SCIENTIFIC CULTURE
www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 12, No. 4, (2026), pp. 588-617
Open Access. Online & Print

DOI: 10.5281/zenodo.12426152

QUADRUPLE HELIX MODEL AND AGENT MODEL: HIGHER EDUCATION INSTITUTIONS AND THEIR TRANSFER FOCUS

Astelio Silvera Sarmiento[1]*, Alicia Inciarte González[2], Alejandro Valencia-Arias[3], Luis Fernando Garces Giraldo[4]

[1]Institución Universitaria Digital de Antioquia – IDITEK, Colombia.
Fundación para la Investigación, el Desarrollo, la Innovación y la Educación Superior – Fundación IDIES.
Email: astelio@iditek.edu.co; silvera.astelio@gmail.com, ORCID iD: https://orcid.org/0000-0001-9416-0264
[2]Universidad de la Costa – CUC, Colombia. Email: ainciart1@cuc.edu.co,
ORCID iD: https://orcid.org/0000-0002-9972-0272
[3]Vicerrectoría de Investigación y Postgrado, Universidad de Los Lagos, 5290000, Chile.
Email: javalenciar@gmail.com, ORCID iD: https://orcid.org/0000-0001-9434-6923
[4]Universidad Continental, Perú. Email: garces@continental.edu.pe,
ORCID iD: https://orcid.org/0000-0003-3286-8704

Received: 09/09/2025
Accepted: 01/02/2026

Corresponding Author: Astelio Silvera Sarmiento (astelio@iditek.edu.co)

ABSTRACT

This article explores the application and synergy between the Quadruple Helix model and the agent model in Higher Education Institutions (HEIs), highlighting how these frameworks can be integrated to enhance knowledge transfer and foster innovation. It discusses the relevance of cooperation among government, academia, industry, and civil society as proposed by Carayannis and Campbell, and analyzes the contribution of agents in this collaborative process. The research employs a mixed-methodological approach, combining quantitative and qualitative elements, allowing an in-depth analysis of the interactions among different actors within the innovation ecosystem. The study focuses on how the university, acting as a main agent, can collaborate with other stakeholders to co-create innovative solutions that meet current social and business needs. The findings indicate that integrating the Quadruple Helix and agent models facilitates a dynamic environment where knowledge transfer is optimized and innovation is accelerated. This paper presents case studies where the implementation of these models has resulted in significant enhancements in the innovation capabilities of HEIs. The conclusion is that for effective implementation of these models, the development of policies promoting multidisciplinary and multi-sectoral collaboration is crucial, ensuring that all actors are equitably involved in the innovation process. This approach not only expands the capabilities of HEIs to innovate but also strengthens the connection between higher education and the broader socioeconomic fabric. This study contributes to the academic field by providing a comprehensive framework for the effective integration of innovation models that can be adopted by other educational institutions seeking to enhance their innovative impact.

1. INTRODUCTION

In the context of Higher Education Institutions (HEIs), the Quadruple Helix model and the agent-based model are key approaches for promoting knowledge transfer and innovation (R&D&I). As Carayannis and Campbell (2009, p. 41) highlight, collaboration and cooperation among various stakeholders—including government, academia, industry, and civil society—are essential for fostering innovation within a 4-Helix ecosystem.

Moreover, as Mendoza et al. (2021) point out, the agent-based model plays a critical role in establishing an innovation ecosystem where innovators, investors, entrepreneurs, academics, and policymakers work collectively to drive innovation and knowledge transfer. This approach may include the creation of business incubators, startup accelerators, and support programs for university entrepreneurs.

In the context of knowledge transfer, the Quadruple Helix model and the agent-based model can be integrated to form an interactive and collaborative approach. According to Carayannis and Campbell (2012, p. 201), the Quadruple Helix model serves as a framework to facilitate collaboration between universities, industry, government, and civil society in the co-creation of innovative solutions. Meanwhile, the agent-based model identifies key actors within the innovation ecosystem and fosters their collaboration for knowledge transfer.

In this integrated approach, the university functions as a key knowledge transfer agent, collaborating with various stakeholders within the innovation ecosystem to co-develop innovative solutions. As Ndonzuau et al. (2021, p. 33) suggest, university-stakeholder interaction and collaboration are critical for successful knowledge transfer. This can involve joint R&D collaboration programs, outreach activities to engage civil society, and business incubation programs for university-based startups and entrepreneurial ventures.

Quadruple Helix Model

The Quadruple Helix Model is a theoretical framework developed to drive innovation and sustainable development through collaboration among academia, industry, government, and society. Originally proposed by Etzkowitz and Leydesdorff (2000) as an extension of the Triple Helix Model (academia, industry, and government), this model primarily analyzes the causal relationships between its components, their implications for development, and the role each actor plays in the innovation process. Notably, the 4-Helix model recognizes the fundamental role of civil society in the innovation process (Carayannis & Campbell, 2009), where civil society contributes to the identification of relevant problems and the formulation of innovative solutions, leading to effective and sustainable outcomes.

The 4-Helix model acknowledges the importance of open and collaborative innovation. Chesbrough, Vanhaverbeke, and West (2014) argue that open innovation involves collaboration among different stakeholders to share knowledge and resources, which can generate more effective and sustainable solutions. In this regard, the 4-Helix model is based on the principle that innovation should be a collaborative and participatory process, where various actors contribute their expertise and skills. Additionally, the model recognizes the importance of creativity and diversity in the innovation process (Carayannis & Campbell, 2009), as these elements foster the generation of new ideas and innovative solutions. Therefore, collaboration among actors with diverse perspectives and skills is seen as a driver of creativity and innovation.

The 4-Helix model also emphasizes the significance of social responsibility and sustainability in the innovation process (Carayannis & Campbell, 2009). As a result, innovation must be a responsible and sustainable process, considering the social and environmental impact of proposed solutions, ensuring ethical and sustainable approaches that contribute to equitable and sustainable socio-economic development. Consequently, the 4-Helix model serves as a theoretical framework that underscores the importance of collaboration among academia, industry, government, and civil society to foster innovation and drive sustainable development.

Agent-Based Innovation Model

The Agent-Based Innovation Model is a theoretical framework designed to understand how innovations emerge and spread within a society. It is based on the premise that innovations do not arise in isolation but are instead the result of interactions among different agents engaged in the innovation process.

Joseph Schumpeter (1911) argued that the innovation process is driven by visionary entrepreneurs who introduce new technologies or business models, thereby initiating creative destruction—the process of eliminating obsolete technologies and business models to make way for new methods of production.

Meanwhile, Everett Rogers (1962) explored how innovation adoption depends on interactions among various agents, including innovators, early adopters, late adopters, and laggards. His work introduced the concept of the adoption curve, which describes the rate at which an innovation is adopted over time.

A more contemporary perspective, closely aligned with today's reality, is presented by Carliss Baldwin and Kim Clark (2000). Their theory posits that innovation occurs when different agents work independently on specific modules of a product or service and later combine these modules in an innovative manner to develop new products or services. In this regard, modularity allows agents to work autonomously on different components, enhancing flexibility in the innovation process.

The Agent-Based Innovation Model has become a valuable tool for understanding the innovation process in a highly complex and interconnected society.

2. MATERIALS AND METHODS

This study is based on a mixed-methods approach, integrating Pearson correlation techniques (Guardia Olmos, J., 2008) and convergent correlation analysis (Loevinger, 1948). The combination of qualitative and quantitative correlation methods allows for the classification of relationships between variables/categories based on opposition and discrimination factors, ensuring meaningful differentiation between subgroups/categories within the dataset.

The study utilized VOSviewer (developed in JAVA) to construct and visualize bibliometric networks, establishing relationships based on co-authorship, co-citation, and co-relation between researchers and keywords. Data were extracted from the Web of Science (2023-04) and Scopus (2023-04) databases. The analysis was conducted using:

- Pearson correlation coefficient: Measuring the degree of relationship between quantitative and continuous variables.
- Jaccard coefficient: Assessing similarity between two sets, determining their correlation strength and interrelations for network construction (Riaño, E., 2018).

Content and Context Analysis Elements

- Innovation Process Phases:
  - Positive phases (FP)
  - Negative phases (FN)
- Types of Innovation:
  - Radical Innovation (IR)
  - Disruptive Innovation (ID)
  - Incremental Innovation (i2)
- Innovation Model Approaches:
  - Quadruple Helix (4H)
  - Agent-Based Model (M-A)
  - Hybrid Approaches (4H+M-A)
- Research Context Analysis:
  - Method
  - Category
  - Classification
  - Relation

Where (FP) represents positive phases, (EP) denotes positive elements, (FN) refers to negative phases, and (EN) corresponds to negative elements.

Additional evaluative measures can be applied to assess the capacity and influence of the innovation model approaches in projecting new implementations, which include: Work Engagement (Strategic Goal 1); Connection (Strategic Goal 2); Soft Skills (Strategic Goal 3); Active Learning (Strategic Goal 4); Dynamic Organism (Strategic Goal 4).

These components are defined as follows:

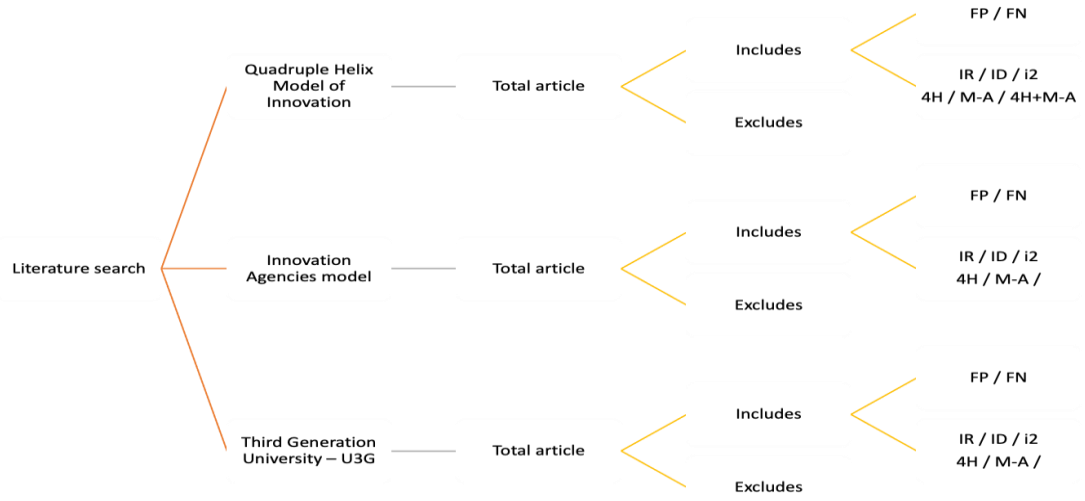

Figure: Structure of the selection and debugging of consulted sources.

Table: Summary of research, approach to addressing the categories and innovation contexts (Elsevier).

References	Categories	Central	Problem	Scope Paper	Implementation		
					4 helix	Agents	U3G
Kriz A., Bankins S., Molloy C. (2018)	Innovation, Smart Specialisation, Quadruple Helix, and key human-centred micro-processes.	How connections between individuals are developed and maintained during the development of quadruple helix collaboration in regions	FP / FN IR / ID / i2	4H	x		Work engagement
Kang Y., Jiang J. (2020)	knowledge-based and innovation-led economy, HE institutions, the Quadruple Helix Model, and cross-boundary innovation systems.	Lack of knowledge on how higher education institutions can connect different innovation systems and influence cities	FP / FN ID / i2	4H M-A	x	x	Conexion
Machado H.V., Lazzarotti F., Bencke F.F. (2018)	Technological parks, interactions between technological parks and agents in innovation models, triple, quadruple and quintuple helix models, and the contribution of current study to technological parks.	Forms of interaction between technology parks and the agents mentioned in interactive innovation models, and contributing to the implementation of innovation models and the construction of strategies for technology parks.	FP IR / i2	M-A		x	Soft skills
Meyer C., Gerlitz L., Klein M. (2022)	Sustainable tourism, South Baltic Sea Region (SBSR), resilience, recovery, cultural and creative industries (CCIs), smart specialization strategies (S3), and sustainable development goals (SDGs).	Lack of connection between cultural and creative industries and the sustainable tourism sector and how these industries can contribute to sustainable innovation and resilience	FP / FN IR / i2	4H M-A	x	x	Active learning
Unceta A., Barandiaran X., Lakidain A. (2021)	Digitization, creative economy, collaborative governance, innovation laboratories, synergies, value chain coordination, talent attraction, experimentation and innovation.	Digitalization in the creative economy through public-private collaboration, the role of innovation laboratories in sectoral articulation	FN IR / ID	4H M-A 4H+M-A	x	x	Dynamic organism
Padial M., Pinzón S., Navarro B., San Juan P., Ruiz J., Espinosa J.M. (2019)	Implementation, innovation model, Quadruple Helix, Design Thinking, data collection techniques, qualitative data analysis.	Practical implementation of the Quadruple Helix innovation model through the Design Thinking method, and the role of collaboration among agents in creating products and services	FP / FN ID / i2	4H 4H+M-A	x		Work engagement
Mineiro A.A.C., Arantes R.C., Vieira K.C., Castro C.C., Carvalho E.G., Amaral M.G. (2023)	Science and Technology Parks (STPs), Quadruple and Quintuple Helix (QQH), future vision of STPs, companies associated with STPs, positive relationship between QQH and STPs.	Need to analyze the practices and relationships of companies established in Science and Technology Parks (STP) as drivers of the Quadruple and Quintuple Helix (QQH) and determinants to align with the future vision of STP.	FP / FN IR / ID	4H M-A	x	x	Conexion

