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SYNERGY OF SCIENCE-EDUCATION-BUSINESS (SEB) COLLABORATIONIN THE ESTABLISHMENT OF RESEARCH UNIVERSITIES: THE CASE OF AZERBAIJAN

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ABSTRACT

This study analyzes the current state and development dynamics of science–education–business (SEB) collaboration in Azerbaijan, focusing on the mechanisms that enable multidimensional synergies within the national innovation ecosystem. The research adopts a qualitative methodology based on comparative evaluation and SWOT analysis, allowing for a systematic assessment of institutional frameworks, policy documents, and collaborative practices regulating interactions among universities, research institutes, and the business sector. The findings reveal that Azerbaijan has considerable institutional potential for SEB integration. Key strengths include modernized material and technical infrastructure, strategic state programs supporting higher education development, and an evolving regulatory framework that encourages innovation activities. However, several challenges remain. These include limited commercialization of scientific research outcomes, misalignment between educational programs and labor market demands, and weak, unsustainable university–industry collaboration. Furthermore, the study identifies structural limitations such as underdeveloped technology transfer mechanisms, insufficient support for spin-offs and start-ups, and a lack of diversified research funding sources. The research contributes to the literature by examining SEB collaboration within a developing innovation system context. It also offers practical and policy-oriented recommendations aimed at enhancing innovation management, strengthening human capital, and establishing a sustainable and effective SEB collaboration model in Azerbaijan.

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ELM-TƏHSİL-BİZNES ƏMƏKDAŞLIĞININ TƏDQİQAT UNİVERSİTETLƏRİNİN FORMALAŞMASINDA SİNERJİSİ: AZƏRBAYCAN NÜMUNƏSİ

Bu tədqiqat Azərbaycanda elm-təhsil-biznes əməkdaşlığının mövcud vəziyyətini və inkişaf dinamikasını təhlil edir, milli innovasiya ekosistemi daxilində çoxölçülü sinerjilərin formalaşmasını təmin edən mexanizmlərə diqqət yetirir. Tədqiqat keyfiyyət metodologiyasına əsaslanır və müqayisəli qiymətləndirmə ilə GZİT analizindən istifadə edir. Bu yanaşma universitetlər, elmi-tədqiqat institutları və biznes sektoru arasında qarşılıqlı əlaqələri tənzimləyən institusional çərçivələrin, siyasət sənədlərinin və əməkdaşlıq praktikalarının sistemli şəkildə qiymətləndirilməsinə imkan yaradır. Nəticələr göstərir ki, Azərbaycan elm-təhsil-biznes inteqrasiyası üçün əhəmiyyətli institusional potensiala malikdir. Əsas üstünlüklərə müasirləşdirilmiş maddi-texniki infrastruktur, ali təhsilin inkişafını dəstəkləyən strateji dövlət proqramları və innovasiya fəaliyyətlərini təşviq edən inkişaf edən normativ-hüquqi baza daxildir. Bununla yanaşı, bir

sıra problemlər də mövcuddur. Bunlara elmi tədqiqat nəticələrinin kommersiyalaşdırılmasının zəif olması, təhsil proqramları ilə əmək bazarının tələbləri arasında uyğunsuzluq və davamlı olmayan universitet–sənaye əməkdaşlığı daxildir. Bundan əlavə, tədqiqat texnologiya transferi mexanizmlərinin zəif inkişafını, spin-off və startapların dəstəklənməsində çatışmazlıqları, eləcə də tədqiqat maliyyələşməsi mənbələrinin kifayət qədər şaxələndirilmədiyini müəyyən edir. Tədqiqat inkişaf edən innovasiya sistemi kontekstində elm-təhsil-biznes əməkdaşlığını araşdırmaqla elmi yenilik təqdim edir və innovasiya idarəçiliyinin təkmilləşdirilməsi, insan kapitalının gücləndirilməsi və Azərbaycanda davamlı elm-təhsil-biznes əməkdaşlıq modelinin qurulması üçün praktik və siyasət yönümlü tövsiyələr irəli sürür.

Açar sözlər: tədqiqat universiteti, elm–təhsil–biznes əməkdaşlığı, ali təhsil, texnologiya transferi, GZİT təhlili

1. Introduction

In the contemporary knowledge-based economy, the effectiveness of innovation ecosystems depends on the level of interaction among science, education, and business. Globally, strengthening collaboration between these sectors is of strategic importance for enhancing economic competitiveness, expanding innovation potential, and developing highly skilled human capital. The expansion of applied research, the development of technology-oriented learning environments, and the evolving demands of the labor market are directing academic institutions toward closer collaborative models with business and governmental organizations. Thus, science–education–business integration is not only a form of institutional cooperation but also a key developmental mechanism that determines the resilience and agility of national innovation systems.

The Triple Helix model serves as a theoretical foundation for understanding the formation of dynamic innovation ecosystems through interactions and resource sharing among science, education, and business. The model demonstrates that while each actor preserves its functional autonomy, it also supports the activities of other stakeholders, thereby creating a multidimensional environment of mutual influence. Spiral integration strengthens universities' role as producers of knowledge and technology, transforms business into a platform for practical application and commercialization, and engages the state as an incentivizing and regulatory actor, thereby deepening collaborative innovation. This approach holds both theoretical and practical significance, particularly for emerging and developing innovation ecosystems.

Within the context of the global innovation economy, reinforcing the interface between science, education, and business is considered a strategic component of economic and social development. Planned exchanges of knowledge and technology, the organization of innovative projects, and professional practice programs foster multidimensional synergies between education and business. Such collaboration not only strengthens technology transfer but also enhances the effectiveness of innovation activities.

