023	Public	57.982	3.961	61.943	7.658	0	7.658
	Private	83.173	69.055	152.228	8.313	6.160	14.473
	Total	**141.155**	**73.016**	**214.171**	15.971	6.160	22.131
Δ 2010/2023		1,29	**8,21**	1,80	1,27	**6,42**	1,64

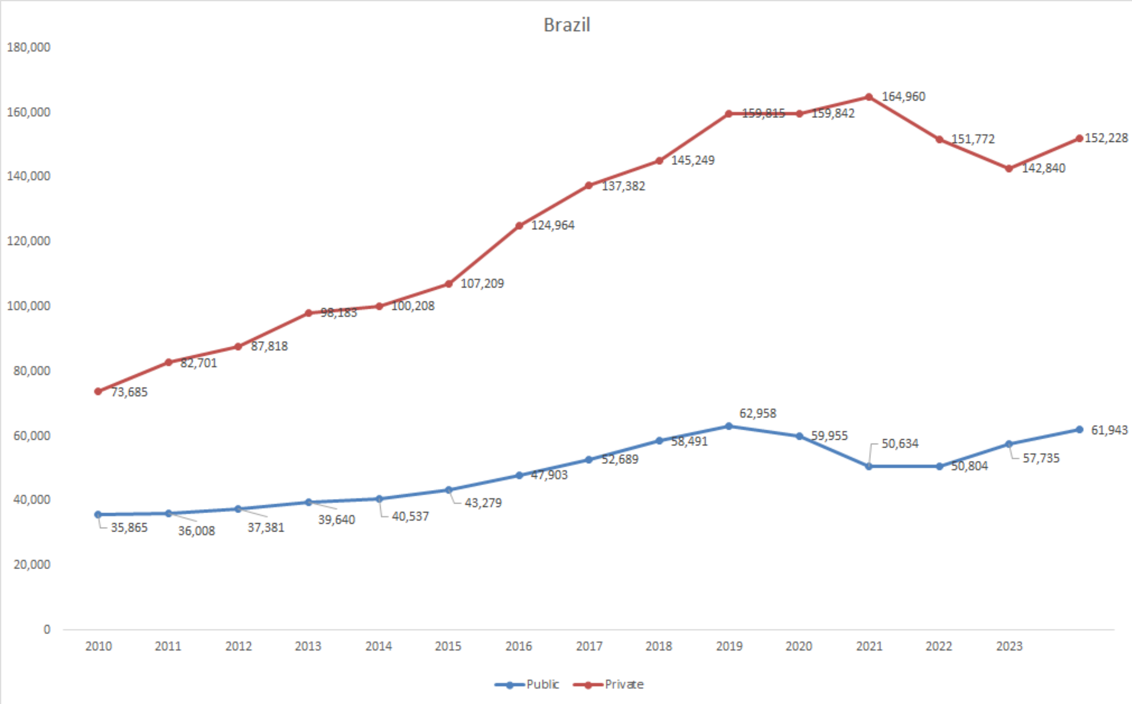
***Source**: INEP, Higher Education Census microdata, 2010 and 2023. Own elaboration.*

Figure 6 - Higher education STEM completions from public and private sectors: Minas Gerais and Brazil - 2010 to 2023

a)