Lugovic S., Dunder I., Horvat M. (2017)	Complex dynamics, technology, data collection and processing, information system design, human behavior, Science 2.0.	Design of information systems that support Science 2.0 and the need to address the change in human behavior	FP / FN IR / ID / i2	4H+M-A	x		Soft skills
Salmelin B. (2016)	Conceptual innovation model, Open Innovation 2.0, virtual, holonic, and fractal companies, MIT Living Lab, successful innovation rate, Quadruple Helix model, national prosperity.	Need to develop a conceptual Open Innovation 2.0 innovation model that integrates the quadruple helix and active citizen participation in innovation	FP / FN i2	4H M-A	x	x	Active learning
Trisetyarso A., Hastiadi F.F. (2022)	Computational model, innovation ecosystem, disruptive Quadruple Helix innovation, quantum computing, innovation dynamics, Christensen effect.	Dynamics of disruptive innovations in a quadruple helix innovation ecosystem, quantum innovation ecosystem, and ecosystem dynamics in disruptive innovations.	FP ID / i2	4H M-A	x	x	Dynamic organism
Sjafrina N., Marimin, Udin F., Anggraeni E. (2020)	Value-added products, product supply chain, agent-based modeling, Quadruple Helix approach.	Agro-industrial product supply chain and how to design interaction between actors to support innovation	FP / FN i2	4H	x		Active learning
Salmelin B. (2018)	Innovation, innovation transition, innovation behavior and processes, OI 2.0, interdependencies, complexity management, interactions, co-creation of solutions, scalability, Quadruple Helix.	Moving from innovation on a single axis to open innovation 2.0 based on quadruple helix innovation processes and how to involve end users as co-creators in the innovation process.	FP / FN IR / i2	4H M-A	x	x	Active learning
Dias A., Salmelin B. (2018)	Virtual companies, holonic companies, fractal companies, MIT Living Lab concept, Quadruple Helix, active agents, structural intellectual capital, nonlinear innovation process, dynamic and fractal organizations, real market creation with co-creating users.	Conceptual model of open innovation 2.0 based on virtual companies, holonic companies, and fractals: citizens as active agents in the innovation process.	FP / FN IR / ID / i2	4H M-A	x	x	Active learning

Table: Summary of research, approach to addressing the categories and innovation contexts (Web Of Science).

References	**Categories**	**Central discussion**	**Problem**	**Scope Paper**	**Implementation**		
					4 helix	Agents	U3G
Trisetyarso, A; Hastiadi, FF (2019)	modelo computacional, ecosistema de innovación de cuatro hélices, innovación disruptiva, computación cuántica, dinámica del ecosistema, modelo Dirac-Solow-Swan, acumulación de capital, efecto Christensen, factores disruptivos, antigua y nueva industria, ecuaciones incumbentes.	Modelo de ecosistema de innovación de cuádruple hélice y la computación cuántica para causar innovaciones disruptivas	FP / FN IR / ID / i2	4H	x		Work engagement Conexion

Padial, M; Pinzon, S; Navarro, B; San Juan, P; Ruiz, J; Espinosa, JM (2019)	implementación práctica, modelo de innovación basado en cuatro hélices, sitios de referencia, Comisión Europea, método Design Thinking, cinco fases, recopilación de datos cualitativos, diseño de acción de investigación, productos y servicios, envejecimiento activo y saludable, participación de usuarios.	Cómo aplicar el modelo de innovación de cuádruple hélice en sitios de referencia a través del método de pensamiento de diseño	FP / FN ID / i2	4H M-A	x	x	Conexion Soft skills
Mineiro, AAD; Arantes, RD; Vieira, KC; Castro, CC; Carvalho, EG; do Amaral, MG (2023)	parques científicos y tecnológicos (STP), hélice cuádruple y quintuple (QQH), impulsores, visión futura, encuesta, técnica del modelo de ecuaciones estructurales, colectivos, actores de QQH, entornos de innovación, sostenibilidad, movilización del ecosistema.	Cómo los colectivos de empresas que forman la cuádruple hélice pueden ayudar a alinear la visión futura de los Parques Científicos y Tecnológicos (PCTs) para contribuir a la sostenibilidad y la movilización del ecosistema de innovación	FP IR / i2	M-A		x	Soft skills Work engagement
Kang, YY; Jiang, J (2020)	instituciones de educación superior, Modelo de la Cuádruple Hélice, dinámica de la innovación, sistemas de innovación transfronterizos.	Influencia de las instituciones de educación superior (IES) en diferentes sistemas de innovación	FP / FN IR / i2	4H M-A	x	x	Active learning Soft skills
Guarin-Manrique, LD; Martinez-Ardila, HE (2022)	agentes intermedios, transferencia de conocimiento y tecnología, academia, industria, gobierno, sociedad civil, sistemas de innovación sectorial.	Sistemas de innovación sectorial en países en desarrollo, agentes intermediarios y tecnologías	FP / FN i2	4H M-A	x	x	Dynamic organism Work engagement
Nascimento, SD; Lima, MC; Gondim, IJC (2022)	ecosistema de innovación, colaboración, transferencia de conocimiento, metodología, estudio de caso múltiple, investigación cualitativa, análisis de contenido, academia, empresa, gobierno, sociedad, modelo analítico.	Colaboración entre los actores del ecosistema de innovación y la transferencia de conocimiento: Educación, Ciencia y Tecnología en Brasil.	FP / FN ID / i2	4H 4H+M-A	x		Work engagement
Kriz, A; Bankins, S; Molloy, C (2018)	Innovación, Desarrollo Regional, Especialización Inteligente, Cuádruple Hélice, Investigación Acción, Dinámica del Capital Humano, Colaboración.	Desarrollo regional tiene importantes consecuencias económicas y sociales	FP / FN IR / ID	4H M-A	x	x	Conexion Work engagement
Unceta, A; Barandiaran, X; Lakidain, A (2021)	Digitalización, Economía Creativa, Gobernanza Colaborativa, Laboratorios de Innovación, Producción Audiovisual, Gastronomía Digital, Articulación Sectorial, Estrategia de Especialización Inteligente, Agentes de Cuádruple Hélice	Gobernanza colaborativa y laboratorios de innovación pública	FP / FN IR / ID / i2	4H+M-A	x		Soft skills Dynamic organism
Meyer, C; Gerlitz, L; Klein, M (2022)	Turismo Sostenible, Región del Mar Báltico Sur, Región del Mar Báltico, Resiliencia, Recuperación, Sostenibilidad, Industrias Culturales y Creativas (CCIs), Estrategias de Especialización Inteligente, Redes de Cuádruple Hélice, Innovación Sostenible, Brokers de Transición, Marginalización Rural.	Industria cultural y creativa (CCIs): agentes de innovación sostenible y transición en asociaciones cuádruples	FP / FN i2	4H M-A	x	x	Active learning Dynamic organism

Sa, E; Casais, B; Silva, J (2019)	Instituciones de educación superior (IES), compromiso socioeconómico, transferencia de conocimiento, valoración, proyecto transnacional, actores políticos y sociales, revisión de literatura, análisis estadístico, análisis de políticas, planes de estudio, educación cultural, múltiples formas de valor, agentes.	Triple Hélice (universidad, industria y gobierno) para fomentar el emprendimiento rural y el desarrollo local	FP / FN ID / i2	4H 4H+M-A	x		Work engagement Conexion
Almeida, RN; Cruz, AR; Costa, P; Gato, MA; Perestrelo, M (2020)	sistemas colaborativos, problemas públicos, ciudadanos, participantes organizacionales, desequilibrios de poder, laboratorios vivos, laboratorios urbanos vivos, Cataluña, mecanismo de banca de poder, discursos de Cuádruple Hélice.	Instituciones de educación superior: transferir y valorar el conocimiento en el sector de las actividades culturales y creativas	FP / FN IR / ID	4H M-A	x	x	Conexion Dynamic organism
Nguyen, HT; Marques, P; Benneworth, P (2022)	operaciones complejas, absorción y difusión de diversas tecnologías, operaciones técnicas y políticas, análisis bibliométrico, agentes de transferencia, partidarios, objeto, canales, entorno de demanda, gestión de la TT, efectos e impactos.	Ciudades inteligentes, desequilibrios de poder entre los ciudadanos y otros participantes organizacionales desde los laboratorios urbanos vivos.	FP / FN IR / ID / i2	4H+M-A	x		Soft skills Conexion

In this regard, the qualitative and quantitative analysis of the scope and work approaches serves as a mechanism to select optimal models while disregarding suboptimal ones. This study is grounded in a modeling concept defined as the Transformational Productive Training Model (FTP + Learning by Doing), which incorporates key elements such as interdisciplinarity, competency-based training, Learning by Doing, Third-Generation University (U3G – 4 Helix), and Innovation.

A qualitative correlation of the results presented in Tables 1–2, derived from articles published between 2013 and 2023, based on the previously defined criteria, demonstrates the increase in related publications and their impact across sectors and subsectors where the Third-Generation University (U3G) interacts within the 4-Helix models and agent-based models for innovation management.

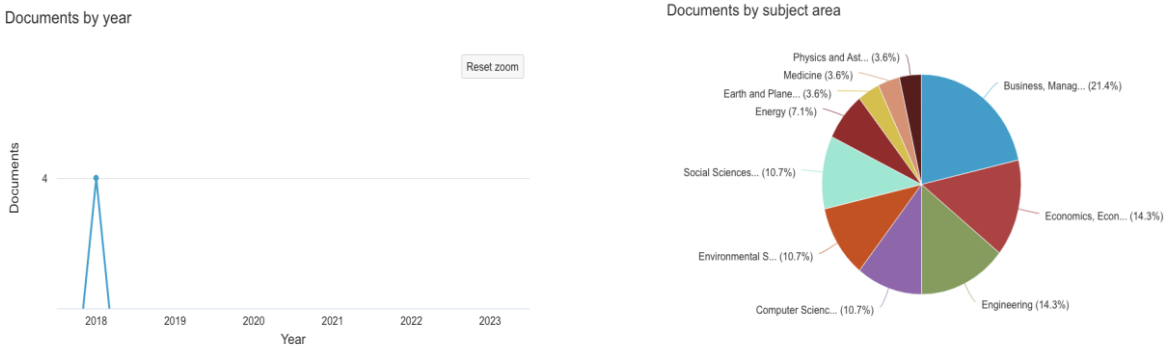

Figure: Summary of research the categories and innovation contexts (Elsevier).
Fuente: Elsevier (TITLE-ABS-KEY (quadruple AND helix AND innovation AND model) AND TITLE-ABS-KEY (agents AND models AND innovation AND model)

The percentage of publications on the Quadruple Helix models is increasing, while the percentage of publications on agent-based models is slightly lower but also growing, driven by the emergence of new Quintuple Helix models.

Additionally, a causal relationship is observed regarding the role of universities as key actors in the innovation process and their impact on the type of innovation generated within communities and business ecosystems.

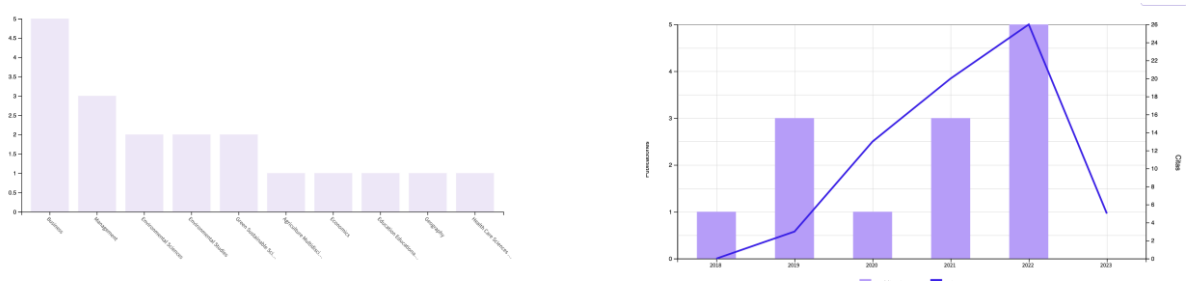

Figure: Summary of research the categories and innovation contexts (Elsevier).
Fuente: Elsevier (TITLE-ABS-KEY (quadruple AND helix AND innovation AND model) AND TITLE-ABS-KEY (agents AND models AND innovation AND model)

This research has applied qualitative correlation techniques and frequency analysis to examine innovation concepts and their relationship with published studies indexed in WOS and ELSEVIER. The following subsections provide a general overview of the reviewed research, along with their theoretical frameworks, as well as the convergences and divergences between the Quadruple Helix Model and the Agent-Based Model. These models are considered as two key approaches for technology and knowledge transfer, focusing on the analysis of innovative strategies in higher education management.

3. DISCUSSION

The Quadruple Helix Model and the Agent-Based Model are two key approaches aimed at enhancing technology and knowledge transfer between Higher Education Institutions (HEIs) and society. The Quadruple Helix Model (Carayannis & Campbell, 2009) advocates for collaboration among four main stakeholders: academia, industry, government, and civil society. This model seeks to establish an innovation ecosystem that integrates these stakeholders and fosters co-creation of knowledge and technology.

Conversely, the Agent-Based Model (Etzkowitz, 2012) focuses on the development of innovation networks, led by entrepreneurs and scientists, who act as "agents" connecting HEIs with society and the market.