When innovation processes in education are enriched through partnership-based models, students' learning experiences are more effectively linked with both theoretical and practical knowledge. Global evidence shows that collaboration among universities, businesses, and local communities helps close curriculum gaps, improves teaching quality, and creates student-centered learning environments (Aithal & Maiya, 2023).

Table 1.

Schimago country ranking (1996-2024)

Country	Documents	Citable documents	Citations	Self-citations	Citations per document	H-index
Turkey	1005684	929722	15238939	2945992	15.15	647
Kazakhstan	64913	62362	505534	104684	7.79	183
Uzbekistan	38873	37684	275584	90214	7.09	144
Georgia	34609	30219	734321	73505	21.22	268
Azerbaijan	29340	28398	302769	58925	10.32	167

Source: Schimago country ranking https://www.scimagojr.com/countryrank.php

As shown in Table 1, based on Scimago country rankings covering the period 1996–2024, Azerbaijan has produced 29,340 scientific publications and achieved an H-index of 167. Although its citations per document indicator is slightly lower than those of Georgia and Turkey, it is higher than that of Uzbekistan and Kazakhstan, indicating the existence of multidimensional collaboration opportunities among science, education, and business in the country. While Turkey benefits from more established university-industry collaboration mechanisms, Georgia shows higher citation efficiency, indicating stronger research impact. This comparison suggests that Azerbaijan's challenge is not only increasing research output but also improving the quality, visibility, and commercialization of scientific results. International literature emphasizes that, to generate such multidimensional synergies, it is essential to simultaneously consider curriculum and pedagogical methods, technology transfer mechanisms, and institutional support.

The aim of this study is to examine the mechanisms through which science–education–business collaboration affects innovation potential in Azerbaijan and to analyze the principles underlying the formation of multidimensional synergies within the context of the Triple Helix model. The theoretical significance of the findings lies in the innovation-oriented organization of pedagogical processes and the development of teaching methods and practical training programs. At the same time, the practical significance is reflected in strategic directions such as strengthening the integration of higher education institutions with business, organizing innovative projects, and ensuring the sustainable synthesis of economic development.

Despite the extensive application of the Triple Helix model in global innovation studies, its empirical adaptation to emerging innovation systems remains limited. In particular, there is a lack of context-specific analysis focusing on Azerbaijan's higher education and innovation ecosystem.

This study contributes to the literature in three main ways:

1. It provides a context-specific assessment of science–education–business collaboration in Azerbaijan;

2. It integrates SWOT analysis with the Triple Helix framework to evaluate institutional and structural dynamics;

3. It offers policy-oriented insights based on the specific challenges and opportunities of a developing innovation system.

Thus, unlike previous studies, this research goes beyond theoretical synthesis by applying the Triple Helix model to a national context with practical implications.

2. Literature review

Globalization, digitalization, and the dynamic transformation of labor markets have posed new challenges for contemporary education systems. Addressing these challenges has led to the emergence of new conceptual approaches that view education not merely as a mechanism for the transmission of knowledge, but also as a social institution that generates and applies innovation. In this context, the establishment of interactive linkages among science, education, and business plays a decisive role. One of the principal theoretical frameworks explaining the nature of these interactions is the Triple Helix model.

Proposed by Leydesdorff and Etzkowitz, the Triple Helix model conceptualizes science-education-business relations as the core driving mechanism in the formation of innovation systems. According to the model, universities are not confined to their traditional functions of teaching and research; rather, they act as proactive agents in the commercialization of knowledge, the application of new technologies, and the promotion of socio-economic development. Within the neo-evolutionary perspective, these relationships are interpreted through three interacting selection environments markets, organizations, and technological opportunities. Correspondingly, the social functions of these environments are defined as wealth creation, organizational control, and the structuring of knowledge production. From the authors' standpoint, it is precisely this mechanism of interaction that shapes innovation processes, technological development trajectories, and institutional regimes within a knowledge-based economy. The theoretical foundations of the model are constructed through the synthesis of diverse scholarly traditions, including evolutionary economics, the sociology of science and technology, the sociology of higher education, and policy analysis (Leydesdorff & Etzkowitz, 1996; Leydesdorff & Etzkowitz, 2000; Leydesdorff & Etzkowitz, 2010). Ponce Jaramillo & Güemes Castorena (2016) by analyzing the state of research on innovation and the Triple Helix model in Mexico, the authors find that universities' predominant focus on teaching significantly constrains their innovative capacity. They argue that weak and fragmented linkages among the actors involved in the innovation process undermine the effectiveness of the Triple Helix model. Consequently, the identification and implementation of mechanisms that strengthen the role of universities within the Triple Helix framework are deemed essential. By systematizing the existing literature, Cai et al. (2015) systematically identified the conditions that facilitate Triple Helix interactions among science, education, and business. These conditions may be material in nature related to the technical and infrastructural environment or intangible, reflecting the institutional and regulatory context. Cai and Amaral (2021), by analyzing the concept aimed at fostering innovation through interactions among science, education, and business, examined both its implementation potential and inherent limitations. The authors emphasize that although the model is widely applied in the academic literature, scholarly debates regarding its boundaries of applicability and the extent to which it can be generalized across all social domains remain ongoing. The study also offers a reflexive academic perspective on the potential role of the Triple Helix model as a theoretical framework for future innovation research. Leydesdorff and Porto-Gomez (2019) conceptualize the Triple Helix model as a theoretical framework that explains the complex dynamics of innovation processes and serves as an alternative to traditional approaches. The model portrays the evolutionarily shaped interactions among science, education, and business as a "Triple Helix" policy network, highlighting how these interactions accelerate the generation of innovative ideas and technological solutions, thereby fostering the sustainable development of innovation ecosystems. Cai and Etzkowitz (2020)

further distinguish the Triple Helix model from earlier approaches by foregrounding the leading role of universities in the transition toward a knowledge-based society within innovation studies. While conventional models primarily focus on firms or state-industry relations, the Triple Helix framework emphasizes the expanding influence of universities in technology transfer, organizational formation, and regional development.

