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A Decade of Transformation in Higher Education and Science in Kazakhstan: A Literature and Scientometric Review of National Projects and Research Trends

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Abstract

Higher education and science (HES) is one of the key drivers of a country's economic growth. In this study, we examine national projects and research capacity in HES in Kazakhstan from 2014 to 2024. We conducted a content review and scientometric analysis with network and temporal visualizations. Our data sources included policy documents, statistical reports, and the Scopus database. Our findings suggest that, while Kazakhstan aligns with global trends in the field (e.g., digitalization, scientometrics monitoring, and internationalization), these are achieved through a state-led, policy-driven approach shaped by its post-Soviet context. Additionally, we note a dual structure in Kazakhstan's HES sector, characterized by a strong top-down direction and increasing institutional engagement. In terms of the thematic trends from the temporal analysis, the country experienced a three-staged evolution: foundational reforms and system modernization (2014–2017), capacity building and evaluation (2018–2021), and, most recently, strategic expansion, inclusivity, and globalization (2022–2024). Throughout the analyzed period, low R&D intensity, disciplinary imbalances, and structural barriers still undermine desired development efforts in HES. The analyzed case of Kazakhstan can serve as "lessons learned" for policymakers and researchers working in the science evaluation and scholarly communication area in similar emerging or transition countries.

Keywords: content analysis; higher education; Kazakhstan; research trends; science policy; scientometric analysis

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1. Introduction

Higher education and science (HES) as a driver for economic growth have been studied by many authors. Among them, recent research has increasingly focused on exploring the role of HES in economies under transition. Such countries are characterized by their internal economic changes, adoption of market-oriented principles, and emerging investments in knowledge-intensive areas that contribute to the country's economic development (Kim et al., 2025; Lovakov & Yudkevich, 2021; Matveeva et al., 2023). However, the realization of such reforms requires governments to implement policy changes that support innovation-driven growth, such as national projects and state programs.

Kazakhstan, a transition economy following the collapse of the Soviet Union, experienced a period of stagnation in higher education and a decline in research. Major national

initiatives during the 1990s failed to offer the expected solutions to the then-existing problems, such as an outflow of researchers from science and a decline in overall publication output and quality (Amirbekova et al., 2022; Kudaibergenova et al., 2022; Kuzhabekova & Ruby, 2018).

However, since the 2000s, the government has begun to take significant steps to support the advancement of the HES sector, recognizing its long-term role (NAS Kz, 2023). These reforms mainly targeted such areas as the national university system, young talent capacity, doctoral programs capacity, university ranking, and digitalization of the entire HES sector (Kangalakova et al., 2023; Ungureanu et al., 2024).

Even though previous studies have examined national projects and trends in the HES sector in developing countries, few have specifically focused on Kazakhstan. No prior research has explicitly compared international academic discourse and Kazakhstan's scientific narratives in HES.

The current study aims to examine national projects and research in the HES sector in Kazakhstan and assess their impact on the sector from 2014 to 2024. Our materials included the academic literature from Scopus as well as policy documents and statistical reports on Kazakhstan. We conducted two types of analysis: a content analysis and a scientometric analysis. The content analysis involved analyzing 75 articles, policy documents, and statistical reports to assess the contribution of national projects and research to the country's science capacity building. The scientometric analysis included an examination of the cluster networks of Kazakhstani literature on HES and the temporal evolution of key themes. We also compared the results of the cluster networks in Kazakhstan with those on the global scale. Lastly, based on the temporal evolution analysis, we proposed a three-phased evolution of the HES sector from 2014 to 2024.

We put forward the following research questions (RQs) to achieve our aim:

RQ1: How have the national projects and research in the field contributed to the enhancement of HES in Kazakhstan over the past decade?
RQ2: What are the key trends in the field that improved HES in the country in comparison to the global trends?
RQ3: What are the key themes in the national projects and research that have evolved during 2014–2024?

The contribution of our study to the body of knowledge on research policy and scholarly communication is two-fold. First, the findings offer insights into the impact of major national initiatives and practices in the country that promote research and development (R&D) investments, institutional research funding, and commercialization. Second, this study offers a new perspective on understanding the alignment and divergence in the discourse between the global and Kazakhstani literature on HES sector development. Overall, the case of Kazakhstan can serve as an exemplary model for similar countries undergoing transition. The study findings can serve as "lessons learned" for policymakers and researchers working in the research policy, science evaluation, and scholarly communication areas.