Both models have been extensively examined in academic literature, aiming to understand their key categories, theoretical foundations, outcomes, and applications within HEIs. Studies have identified that the successful implementation of these models necessitates collaboration and dialogue among stakeholders, along with the cultivation of an innovation and entrepreneurship culture within HEIs (Mendoza et al., 2021). Additionally, funding and incentives have been highlighted as critical factors in supporting technology and knowledge transfer, as well as the need for adequate legislation to protect intellectual property and facilitate technology commercialization (Ndonzuau et al., 2021).

The applicability of these models within higher education (HEIs) is compared based on the following criteria:

- Phases of the Innovation Process: Positive Phases (FP); Negative Phases (FN)
- Types of Innovation: Radical Innovation (IR), Disruptive Innovation (ID), Incremental Innovation (i2)
- Innovation Model Approaches: Quadruple Helix (4H), Agent-Based Model (M-A), Hybrid Approaches (4H+M-A)
- Research Context Analysis: Method, Category, Classification, Relation

It is crucial to define the Quadruple Helix (4H) innovation model, as it represents a collaborative process involving four primary helices: government, industry, academia, and civil society (Carayannis & Campbell, 2012). This model is primarily based on the concept of genuine innovation, emerging from active and sustainable collaboration among these four key actors. Carayannis and Campbell (2009, p. 210) conceptualize the process as innovation driven by a single helix, where sustainable and effective cooperation among the four helices leads to successful innovation. In this framework, the government can provide appropriate policies and regulations to foster innovation, the industry can develop new products and technologies, the academia can conduct research and provide specialized knowledge, and civil society can offer feedback and support for the adoption of innovations (Carayannis & Campbell, 2012, p.10).

Nonetheless, the Quadruple Helix model has been widely utilized in innovation research across various contexts, ranging from technology to public policy and economic development (Carayannis & Rakhmatullin, 2014, p. 1168). This framework is employed in innovation policy evaluation (Edquist, 2011), in the analysis of inter-organizational

cooperation effects on innovation (Huggins et al., 2018), and in the study of citizenship and participation in social innovation (Moulaert et al., 2013). Consequently, the nature and role of each helix in innovation allow for a comprehensive assessment of its impact across different sectors where it is applied (Carayannis & Campbell, 2012). Thus, the Quadruple Helix model serves as a valuable tool for understanding the innovation process and collaboration among different stakeholders within it.

Conversely, the Agent-Based Innovation Model focuses on the role of individual actors and social networks in the innovation process. Individual actors (entrepreneurs, researchers, and investors) collaborate within a network of cooperation to generate new ideas and transform them into innovative products and services (Leydesdorff & Etzkowitz, 1998). This model contrasts with the traditional linear innovation model, which emphasizes knowledge transfer from universities and research centers to businesses.

According to Chesbrough (2003), within the framework of "Open Innovation", companies should seek and leverage external ideas and resources, as innovation is not confined to internal organizational capabilities. Instead, "internal and external knowledge can be combined and utilized to create value" (p. 3). Another notable approach is that of Von Hippel (2005), who conceptualizes innovation through agents (users) and decentralized innovation within communities. He argues that advanced users can serve as a valuable source of novel ideas and innovative solutions. Furthermore, "end users frequently innovate for themselves, often outperforming commercial goods and service providers" (2005, p. 18).

As a result, agent-driven innovation has gained significant traction in recent years as a more dynamic and collaborative approach to the generation of new ideas and innovative products.

Table: Resume estadísticas, así como elementos descriptivos sobre la naturaleza de las 596ategorías desde los modelos de 4h y agentes (Elsevier).

Articles	Node models	Problem	Edge type	#Class node 1	#Class del node 2	#Class node 3	Articulation	Nodes	Limit
Trisetyarso, A; Hastiadi, FF (2019)	4H	FP / FN IR / ID / i2	Innovation	Work engagement Conexion	Practical implementation: Concrete action, real-world application.	Open innovation, citizen participation, active aging.	Practical implementation, four-helix-based innovation model, reference sites, European Commission, Design Thinking method, five stages, qualitative data collection, research action design, products and services, active and healthy aging, user participation.	1,47%	15
Padial, M; Pinzon, S; Navarro, B; San Juan, P; Ruiz, J; Espinosa, JM (2019)	4H M-A	FP / FN ID / i2	Innovation	Conexion Soft skills	Four helix model of innovation: Comprehensive approach, interaction of actors.	Knowledge transfer, intersectoral collaboration, innovation systems.	Intermediate agents, knowledge and technology transfer, academia, industry, government, civil society, sectoral innovation systems.	1,17%	12
Mineiro, AAD; Arantes, RD; Vieira, KC; Castro, CC; Carvalho, EG; do Amaral, MG (2023)	M-A	FP IR / i2	Innovation	Soft skills Work engagement	Reference sites: Iconic and interesting locations.	Open innovation, citizen participation, active aging.	Practical implementation, four-helix-based innovation model, reference sites, European Commission, Design Thinking method, five stages, qualitative data collection, research action design, products and services, active and healthy aging, user participation.	0,59%	6

Kang, YY; Jiang, J (2020)	4H M-A	FP / FN IR / i2	Innovation	Active learning Soft skills	Intermediary agents: Key intermediaries, facilitators of knowledge and resource transfer.	University innovation, public-private collaboration, cross-border innovation.	Higher education institutions, Quadruple Helix Model, innovation dynamics, cross-border innovation systems.	0,29%	3
Guarin-Manrique, LD; Martinez-Ardila, HE (2022)	4H M-A	FP / FN i2	Innovation	Dynamic organism Work engagement	Transfer of knowledge and technology: Exchange of knowledge and resources.	Technology parks, quintuple helix innovation, ecosystem mobilization.	Science and Technology Parks (STP), Quadruple and Quintuple Helix (QQH), drivers, future vision, survey, structural equation modeling technique, QQH actors, innovation environments, sustainability, ecosystem mobilization.	0,29%	3
Nascimento, SD; Lima, MC; Gondim, IJC (2022)	4H 4H+M-A	FP / FN ID / i2	Innovation	Work engagement Soft skills	Sectoral innovation systems: Specific focus within a determined field.	Open innovation, citizen participation, active aging.	Practical implementation, four-helix-based innovation model, reference sites, European Commission, Design Thinking method, five stages, qualitative data collection, research action design, products and services, active and healthy aging, user participation.	0,29%	3
Kriz, A; Bankins, S; Molloy, C (2018)	4H M-A	FP / FN IR / ID	Innovation	Conexion Work engagement	Higher education institutions: Academic organizations, talent-forming institutions.	Open innovation, citizen participation, active aging.	Practical implementation, four-helix-based innovation model, reference sites, European Commission, Design Thinking method, five stages, qualitative data collection, research action design, products and services, active and healthy aging, user participation.	0,20%	2
Unceta, A; Barandiaran, X; Lakidain, A (2021)	4H+M-A	FP / FN IR / ID / i2	Innovation	Soft skills Dynamic organism	Four helix model: Collaborative approach, integration of actors.	University innovation, public-private collaboration, cross-border innovation.	Higher education institutions, Quadruple Helix Model, innovation dynamics, cross-border innovation systems.	0,20%	2
Meyer, C; Gerlitz, L; Klein, M (2022)	4H M-A	FP / FN i2	Innovation	Active learning Dynamic organism	Transborder innovation systems: International focus, collaboration between countries.	University innovation, public-private collaboration, cross-border innovation.	Higher education institutions, Quadruple Helix Model, innovation dynamics, cross-border innovation systems.	0,10%	1

Sa, E; Casais, B; Silva, J (2019)	4H 4H+M-A	FP / FN ID / i2	Innovation	Work engagement Conexion	Science and Technology Parks (STP): Innovation spaces, concentration of resources.	Open innovation, citizen participation, active aging.	Practical implementation, four-helix-based innovation model, reference sites, European Commission, Design Thinking method, five stages, qualitative data collection, research action design, products and services, active and healthy aging, user participation.	Null	Null
Almeida, RN; Cruz, AR; Costa, P; Gato, MA; Perestrelo, M (2020)	4H M-A	FP / FN IR / ID	Innovation	Conexion Dynamic organism	Quadruple and quintuple helix (QQH): Expanded model, collaborative approach.	University innovation, public-private collaboration, cross-border innovation.	Higher education institutions, Quadruple Helix Model, innovation dynamics, cross-border innovation systems.	Null	Null
Nguyen, HT; Marques, P; Benneworth, P (2022)	4H+M-A	FP / FN IR / ID / i2	Innovation	Soft skills Conexion	Ecosystem mobilization: Joint action, involvement of key actors.	University innovation, public-private collaboration, cross-border innovation.	Higher education institutions, Quadruple Helix Model, innovation dynamics, cross-border innovation systems.	Null	Null

Notes:
Node models: implementation of the model type within the logic of the article
Problem: central problem and its association with innovation
Edge type: axis of content analysis of the article
#Class node 1: Third-generation universities (constituent elements)
#Class of node 2: 4-helix model (associated categories)
#Class node 3: Agent model (associated categories)
Articulation: helix convergences (associated categories)
Nodes: weight of articles in JCR/SJR citation
Limit: citations
Source: Elsevier, 2023-03

Table: Resume estadísticas, así como elementos descriptivos sobre la naturaleza de las 598ategorías desde los modelos de 4h y agentes (Web of Science).

Articles	Node models	Problem	Edge type	#Class node 1	#Class del node 2	#Class node 3	Articulation	Nodes	Limit
Kriz A., Bankins S., Molloy C. (2018)	4H	FP / FN IR / ID / i2	Innovation	Work engagement	Collaborative innovation, citizen participation, active aging.	User involvement, active and healthy aging, Design Thinking method.	Practical implementation, innovation model based on four helixes, reference sites, European Commission, Design Thinking method, five phases, qualitative data collection, research action design, products and services, active and healthy aging, user involvement.	3,23%	33

Kang Y., Jiang J. (2020)	4H M-A	FP / FN ID / i2	Innovation	Conexion	User-centered design, open innovation, qualitative research.	User involvement, active and healthy aging, Design Thinking method.	Intermediate agents, knowledge and technology transfer, academia, industry, government, civil society, sectoral innovation systems.	0,98%	10
Machado H.V., Lazzarotti F., Bencke F.F. (2018)	M-A	FP IR / i2	Innovation	Soft skills	Knowledge transfer, innovation systems, innovation actors.	Intermediate agents, knowledge transfer, innovation systems.	Design Thinking method, five phases, qualitative data collection, research action design.	3,71%	38
Meyer C., Gerlitz L., Klein M. (2022)	4H M-A	FP / FN IR / i2	Innovation	Active learning	Action-oriented research, iterative design, qualitative analysis.	Design Thinking method, qualitative data collection, research action.	Science and Technology Parks (STP), quadruple and quintuple helix (QQH), drivers, future vision, survey, structural equation modeling technique, collectives, QQH actors, innovation environments, sustainability, ecosystem mobilization.	6,26%	64
Unceta A., Barandiaran X., Lakidain A. (2021)	4H M-A 4H+M-A	FN IR / ID	Innovation	Dynamic organism Work engagement	Innovation ecosystem, sustainability, structural analysis.	Science and technology parks, quadruple and quintuple helix, sustainability.	Intermediate agents, knowledge and technology transfer, academia, industry, government, civil society, sectoral innovation systems.	5,87%	60
Padial M., Pinzón S., Navarro B., San Juan P., Ruiz J., Espinosa J.M. (2019)	4H 4H+M-A	FP / FN ID / i2	Innovation	Work engagement	Innovation networks, technology transfer, intersectoral collaboration.	Intermediate agents, knowledge transfer, innovation systems.	Science and Technology Parks (STP), ecosystem dynamics, structural equation modeling technique, sustainability, ecosystem mobilization, innovation dynamics, sectoral innovation systems.	5,77%	59

Mineiro A.A.C., Arantes R.C., Vieira K.C., Castro C.C., Carvalho E.G., Amaral M.G. (2023)	4H M-A	FP / FN IR / ID	Innovation	Conexion	Ecosystem mobilization, open innovation, sustainability.	Science and technology parks, quadruple and quintuple helix, sustainability.	Practical implementation, user involvement, methodology, multiple case study, qualitative research, content analysis, collaboration.	4,79%	49
Lugovic S., Dunder I., Horvat M. (2017)	4H+M-A	FP / FN IR / ID / i2	Innovation	Soft skills	Citizen participation, qualitative research, interdisciplinary collaboration.	User involvement, qualitative research, collaboration.	Intermediate agents, knowledge and technology transfer, academia, industry, government, civil society, sectoral innovation systems.	12,51%	128
Salmelin B. (2016)	4H M-A	FP / FN i2	Innovation	Active learning	Knowledge transfer, innovation systems, public-private collaboration.	Intermediate agents, knowledge transfer, innovation systems.	Science and Technology Parks (STP), innovation ecosystem dynamics, structural equation modeling technique, sustainability, ecosystem mobilization, innovation dynamics, sectoral innovation systems.	20,14%	206
Trisetyarso A., Hastiadi F.F. (2022)	4H M-A	FP ID / i2	Innovation	Dynamic organism	Innovation ecosystem, sustainability, structural analysis.	Science and technology parks, innovation dynamics, sustainability.	Practical implementation, innovation model based on four helixes, reference sites, European Commission, Design Thinking method, five phases, qualitative data collection, research action design, products and services, active and healthy aging, user involvement.	7,53%	77
Sjafrina N., Marimin, Udin F., Anggraeni E. (2020)	4H	FP / FN i2	Innovation	Active learning	Collaborative innovation, citizen participation, active aging.	User involvement, active and healthy aging, Design Thinking method.	Higher education institutions, Quadruple Helix Model, innovation dynamics, cross-border innovation systems.	8,80%	90
Salmelin B. (2018)	4H M-A	FP / FN IR / i2	Innovation	Active learning	Transborder innovation, four helix model, interinstitutional collaboration.	Quadruple helix, cross-border innovation systems.	Design Thinking method, five phases, qualitative data collection, research action design.	8,80%	90

Dias A., Salmelin B. (2018)	4H M-A	FP / FN IR / ID / i2	Innovation	Active learning	Action-oriented research, iterative design, qualitative analysis.	Design Thinking method, qualitative data collection, research action.	High education institutions, Quadruple Helix Model, innovation dynamics, cross-border innovation systems.	7,04%	72

Notes:
Node models: implementation of the model type within the logic of the article
Problem: central problem and its association with innovation
Edge type: axis of content analysis of the article
#Class node 1: Third-generation universities (constituent elements)
#Class of node 2: 4-helix model (associated categories)
#Class node 3: Agent model (associated categories)
Articulation: helix convergences (associated categories)
Nodes: weight of articles in JCR/SJR citation
Limit: citations
Source: Web of Science, 2023-03

4. RESULTS

Scientific advancements in technology and innovation have had significant impacts on both business and institutional levels. Several authors, including Kriz, Bankins, and Molloy (2018); Kang and Jiang (2020); Machado, Lazzarotti, and Bencke (2018); Meyer, Gerlitz, and Klein (2022), emphasize the value of integrating the Quadruple Helix and Agent-Based models.