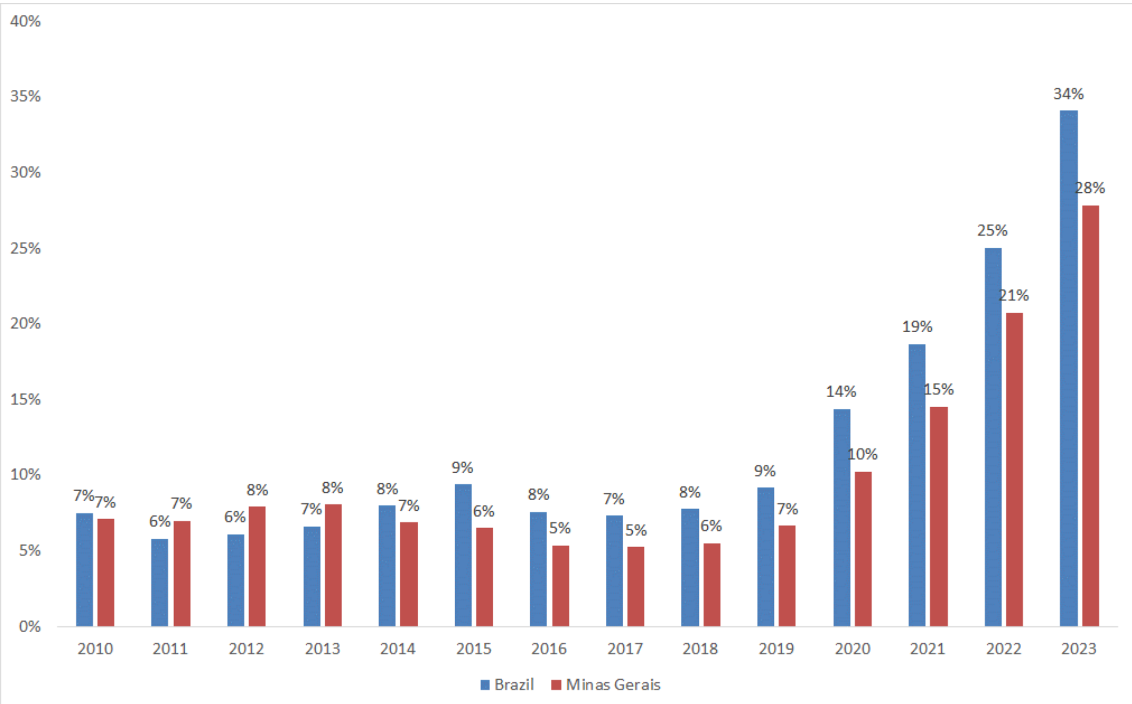


b)



Source: *INEP, Higher Education Census microdata, 2010 and 2023. Own elaboration.*

Figure 7 - Percentage of higher education STEM completions in distance education relative to total completions: Minas Gerais and Brazil - 2010 to 2023

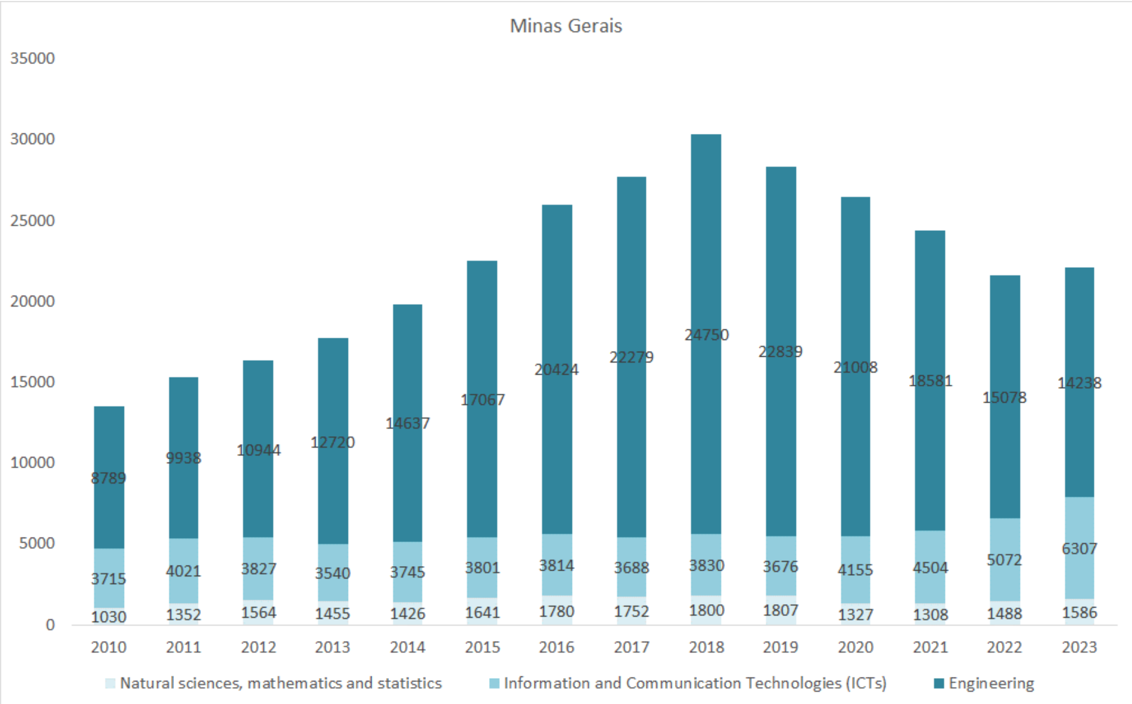


Source: *INEP, Higher Education Census microdata, 2010 and 2023. Own elaboration.*