In the next section, we provide an overview of the research background. Section 3 presents the methodology, including materials and methods. In Section 4, we analyze the main results of the content analysis, network visualization analysis, and temporal visualization analysis. Section 5 discusses the main findings of this study. Section 6 summarizes this study, presents the research limitations, and provides recommendations for policymakers and future research directions for researchers working in the higher education and scholarly communication area.

2. Background

2.1. The Post-Soviet Context

During the 1990s, Kazakhstan and other countries of the former Soviet Union shared characteristics that were no longer relevant after the collapse of the Union. The changes that followed the collapse were associated with significant shifts in policy and government influence on HES. These changes impacted the government's targets and expectations set at the country level, specifically related to openness to the global economy and competitiveness. Therefore, the "post-Soviet" countries went through the experience of finding their path to development in HES. The past centralized experience in managing HES institutions has been replaced by more autonomous mechanisms, with new targets such as publication activity in Scopus and Web of Science, international rankings, and international faculty and student mobility (Chankseliani et al., 2021; Smolentseva & Platonova, 2023).

Baltic countries, such as Estonia, Latvia, and Lithuania, adopted a different policy, which shaped a new system of HES (Lovakov et al., 2022). Similarly to Kazakhstan, other non-EU post-Soviet countries, such as Azerbaijan, Armenia, Georgia, Moldova, and Ukraine, joined the Bologna process and aligned their HES system accordingly (Amirbekova et al., 2025). On the contrary, neighboring countries like Kyrgyzstan and Uzbekistan followed a different path, maintaining a system where researchers were trained through the Candidate of Science and Doctor of Science degrees.

Another important element of transformation in HES was its internationalization, as reflected in publication activity and mobility. Kazakhstan had a significant requirement to publish in peer-reviewed journals indexed in Scopus and Web of Science. In contrast, other post-Soviet countries, such as Tajikistan and Turkmenistan, did not have such requirements (Hladchenko & Moed, 2021). Access to international mobility through international grant projects and other funding sources has been a significant dimension of the post-Soviet changes in HES, offering a new opportunity to establish collaboration with international peers (Kuzhabekova et al., 2022).

2.2. Major Developments in HES

During the 2000s, the government began to take significant steps to support the advancement of the HES sector, recognizing its long-term role (NAS Kz, 2023). These reforms mainly targeted such areas as the national university system, young talent capacity, doctoral programs capacity, university ranking, and digitalization of the entire HES sector (Kangalakova et al., 2023; Ungureanu et al., 2024).

For example, during the 2000s, the reforms aimed at aligning with the Bologna declaration were crucial in reshaping and enhancing HES in the country (Lodhi & Ilyassova-Schoenfeld, 2023). According to (Merrill, 2020), joining the Bologna Process brought to Kazakhstan significant positive changes in its higher education accreditation and degree structure. The establishment of a three-level educational system (bachelor, master, and PhD) was legally supported and implemented to meet international educational standards (Kataeva et al., 2023; Movkebayeva et al., 2020; Yelibay et al., 2022). Meanwhile, greater autonomy was granted to private higher education institutions, and initiatives promoting student and faculty mobility programs were encouraged. In science, Zhanbayev et al. (2020) noted the importance of using the foresight methodology to develop a qualitative evaluation algorithm for research outputs, improving the performance of the scientific sector in Kazakhstan.

In terms of young talent growth, in 2006, the state-funded Bolashak Program, which supports outstanding students in studying for bachelor's and master's programs abroad, expanded to support doctoral students. Also, the old system regulating a Doctor of Science degree was replaced by a Western-style PhD program. Obtaining a PhD degree requires

doctoral students to also publish in international journals, which necessitates higher-quality research, international collaboration, and publication in English (Kuzhabekova, 2021).

During the 2010s, the government implemented several major projects in the HES sector, enhancing the quality of education and research services in the international arena. The government intensified its support for establishing Nazarbayev University (NU) as a world-class research institution. Over the past five years, NU has significantly increased its publications in top-tier Q1 journals, accounting for over a third of all Kazakhstani publications in such journals. Additionally, all universities have been granted autonomy in staff recruitment, promotion, and the development of academic programs. The implementation of digital technologies and government projects through a project management approach has been an effective way to modernize the HES sector (Kozhakhmetova et al., 2024; Nurtayeva et al., 2024). As of 2016, Kazakhstan ranked 85th among 218 countries in terms of research publications and 108th in citations (NAS Kz, 2023). On average, Kazakh researchers produced about 200 articles per year in journals indexed in Scopus, with an average of 4.7 citations per publication (Kuzhabekova & Ruby, 2018).