A key aspect in this integration is the role of Information and Communication Technologies (ICTs) in enhancing efficiency and productivity across various sectors (Kriz, Bankins & Molloy, 2018). For example, real-time tracking and monitoring tools—when transferred to inter-institutional cooperation models—demonstrate the collaborative network chains (Unceta, Barandiaran & Lakidain, 2021), optimizing decision-making processes in both public and private sectors.

Furthermore, technology enhances the responsiveness of actors and participants in the innovation process (Kang & Jiang, 2020), addressing rapidly evolving market needs. This is particularly evident in the integration of the Internet of Things (IoT) and Artificial Intelligence (AI), which contribute to enhancing products and services across corporate, institutional, and societal domains.

Machado, Lazzarotti, and Bencke (2018) argue that technology also plays a critical role in ensuring the sustainability of innovation-driven operations and initiatives. Similarly, Meyer, Gerlitz, and Klein (2022) highlight the interconnection between communication, dynamic business capabilities, and innovation management.

The interplay among different stakeholders and subsectors is central to innovation enhancement (Padial, Pinzón, Navarro, San Juan, Ruiz & Espinosa, 2019; Mineiro, Arantes, Vieira, Castro, Carvalho & Amaral, 2023; Lugovic, Dunder & Horvat, 2017). This collaborative approach necessitates strong coordination, transparency, and traceability in actions and results (Unceta, Barandiaran & Lakidain, 2021).

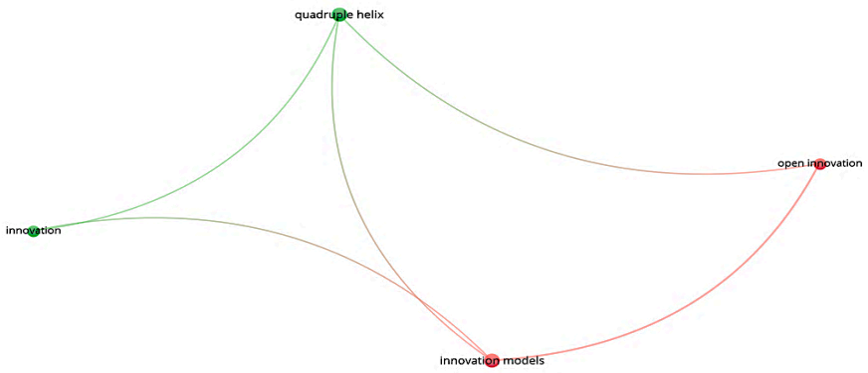

Figure: Map base and bibliographic data (analysis and counted methos keywords).
Fuente: Scopus review, 2023) (TITLE-ABS-KEY (quadruple AND helix AND innovation AND model) AND TITLE-ABS-KEY (agents AND models AND innovation AND model)) Structure of the selection and debugging of consulted sources

Research is a constantly evolving field that addresses complex problems and challenges (Salmelin, 2016; Trisetyarso & Hastiadi, 2022; Sjafrina, Marimin, Udin & Anggraeni, 2020). In this regard, an analysis of some of the most influential sources in recent research, focusing on their relevance and contributions to their respective fields, reveals significant insights.

For instance, Trisetyarso and Hastiadi (2019) present a work approach centered on innovation and creativity, which are fundamental elements for enhancing service quality and increasing satisfaction. Similarly, Padial et al. (2019) found a strong correlation between job satisfaction and organizational performance, which are critical criteria for both the Quadruple Helix and Agent-Based models (Etzkowitz, 2012). These models emphasize the cooperation and active collaboration of stakeholders throughout their phases, suggesting that businesses and institutions should focus on performance improvement.

From a more specific perspective, Mineiro et al. (2023) examine innovation in higher education, advocating for virtual learning environments that enhance educational effectiveness compared to traditional face-to-face education. Their findings suggest that higher levels of self-discipline and motivation are crucial for achieving similar learning outcomes through innovative digital platforms. These insights are particularly relevant given the surge in online learning during the COVID-19 pandemic.

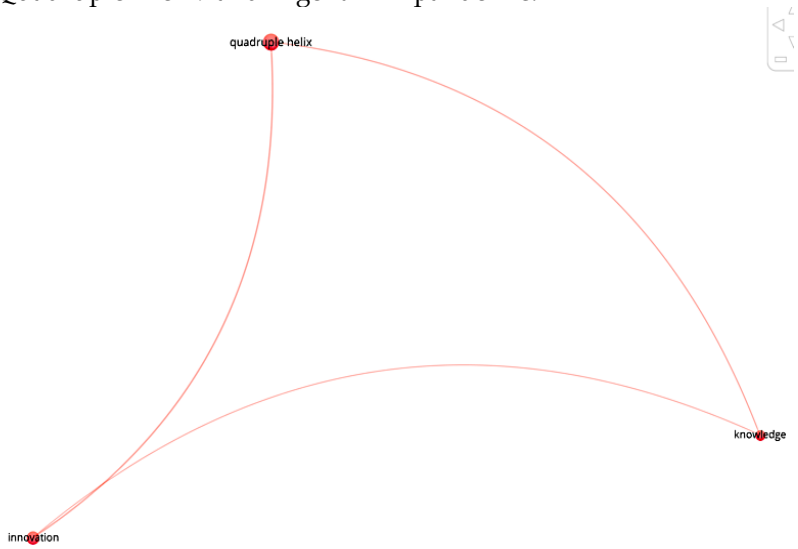

Figure: Map base and bibliographic data (analysis and counted methos).

Fuente: Web of Science, 2023) quadruple helix innovation model (Todos) and agents models innovation (Todos)

Thus, the integration of innovation—through the Quadruple Helix model—and knowledge establishes a direct relationship between emotional intelligence and effective leadership (Kang & Jiang, 2020). Emotional intelligence is recognized as a key predictor of leadership effectiveness, and evidence suggests that emotional skills can be developed and enhanced. These findings are particularly relevant for leadership training in both organizational and educational settings.

Furthermore, Guarin-Manrique and Martinez-Ardila (2022) identify a direct correlation between self-confidence and decision-making in business and institutional contexts, demonstrating that higher levels of self-confidence positively impact leaders' decision-making processes. Their study underscores the importance of integrating leadership development and coaching programs to enhance decision-making capabilities.

At this point, a crucial element emerges in establishing a logical framework for the innovation process, whether through the Quadruple Helix or Agent-Based models (Etzkowitz, 2012). In this regard, workplace empathy (Nascimento et al., 2022) is recognized as a key factor in fostering innovation, as it improves communication, job satisfaction, and interpersonal relationships while also enhancing soft skills within the productive sector.

Returning to virtual learning environments and technology-mediated education, another critical integration point between the Quadruple Helix and Agent-Based models is learning motivation (Kriz et al., 2018). Motivation is a fundamental factor in learning, as it ensures that actors remain engaged and committed to achieving success in innovation and entrepreneurial environments.

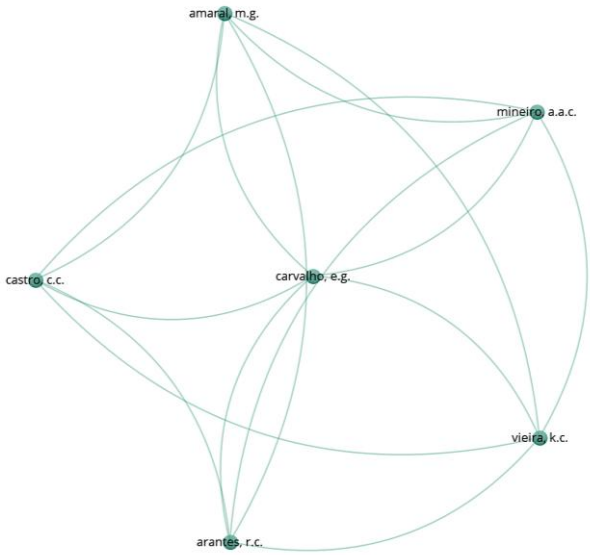

Figure: Map base and bibliographic data (analysis and counted methos co-authors).
Fuente: Scopus review, 2023) (TITLE-ABS-KEY (quadruple AND helix AND innovation AND model) AND TITLE-ABS-KEY (agents AND models AND innovation AND model)) Structure of the selection and debugging of consulted sources

There is a correlation between emotional intelligence and decision-making (Unceta et al., 2021). Emotional intelligence serves as a key predictor of success in innovative ideas and processes, influencing how actors and innovators can enhance their emotional intelligence through training and practice.

This relationship between leadership and diversity (Meyer et al., 2022) facilitates a variation in leadership approaches, framing it as inclusive leadership, which aims to enhance diversity and promote a research-driven culture. These elements are essential for innovation management, particularly in resource allocation within businesses and organizations.

Moreover, this dynamic establishes a direct link between creativity and innovation (Sa et al., 2019), both of which are fundamental for success. The cultivation of creative and innovative skills throughout management processes plays a crucial role in both the Quadruple Helix and Agent-Based models.

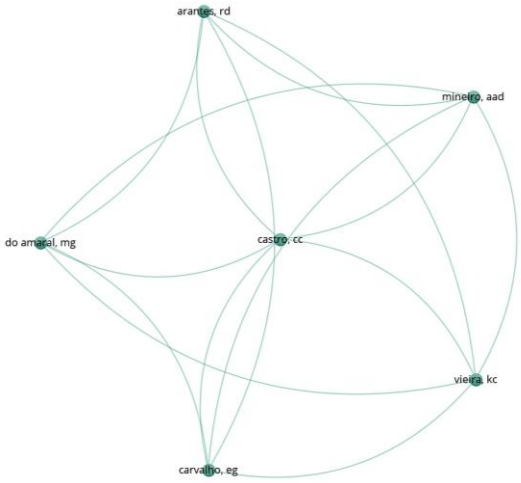

Figure: Map base and bibliographic data (analysis and counted methos co-authors).
Fuente: Web of Science, 2023) quadruple helix innovation model (Todos) and agents models innovation (Todos)

Nguyen et al. (2022) focus on the relationship between research and local economic development, demonstrating that innovation can have a positive impact on regional economic growth. However, their findings indicate that appropriate policies and strategies (Quadruple Helix) are necessary to fully leverage this potential (Agent-Based models). These insights are particularly relevant for economic planning and development within local communities.

Each of these studies presents a unique perspective on critical issues and challenges across diverse fields such as education, business, sports, and architecture. While each study has its own limitations and areas for improvement, collectively, they provide a robust foundation for future research and advancements in these disciplines. Additionally, these studies emphasize the role of research in addressing complex problems and enhancing quality of life within communities worldwide.

Projected Approaches for the Third-Generation University (U3G)

The integration of these models (Quadruple Helix and Agent-Based) facilitates the consolidation of a new framework for Innovation Management and Preservation, emphasizing science, technology, and innovation through project-based initiatives. This approach drives innovation and disruption in educational transformation management, strengthening the various dimensions of knowledge management and preservation while transitioning towards knowledge transfer in real-world contexts.

The following section explores how global trends provide insights into the realities of research management, knowledge conservation, and innovation transfer from a project-based and business investment perspective.

Cuadro: Tendencias mundiales sobre Gestión y conservación de la Innovación y el conocimiento.