The Triple Helix innovation model provides both a theoretical and practical framework for promoting regional economic development and supporting entrepreneurship by analyzing the dynamics of interactions among three core institutional spheres science, education, and business. According to Etzkowitz and Zhou (2017), when functional weakening occurs in any one of these spheres, the sustainability of the system is maintained through a mechanism of "role substitution," whereby the remaining spheres partially assume the functions of the weakened actor. In particular, interactions established by entrepreneurial individuals and organizations at the regional and local levels play a decisive role in mobilizing knowledge potential and ensuring the sustainable development of innovation activities. Ranga and Etzkowitz (2013) argue that the material conditions of the Triple Helix system primarily consist of components that support its structure and functions. These components encompass the interactions among science, education, and business, the sharing of resources, and the efficiency of innovation processes, including:

- the core competencies of universities in knowledge and technology creation and dissemination;
- the capacity of business actors and innovators to absorb knowledge and technology, as well as their demand for them;
- infrastructural measures, including policy and financial support, aimed at the establishment and development of high-technology start-ups, university spin-offs, and other institutional structures for university technology transfer;
- institutional entrepreneurs who articulate a vision for knowledge-based development and integrate leadership across science, education, and business.

Ivanova et al. (2021) examine the formation of the regional "science-education-business" ecosystem and its role in the technological and economic development of regions. The authors emphasize that the effective functioning of this ecosystem depends on the degree of integration among universities, research institutes, and business enterprises. They highlight the importance of using digital models and establishing analytical and forecasting laboratories in the design of ecosystem development strategies. Donina et al. (2022) underscore the central role of educational institutions in shaping regional innovation ecosystems. They demonstrate that higher education institutions are increasingly becoming hubs of innovation processes not only through teaching, but also via research and social engagement activities. Empirical evidence indicates that the efficiency of a region's innovation ecosystem is closely linked to the quality and number of educational institutions, as well as the intensity of their interactions with other social institutions. Similarly, the findings of Olo et al. (2021) show that higher education institutions make substantial contributions to human capital development, innovation promotion, and the strengthening of science-education-business collaboration through their missions of teaching, research, and community service. The authors further stress that globalization and digitalization constitute major challenges shaping the future trajectories of higher education development. Culkin (2016) highlights the significance of universities as "anchor institutions" within regional

innovation systems-organizations that serve as stabilizing pillars for local communities. The author argues that universities can play a pivotal role in regional development by providing small and medium-sized enterprises with knowledge, resources, and advisory support. Strengthening science-education-business collaboration, in this view, contributes to the formation of an innovation-oriented culture and to the sustainable growth of small enterprises. Adshead and Quillinan (2017) emphasize that building more effective relationships between universities and local communities has become an increasingly important issue. However, unlike traditional teaching and research approaches, this process requires substantial organizational change. Although research on community-oriented activities remains fragmented, its synthesis reveals a set of good practice principles that enable universities to integrate teaching, research, and civic engagement more effectively. As an illustrative example, the authors refer to the institutional approach of the University of Limerick, which combines community-oriented research and teaching. Wu and Liu (2021) find that the development of higher education and technological innovation has a significant impact on the restructuring of business sectors across regions in China. Their analysis reveals that higher education exerts an indirect positive effect, whereas technological innovation has a predominantly direct positive impact. According to the authors, the effective governance of these two factors strengthens the interaction between the education system and the economy, thereby fostering the sustainable development of regional business sectors and enhancing the quality of human capital. Despite notable advances in the theoretical foundations of the Triple Helix model, its explanatory potential remains rich with opportunities for further development. This can be achieved through meso-level theoretical frameworks capable of linking macro and micro-level analyses. The robustness of the model is largely assessed by its capacity to explain innovation dynamics in contemporary societies-for instance, the widespread adoption of entrepreneurial universities across diverse historical and academic contexts, pursuing different objectives and operating under radically varied social conditions. Given that the Triple Helix model is firmly grounded in classical sociological theory and institutional economics, further strengthening of its theoretical underpinnings is expected through the integration of interdisciplinary perspectives from across the social sciences.

2.2. Technology Transfer and Science-Education-Business Collaboration

Science-education-business collaboration and technology transfer have recently emerged as key priorities within innovation policy and knowledge-based economies. Research indicates that higher education institutions not only serve as sources of knowledge and technology but also function as strategic platforms for the commercialization of research outcomes and their application within economic sectors. Models and integrative collaboration mechanisms implemented in various countries have identified the principal factors influencing the effectiveness of science-education-business interactions, while also offering practical and methodological recommendations for enhancing these partnerships.