3. Materials and Methods

Table 1 provides an overview of the methodology, outlining its main steps along with corresponding actions and outputs. For our data collection and analysis, we followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses reporting guidelines (Borrego et al., 2014; Siddaway et al., 2019). It is a standard tool for reporting the literature screening steps, including retrieval, deduplication, screening, eligibility assessment, and final inclusion. This approach enables readers to intuitively understand our steps and the reasons for excluding literature screening.

Table 1. Outline of the research methodology.

Steps	Actions and Outputs
1. Data collection and screening	Action: A search was conducted in Scopus using the title, abstract, and keyword fields, with terms such as national projects, initiatives, higher education, science, and research. The data were further filtered to include articles published in English between 2014 and 2024, by country, with Kazakhstan selected to identify relevant national publications.
	Output: The global search returned a total of 5639 articles. After applying a country-specific filter for Kazakhstan, 75 relevant articles were retrieved.
2. Content analysis	Action: Review of policy documents, statistics on global and local HES, and academic literature (from Scopus).
	Output: Provided a comprehensive background on Kazakhstan's HES landscape and alignment with global benchmarks. Identified key policy initiatives and investment gaps that help explain observed publication patterns and institutional priorities from 2014 to 2024. The analysis responds to our RQ-1.
3. Scientometric analysis: Network analysis	Action: Keyword co-occurrence mapping was generated in VOSviewer Version 1.6.20 using both global and Kazakhstan-specific academic publications.
	Output: Keyword cluster maps of the research on HES globally and in Kazakhstan. The analysis responds to our RQ-2.
4. Scientometric analysis: Temporal analysis	Action: A temporal visualization was generated in VOSviewer using the Kazakhstani dataset to reveal the national focus.
	Output: A temporal map with three evolution phases of the HES sector in Kazakhstan. The analysis responds to our RQ-3.

3.1. Data Collection from Scopus and Screening

In the first stage of our methodology (Table 1), bibliometric data were collected from the Scopus database. A keyword search was conducted using terms such as national projects, initiatives, higher education, science, and research in the title, abstract, and keyword fields. After that, we filtered the results to include only English-language articles from the period 2014 to 2024. This search resulted in 5639 results on a global scale.

Further, to focus on national-level output, we applied a country filter using the advanced search field code AFFILCOUNTRY(KAZAKHSTAN). This search resulted in 75 publications. Our screening process consisted of a preliminary review of titles and abstracts to assess their thematic relevance to national projects related to HES. Studies were included if their content directly addressed national-level policies, projects, or trends in the field of HES in Kazakhstan.

3.2. Content Analysis

The primary materials for this study consisted of bibliographic and statistical data retrieved from both international and national sources. At this stage, we conducted an in-depth review of the 75 Kazakhstan-affiliated articles obtained from Scopus, along with official documents and statistical reports published on Kazakhstan's government and public websites. For example, we reviewed the National Report on Science by the National Academy of Sciences of the Republic of Kazakhstan (NAS Kz, 2023) and the Bolashak Scholarship Program report (Bolashak, 2023). These documents provided data on current trends in science development, the country's Gross Domestic Product (GDP), and R&D investments, as well as targeted policy initiatives, reforms, and, specifically, the Science, Technology, Engineering, and Mathematics (STEM) research in the country. Moreover, data retrieved from the United Nations Educational, Scientific and Cultural Organization (UNESCO) Institute for Statistics have provided information about Kazakhstan's position in the global research landscape (UNESCO, 2025). We have also utilized reports from the Organization for Economic Cooperation and Development (OECD) (OECD, 2017, 2019, 2020b, 2020a).