2022	2021	2020
Knowledge retention; Medical education; Progress testing; Retrieval practice; Spaced learning; The forgetting curve	Soccer passing networks; Sports visualizations; Temporal networks; Visual analytics	Child protection; Complex trauma; Epistemic trust; Parental non-engagement; Recurrent care proceedings
Blockchain; Industry 4.0; Internet of Things; SmartEnvironments	Blockchain; Evidence-based trust; Internet of things; Security; Trust management; Trust modelling; Verifiable interaction	Big data; Crowdsourcing; Crowdworking; Disaster management; Emergency management
External knowledge; Family firm; Innovation performance	intelligent transport systems (ITS); smart city; smart mobility	Data access; Existential rules; Horn description logics; Ontology-mediated query answering
ADMM; Communication cost; Distributed optimization; Information-theoretic; PDMM; Privacy; Quantization	Bio-inspired computation; Dynamical systems; K-winners-take-all; Nonlinear dynamics; Spiking neural networks	Blockchain; Homomorphic cryptosystem; Internet of things data; Privacy protection; Supervised learning
Artificial night light; Lighting design; Night-time activities; Recreational activities; Safety; Urban design	generative principles; generative theory; Theory	Postgraduate medical education; Reflection; Safe learning environment; Social context; Workplace learning
Blockchain; Edge; Peer-to-peer networks	Foundations; Internet of Things; path forward; reliability and security challenges; systems and networking challenges	Data visualization; Economics; Network exploration; Supply chain
Clustering; Data projection; Joint probability density estimation; Non-parametric techniques	administration-politics relationship; civil service; content analysis; discourse analysis; public statements; Russia	Computational collaborative scheduling strategy; Double DQN algorithm; Kalman filter; Mobile edge computing; Privacy of vehicle location
Electronic healthcare records; Healthcare applications; Healthcare data; Healthcare professionals; Rule based systems; Rule-based approach	audiovisual content; cheap fakes; configuration; deepfakes; politics of evidence	Blockchain; Medical data; Privacy protection; Secure data sharing; Smart contract; Zero-knowledge proof
Blockchain; Differential privacy; Distributed ledger technology; Federated machine learning; Zero-knowledge proof	Boosting; Ensemble learning; Multi-target regression; Prior knowledge; Quantum computing; Stacking	Crowdsourcing; Deep learning; Information retrieval; Relevance evaluation
Citizen science; Elicitation; Information practices; Interview methods; Methodology; Practice-based studies; Sociomateriality; Trace ethnography; Visual methods	3D printing model; Congenital heart disease; Teaching; Undergraduate medical students	Building performance; condition assessment; occupant complaints; post-occupancy evaluation (PoE)

5G networks; Authentication; Cryptanalysis; Internet of Drones; Lightweight	5G networks; Big data; Network coding; Wireless mesh network	Classification model; Ensemble learning; Machine learning; Model combination; Probability weight; Weight voting
Clusterization; Co-reference resolution; De-identification; NER; Transfer learning	Blockchain; Data-chains partitioning algorithm; Intelligent manufacturing; Multi-chain	Hybrid modeling; Neural networks; Particle Swarm Optimization; Physics-aware machine learning; Unmanned aerial vehicle
3D modeling; 3D reconstruction; Immersive environments	Data protection regulation; Federated learning; GDPR; Personal data; Privacy; Privacy preservation	Blockchain; Healthcare; Medical data; Systematic literature review
Building energy consumption; Energy efficiency; Energy prediction; Machine learning	Blockchain; Cybersecurity	Biomedical support; Digital technologies; Functional status assessment; Gifted children; Monitoring; Sports selection
Cultural management; Generative algorithms; HBIM; Structural systems reverse engineering; Terrestrial laser scanning	animation; functional methods; LBS; skeleton transfer	Digital humanities; Project documentation; Project management; Sustainable publishing models
Application; Network; Uncertainty	Academic Library; Cultural development; Economical development; Educational development; Library; Political development; Public Library; Social development	6G; Blockchain; Network slicing; Resource management; Wireless blockchain
Autonomy; Blockchain; Internet of Things; Protection; Reliability; Reputation; Trust	6G; intelligent transportation system (ITS); large-scale traffic management; massive Internet of Things (IoT); short-term traffic forecasting; time-aware locality-sensitive hashing (LSH)	6G; Communication; Cyber security; Privacy preservation
BACS; building automation and control systems; Home automation; KNX; privacy; safety; security; smart building	Cryptography; E-health cloud; EHR; Generalization; Privacy	Accountability; experimental methods; public administration; retrospective voting
Indigenous education; Teaching materials; Traditional knowledge	ethnography; hybridity; identity; mixed race; race; sport; superdiversity	Leadership; Network; Performance

Fuente: Survey Data ScienceDirect, Scopus, 2022

The existence of management and innovation contexts in Colombia enables each of the key elements required for the creation of a modern Higher Education Institution (HEI) with the capacity to respond to innovation and the development of new inventions and prototypes. This adaptability allows small and medium-sized enterprises (SMEs) to adopt new behavioral models, where innovation drives significant improvements while also redefining corporate engagement in training, education, and human capital transformation.

An approach to innovation models from the perspective of actors and institutions within the logic of higher education management must shift its training and productive transformation processes toward a hybrid model of active and disruptive participation. This transition should be based on learning-by-doing frameworks within a cooperative structure among individuals and institutions, encompassing:

- A system of concrete actions, both individually planned and collectively implemented.
- Systemic observation strategies, analyzing effects and impacts.
- A practical framework for defining and implementing creative and innovative solutions.
- The management of learning outcomes, ensuring that actions translate into tangible impacts on social, business, and productive transformation.

The following section presents the global landscape and its impact on the key categories of innovation in university education:

Table: Global Trends in Multidisciplinary Educational Innovation.

2022	2021	2020
Culture; ICT; Intercultural communication; Intercultural education; Mass media; Media literacy; Radio	Competence; Didactic resources; Didactic strategies; Learning styles; Sensory systems; Teaching styles	Curriculum research; Early childhood education; Family involvement; Family school relationship; School organization
Articulation; Childhood; Continuity of education; Early childhood education; Transition	Leadership styles; Professional capital; School management; Teacher involvement	Education; Peace; Teachers; Training; University
COVID 19; Education; Knowledge management; Law	Administration; Curriculu; Hermeneutic phenomenology; Knowledge management	Emotional intelligence; ICT; Teaching-learning; Virtual education

Audiovisual aid; Career development; MOOC; Teaching aid	Gamification; Innovation; Knowledge; Serious games; Training and development	Education; Innovative; Integral; Leadership; Values
Distance learning; Educational media; Educational technology; University studies	Cognitive mediation; Information and Communication Technology (ICT); Reading; Reading fluency	Information technologies; Mathematics teaching; Natural science teaching; Pedagogy; Professional update; Scientific education; Scientific thinking skills; Skills
Analysis tool; Families; Participation; School community; Students	Motivation; Scale validation; Skill; Textbook	Pedagogical experience; Self-learning; Teacher apprentice; Teaching styles
	Social representations; Teaching; University teachers	Cultural change; educational change; learning; schooling; student well-being
Covid-19; Digital skills; Digitization; Innovation; Teacher training	Teacher training; Teachers' beliefs; Teaching competences; Theory of planned action	Cognitive style; Conceptual understanding; PjBL; Science-integrated; Website learning
Civil engineer; Competences; Didactics; Rubric; Static	Education and employment; Higher education; Life skills; Social networks; Training; Universities	Collaboration; Communities; Critical friend; Educational networks; Professional learning; School leadership
	Identity; Innovation Cooperative learning; Inclusive education; Social skills; Student with special needs; Teacher training; Teacher; Training	Data processing; Higher education; Literature review; Social media; Teaching practice; Twitter
Comparative education; Conflict; Education in emergencies; International education; Lecture-Performance	Learning; Multi-Series Class; Teaching; Teaching Practices	Digital identity; Educational narrative; Educational technology; Educational use; Humanism; Initial teacher training.; Technology appropriation; Visualization
	Digital education; MOOC; Social learning; Social networks; Sustainable distance education; Virtual learning communities	Educational technology; Information and communication technology; Teaching-learning
	Collaborative action-research; Lesson study; Professional development; University teacher training	Digital skills; Integration of ICT; Pandemic; Technological skills; Virtual learning
Portugal. Pinhal Interior Sul. Graded school. Rural school. Educational municipal policy paper	City and creativity; Fashion runway; Teaching innovation; University	Criticism of technology; Heidegger; Legal education; Power; Technological innovation; Technology
	Communication; Higher education; Interactions; Open innovation; Student university; Topics; Web surfing	Educational innovation; Higher education teaching; Social education
Educational innovation; Interactive learning; Journalism; Participation; Wooclap	Competence; internationalization; KIKS format; project-based learning; secondary education; STEAM	Collaborative learning; Student satisfaction; Teaching competences; Teaching role; Technological programs
	Digital competence; Educational innovation; ICTs; Online gaming; University teaching	Argument skills; Argumentation; Educational interventions

Fuente: Survey ScienDirect, Scopus, to 2023

This entails the implementation of a competitiveness model aimed at enhancing investment opportunities and securing resources, with its structural foundation based on the development of strategies to overcome economic and social inequalities among communities and stakeholders. This model seeks to reduce levels of poverty, marginalization, segregation, lack of access to technology, deficiencies in innovation, and limited access to goods and services.

The following section presents the interconnections between innovation models, innovation management, and the consolidation of spaces and challenges for disruption in educational contexts:

Table: Summary of research, approach to addressing the U3G and contexts (Web Of Science).

References	Categories	Central discussion	Problem	Scope Paper	Implementation		
					4 helix	Agents	U3G
Chilakamarry et al., (2021)	Renewable and sustainable energy sources, Advances in production, third generation, byproducts, sustainable alternative, Challenges and opportunities, environmental impact	Need to find renewable and sustainable sources of energy due to the depletion of fossil fuel reserves and the constant increase in energy demand.	FP / FN i2	4H	x		Work engagement Dynamic organism

Cortese et al., (2023)	Neurodevelopmental disorders, valid and reliable biomarkers, systematic review, disorders, specificity and sensitivity, multivariable and multilevel approaches	Biomarker for neurodevelopmental disorders that meets the criteria of specificity and sensitivity.	FP / FN i2	4H M-A	x	x	Conexion
Fiaz et al., (2021)	World without hunger, sustainable food production, distribution, poverty elimination, scientific, logistical, and humanitarian approaches, food security, policies and governments, quality and performance, innovation in improvement, agricultural challenges, sustainable crops, production improvements	The need to sustainably increase food production and distribution, and the importance of innovation and application of techniques to achieve sustainable agricultural production.	FP IR / i2	4H M-A	x	x	Soft skills
Ma et al., (2021)	Genome, viral protein characteristics, technology limitations, COVID-19, bioinformatics, prediction, drug and vaccine discovery, third-generation sequencing (TGS), development and identification of suitable vaccines.	Risks of pandemic diseases and their impact on social development and sustainability of communities.	FN IR / ID	4H M-A 4H+M-A	x	x	Dynamic organism Soft skills
Shao et al., (2023)	Alternatives to conventional energy resources, effectiveness and cost of photovoltaic solar energy (PV), cost terms, most cost-effective alternative, stability and efficiency	Need to find alternatives to conventional energy resources due to scarcity and concerns about pollution.	FP / FN i2	4H M-A	x	x	Conexion Dynamic organism
Tan et al., (2018)	Drug delivery, controlled release, bioscience, tissue engineering and medicine, progressive market growth, economically viable, scalable, sustainable technologies, tissue engineering, development prospects, industrialization of vehicles.	Economically viable, scalable, and sustainable technologies for large-scale production of drug delivery vehicles.	FP / FN i2	4H M-A	x	x	Conexion
Tapa et al., (2021)	Energy, promising alternatives, energy efficiency, environmentally friendly characteristics, material development, reaction mechanisms, challenges and opportunities, development.	Promising alternative from energy efficiency and environmentally friendly characteristics.	FP / FN i2	4H M-A	x	x	Dynamic organism Soft skills

Fuente: Elsevier, 2023. (TITLE-ABS-KEY (third AND generation AND university) AND TITLE-ABS-KEY (innovation)) AND PUBYEAR > 2003 AND PUBYEAR < 2024 AND (LIMIT-TO (EXACTKEYWORD , "Article")) AND (LIMIT-TO (SRCTYPE , "j"))

Table: Summary of research, approach to addressing the U3G and contexts (Scopus).

References	Categories	Central discussion	Problem	Scope Paper	Implementation		
					4 helix	Agents	U3G
Zygmunt M.; Kampe C. (2014)	European Union; Federal Ministry of Education and Research; Funding; Research, sectors, actors	Increasing dependence on external funding sources for research in higher education, and a lack of motivated young researchers to carry out research.	FN ID / i2	4H	x		Conexion Active learning

Zelko H.; Zammar G.R.; Bonilauri Ferreira A.P.; Phadtare A.; Shah J.; Pietrobon R. (2010)	scientific innovation, high impact publications, researchers, heuristics, positive feedback, communication skills, psychological attributes, randomness, serendipity, policy model.	Understanding how high-impact researchers generate high-quality publications and how these mechanisms can be incorporated into coaching and institutional research programs to promote high-impact research on a broader level.	FN ID / i2	4H	x		Conexion Active learning
Toshmali G.; Alimohammadzadeh K.; Maher A.; Hosseini S.M.; Bahadori M. (2020)	University of Entrepreneurship, industry-academia relationship, Iran, demographic composition, youth, job opportunities, economic development, scientific entrepreneurship, third millennium universities, medical sciences education, counseling, research and development, technology transfer, scientific parks, entrepreneurial culture	Structural relationships of dependence and leverage of ventures in industry and academia.	FP / FN i2	4H M-A	x	x	Conexion Active learning
Liu Z.; Le K.; Zhou X.; et.al (2023)	medical science, sustainable development, medicine, institutional research, innovation management	The impact of institutional research development on the advancement of medical science and research.	FP i2	4H M-A	x	x	Dynamic organism
Schadt E.E.; Turner S.; Kasarskis A. (2010)	technologies, scientific fields, encoded information, current technologies, new generation of technologies, third-generation sequencing technologies.	Limitations of current sequencing technologies to address certain applications and aspects of science.	FP / FN i2	4H M-A	x	x	Dynamic organism Soft skills

Fuente: Elsevier, 2023. (TITLE-ABS-KEY (third AND generation AND university) AND TITLE-ABS-KEY (innovation) AND PUBYEAR > 2003 AND PUBYEAR < 2024 AND (LIMIT-TO (EXACTKEYWORD , "Article")) AND (LIMIT-TO (SRCTYPE , "j"))

All of this requires a systemic and interdisciplinary dialogue between the dimensions of human development and the needs for management and transformation within productive sectors and communities (Quadruple Helix Model). This interaction fosters innovation through Transformational Productive Training (FTP).