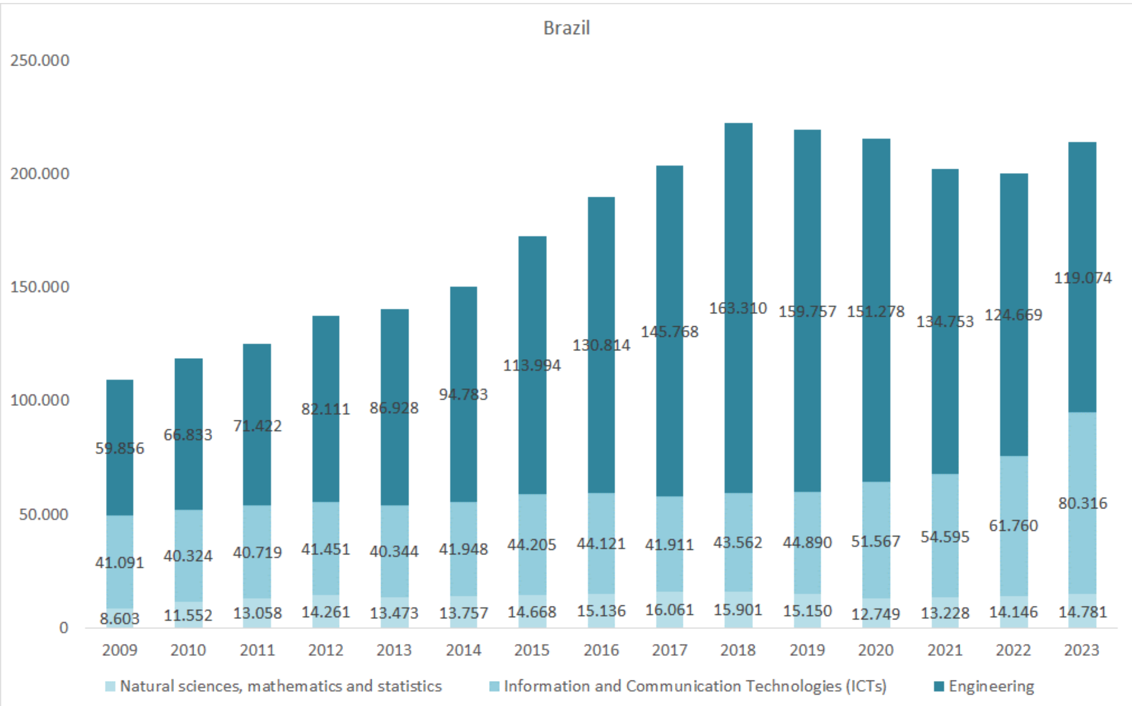
Considering STEM areas in their constituent parts between 2010-2023 (Figure 8), engineering areas have the largest participation share within STEM areas in both Minas Gerais and Brazil. However, in Brazil overall, graduates linked to information and communication technology (ICT) areas have shown slightly higher growth rates than Minas Gerais: 1.9, jumping from 41,091 to 80,306 completions. For Minas Gerais, this rate was 1.7 (jumping from 3,715 to 6,307 completions).

Figure 8 - STEM completions according to constituent areas: Minas Gerais and Brazil - 2010 to 2023

a)



b)



Source*: INEP, Higher Education Census microdata, 2010 to 2023. Own elaboration.*