To ensure the reliability of the content analysis, we constructed a coding framework to capture recurring themes in the selected articles (Table A1 in Appendix A). We followed the OECD's framework for assessing national research capabilities and manually coded four thematic categories: National R&D strategy, Higher education reform programs, Institutional research support, and Research capacity and output (OECD, 2019). We applied Krippendorff's Alpha to measure the inter-coder consistency of the reviewed articles. It evaluates agreement among multiple coders and is suitable for nominal, ordinal, and interval data (Krippendorff, 2019). A minimum of from 10 to 15 units is typically sufficient for meaningful reliability. The three researchers (co-authors of the current study) independently coded 15 randomly selected articles from the total sample of 75 (20% of the total sample) and negotiated to resolve any disagreements to reach a consensus. The Alpha for each thematic category was calculated using the ReCal3 software. The value higher than 0.7 indicates that a coding process has high inter-coder reliability.

Table A2 in Appendix A presents the results for a sample article, and Table A3 in Appendix A presents the results for the whole dataset.

In analyzing the articles, we also drew on relevant perspectives from the sociology of science, particularly on Merton's conception of science as a social institution and Bourdieu's notion of scientific capital. Based on these, we view HES institutions as strategic actors in national development and research policy formation (Bourdieu, 1988; Merton, 1973).

This content analysis part provided a foundational understanding that informed the interpretation of the scientometric results presented in the following sections.

3.3. Scientometric Analysis

In Steps 3 and 4 of our methodology (Table 1), a scientometric analysis was conducted using the VOSviewer tool to create keyword co-occurrence visualizations, which identified recent trends and emerging topics in both global and Kazakhstani literature. To facilitate meaningful comparison, the scientometric analysis was structured in two stages. Initially, the 5639 global publications were analyzed using VOSviewer to generate network and temporal visualizations. The network visualizations effectively illustrated how frequently certain keywords co-occurred, revealing the structure of major thematic clusters in the literature. Additionally, a temporal visualization was produced for the Kazakhstani dataset. Since the primary focus of this study is Kazakhstan's research development, the global dataset—being larger and more thematically diverse—was used primarily as a baseline for contextual comparison only within international trends.

The visualizations were constructed in VOSviewer using the full counting method for keyword co-occurrence analysis, and authors' keywords were selected to reduce noise. As a result, topic clusters were automatically classified by VOSviewer based on the co-occurrence intensity between keywords, ensuring robustness and reproducibility of the results through a fully data-driven process.

To filter the most relevant keywords in the global dataset, 13,994 keywords were identified, with a minimum occurrence threshold of 27, and 78 keywords were included in the scientometric analysis. The cleaning stage helped ensure that only thematically significant terms were used and mapped, thereby improving the clarity and interpretability of the final visualization. For the Kazakhstan dataset, the threshold for keyword occurrence was lowered to two due to the smaller size. This has enabled us to incorporate a broader range of relevant terms into the analysis. VOSviewer grouped frequently co-occurring keywords into color-coded clusters, each indicating a thematic focus of the literature. This provided a structured foundation for interpreting thematic clusters and keyword trends, which will be discussed in the following sections.

4. Results and Analysis

4.1. Content Analysis of the Trends in HES

Following the study methodology outlined in Table 1, this section is divided into three subsections: R&D investments, national programs in higher education, and institutional research funding and commercialization. We identified these as core pillars of Kazakhstan's science and innovation ecosystem, which aligns with global best practices, such as the OECD framework for assessing national research capabilities (OECD, 2019). This document emphasizes macro-level investments, education policy frameworks, and institutional mechanisms for supporting research and facilitating commercialization. In the following parts, we examine each of these dimensions individually. Although private sector R&D is also important, it often provides secondary effects or derivative results of these three basic aspects. By analyzing these results, we respond to our RQ-1.

4.1.1. R&D Investment

National strategies for developing research infrastructure should be consistent with overall R&D policies and socio-economic goals (OECD, 2020b). Such strategies underscore the importance of effective planning, funding, and governance frameworks in ensuring long-term sustainability and optimal utilization of research infrastructure. Therefore, this part utilized macro-level R&D investment as the primary dimension for understanding national research capacity, aiming to demonstrate the core role of funding allocation in shaping research capacity, promoting scientific research output, and supporting the implementation of policies.