The following section presents the elements derived from the integration of actors and institutions:

Cuadro: Referentes Teóricos del Modelo Transformacional Productiva (FTP + Learning by Doing).

Theories	Author	Approach	Characteristics	Strategies
Interdisciplinariedad	Nicolescu, B. (2012); Silvera (2017)	. Interdisciplina como herramienta; Resignificación del tejido social	. Integración de las dimensiones del ser; Formación integral del profesional	. Trabajo cooperativo-colaborativo; Análisis contextual
Formación para el hacer	Danermark, B. et al. (2019); Dewey (1995)	. Democratización del saber y el conocimiento; Efectividad, eficiencia, eficacia	. Transferencia a sectores y comunidades focalizadas; Diálogo interinstitucional	. Proyectos de investigación; Consultoría científica; Innovación tecnológica
Learning by Doing	Schank, R. (2011); Dewey (2004)	. Narrativas y prácticas de gestión; Desarrollo cognitivo integrador	. Construcción de saberes e innovación; Co-gestión de conocimientos	. Design Thinking lab; ABP; Investigación formativa

Universidad de tercera generación – U3G (4 Hélices)	United Nations (2009); Klaus Schwab (2016)	. Meta-tecnologías; Interinstitucionalidad; Co-gestión; Sostenibilidad	. Apalancamiento de la investigación; Solución de problemas reales; Propuestas de valor; Transformación productiva	. Extensión universitaria; Consultoría técnica; Transferencia tecnológica
Innovación	Schank, R. (2011); Dewey (1995); Kim & Maloney (2020); Fals Borda (1985; 2010)	. Innovación; Gestión; Revolución del conocimiento; Deconstrucción	. Relacionamiento empresarial; Innovación desde el aprendizaje; Transformación del pensamiento y la acción	. Ideación; Prototipado; Creación artística; Desarrollo tecnológico; Innovación social y productiva

Fuente: elaboración propia, to 2023

Based on these postulates, an innovation process is established to support the management of a reflective and critical pedagogical structure, characterized by its orientation towards technological development, innovation, and productivity (Silvera, 2022). This is made possible through the integration of the educational community into new systemic dialogue frameworks with business and productive sectors, both during and after their training process, positioning them as integral actors within society and the regional and national economy. This process involves the integration of multiple sources of knowledge access and management (Dewey, 1995; Silvera, A. 2017), generating relevant and contextualized training, innovation, and entrepreneurship practices (Roberts, 2012), thereby fostering creativity and disruption.

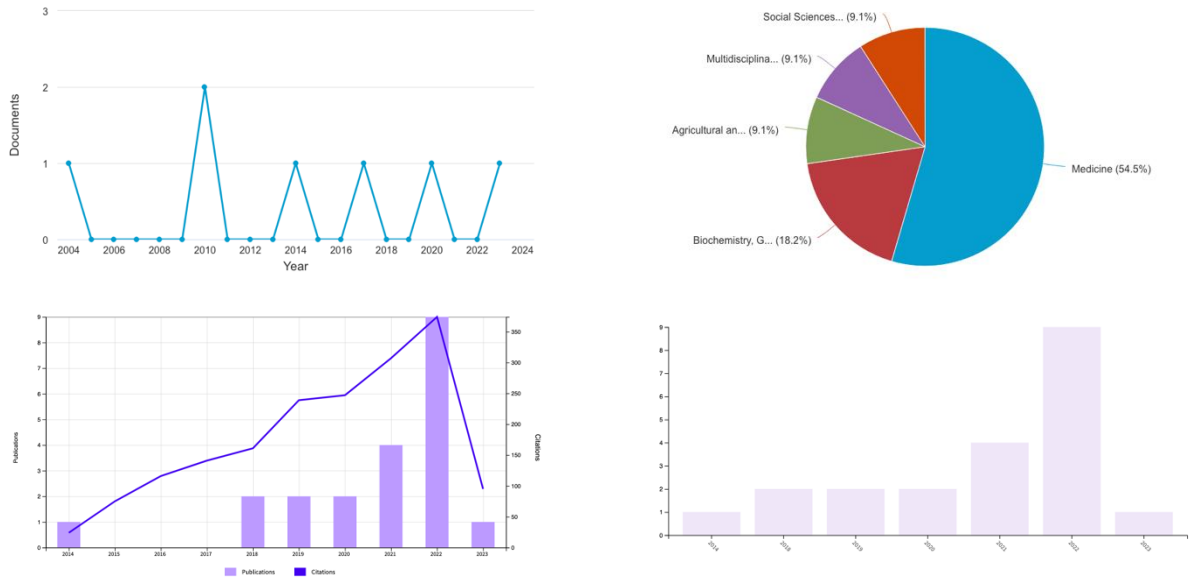

Figure: Summary of research the categories and innovation contexts (Elsevier/WOS).

Fuente: Elsevier, 2023. (TITLE-ABS-KEY (third AND generation AND university) AND TITLE-ABS-KEY (innovation)) AND PUBYEAR > 2003 AND PUBYEAR < 2024 AND (LIMIT-TO (EXACTKEYWORD , "Article")) AND (LIMIT-TO (SRCTYPE , "j"))

5. CONCLUSIONS

This study has provided an in-depth analysis of the implementation and effectiveness of the Quadruple Helix Model and the Agent-Based Model in Higher Education Institutions (HEIs), emphasizing the significant influence these models exert on fostering innovation and knowledge transfer. Through strategic collaboration between government, academia, industry, and civil society, it has been demonstrated that creating a robust and dynamic innovation ecosystem is possible, where universities play a central role as facilitators and catalysts.

The findings of this study indicate that the effective integration of these models not only fosters a favorable environment for innovation but also optimizes knowledge transfer processes. Universities, acting as key agents within this framework, have the capacity to connect various stakeholders and leverage their unique resources and capabilities to address complex challenges and

generate innovative solutions.

This review encompassed fundamental aspects for the development and consolidation of Third-Generation Universities (U3G), utilizing the Quadruple Helix and Agent-Based Models to foster innovation and knowledge transfer. The results obtained from the Web of Science review highlight the significant evolution of innovation and knowledge management strategies, as well as the growing importance of multidisciplinary educational innovation.

- Dynamic Platforms for Knowledge Co-Creation: Universities are evolving into dynamic platforms for co-creation and knowledge exchange, where interaction between academia, industry, government, and civil society is fundamental. The implementation of Quadruple Helix and Agent-Based Models fosters an innovation ecosystem that not only adapts institutions to current societal and technological demands but also enables them to lead in the creation of socially relevant and sustainable solutions.
- Global Statistics and Trends: Statistical and descriptive analysis of the Quadruple Helix (4H) and Agent-Based Models reveals an increase in adoption and positive outcomes of these models worldwide. This growth trend indicates a shift toward a more integrated and collaborative approach to innovation management in Higher Education Institutions (HEIs), highlighting the necessity for strategies that address both knowledge conservation and transformation.
- Global Trends in Innovation and Knowledge Management: At a global level, there is an increasing focus on sustainability and social responsibility in innovation management. The adaptation of HEIs to these trends is crucial not only for their relevance and long-term sustainability but also for their ability to contribute to global socio-economic development.
- Global Trends in Multidisciplinary Educational Innovation: Educational innovation is undergoing a transformation towards more inclusive and collaborative approaches, where multidisciplinarity and interdisciplinarity play a crucial role. These trends emphasize the importance of adapting curricula and pedagogical methods to foster critical thinking, creativity, and problem-solving skills among students.
- Research in U3G Contexts: A literature review on Third-Generation Universities (U3G) highlights that the effectiveness of innovation strategies largely depends on the universities' ability to integrate and apply Quadruple Helix and Agent-Based Models in a way that addresses the specific challenges of their respective regional and institutional contexts.
- Theoretical Frameworks for the Transformational Productive Model (FTP + Learning by Doing): The theoretical models supporting Transformational Productive Learning provide a robust framework for education in U3G. These models align labor market needs with academic training, emphasizing "learning by doing" as a practical and highly relevant pedagogical approach.

Through a detailed analysis, it has been demonstrated how strategic collaboration among government, academia, industry, and civil society can establish a robust and dynamic innovation ecosystem, where the university plays a central role as a connector and facilitator. In this regard, the university's role as a key actor in the innovation ecosystem is reaffirmed, highlighting its ability to bring together diverse stakeholders to co-create innovative solutions that address complex social and business challenges. The effective implementation of the Quadruple Helix and Agent-Based Models has been identified as a key strategy to enhance the innovation capacity of Higher Education Institutions (HEIs), aligning with the transformational development objectives proposed in the associated doctoral thesis.

Recommendations for Future Research

- Comparative Studies: Conducting comparative studies would be beneficial to examine the effectiveness of the Quadruple Helix Model across different cultural and economic contexts, identifying critical factors that influence its success or failure.
- Technology and Digitalization: Future research should explore the impact of technology and digitalization in facilitating intersectoral collaboration, particularly in how digital platforms can enhance communication and integration among the four helices.
- Policy Evaluation: Investigating the development and implementation of policies that promote effective collaboration between different sectors, assessing their impact on innovation and knowledge transfer within Higher Education Institutions (HEIs).
- Long-Term Impact Assessment: It is essential to conduct longitudinal studies to evaluate the long-term impact of these models on the innovation capacity of HEIs. Future research should explore how variations in the implementation of these models affect outcomes over time and across

different institutional and geographical contexts.

- Policy Development: It is recommended to develop studies focusing on policy creation and evaluation that promote and facilitate effective intersectoral collaboration. These policies should be designed to eliminate barriers to collaboration and provide incentives that encourage active participation from all relevant stakeholders.
- Technology and Digitalization: Further research should delve deeper into how emerging technologies and digitalization can be leveraged to facilitate and enhance interaction among the different actors in the Quadruple Helix Model. Specifically, how digital tools can assist in managing collaboration and measuring the impact of innovation initiatives.

Implementing these research directions will not only strengthen existing innovation models but also propose new pathways for their evolution, ensuring that universities do not merely adapt to changes in the global environment but also lead the way in innovation and sustainable development.

The adoption of these practices and models has the potential to transform the landscape of higher education, positioning HEIs not just as learning centers but as engines of social and economic change.

Conclusion

This article underscores the importance of the Quadruple Helix and Agent-Based Models in enhancing the higher education landscape through systematic innovation and knowledge transfer. By adopting an integrated and collaborative approach, HEIs can significantly improve their impact on social and economic development, laying the groundwork for future advancements in the fields of education and innovation.

REFERENCIAS

Ackoff, R. L. (2010). Memories. Triarchy Press Limited.

Akhondzadeh, S., Ebadifar, A., Eftekhari, M. B., & Falahat, K. (2017). Medical science and research in iran. Archives of Iranian Medicine, 20(11), 665-672. Retrieved from www.scopus.com

Aldrich, C. (2005). Aprender haciendo: una guía completa de simulaciones, juegos de computadora y pedagogía en e-learning y otras experiencias educativas . John Wiley e hijos.

Almeida, R., Cruz, A., & Perestrelo, M. (2020). Knowledge transfer in the cultural and creative activities: Comparative notes from regions of the Atlantic area. Finisterra-Revista Portuguesa De Geografia, 55(113), 63-88.

Arboniés, Á. L., & Ortíz, Á. L. A. (2008). La disciplina de la innovación: rutinas creativas. Ediciones Díaz de Santos.

Aydin, C. (2021). Extimate technology: Self-formation in a technological world. Extimate technology: Self-formation in a technological world (pp. 1-321) doi:10.4324/9781003139409

Bain, K. (2005). Lo que hacen los mejores profesores univ. Universitat de València.

Balkun, M. M., & Deyrup, M. M. (2020). Transformative digital humanities: Challenges and opportunities. Transformative digital humanities: Challenges and opportunities (pp. 1-182) doi:10.4324/9780429399923

Borda, O. F. (2010). Antología Orlando Fals Borda. Universidad Nacional de Colombia.

Bradbury, J. (2019). Narrative psychology and vygotsky in dialogue: Changing subjects. Narrative psychology and vygotsky in dialogue: Changing subjects (pp. 1-198) doi:10.4324/9781315147826

Carayannis, E. G., & Campbell, D. F. (2009). Mode 3 and quadruple helix: Toward a 21st century fractal innovation ecosystem. International Journal of Technology Management, 46(3-4), 201-234. doi: 10.1504/IJTM.2009.023374

Carayannis, E. G., & Campbell, D. F. (2012). Triple helix, quadruple helix and quintuple helix and how do knowledge, innovation and the environment relate to each other? A proposed framework for a trans-disciplinary analysis of sustainable development and social ecology. International Journal of Social Ecology and Sustainable Development, 3(1), 41-69. doi: 10.4018/jsesd.2012010104

Cebrián, M. (2003). Enseñanza virtual para la innovación universitaria (Vol. 3). Narcea Ediciones.