3.2.2. Higher Education STEM Completions by Minas Gerais Region

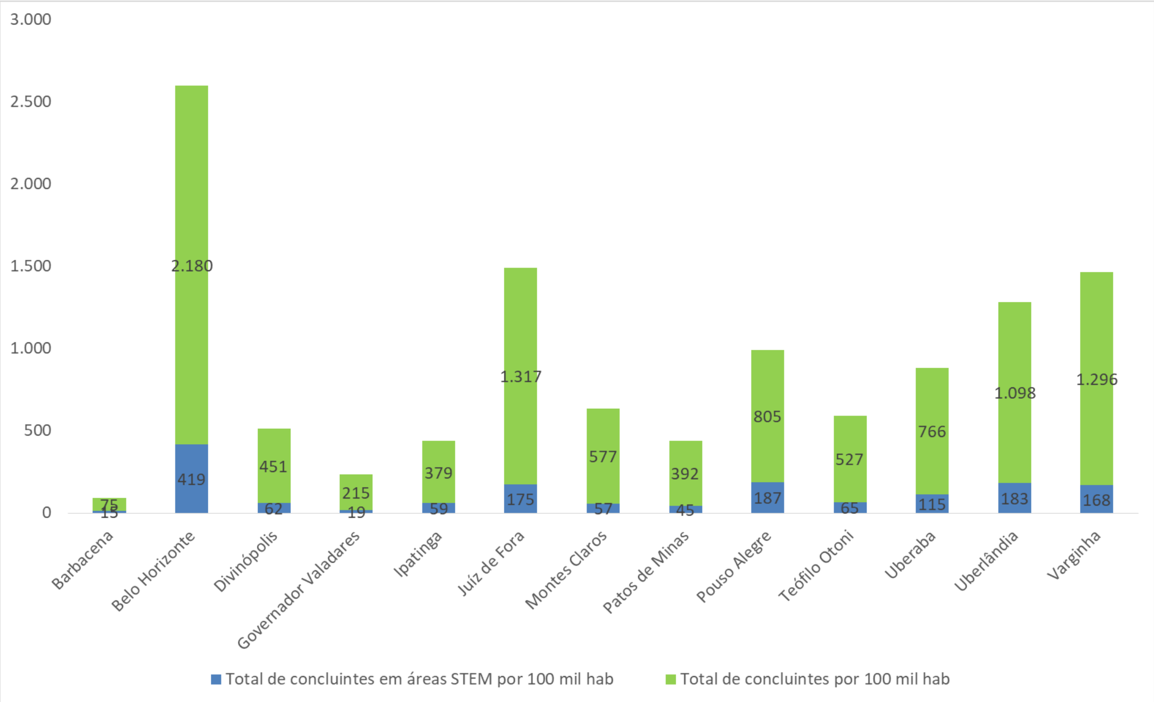
Regarding higher education STEM completion concentration by Minas Gerais regions, the Belo Horizonte region has the highest completion concentration and increased this concentration during the period from 40% to 42%. During this period, real completion growth nearly doubled from 5,357 to 9,233. Some regions experienced slight growth in their participation, such as Barbacena and Teófilo Otoni, while others, like Montes Claros, Juiz de Fora, and Uberlândia, lost participation, and others remained stable. This information points to the relative importance of the Minas Gerais capital and its surroundings regarding infrastructure supporting course offerings of this nature. This information can be observed in Table 6. Map 1 and Figure 9 shows the geographical distribution of these completions for 2022 per 100,000 inhabitants, indicating that even when weighted by population, the Minas Gerais regions contributing most to state STEM education are Belo Horizonte, Uberlândia, Juiz de Fora, and Pouso Alegre. The concentration of STEM completions in the Belo Horizonte region reinforces its strategic role as an articulating center for technological higher education in Minas Gerais. This pattern can be explained by greater higher education institution presence, adequate infrastructure availability, and articulation with research centers and knowledge-intensive productive sectors.
The high concentration of completions in the Belo Horizonte region evidences profound regional asymmetries in qualified workforce formation in Minas Gerais, even when considering population dimensions. This inequality tends to limit regional innovation ecosystem strengthening in other parts of the state. Therefore, the trend toward STEM graduate concentration in Belo Horizonte, while seemingly indicating local advancement, probably contributes to perpetuating or even deepening spatial inequalities in the state, demanding public policies aimed at scientific-technological development interiorization and more equitable distribution of educational and professional opportunities. Kempton et al. (2021) highlight that universities contribute to regional development through multiple channels, but their effectiveness depends on adequate territorial distribution. Excessive concentration in the Belo Horizonte metropolitan region may limit knowledge spillovers to other state regions, reducing balanced regional development potential.

Table 6 - Percentage of higher education STEM completions according to Intermediate Geographic Regions (IGRs) of Minas Gerais: 2010 to 2023

IGR	2010 (%)	Total STEM Graduates (2010)	2023 (%)	Total STEM Graduates (2023)
Barbacena	2%	311	5%	1,141
Belo Horizonte	40%	5,357	42%	9,233
Divinópolis	4%	544	4%	882
Governador Valadares	2%	290	1%	283
Ipatinga	4%	587	3%	736
Juiz de Fora	12%	1,614	10%	2,125
Montes Claros	6%	843	3%	619
Patos de Minas	2%	239	3%	594
Pouso Alegre	7%	967	9%	1,961
Teófilo Otoni	1%	121	2%	494
Uberaba	5%	654	4%	805
Uberlândia	8%	1,054	8%	1,856
Varginha	7%	953	6%	1,402
Total	**100%**	**13,534**	**100%**	**22,131**

Source: *INEP, Higher Education Census microdata, 2022; IBGE, Demographic Census, 2022. Own elaboration.*

Figure 9 - Higher education completions in all areas and STEM areas by Minas Gerais IGRs per 100,000 inhabitants - 2022



Source: *INEP, Higher Education Census microdata, 2022; IBGE, Demographic Census, 2022. Own elaboration.*

Map 1 - Higher education STEM completions per 100,000 inhabitants – IGRs: 2022

Source: *INEP, Higher Education Census microdata, 2022; IBGE, Demographic Census, 2022. Own elaboration.*

4. Discussion: Interpreting the Data through a Theoretical Lens

Based on the theoretical framework and empirical findings, this study highlights key challenges and implications regarding STEM education in Brazil, particularly in Minas Gerais, within the context of technological paradigms, university missions, and innovation systems.

The empirical evidence reveals a significant quantitative expansion of STEM education in Brazil, aligning with theoretical expectations about the growing importance of STEM competencies in the current information and communication technologies paradigm (PEREZ, 2024) and responding to documented industry demands, such as BRASSCOM's (2023) identified annual deficit of 106,000 ICT professionals. However, this growth, largely propelled by the rapid expansion of distance education and the predominant role of private institutions (accounting for 70-73% of STEM graduates), is accompanied by notable quality concerns. ENADE 2023 results, for instance, show a stark disparity, with only 1.3% of distance programs achieving maximum scores compared to 42% of face-to-face programs.