Investment in R&D is an important indicator for evaluating research capacity worldwide (Kireyeva et al., 2021). According to recent data on R&D expenditure from UNESCO's Institute for Statistics, in 2022, the top five countries with the highest R&D spending encompass all major economies: the United States, followed by China, Japan, Germany, and South Korea (UNESCO, 2025). Moreover, more than 60% of global R&D expenditure was concentrated in three major sectors: ICT software, hardware, and healthcare industries (Statista, 2025). Furthermore, different regions emphasize different sectors. For example, the United States and the European Union prioritize aerospace and defense R&D, while China places a greater focus on research in the construction sector. Following the COVID-19 pandemic in 2020, market predictions demonstrated the importance of R&D in both healthcare and technology.

In terms of R&D intensity, we note a considerable difference between the country and major innovation-driven nations (NAS Kz, 2023). Although the annual allocation of funds to R&D in Kazakhstan increased steadily from KZT 66 billion in 2014 to KZT 173 billion in 2023, its share in GDP remained comparatively low during this period, ranging from 0.12% to 0.17% (Figure 1).

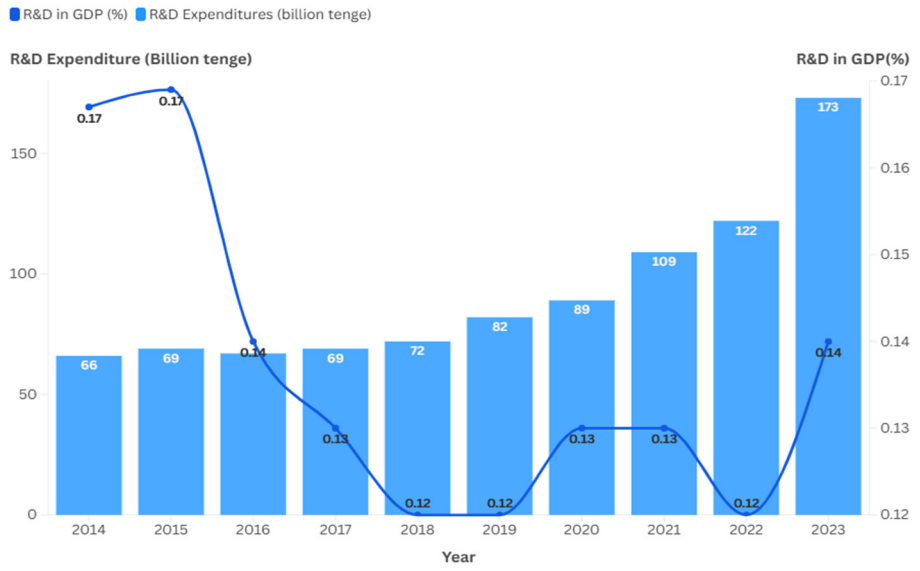


Figure 1. R&D spending and its share in GDP in Kazakhstan (2014–2023).

We also compared the Gross Domestic Expenditure on Research and Development (GERD) as a percentage of GDP in Kazakhstan with other leading economies, such as the Russian Federation, China, Japan, the United States, and South Korea (UNESCO, 2025) (Figure 2). Kazakhstan allocates a small portion of its GDP to R&D, with GERD accounting for less than 0.20%. This is significantly lower than all the other countries presented. For instance, the Russian Federation spends slightly under 1.00%, while China allocates 2.40%. Japan and the United States invest over 3.00%, with approximately 3.40% and 3.60%, respectively. Israel stands out as the leader, spending over 6.00%. This comparison highlights a considerable gap in research investment between Kazakhstan and the more developed economies, presenting potential areas for strategic development and policy improvement in Kazakhstan's science sector.

In addition to the comparisons with developed countries, Figure 3 presents data from developing countries (UNESCO, 2025). For instance, the average R&D expenditure of the Latin American countries is about 0.60% of GDP. Among the former Soviet Union countries, Uzbekistan had a GERD of 0.16% in 2022, while Ukraine and Georgia reached about 0.27% and 0.32%, respectively, which are comparatively higher in the region, but still lower than

the OECD average of 2.70%. It shows that, despite differences in geographical location, resource endowment, and political system, these developing countries still face structural challenges in prioritizing the allocation of research funds in their national budgets.