Chilakamarry, C. R., Sakinah, A. M. M., Zularisam, A. W., Pandey, A., & Vo, D. V. N. (2021). Technological perspectives for utilisation of waste glycerol for the production of biofuels: A review. ENVIRONMENTAL TECHNOLOGY & INNOVATION, 24. https://doi.org/10.1016/j.eti.2021.101902

Cifuentes Gil, R. (2016). Didácticas en la universidad: Perspectivas desde la docencia. Volumen 10 de Colección Docencia universitaria. Docencia Universitaria Series. Universidad de la Salle

Cohen, E. (2021). The university and its boundaries: Thriving or surviving in the 21st century. The university and its boundaries: Thriving or surviving in the 21st century (pp. 1-104) doi:10.4324/9781003102953

Cortese, S., Solmi, M., Michelini, G., Bellato, A., Blanner, C., Canozzi, A., Eudave, L., Farhat, L. C., Hojlund, M., Kohler-Forsberg, O., Leffa, D. T., Rohde, C., de Pablo, G. S., Vita, G., Wesselhoeft, R., Martin, J., Baumeister, S., Bozhilova, N. S., Carlisi, C. O., … Correll, C. U. (2023). Candidate diagnostic biomarkers for neurodevelopmental disorders in children and adolescents: a systematic review. WORLD PSYCHIATRY, 22(1), 129–149. https://doi.org/10.1002/wps.21037

da Silva, V., Kovaleski, J., & Pagani, R. (2022). Fundamental elements in Technology Transfer: An in-depth analysis. Technology Analysis & Strategic Management, 34(2), 223-244.

Danermark, B., Ekström, M., & Karlsson, J. C. (2019). Explaining society: Critical realism in the social sciences. Explaining society: Critical realism in the social sciences (pp. 1-228) doi:10.4324/9781351017831

Danermark, B., Ekström, M., & Karlsson, J. C. (2019). Explaining society: Critical realism in the social sciences. Explaining society: Critical realism in the social sciences (pp. 1-228) doi:10.4324/9781351017831

Davis, B., Francis, K., & Friesen, S. (2019). STEM education by design: Opening horizons of possibility. STEM education by design: Opening horizons of possibility (pp. 1-136) doi:10.4324/9780429025143

Dewey, J. (1984). Experience and Education. The Kappa Delta Pi Lecture Series. Editor. Peter Smith Pub.

Dewey, J. (1995). Democracia y educación: una introducción a la filosofía de la educación. Ediciones Morata.

Dewey, J. (1995). Democracia y educación: una introducción a la filosofía de la educación. Ediciones Morata.

Dias, A., & Salmelin, B. (2018). Living labs and open innovation in European context. In Springer Proceedings in Business and Economics (pp. 7-18). Retrieved from www.scopus.com. doi:10.1007/978-3-319-67101-7_2

Didriksson, A. (2005). La Universidad de la Innovacion/The University of Innovation: Una estrategia de transformacion para la construccion de la universidades del futuro/A Strategy of Transformation for the Construction of Future Un. Plaza y Valdes.

Domash, L. (2020). Imagination, creativity and spirituality in psychotherapy: Welcome to wonderland. Imagination, creativity and spirituality in psychotherapy: Welcome to wonderland (pp. 1-187) doi:10.4324/9780429299148

Dreamson, N. (2019). Critical understandings of digital technology in education: Meta-connective pedagogy. Critical understandings of digital technology in education: Meta-connective pedagogy (pp. 1-200) doi:10.4324/9780429277528

Drucker, P. F. (1999). Knowledge-worker productivity: The biggest challenge. California management review, 41(2), 79-94.

Drucker, P. F. (1999). Los desafíos de la gerencia para el siglo XXI. Editorial Norma.

Drucker, P. F., & Drucker, P. F. (2004). Managing the non-profit organization: Practices and principles. Taylor & Francis.

Fals-Borda, O. (1985). El problema de cómo investigar la realidad para transformarla: por la praxis. Tercer mundo.

Fayol, H. (1916). General principles of management. Classics of organization theory, 2(15), 57-69.

Fayol, H., & Taylor, F. (1987). Administración industrial y general (No. 658 F3.). Orbis

Fiaz, S., Ahmar, S., Saeed, S., Riaz, A., Mora-Poblete, F., & Jung, K. H. (2021). Evolution and Application of Genome Editing Techniques for Achieving Food and Nutritional Security. INTERNATIONAL JOURNAL OF MOLECULAR SCIENCES, 22(11). https://doi.org/10.3390/ijms22115585

Frodeman, R. (2019). Transhumanism, nature, and the ends of science: A critique of technoscience. Transhumanism, nature, and the ends of science: A critique of technoscience (pp. 1-160) doi:10.4324/9780429199363

Gadotti, M. (2002). Historia de las ideas pedagógicas. Siglo XXI.

Gallagher, S., & Zahavi, D. (2020). The phenomenological mind. The phenomenological mind (pp. 1-294) doi:10.4324/9780429319792

Gharajedaghi, J., & Ackoff, R. L. (1984). Mechanisms, organisms and social systems. Strategic Management Journal, 5(3), 289-300.

González Martínez, M. N., Vásquez De la Hoz, F., Campo Ternera, L., Miranda Medina, C. F., Silvera Sarmiento, A., Agudelo Gómez, C. J., & Parra Vega, J. A. (2014). Estilos de enseñanza y docencia Universitaria. Ediciones Universidad Simón Bolívar.

Guarin-Manrique, L., & Martinez-Ardila, H. (2022). Intermediation in Agro-Industrial Innovation Systems. Cuadernos De Desarrollo Rural, 19(88).

Herrscher, E. G., & Ackoff, R. L. (2003). Pensamiento sistémico: caminar el cambio o cambiar el camino. Ediciones Granica SA.

Jacob-Lopes, E., Zepka, L. Q., & Deprá, M. C. (2021). Interdisciplinary applications of the life cycle assessment tool. Interdisciplinary applications of the life cycle assessment tool (pp. 1-195)

Jameson, J. (2019). International perspectives on leadership in higher education: Critical thinking for global challenges. International perspectives on leadership in higher education: Critical thinking for global challenges (pp. 1-195) doi:10.4324/9781315122410

Kang, Y. Y., & Jiang, J. (2020). Revisiting the innovation systems of cross-border cities: the role of higher education institution and cross-boundary cooperation in Hong Kong and Shenzhen. JOURNAL OF HIGHER EDUCATION POLICY AND MANAGEMENT, 42(2), 213–229. https://doi.org/10.1080/1360080X.2019.1701849

Kang, Y., & Jiang, J. (2020). Revisiting the innovation systems of cross-border cities: the role of higher education institution and cross-boundary cooperation in Hong Kong and Shenzhen. Journal of Higher Education Policy and Management, 42(2), 213-229.

Kang, Y., & Jiang, J. (2020). Revisiting the innovation systems of cross-border cities: The role of higher education institution and cross-boundary cooperation in Hong Kong and Shenzhen. Journal of Higher Education Policy and Management, 42(2), 213-229. doi:10.1080/1360080X.2019.1701849

Kidd, K. B. (2020). Theory for beginners: Children's literature as critical thought. Theory for beginners: Children's literature as critical thought (pp. 1-203)

Kim, Joshua & Maloney, Edward (2020). Learning Innovation and the Future of Higher Education. Tech.edu: A Hopkins Series on Education and Technology. JHU Press

Kim, Joshua & Maloney, Edward (2020). Learning Innovation and the Future of Higher Education. Tech.edu: A Hopkins Series on Education and Technology. JHU Press

Kriz, A., Bankins, S., & Molloy, C. (2018). Readying a region: Temporally exploring the development of an Australian regional quadruple helix. R&D Management, 48(1), 25-43. https://doi.org/10.1111/radm.12294

Larkley, Jasmine E. & Maynhard, Viola B. (2008). Innovation in Education. Nova Publishers,

Lemarchand, G. (2018). Relevamiento de la Investigación e Innovación en la República del Paraguay. UNESCO Publishing.

Liu, Z., Le, K., Zhou, X., Alexander, J. L., Lin, S., Bewshea, C., . . . Bishop, J. (2023). Neutralising antibody potency against SARS-CoV-2 wild-type and omicron BA.1 and BA.4/5 variants in patients with inflammatory bowel disease treated with infliximab and vedolizumab after three doses of COVID-19 vaccine (CLARITY IBD): An analysis of a prospective multicentre cohort study. The Lancet Gastroenterology and Hepatology, 8(2), 145-156. doi:10.1016/S2468-1253(22)00389-2

Lugović, S., Dunder, I., & Horvat, M. (2017). Primary and secondary experience in developing adaptive information systems supporting knowledge transfer. Paper presented at the 2017 40th International Convention on Information and Communication Technology, Electronics and Microelectronics, MIPRO 2017 - Proceedings, 1207-1210. https://doi.org/10.23919/MIPRO.2017.7973607

Lybeck, E. (2021). The university revolution: Outline of a processual theory of modern higher education. The university revolution: Outline of a processual theory of modern higher education (pp. 1-214) doi:10.4324/9781351017558

Ma, L. F., Li, H. Y., Lan, J. P., Hao, X. Q., Liu, H. Y., Wang, X. M., & Huang, Y. (2021). Comprehensive analyses of bioinformatics applications in the fight against COVID-19 pandemic. COMPUTATIONAL BIOLOGY AND CHEMISTRY, 95. https://doi.org/10.1016/j.compbiolchem.2021.107599

Machado, H. V., Lazzarotti, F., & Bencke, F. F. (2018). Innovation models and technological parks: Interaction between parks and innovation agents. Journal of Technology Management and Innovation, 13(2), 104-114. https://doi.org/10.4067/S0718-27242018000200104

McGowan, J. J., Overhage, J. M., Barnes, M., & McDonald, C. J. (2004). Indianapolis I3: The third generation integrated advanced information management systems. Journal of the Medical Library Association, 92(2), 179-187. Retrieved from www.scopus.com

Melendez, J. R., Matyas, B., Hena, S., Lowy, D. A., & El Salous, A. (2022). Perspectives in the production of bioethanol: A review of sustainable methods, technologies, and bioprocesses. RENEWABLE & SUSTAINABLE ENERGY REVIEWS, 160. https://doi.org/10.1016/j.rser.2022.112260

Mendoza, J., Vargas, J., & Winkler, H. (2021). Entrepreneurship ecosystem and university entrepreneurship: A review of literature. Journal of Innovation and Entrepreneurship, 10(1), 1-16. doi: 10.1186/s13731-020-00147-3

Mercer, N. (2019). Language and the joint creation of knowledge: The selected works of neil mercer. Language and the joint creation of knowledge: The selected works of neil mercer (pp. 1-426) doi:10.4324/9780429400759

Meyer, C., Gerlitz, L., & Klein, M. (2022). Creativity as a key constituent for smart specialization strategies (S3), what is in it for peripheral regions? Co-creating sustainable and resilient tourism with cultural and creative industries. Sustainability, 14(6), 3469. https://doi.org/10.3390/su14063469

Meyer, C., Gerlitz, L., & Klein, M. (2022). Creativity as a Key Constituent for Smart Specialization Strategies (S3), What Is in It for Peripheral Regions? Co-creating Sustainable and Resilient Tourism with Cultural and Creative Industries. Sustainability, 14(6).

Mineiro, A. A. C., Arantes, R. C., Vieira, K. C., Castro, C. C., Carvalho, E. G., & Amaral, M. G. (2023). Business practices for strengthening the quadruple and quintuple helix: A study using structural equation modeling. International Journal of Innovation Science, 15(1), 1-18. https://doi.org/10.1108/IJIS-02-2021-0049

Mineiro, A., Arantes, R., & do Amaral, M. (2023). Business practices for strengthening the quadruple and quintuple helix: A study using structural equation modeling. International Journal of Innovation Science, 15(1), 1-18.

Mintzberg, H., & Waters, J. A. (1982). Tracking strategy in an entrepreneurial firm. Academy of management journal, 25(3), 465-499.

Munoz-Barrera, A., Rubio-Rodriguez, L. A., Diaz-de Usera, A., Jaspez, D., Lorenzo-Salazar, J. M., Gonzalez-Montelongo, R., Garcia-Olivares, V., & Flores, C. (2022). From Samples to Germline and Somatic Sequence Variation: A Focus on Next-Generation Sequencing in Melanoma Research. LIFE-BASEL, 12(11). https://doi.org/10.3390/life12111939

Nascimento, S., Lima, M., & Gondim, R. (2022). Level of collaboration and knowledge transfer among actors of the innovation ecosystem: The proposition of an analytical model. International Journal of Innovation, 10(3), 434-460.

Ndhlovu, F., & Makalela, L. (2021). Decolonising multilingualism in africa: Recentering silenced voices from the global south. Decolonising multilingualism in africa: Recentering silenced voices from the global south (pp. 1-208)

Ndonzuau, F. N., Menga, U., Ndomb, L. B., & Kamdjoug, J. R. (2021). Promoting technology transfer through university-industry collaboration: A systematic literature review. Journal of Technology Transfer, 46(1), 1-35. doi: 10.1007/s10961-019-09743-2

Nguyen, H., Marques, P., & Benneworth, P. (2022). Living labs: Challenging and changing the smart city power relations? Technological Forecasting and Social Change, 183.