Beyond the concerns about instructional quality, the quantitative expansion driven by private institutions also raises questions about its alignment with the university's Third Mission (TM) and could be limiting its effects, since in Brazil these institutions are widely recognized as being more focused on teaching functions than on other missions (MACULAN; MELLO, 2009). It is the public Higher Education Institutions (HEIs) in Brazil that are primarily responsible for this role (SUZIGAN; ALBUQUERQUE, 2011).

From the perspective of Compagnucci and Spigarelli's (2020) third mission framework, this suggests that quantitative expansion alone does not automatically translate into effective knowledge transfer capabilities. This tension between access democratization, central to the vinculación model (CUESTA-DELGADO et al., 2024), and the quality requirements for effective university-industry collaboration, indicates that current expansion patterns may compromise the formation of "Triple Helix workers" essential for effective third mission implementation. The predominance of private institutions and associated quality concerns further imply that effective vinculación necessitates more sophisticated governance mechanisms capable of simultaneously optimizing social access and educational quality.

Furthermore, despite this quantitative growth, Brazil's 15% STEM graduate share in 2021 remains substantially below OECD benchmarks (e.g., Germany 35%, Korea 32%, USA 24%), suggesting that the country's STEM education system has not yet achieved the scale necessary to fully participate in the global knowledge economy, as theorized by technological paradigms literature (PEREZ, 2002).

The case of Minas Gerais provides crucial insights into the interplay between STEM education and territorial development, revealing an increasing concentration of STEM graduates in the Belo Horizonte metropolitan region. This spatial concentration, despite the presence of federal universities across all state regions and the post-2018 stagnation of STEM graduate numbers in the state (contrasting with continued national growth), contradicts theoretical expectations that universities act as "engines of social, economic and cultural development of the regions in which they operate" (COMPAGNUCCI; SPIGARELLI, 2020). Instead of promoting balanced regional development, this pattern appears to reinforce existing spatial inequalities, potentially limiting knowledge spillovers to other regions and hindering the development of broader innovation ecosystems.

The spatial distribution of higher education institutions (HEIs) plays a significant role in fostering regional development and human capital formation. In this regard, Seri and Compagnucci (2024) offer a compelling analysis of the contributions of university satellite campuses to local municipalities and regions in Italy. Their findings underscore how these distributed university presences can act as vital anchors for economic diversification, innovation diffusion, and skill development in areas beyond major metropolitan centers. By providing access to higher education and research facilities closer to communities, satellite campuses can bridge geographical disparities in educational opportunities and align academic offerings with specific regional needs. This perspective is particularly relevant for understanding the strategic importance of expanding STEM education initiatives into subnational contexts, as it suggests that the physical presence and local embeddedness of HEIs are critical for translating educational investments into tangible regional development outcomes, especially in regions facing challenges of educational concentration or brain drain.

Compounding this territorial concentration is a critical structural mismatch between STEM human capital formation and innovation system absorption capacity, particularly evident at the postgraduate level. The concerning finding that only 2% of STEM master's and PhD holders in Minas Gerais work in private R&D activities (compared to 4% nationally) suggests profound structural disconnections between educational output and regional innovation systems.

This mismatch indicates that the expected innovation diffusion mechanisms theorized by Pavitt's (1984) science-based sectors typology might not be functioning effectively in the regional context. From a National Innovation Systems perspective (NELSON; WINTER, 1982), this suggests either insufficient demand from the productive sector or inadequate alignment between educational offerings and industry needs. The limited absorption of highly qualified professionals by the private sector, contrasting with more developed innovation systems where private R&D employment provides clear career pathways (OECD, 2021), highlights structural constraints in Brazil's innovation system that transcend educational policy alone.

One of the factors contributing to this scenario is the absence of strong industrial policies that provide clear missions and pathways to be followed, and the lack of a long-term agenda for innovation that provides a sense of mission (CORRÊA; CARIO, 2022). In this context, policy discontinuity often frustrates the long-term innovation plans of firms (MAZZUCATO; PENNA, 2016; JANSSEN, et al. 2021) and is potentially a factor that weakens universities' Third Mission (TM) activities.

Finally, the Brazilian experience with STEM education expansion offers important lessons for understanding the challenges of implementing universities' third mission in developing country contexts. While quantitative expansion is important for achieving key social objectives, realizing the full potential of STEM education for regional development requires more sophisticated approaches that can simultaneously address challenges of access, quality, territorial distribution, and integration with coordinated industrial and science, technology, and innovation (ST&I) policies.

5. Final Considerations

STEM fields are fundamental to understanding economic growth and development. This article examines transformations within these disciplines over the past decade. Although not the sole determinant, a qualified workforce engaged in activities aligned with the current technological paradigm is essential for building endogenous technological capabilities. It serves as a critical determinant for addressing appropriability challenges and facilitating the diffusion of General-Purpose Technologies (GPTs) embedded in the prevailing techno-economic paradigm. Such human capital enables not only the creation of new technologies but also their transfer and adaptation.