Artyukhov et al. (2021) analyzed the main models of technology transfer in Europe, the USA, Japan, and China, examining the national legislative frameworks governing this field. Their study identifies the key mechanisms that influence the successful implementation of technology transfer at the system level and outlines development trends in leading countries. The authors justify the establishment of technology transfer centers within universities as crucial platforms for concentrating national intellectual potential and propose a comprehensive approach to enhance the efficiency of research commercialization and application. Gachie (2020) emphasizes the strategic importance of strengthening collaboration between higher education institutions

and the private sector, noting that the commercialization of research outcomes should be a key policy priority within the Triple Helix framework. The author further highlights that the model's effectiveness relies on continuous adaptation to the evolving needs of network participants and the dynamic nature of their interactions. Science-education-business collaboration holds significant potential in the areas of technology transfer and knowledge circulation. Blankesteijn et al. (2021) demonstrate that science-based entrepreneurship education reinforces technology transfer. Laine et al. (2015) stress the importance of planned, needs-driven knowledge transfer, proposing the "innovation-oriented participatory research process" model, which positions universities as primary sources of knowledge and technology while emphasizing the necessity of sustained dialogue for open innovation. According to Vásquez-Urriago et al. (2016), a central objective of national system development is the establishment of interaction mechanisms based on synergy principles among the science, education, and business components. Such mechanisms facilitate the creation of new products with enhanced features, provide favorable conditions for the development of innovators' initiatives, and expand opportunities for the effective commercialization of intellectual property. Bakouros et al. (2002) note that the educational environment must adapt flexibly to the dynamic demands of the labor market, with universities acting as practical and innovative institutions that ensure students acquire skills relevant to real work conditions. A study of three science parks in Greece revealed uneven development of science-education-business relations: only one park had formalized collaboration, while the other two remained in initial stages, with inter-firm synergy largely limited to commercial and social interactions. Ng et al. (2019) observe that contemporary higher education institutions have begun to align their development strategies with a new institutional model focused on strengthening interactions among education, research activities, and real economic sectors. This approach enhances the systematic organization of all stages of intellectual activity, encompassing teaching, practical engagement, research, innovation development, and the market-oriented commercialization of innovations. Osipov et al. (2022) analyzed an integrative collaboration model within the science-education-business triangle, identifying gaps and providing methodological recommendations for preparing financial managers through university degree programs. Their study, based on surveys of over 400 financial managers and case analyses, offered practical proposals to strengthen university-business collaboration, targeting the preparation of workforce competitive in the global labor market. Klimuk et al. (2020) focus on the real interactions among science, education, and business, discussing contentious issues related to the socio-economic modernization vector. The authors also examine existing regulatory and legal frameworks governing collaboration within the Triple Helix, highlighting the importance of structured institutional support for effective partnerships.

2.3. Human Capital and the Quadruple Helix Model

Studies indicate that higher education institutions not only serve as producers of knowledge and technology but also play a critical role in the commercialization and practical application of research outcomes, as well as in preparing a workforce aligned with labor market demands. Collaboration-based research mechanisms, institutional adaptations, local and international contexts, and the Triple and Quadruple Helix models are recognized as key factors influencing the effectiveness of science-education-business interactions. These approaches provide opportunities to enhance the innovation potential of faculty and students, integrate scientific results with practical solutions, and facilitate the seamless incorporation of research into the business sector.

Liu and Jiang (2025) conducted a study in Guizhou Province examining the impact of science-education-business collaboration on faculty innovation capabilities. The findings indicate that this impact is determined through six key factors: collaboration-based research mechanisms, individual and professional characteristics of faculty, mechanisms of science-education-business collaboration and cultural differences, intellectual property and legal issues, resource support and innovation environment, as well as project motivation and implementation constraints. Based on these results, the authors recommend implementing innovation-oriented development strategies in China and optimizing collaboration mechanisms. Zhuang et al. (2021) highlight that the Triple Helix model has a three-tiered significance: first, the state, universities, and businesses operate both independently and interactively in the process of forming the helix; second, the roles and functions of these actors are integrated and partially transformed within the helix; third, the interactions among the three spiral chains give rise to new overlapping organizational structures and networks, providing a platform for creative science-education-business collaboration. Menezes and Pinto (2016) note that in India, universities do not fully fulfill their role in producing graduates with the knowledge and skills demanded by business, leaving workforce needs unmet. Recent years have seen higher education planners focus on establishing effective links between universities, research institutes, and business. Their study examines opportunities to enhance the value of university knowledge products and to increase this value through business financial mechanisms. Navruzova (2025) emphasizes that institutional misalignments between the education system and the business sector hinder the preparation of professionals meeting labor market requirements. The predominance of theory-focused curricula in universities does not align with the practical knowledge and applied skills demanded by business entities, particularly in high-tech fields such as automation and robotics. In this context, the establishment of advisory boards, systematic labor market monitoring, and the application of AI-based forecasting mechanisms are considered critical institutional tools to address these misalignments and align educational outcomes with real-sector requirements. Berkowitz and Simmons (2003) find that collaboration-based approaches in science education significantly contribute to developing students' scientific thinking, problem-solving skills, and lifelong learning habits. Inquiry-based learning models encourage analytical thinking and allow students to create alternative explanations and structure knowledge more effectively through scientific visualization. These methodologies integrate individual and group-based activities, enhancing students' problem-solving competencies and practical application skills as pedagogical strategies. Shyiramunda and van den Bersselaar (2024) studied local community development in Rwanda within the "Quadruple Helix" framework an extended form of the Triple Helix model. They present the local community as the fourth actor, demonstrating that community-oriented innovations strengthen teaching processes and integration into the labor market. Zhuang et al. (2025) conducted a comparative study of public perceptions of science-education-business collaboration in China, Japan, and Singapore. Multimodal discourse analysis shows that collaboration plays a priority role in promoting innovation in all three countries: China applies business dynamism to advance pedagogical reform and economic development; Japan emphasizes collaboration to enhance international competitiveness and address social challenges; Singapore prioritizes research collaboration and internationalization. The authors recommend that governments develop balanced science-education-business collaboration, establish robust partnership frameworks, foster inter-sectoral trust, and align long-term objectives with business needs.