Nicolescu, B. (2012). The need for transdisciplinarity in higher education in a globalized world. Transdisciplinary Journal of Engineering & Science, 3.

Nicolescu, B. (2014). From modernity to cosmodernity: Science, culture, and spirituality. SUNY Press.

Nordic-American cooperation (2018). Higher education, Research and Innovation: A feasibility study on how to strengthen . Oxford Research A/S. Nordic Council of Ministers

O'Rourke, M., & Fam, D. (2020). Interdisciplinary and transdisciplinary failures: Lessons learned from cautionary tales. Interdisciplinary and transdisciplinary failures: Lessons learned from cautionary tales (pp. 1-277) doi:10.4324/9780367207045

Ouyang, Z. X., Li, H. W., Zhai, Z. J., Xu, J. K., Dass, C. R., Qin, A., & Dai, K. R. (2018). Zoledronic Acid: Pleiotropic Anti-tumor Mechanism and Therapeutic Outlook for Osteosarcoma. CURRENT DRUG TARGETS, 19(5), 409–421. https://doi.org/10.2174/1573399811666150615145409

Padial, M., Pinzon, S., & Espinosa, J. (2019). Effective implementation of the Quadruple Helix-Based Innovation Model for active ageing. Gaceta Sanitaria, 33(5), 491-494.

Padial, M., Pinzón, S., Navarro, B., San Juan, P., Ruiz, J., & Espinosa, J. M. (2019). Effective implementation of the quadruple helix-based innovation model for active ageing. [Implantación efectiva de la Cuádruple Hélice basada en el Modelo de Innovación en envejecimiento activo] Gaceta Sanitaria, 33(5), 491-494. https://doi.org/10.1016/j.gaceta.2018.08.003

Padial, M., Pinzon, S., Navarro, B., San Juan, P., Ruiz, J., & Espinosa, J. M. (2019). Effective implementation of the Quadruple Helix-Based Innovation Model for active ageing. GACETA SANITARIA, 33(5), 491–494. https://doi.org/10.1016/j.gaceta.2018.08.003

Pal, P., Chew, K. W., Yen, H. W., Lim, J. W., Lam, M. K., & Show, P. L. (2019). Cultivation of Oily Microalgae

for the Production of Third-Generation Biofuels. SUSTAINABILITY, 11(19). https://doi.org/10.3390/su11195424

Pélissier, C. (2019). Learner support in online learning environments. Learner support in online learning environments (pp. 1-224) doi:10.1002/9781119618096

Penprase, B. E. (2020). STEM education for the 21st century. STEM education for the 21st century (pp. 1-133) doi:10.1007/978-3-030-41633-1

Porsdam, H. (2019). The transforming power of cultural rights: A promising law and humanities approach. The transforming power of cultural rights: A promising law and humanities approach (pp. 1-260) doi:10.1017/9781108580182

Ramli, A. A., Ismail, A. K., Hashim, M. F., & Muhammad, R. (2022). A MINI-REVIEW OF RECENT STUDIES ON LEAD AND LEAD-FREE PEROVSKITE MATERIALS FOR SOLAR CELLS APPLICATION AND THEIR ISSUES. JURNAL TEKNOLOGI-SCIENCES & ENGINEERING, 84(6), 135–146. https://doi.org/10.11113/jurnalteknologi.v84.18208

Rawluk, A., Beilin, R., Bender, H., & Ford, R. (2019). Practices in social ecological research: Interdisciplinary collaboration in 'adaptive doing'. Practices in social ecological research: Interdisciplinary collaboration in 'adaptive doing' (pp. 1-125) doi:10.1007/978-3-030-31189-6

Roberts, JW (2012). Más allá de aprender haciendo: corrientes teóricas en la educación experiencial . Routledge.

Ruan, H., Wang, P. C., & Han, L. (2023). Characterization of circular RNAs with advanced sequencing technologies in human complex diseases. WILEY INTERDISCIPLINARY REVIEWS-RNA, 14(1). https://doi.org/10.1002/wrna.1759

Sa, E., Casais, B., & Silva, J. (2019). Local development through rural entrepreneurship, from the Triple Helix perspective: The case of a peripheral region in northern Portugal. International Journal of Entrepreneurial Behavior & Research, 25(4), 698-716.

Sallán, J. G., & Rodríguez-Gómez, D. (2011). Cambio y mejora en las organizaciones educativas.

Salmelin, B. (2016). Living labs and open innovation in European context. In A. T. M. Newell, & M. Devismes (Eds.), Open innovation: A multifaceted perspective (pp. 273-285). Retrieved from www.scopus.com

Salmelin, B. (2018). Connecting dots: From clusters to ecosystems. In H. Chesbrough, M. S. Bogers, & A. T. C. J. van den Hende (Eds.), Exploring the culture of open innovation: Towards an altruistic model of economy (pp. 163-179). doi:10.1108/978-1-78743-789-020181006 Retrieved from www.scopus.com

Santomé, J. T. (1994). Globalización e interdisciplinariedad: el currículum integrado. Ediciones morata.

Santomé, J. T. (1994). Globalización e interdisciplinariedad: el currículum integrado. Ediciones morata.

Schadt, E. E., Turner, S., & Kasarskis, A. (2010). A window into third-generation sequencing. Human Molecular Genetics, 19(R2), R227-R240. doi:10.1093/hmg/ddq416

Schank, Roger C. (2011). Teaching Minds: How Cognitive Science Can Save Our Schools

Schank, Roger C. (2011). Teaching Minds: How Cognitive Science Can Save Our Schools

Schwab, Klaus (2016). La cuarta revolución industrial. Penguin Random House Grupo Editorial España

Shao, J. Y., Li, D. M., Shi, J. J., Ma, C., Wang, Y. S., Liu, X. M., Jiang, X. Y., Hao, M. M., Zhang, L. Z., Liu, C., Jiang, Y. T., Wang, Z. H., Zhong, Y. W., Liu, S. F., Mai, Y. H., Liu, Y. S., Zhao, Y. X., Ning, Z. J., Wang, L. Z., … Meng, Q. B. (2023). Recent progress in perovskite solar cells: material science. SCIENCE CHINA-CHEMISTRY, 66(1), 10–64. https://doi.org/10.1007/s11426-022-1445-2

Sharma, R., Sharma, A., Agarwal, S., & Dhaka, M. S. (2022). Stability and efficiency issues, solutions and advancements in perovskite solar cells: A review. SOLAR ENERGY, 244, 516–535. https://doi.org/10.1016/j.solener.2022.08.001

Shi, L. L., Chen, K. Q., Zhai, A. P., Li, G. H., Fan, M. M., Hao, Y. Y., Zhu, F. R., Zhang, H., & Cui, Y. X. (2021). Status and Outlook of Metal-Inorganic Semiconductor-Metal Photodetectors. LASER & PHOTONICS REVIEWS, 15(1). https://doi.org/10.1002/lpor.202000401

Silvera, A. (2017). Ecosistemas y ecoformación: Perspectivas para una sociedad sostenible y sustentable. Revista Lasallista de Investigación, 14(1), 11-12.

Simon, H. A. (1965). The architecture of complexity. General systems, 10(1965), 63-76.

Sjafrina, N., Marimin, Udin, F., & Anggraeni, E. (2020). A mapping of current downstream shallot supply chain based on agent-based modeling and quadruple innovation helix: A case study at Cirebon district, Indonesia. Paper presented at the IOP Conference Series: Earth and Environmental Science, 472(1). doi:10.1088/1755-1315/472/1/012056 Retrieved from www.scopus.com

Stelmach, A., Guzek, K., Roznowska, A., Najbar, I., & Sadakierska-Chudy, A. (2023). Antipsychotic drug-

aripiprazole against schizophrenia, its therapeutic and metabolic effects associated with gene polymorphisms. PHARMACOLOGICAL REPORTS, 75(1), 19–31. https://doi.org/10.1007/s43440-022-00440-6

Stylianou, A. (2019). Social and ethnic inequalities in the cypriot education system: A critical realist view on empowerment. Social and ethnic inequalities in the cypriot education system: A critical realist view on empowerment (pp. 1-136) doi:10.4324/9780203730195

Swann, G. M. P. (2019). Economics as anatomy: Radical innovation in empirical economics. Economics as anatomy: Radical innovation in empirical economics (pp. 1-250) doi:10.4337/9781786434869

Tan, C. S., Kumarakulasinghe, N. B., Huang, Y. Q., Ang, Y. L. E., Choo, J. R. E., Goh, B. C., & Soo, R. A. (2018). Third generation EGFR TKIs: current data and future directions. MOLECULAR CANCER, 17. https://doi.org/10.1186/s12943-018-0778-0

Tapa, A. R., Xiang, W. C., & Zhao, X. J. (2021). Metal Chalcogenides (M x E y E=S, Se, and Te) as Counter Electrodes for Dye-Sensitized Solar Cells: An Overview and Guidelines. ADVANCED ENERGY AND SUSTAINABILITY RESEARCH, 2(10). https://doi.org/10.1002/aesr.202100056

Taylor, F. W. (1919). The principles of scientific management. Harper & brothers.

Teaching Minds: How Cognitive Science Can Save Our Schools. Teachers College Press

Tikly, L. (2019). Education for sustainable development in the postcolonial world: Towards a transformative agenda for africa. Education for sustainable development in the postcolonial world: Towards a transformative agenda for africa (pp. 1-264) doi:10.4324/9781315211343

Torres Santomé, J. (2002). La cultura escolar: otra construcción del conocimiento. Cuadernos de Pedagogía.

Toshmali, G., Alimohammadzadeh, K., Maher, A., Hosseini, S. M., & Bahadori, M. (2020). Conceptualization of entrepreneurial university and pattern design of third generation university. Iran Occupational Health, 17(1) Retrieved from www.scopus.com

Trisetyarso, A., & Hastiadi, F. F. (2022). Computational model of quadruple helix innovations ecosystem. Journal of the Knowledge Economy. doi:10.1007/s13132-021-00865-z

Trisetyarso, A., & Hastiadi, F. F. (n.d.). Computational Model of Quadruple Helix Innovations Ecosystem. JOURNAL OF THE KNOWLEDGE ECONOMY. https://doi.org/10.1007/s13132-021-00865-z

Unceta, A., Barandiaran, X., & Lakidain, A. (2021). Digitalisation of creative industries fostered by collaborative governance: Public innovation labs in Gipuzkoa. Sustainability (Switzerland), 13(5), 1-20. doi:10.3390/su13052568

Unceta, A., Barandiaran, X., & Lakidain, A. (2021). Digitalisation of Creative Industries Fostered by Collaborative Governance: Public Innovation Labs in Gipuzkoa. Sustainability, 13(5).

Vikulina, A., Voronin, D., Fakhrullin, R., Vinokurov, V., & Volodkin, D. (2020). Naturally derived nano- and micro-drug delivery vehicles: halloysite, vaterite and nanocellulose. NEW JOURNAL OF CHEMISTRY, 44(15), 5638–5655. https://doi.org/10.1039/c9nj06470b

Waldeck, R. (2019). Methods and interdisciplinarity. Methods and interdisciplinarity (pp. 1-174) doi:10.1002/9781119681519

Wang, L. Q., Yan, X., Si, W. P., Liu, D. L., Hou, X. G., Li, D. J., Hou, F., Dou, S. X., & Liang, J. (2022). Photoelectrochemical nitrogen reduction: A step toward achieving sustainable ammonia synthesis. CHINESE JOURNAL OF CATALYSIS, 43(7), 1761–1773. https://doi.org/10.1016/S1872-2067(21)64001-9

Warner, J. (2009). Creatividad e Innovación: Perfil de competencias (Vol. 2). Editorial Universitaria Ramón Areces.

Wei, Z. (2019). Constructivism and teachers in chinese culture: Enriching confucianism with constructivism. Constructivism and teachers in chinese culture: Enriching confucianism with constructivism (pp. 1-193) doi:10.1007/9789811326912

Yi, A. L., Wang, C. L., Zhou, L. P., Zhu, Y. F., Zhang, S. B., You, T. G., Zhang, J. X., & Ou, X. (2022). Silicon carbide for integrated photonics. APPLIED PHYSICS REVIEWS, 9(3). https://doi.org/10.1063/5.0079649

Zelko, H., Zammar, G. R., Bonilauri Ferreira, A. P., Phadtare, A., Shah, J., & Pietrobon, R. (2010). Selection mechanisms underlying high impact biomedical research - a qualitative analysis and causal model. PLoS ONE, 5(5) doi:10.1371/journal.pone.0010535

Zheng, Y. F., Gu, X. N., & Witte, F. (2014). Biodegradable metals. MATERIALS SCIENCE & ENGINEERING R-REPORTS, 77, 1–34. https://doi.org/10.1016/j.mser.2014.01.001

Zhou, X. H., & Zhang, X. G. (2019). Thoughts on the Development of Bridge Technology in China. ENGINEERING, 5(6), 1120–1130. https://doi.org/10.1016/j.eng.2019.10.001

Zygmunt, M., & Kampe, C. (2014). Public funding of research in Germany—perspective of gynecologists. [Drittmittelfinanzierung durch öffentliche Geldgeber − Perspektive des Frauenarztes] Gynakologe, 47(12), 913-919. doi:10.1007/s00129-014-3369-1