This article's primary contribution is demonstrating, through exploratory analysis of STEM graduate data, compositional changes in the workforce trained in these areas over the last decade. For policy development, it is important to inform public managers and the business sector about the supply of these professionals over the years, as having knowledge about this movement implies knowing the potentialities of territories in terms of the presence of a continuous flow of qualified professionals.

5.1. Policy Implications and Recommendations

Drawing on the theoretical framework and empirical findings, this study proposes a comprehensive policy agenda structured around five key pillars. The first pillar focuses on Quality and Relevance Enhancement of STEM education. The rapid expansion of distance STEM education, while democratizing access, raises serious quality concerns. Policy interventions in this area could consider implementing specific requirements for laboratory infrastructure in distance courses, mandatory internships in companies or non-academic organizations, the participation of productive sector professionals in curricular committees, and the regular evaluation of training adequacy to regional demands.

The second pillar addresses University-Industry Articulation, which is essential for effective third mission implementation. Recommended policies include expanding student and faculty mobility programs between universities and companies, promoting collaborative research projects between academic and industry partners, the development of industrial doctorate programs adapted to the Brazilian context, and the creation of innovation hubs that facilitate knowledge transfer.

The third pillar, Territorialization and Regional Development, draws on insights from Kempton et al. (2021) regarding multidimensional university contributions. It proposes building differentiated strategies by geographic region, creating regional STEM education poles articulated with local vocations, promoting programs to encourage graduate retention in non-metropolitan regions, and establishing partnerships with local governments for developing innovation ecosystems.

The fourth pillar, Vinculación and Social Function, considers the social orientation of Latin American universities. Policies could promote the integration of extension activities in STEM curricula, the development of projects for applying STEM knowledge to solve social problems, the creation of scientific education programs for local communities, and the articulation between STEM education and sustainable development objectives, emphasizing their integration with the productive sector. E essa vinculação pode estar relacionada ainda com objetivos do setor produtivo. Crucially, this vinculación can also be profoundly aligned with the objectives of the productive sector: directing industrial policies towards solving social problems can become a significant asset, forging a powerful link between the productive sphere and broader societal well-being.

Finally, the fifth pillar concentrates on Governance and Institutional Coordination. Effective alignment of the third mission with integrated ST&I (Science, Technology, and Innovation) policies requires robust governance frameworks (MAZZUCATO; PENNA; JANSSEN et. al, 2021). Key mechanisms may include establishing regional STEM development councils to foster multisectoral collaboration, strengthening institutional coordination among ministries (e.g., education, science and technology, and economic development), implementing integrated information systems to monitor graduate outcomes and skills alignment with labor market needs, and conducting periodic impact evaluations to assess the regional socioeconomic effects of STEM education initiatives.

5.2. Limitations and Future Research Directions

This exploratory analysis of STEM education data provides a foundation for understanding structural changes in territories, but several limitations should be acknowledged. The quantitative approach, while revealing important patterns, cannot capture the qualitative dimensions of university-industry interactions or the specific mechanisms through which STEM education contributes to regional development.

Future research should pursue several directions. First, qualitative investigations of the relationship between STEM education expansion and effective university third mission implementation, examining specific cases of successful and unsuccessful knowledge transfer. Second, studies examining alignment between STEM graduate preparation and occupational performance, including analysis of graduate migration patterns and regional retention factors. Third, esearch examining the relationship between market expectations and the number of professionals trained, assessing whether current volumes are adequate for regional development needs.

From a policy perspective, it becomes fundamental to reinforce the articulation between labor training strategies and industrial and innovation policies, fostering virtuous circles that drive economic development. The misalignment between these spheres tends to produce suboptimal results and compromise the effectiveness of development induction efforts.

5.3. Concluding Remarks

The Brazilian experience with STEM education expansion offers valuable lessons for understanding the relationship between higher education and regional development in the context of university third mission. Although significant quantitative progress has been achieved, the challenge lies in ensuring this expansion translates into meaningful contributions to innovation systems and territorial development.

The theoretical framework developed in this study - integrating third mission concepts, innovation systems theory, mission oriented approach and the Latin American Vinculación perspective - provides a foundation for understanding these complex relationships. The policy recommendations emerging from this analysis reflect the need for sophisticated governance mechanisms that can balance quality, access, social responsibility, and economic development objectives.

Ultimately, the study calls for a reconfiguration of STEM education policies to ensure they fulfill their transformative potential - not just in expanding numbers, but in reshaping regional futures through effective implementation of university third mission objectives. This requires moving beyond simple quantitative targets toward comprehensive strategies that address quality, territorial distribution, industry articulation, and social engagement in integrated ways.

The path forward demands continued research, policy experimentation, and institutional innovation to develop models of STEM education that can effectively serve both social and economic development objectives while contributing to the construction of more robust and inclusive innovation systems.