Overall, the reviewed literature demonstrates that while the Triple Helix model is widely applied across different national contexts, its effectiveness depends on institutional capacity, regulatory frameworks, and the level of interaction among stakeholders. However, most studies focus on developed or large emerging economies, leaving a gap in understanding how the model functions in smaller, resource-dependent economies such as Azerbaijan. This highlights the need for context-specific empirical analysis, which this study aims to address.

3. Materials and methods

The present study adopts a qualitative research design, employing comparative assessment and SWOT analysis as its primary methodological approaches. Within this framework, national policies and regulatory instruments pertinent to the science and higher education sectors, strategic development and operational plans of higher education institutions, as well as conceptual frameworks, indicators, and models derived from international best practices, were systematically and rigorously analyzed. The analytical process is situated within the theoretical premises of the Triple Helix model, allowing for the evaluation of science-education-business interactions at both institutional and strategic levels. Within this conceptual lens, the study identifies the emergence of innovative pedagogical approaches, mechanisms for knowledge and technology transfer, university-industry partnership models, and the extant synergies among governance and coordination structures. The qualitative analysis thus provides a scientifically robust assessment of the current state of science-education-business integration and offers insights into prospective avenues for its further development.

4. Result and Discussion

The classical model of science-education-business integration is grounded in the principles of interaction and collaboration among three primary sectors: science, education, and business. Within this framework, the scientific domain predominantly addresses both fundamental and applied challenges as identified by the business sector. Scientific activity extends beyond the generation of theoretical knowledge to encompass the practical application of research outcomes. The triadic interaction of science, education, and business fosters the development of universities as dynamic, integrative learning ecosystems, thereby reinforcing competency-based educational approaches. Empirical outputs from research activities including monographs, textbooks, scholarly articles, constructive-technological developments, new materials, discoveries, inventions, prototypes, and normative documents are systematically synthesized and disseminated to both educational and business sectors. This process ensures the integration of knowledge creation and utilization. Within this model, the education system functions not only as a consumer of knowledge but also as an active agent in its production. Universities and other higher education institutions contribute to the formation of academic knowledge and actively engage in research endeavors, thereby advancing scientific outcomes. In addition, the education system supports the development of highly qualified specialists aligned with the requirements of both the business and scientific sectors, enhancing the availability of skilled human capital in the labor market and providing a foundation for the practical application of scientific knowledge. The business sector, in turn, utilizes innovative technologies, methodologies, and techniques generated within the science and education domains to produce goods and services, while simultaneously identifying pertinent research problems and prioritizing areas for investigation. This reciprocal arrangement not only augments the practical relevance of scientific research but also facilitates graduate employability. Accordingly, science-education-business integration

ensures the sustained formation of mutually beneficial interactions, thereby contributing to economic development and the effective realization of innovation processes. The classical model's principal advantages lie in its systematic approach, the explicit delineation of interrelations among the three sectors, and the unified governance of knowledge generation and application processes. Moreover, this model is instrumental in addressing gaps within the innovation chain and promoting the efficient commercialization of knowledge.

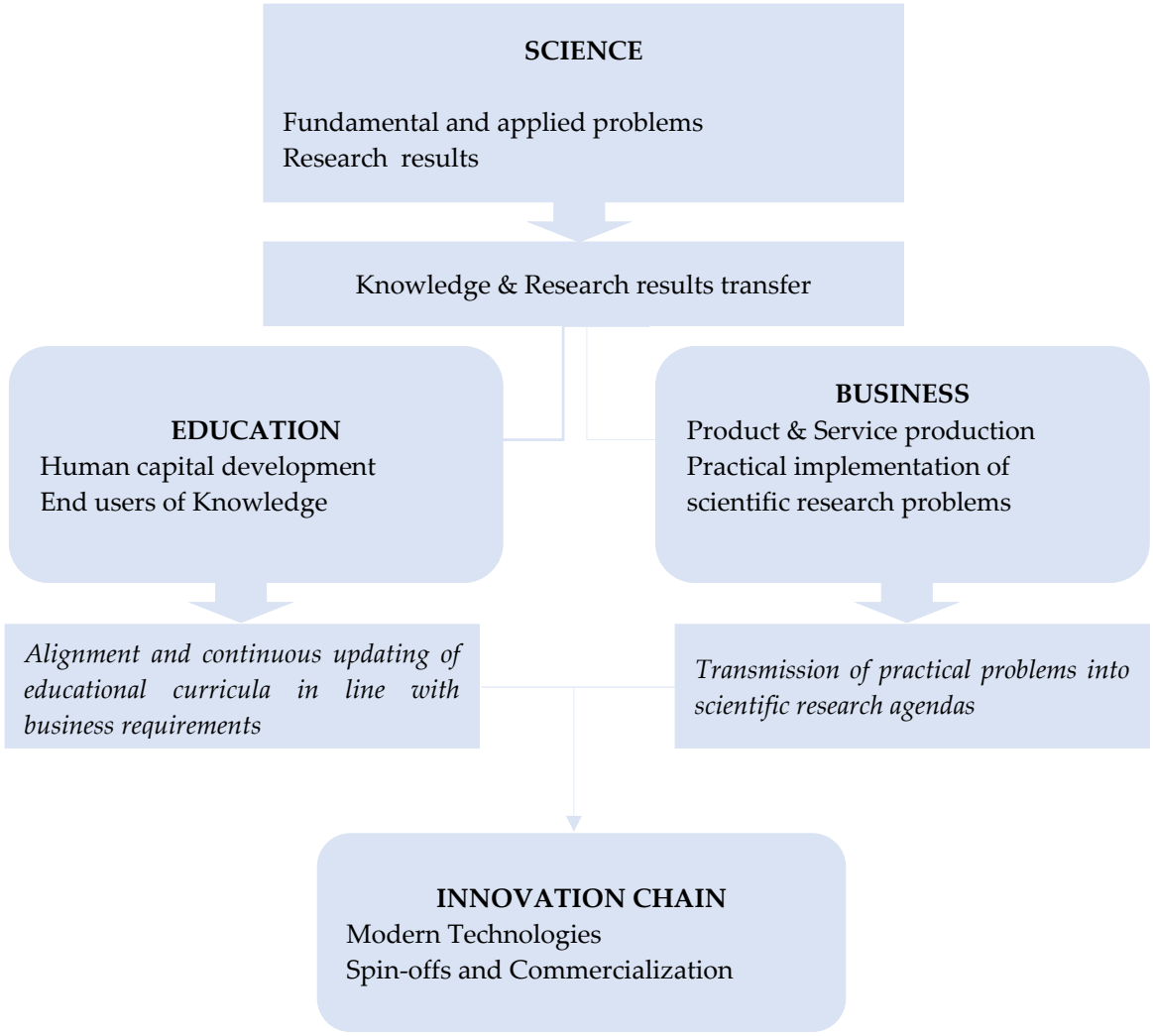


Figure 1. Conceptual framework

Source: Prepared by the author

The transfer of outcomes from fundamental and applied research conducted by higher education institutions to the business sector accelerates innovation and generates mutually beneficial synergies for both universities and enterprises. For universities, this process facilitates the renewal of research agendas and enriches academic inquiry with practical problem-solving. For business entities, it provides a practical platform for collaboration, development, and application of innovative technologies.

Universities, as scientific and intellectual centers of society, play a leading role in the creation, systematization, and integrative development of fundamental and applied research. This scientific potential not only generates knowledge but also forms the initial stage of the

innovation chain. In the rapidly evolving technological context of contemporary economies, the role of universities extends beyond teaching; they also function as strategic partners in addressing real-world business challenges based on scientific principles (Durmaz, 2010).

Continuous technological innovations in the business sector stimulate the modernization of higher education curricula and their alignment with labor market demands. Integration across science, education, and business is particularly evident in sectors such as energy, oil and gas, ICT, chemistry, and agriculture. This collaboration enhances students' practical skills and allows future professionals to be tested within real business environments. For business entities, collaboration offers opportunities to commission innovation projects and to identify potential future employees under practical conditions. For universities, partnership projects provide strategic benefits through access to additional financial resources, integration of research infrastructure, and alignment of academic staff with practice-oriented activities.

Funding for scientific research and innovation activities is provided through state budgets, research foundations, grants, loans, and commercial projects. This financial support ensures the continuity of scientific work and creates the necessary conditions for the commercialization of innovation projects (Aliyev, 2021). For Azerbaijani universities, securing additional financial resources through collaboration with the business sector is critical for enhancing innovation activities, research infrastructure, and the quality of educational processes. However, the current situation indicates that the utilization of research grants, commercially oriented projects, and partnership initiatives remains limited compared to international standards (Sarıbayli, 2025).

The commercialization of scientific knowledge produced by universities constitutes the final stage of the innovation process. At this stage, technological and scientific outputs are integrated into economic circulation, introduced to the market, and assigned economic value. Ineffective commercialization diminishes the economic efficiency of research outcomes and undermines the sustainability of the national innovation system (İsmayilov & Alıyev, 2013).

To better illustrate the practical implementation of the Triple Helix model in Azerbaijan, a case study approach is applied. A notable example of science-education-business (SEB) collaboration in Azerbaijan is the Startup and Technology Transfer Office (TTO) operating within Azerbaijan State Oil and Industry University. This institutional structure serves as a central mechanism for coordinating innovation, entrepreneurship, and technology transfer activities, thereby facilitating the transformation of academic knowledge into economic value. The TTO plays a critical role in strengthening Triple Helix interactions by acting as an intermediary platform connecting university research potential with industry needs and public sector priorities. Its core functions include the identification, evaluation, and development of innovative ideas generated by students, academic staff, and researchers, as well as the support of startup initiatives. Within this framework, the office organizes incubation and acceleration programs, hackathons, and innovation competitions, contributing to the development of an entrepreneurial ecosystem within the university. These initiatives enhance students' practical skills and promote innovation-oriented thinking, aligning educational outcomes with labor market demands. In addition, the TTO actively supports technology transfer processes by establishing collaboration mechanisms with industry partners, providing prototyping and mentoring services, and facilitating market access for innovative projects. Startup teams are supported through comprehensive services, including business model development, market analysis, minimum viable product (MVP) design, investment readiness, and pitching skills. Furthermore, the office

ensures the efficient utilization of the university's innovation infrastructure and laboratory resources, coordinates partnerships with external stakeholders, and contributes to the commercialization of research outcomes. Despite these positive developments, challenges such as limited scalability of startups, insufficient private sector investment, and underdeveloped commercialization frameworks remain. Overall, this case demonstrates that while institutional mechanisms for SEB collaboration exist in Azerbaijan, their effectiveness depends on strengthening industry engagement, expanding financial support instruments, and improving the regulatory environment for innovation.