References

AGHION, P., BOUSTAN, L., HOXBY, C., & VANDENBUSSCHE, J. (2009). The causal impact of education on economic growth: Evidence from US. Brookings Papers on Economic Activity, 2009(1), 1-73.

ALVES, C. (2023). Educação à Distância: Limites e Possibilidades. In Educação à distância: Uma nova concepção de aprendizado e interatividade (pp. 5-27). Futura. https://capacitacao.proj.ufsm.br/pluginfile.php/6094/mod_folder/content/0/Arquivos/livro_ead.pdf

ARCHIBUGI, D., CESARATTO, S., & SIRILLI, G. (1991). Sources of innovative activities and industrial organization in Italy. Research Policy, 20(4), 299-313.

BARBOSA, R. (2025, 29 de julho). Only 14% of distance courses and 42% of face-to-face courses have good or excellent grades. Poder360. https://www.poder360.com.br/poder-educacao/so-14-dos-cursos-ead-e-42-dos-presenciais-tem-nota-boa-ou-otima/

BRASSCOM. (2023). Demanda de Talentos em TIC e Estratégia TCEM: Relatório Setorial 2023. Brasscom. https://brasscom.org.br/pdfs/demanda-de-talentos-em-tic-eestrategia-tcem/

BREINER, J. M., HARKNESS, S. S., JOHNSON, C. C., & KOEHLER, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. School Science and Mathematics, 112(1), 3-11.

BRITTO, G., PEREIRA DOS SANTOS, U., KRUSS, G., & ALBUQUERQUE, E. (2015). Global innovation networks and university-firm interactions: An exploratory survey analysis. Revista Brasileira de Inovação, 14(1), 163-192.

BUSH, V. (1945). Science: The endless frontier. U.S. Government Printing Office. https://nsf.gov/od/lpa/nsf50/vbush1945.htm

CAPES. (2023). Dados Abertos. Fundação Coordenação de Aperfeiçoamento de Pessoal de Nível Superior. https://dadosabertos.capes.gov.br/

CASTELLACCI, F. (2004). How does innovation differ across sectors in Europe? Evidence from the CIS-SIEPI database (TIK Working Paper No. 2004-04). University of Oslo. [suspicious link removed]

CHIARINI, T., PEREIRA, L. S., & SILVA, L. A. (2025). A liderança negra nos grupos de pesquisa no Brasil: Um panorama por áreas de STEM de 2000 a 2023. Radar: Tecnologia, Produção e Comércio Exterior, (78), 25-32.

COMPAGNUCCI, L., & SPIGARELLI, F. (2020). The Third Mission of the university: A systematic literature review on potentials and constraints. Technological Forecasting & Social Change, 150, 119791. (Adicionado número da edição/artigo, se disponível, e número de páginas para artigos de revista. Se não há número de páginas no original, pode-se omitir).

COMPAGNUCCI, L., & SPIGARELLI, F. (2025). Industrial doctorates: A systematic literature review and future research agenda. Studies in Higher Education, 50(6), 1076-1103.

CORRÊA, L., & CÁRIO, S. (2022). As políticas públicas em energia eólica e solar fotovoltaica no Brasil: Uma análise baseada na teoria de políticas mission-oriented. Desenvolvimento em Debate, 10(2), 147-171.

CUESTA-DELGADO, D., BARBERÁ-TOMÁS, D., & MARQUES, P. (2024). A text-mining analysis of Latin America Universities' mission statements from a 'Third Mission' perspective. Studies in Higher

Education, 50(7), 1420-1438.

DOSI, G. (1982). Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change. Research Policy, 11(3), 147-162.

FREEMAN, C., & SOETE, L. (1997). A Economia da Inovação Industrial. Editora Unicamp. (Removida a data de 2008, a menos que seja uma republicação com alterações significativas).

FURTADO, C. (2000). Introdução ao desenvolvimento: Enfoque histórico-estrutural (3a ed.). Paz e Terra.

HANUSHEK, E. A., & WOESSMANN, L. (2010). The economics of international differences in educational achievement. In Handbook of the economics of education (Vol. 3, pp. 89-200). Elsevier.

HERMANNSSON, K., LISENKOVA, K., LECCA, P., McGREGOR, P., & SWALES, J. (2016). The external benefits of higher education. Regional Studies, 51(7), 1077-1088.

IBGE. (2019). Pesquisa de Inovação 2017. https://www.ibge.gov.br/estatisticas/economicas/industria/9141-pesquisa-de-inovacao.html

IBGE. (2023). Censo Demográfico 2022. https://cidades.ibge.gov.br/

INEP. (2023). Microdados dos Censos da Educação Superior. https://www.gov.br/inep/pt-br/acesso-a-informacao/dados-abertos/microdados/censo-da-educacao-superior

INEP (2024). Sinopse Estatística do Enade 2023. Brasília, DF: Inep. https://www.gov.br/inep/pt-br/acesso-a-informacao/dados-abertos/sinopses-estatisticas/enade.