Another important example of science-education-business collaboration in Azerbaijan is the Technopark operating under Baku Engineering University. As one of the first technoparks established within higher education institutions in the country, it represents a structured approach to fostering innovation, entrepreneurship, and technology transfer. The technopark incorporates a Technology Transfer Center (TTC) and an Incubation Center, which jointly support the commercialization of research outputs and the development of startup ecosystems. Its activities are organized across five functional modules, including awareness and education services, grant and project support, university–industry collaboration, intellectual property management, and entrepreneurship development. From a Triple Helix perspective, the technopark plays a significant intermediary role by connecting academic research with industrial needs and facilitating cooperation with public and private stakeholders. In particular, it supports R&D activities, promotes innovation culture, and enhances the integration of scientific knowledge into market-oriented applications. The technopark also provides services related to patenting, licensing, and intellectual property protection, while assisting researchers and startups in accessing national and international funding opportunities. Through incubation and acceleration programs, it encourages the establishment of research-based firms and strengthens entrepreneurial capacity among students and academic staff. Moreover, the modular structure of the technopark allows for a systematic approach to innovation management, ensuring coordination between different stakeholders and improving the efficiency of technology transfer processes. However, similar to other institutions in Azerbaijan, challenges remain in terms of scaling startup activities, attracting private investment, and ensuring long-term sustainability of innovation initiatives. Overall, the BMU Technopark illustrates a more structured and system-oriented implementation of the Triple Helix model, particularly in terms of institutional organization and support mechanisms.

A comparative assessment of Azerbaijan State Oil and Industry University and Baku Engineering University indicates that science-education-business collaboration in Azerbaijan evolves through heterogeneous and context-dependent models, shaped by institutional capacities and disciplinary specialization. At ADNSU, the collaboration model is predominantly industry-oriented and application-driven, reflecting strong linkages with specific sectors. In contrast, BMU adopts a more institutionalized and structured approach, primarily facilitated through technopark-based mechanisms. These distinctions suggest that institutional characteristics play a decisive role in shaping collaboration frameworks, leading to the emergence of differentiated rather than uniform models. Consequently, the Azerbaijani context reflects a pluralistic and adaptive development trajectory, wherein multiple institutional configurations coexist within the broader framework of the Triple Helix model.

To assess the strengths, weaknesses, opportunities, and threats associated with this collaboration within the Azerbaijani higher education system, a SWOT analysis was conducted. The table below presents the results of this analysis.

Table 2. SWOT Analysis of Science-Education-Business Collaboration in Azerbaijan

STRENGTHS	**WEAKNESSES**
Most universities and their structural units have strategic development plans.	In some universities, the quality of teaching is not at the intended level.
Universities have modern and innovative material-technical infrastructure.	The student certification process is slow.
Implementation of policies for developing professional and certified academic staff	Specialized laboratories do not fully reflect the curriculum content.
Application of differentiated salary systems in universities.	Weak international-level scientific productivity.
University staff participate in international projects nationwide.	Programs are insufficiently aligned with labor market needs.
Universities are productive in scientific research	In some universities, students' tendency to use modern teaching methods is low
Quality assurance systems are implemented according to international standards.	Lack of expertise in commercializing research
Policies for staff renewal and preparation of young specialists are continuously implemented.	Alumni relations in some universities are insufficient.
Universities have modern software and technological capabilities.	Virtual laboratories and simulations are insufficient.
Availability of e-learning platforms and Learning Management Systems (LMS).	Shortage of professional academic staff in certain fields.
Opportunities for practical training, start-ups, and incubators.	
Universities cooperate with employers and provide practical training programs for students.	
OPPORTUNITIES	**THREATS**
State support for education is available.	Increasing competition in education.
Opportunities for universities to benefit from international cooperation under the Ministry of Education and Science.	Low population growth and a potentially small number of secondary school graduates
Transparent admission processes for higher education institutio	Low number of incoming foreign applicants
Availability of Education Credit for students.	Risk of reduced state support.
Existence of Certification Training Centers for developing teachers' practical skills.	Universities lagging in global rankings
Adequate level of international cooperation.	Competition with high-ranking universities.
Opportunities to benefit from European countries' educational management practices through international projects.	Educational programs not keeping pace with rapidly changing technological requirements
Opportunities for students to participate in international exchange programs.	
Inclusion of universities' scientific journals in international bibliographic databases	
Growth of online courses and distance learning opportunities.	
Opportunities for workforce training in new technologies and innovation.	
Individual learning opportunities aimed at developing academic and professional skills.	