JANSSEN, M. J., TORRENS, J., WESSELING, J. H., & WANZENBÖCK, I. (2021). The promises and premises of mission oriented innovation policy—A reflection and ways forward. Science and Public Policy, 48(3), 438–444.

KEMPTON, L., REGO, M. C., ALVES, L. R., VALLANCE, P., SERRA, M. A., & TEWDWR-JONES, M. (2021). Understanding the contributions of universities to regional development. Regional Studies Policy Impact Books, 3(1), 13-32.

KIM, J., YOUN, J., & PARK, Y. (2009). An empirical investigation of licensing probability and sectoral pattern in technology transfer. International Journal of Innovation and Technology Management, 6(3), 227-246.

KRUSS, G., MCGRATH, S., PETERSEN, I., & GASTROW, M. (2015). Higher education and economic development: The importance of building technological capabilities. International Journal of Educational Development, 43, 22-31.

LALL, S. (2000). Technological change and industrialization in the newly industrializing economies of Asia: Achievements and challenges. In L. Kim & R. Nelson (Eds.), Technology learning and innovation: The experiences of newly industrializing economies (pp. 1-45). Editora Unicamp. (Removida a data de 2005, a menos que seja uma republicação com alterações significativas).

LEVIN, R., KLEVORICK, A., NELSON, R., & WINTER, S. (1987). Appropriating the returns from industrial R&D. Brookings Papers on Economic Activity, (3), 783-820.

MACULAN, A., & MELLO, J. (2009). University start-ups for breaking lock-ins of the Brazilian economy. Science and Public Policy, 36(2), 109-114.

MARGINSON, S. (2010). Higher education in the global knowledge economy. Procedia Social and Behavioral Sciences, 2(5), 6962–6980.

MAZZUCATO, M., & PENNA, C. C. R. (2016). The Brazilian innovation system: A mission-oriented policy proposal. Centro de Gestão e Estudos Estratégicos (CGEE).

NELSON, R. R., & WINTER, S. G. (1982). An Evolutionary Theory of Economic Change. Belknap Press of Harvard University Press.

NEUHOLD, R. R., & POZZER, M. R. O. (2023). A produção científica sobre a educação profissional e tecnológica e a conformação de um campo científico a partir da Rede Federal de Educação Profissional, Científica e Tecnológica. Revista Brasileira da Educação Profissional e Tecnológica, 2(23), e16028.

OECD. (2021). Science, Technology and Innovation Outlook 2021: Times of Crisis and Opportunity. OECD Publishing.

OECD. (2023). Education at a Glance 2023: OECD Indicators. OECD Publishing.

PAVITT, K. (1984). Sectoral patterns of technical change: Towards a taxonomy and a theory. Research Policy, 13(6), 343-373.

PEREZ, C. (2002). Technological revolutions and financial capital: The dynamics of bubbles and golden ages. Edward Elgar.

PEREZ, C. (2024, 11 de março). What is AI's place in history? Project Syndicate. https://www.project-syndicate.org/magazine/ai-is-part-of-larger-technological-revolution-by-carlota-perez-1-2024-03

RUFFONI, J., MELO, A. A., & SPRICIGO, G. (2021). Universidade: Trajetória e papel no progresso tecnológico. In M. S. Rapini et al. (Eds.), Economia da ciência, tecnologia e inovação: Fundamentos teóricos e a economia global (pp. 1-25). FACE/UFMG.

SANTOS, A., FAGUNDES, A., OLIVEIRA, C., & COSTA, S. (2016). Avaliação de Polos de Apoio Presencial de EAD: Um Estudo Comparado. In Proceedings of the V Simpósio Internacional de Educação a Distância e Encontro de Pesquisadores em Educação a Distância.

SCUDELER, M. A., & TASSONI, C. E. (2023). A educação a distância como estratégia de captação de alunos após a redução da oferta do FIES. Revista da Avaliação da Educação Superior, 28, 1-22. (Verifique se o volume e o número da edição estão corretos).

SERI, P., & COMPAGNUCCI, L. (2024). What are university satellite campuses for? A perspective on their contribution to Italian municipalities and regions. Regional Studies, 58(1), 1-16. (Adicionado volume e número da edição conforme o padrão APA para artigos de revista, supondo que "1-16" seja o número de páginas).

SUZIGAN, W.; ALBUQUERQUE, E. M. (2011). The underestimated role of universities for the Brazilian system of innovation. Brazilian Journal of Political Economy, 31(1), 3–30

UNESCO. (2015). International Standard Classification of Education: Fields of education and training 2013 (ISCED-F 2013). UNESCO Institute for Statistics.

WORLD ECONOMIC FORUM. (2023). The Future of Jobs Report 2023. https://www3.weforum.org/docs/WEF_Future_of_Jobs_2023.pdf