The results of the conducted SWOT analysis comprehensively reveal the current development trajectory, institutional potential, and structural challenges of the higher education system. The analysis indicates that strengthening the material and technical infrastructure of universities, aligning quality assurance systems with international standards, and implementing policies for professional academic staff are key strengths that ensure the institutional sustainability of higher education. These indicators confirm that higher education institutions possess the potential to adopt modern pedagogical approaches and create innovative learning environments. At the same time, the presence of weaknesses demonstrates that certain structural and content-level misalignments persist within the higher education system. In particular, the insufficient quality of teaching in some universities, inadequacy of education programs aligned with labor market demands, and the lack of institutional competence in commercializing research are major factors limiting the socio-economic impact of higher education. These aspects highlight pedagogical gaps in translating learning outcomes into practical competencies. The opportunities identified in the SWOT analysis confirm the existence of a favorable institutional and regulatory environment for the strategic transformation of higher education. State support for education, expanded mechanisms for international cooperation, the application of student loans, and academic mobility programs serve as important instruments to enhance inclusivity and internationalization of higher education. In particular, opportunities to leverage European educational management practices hold strategic significance for modernizing pedagogical models and implementing outcome-oriented teaching approaches. On the other hand, existing threats pose serious risks to the long-term sustainability of the higher education system. Increasing competition in education, slowing demographic growth, low influx of foreign students, and universities' lagging positions in global rankings may weaken the international attractiveness of higher education. Additionally, education programs that do not adapt to rapidly changing technological requirements may reduce graduates' competitiveness in the labor market, thereby diminishing pedagogical effectiveness. The SWOT analysis suggests that strategic alignment between strengths and opportunities can enable significant improvements in quality and efficiency within the higher education system. For instance, if modern technological capabilities and e-learning platforms are integrated with international cooperation and online education opportunities, virtual laboratories, simulation-based learning environments, and flexible learning models can be developed. This would not only increase students' engagement with modern teaching methods but also contribute to the development of their practical skills. In conclusion, the findings from the SWOT analysis emphasize the importance of pedagogically informed strategic decision-making in higher education. Aligning universities' strengths with institutional opportunities, minimizing weaknesses, and establishing adaptive mechanisms against external threats would allow universities to function not only as knowledge-producing institutions but also as active agents of socio-economic development. In this context, purposeful and systematic pedagogical approaches should be considered a fundamental condition for the sustainable development of higher education. Overall, despite existing initiatives for science-education-business collaboration in Azerbaijan, the following areas require further improvement:

- Strengthening the business orientation of scientific research and focusing on practical outcomes;
- Enhancing sustainable commercialization and spin-off mechanisms to bring innovation results to the market;

- Developing clearer and functional normative frameworks for patent policy, copyright, and standard contract models;
- Forming practical competencies aligned with labor market and business needs, further developing industrial training and dual education mechanisms;
- Diversifying financial resources and increasing R&D expenditures to ensure sustainable development of science-education-business collaboration.

The esearch findings indicate that the commercialization of scientific results holds significant importance for the sustainability and efficiency of the national innovation system. The effectiveness of this process depends not only on strengthening the legal and regulatory framework but also on ensuring the systematic functioning of technology transfer offices within universities. Strengthening science-education-business collaboration not only enhances the efficiency of commercialization but also expands the capacity of scientific activities to adapt to evolving social and economic needs. Scientific results integrated with patenting, startup, and spin-off activities not only increase the economic value of intellectual property but also enhance the practical applicability of science. In the context of Azerbaijan, strengthening science-education-business collaboration and establishing technology transfer centers can improve the effectiveness of commercialization and, consequently, ensure the sustainability of the national innovation system. Currently, several universities in Azerbaijan and research institutes under the Azerbaijan National Academy of Sciences (ANAS) demonstrate active initiatives in collaboration with the business sector. At the same time, increasing the volume of innovation demand from the business sector is crucial for deepening this collaboration. Although the activities of techno parks and technology transfer offices have created positive trends, additional opportunities exist to make this collaboration more systematic and sustainable. In this context, the development of science-education-business collaboration requires the improvement of technology transfer, patenting, and commercialization mechanisms, the expansion of financial support, the strengthening of human capital development processes, and the broader implementation of dual education models. Additionally, the development of the regulatory and legal framework as well as innovation infrastructure is of particular importance. While science-education-business collaboration in Azerbaijan holds high potential, its fully systematic and sustainable development necessitates the reinforcement of institutional, financial, and regulatory mechanisms. Strengthening this collaboration will contribute significantly to the advancement of the knowledge economy, the creation of innovative products and technologies, and the enhancement of the country's global competitiveness.

5. Conclusion

This study systematically examines the structural and institutional aspects of science-education-business (SEB) collaboration in Azerbaijan. The findings indicate that state-supported higher education reforms, modernized infrastructure, and increasing international integration provide essential foundations for the formation of multidimensional synergies among universities, research institutions, and the business sector. Universities operate not only as educational institutions but also as knowledge producers and potential innovation hubs, while the business sector demonstrates growing interest in empirical research and skilled human capital. However, the analysis identifies several systemic limitations that constrain the full realization of SEB synergies. Limited commercialization of research results, insufficiently institutionalized technology transfer mechanisms, and the partial integration of business needs into academic

research programs may slow the efficiency of innovation processes. Additionally, the relatively weak alignment between curricula and labor market demands may reduce the adaptive capacity of higher education institutions to economic and technological changes. The study proposes several strategic recommendations:

1.Strengthening technology transfer offices, spin-off ecosystems, and patent commercialization mechanisms to enhance the economic value of scientific outputs;

2. Diversifying research and innovation funding, including private sector participation and competitive grant mechanisms, to ensure sustainable SEB collaboration;

3. Systematic integration of dual education models, industry-based internships, and practice-oriented curricula to improve human capital quality and employability;

4. Establishing clearer institutional frameworks for intellectual property rights and university-industry contracts to facilitate long-term partnerships.

In summary, while SEB collaboration in Azerbaijan demonstrates significant potential, achieving a fully functional and sustainable system requires coordinated institutional reforms, adaptive governance mechanisms, and long-term policy support. Such improvements will not only strengthen national innovation capacities but also promote inclusive economic development and enhance the country's competitiveness in the knowledge-based global economy. Brief resume of the obtained results and their possible practical value.

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