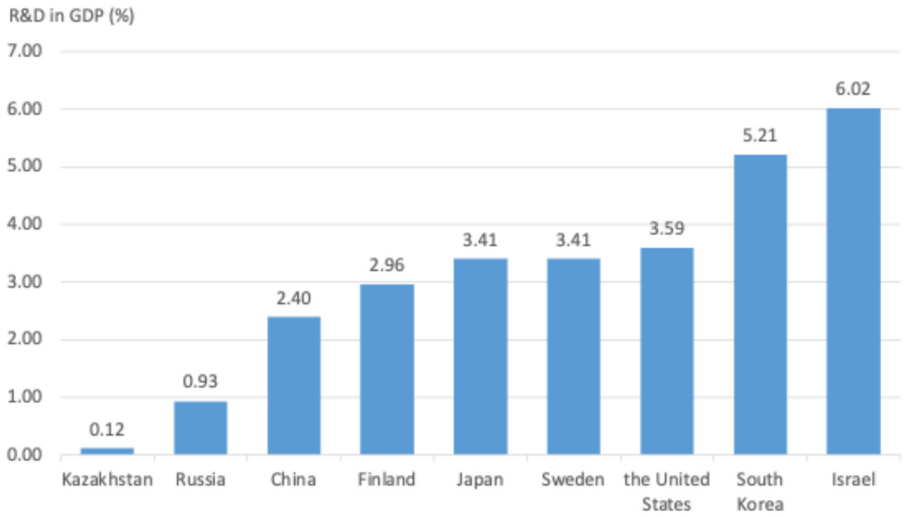


Figure 2. R&D spending share in GDP in Kazakhstan, OECD countries, and global leaders (2022).

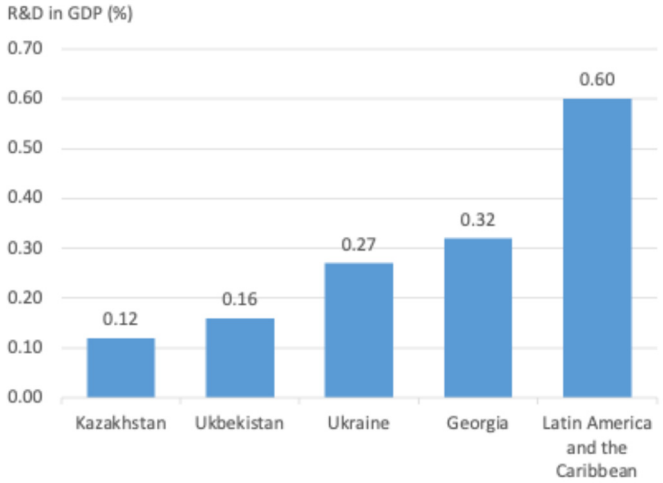


Figure 3. R&D spending share in GDP in Kazakhstan and some developing countries (2022).

4.1.2. National Projects in Higher Education

Since Kazakhstan's independence in 1991, despite limited R&D intensity, the government has promoted HES reforms based on national priorities. OECD (2017) emphasized the three national education programs in Kazakhstan, namely, the Bolashak scholarship program, the Bologna process, and NU. Their implementation outcomes have been extensively acknowledged. Due to their representative roles in capacity building and internationalization of the country's HES, we examined these programs.

The Bolashak Program, launched in 1993, aimed to internationalize Kazakhstan's academic landscape by funding students to pursue degrees abroad (Sagintayeva & Kurakbayev, 2015). More than 15,000 scholarships have been awarded over the 30 years of the program's implementation, including scholarships for bachelor's degrees, postgraduate education, internships, and the most recent project, which involves sending 500 scholars abroad annually.

One of the major highlights associated with the development of higher education is the participation in the Bologna process. Since joining the Bologna Process, Kazakhstan

has undertaken significant structural reforms to align its higher education system with European standards. Key developments included the adoption of a three-cycle degree system, the European Credit Transfer and Accumulation System (ECTS), diploma supplements, academic mobility programs, university autonomy, a national qualifications framework, competency-based curricula, and increased international research engagement. Furthermore, two independent accreditation agencies (IQAA and IAAR) were established to meet Bologna's quality assurance standards. Amirbekova et al. (2025) highlighted that joining the Bologna process had a positive impact on publication activity in the country and has boosted its research capacity.

Additionally, the establishment of NU is a landmark initiative of the Kazakh government. This university has not only cooperated with the world's top universities and scientific research institutions but has also established close ties with domestic and foreign enterprises. The founding of NU introduced a research-oriented, autonomous university model, setting a precedent for academic excellence (Kuzhabekova & Ruby, 2018).

Overall, the three programs and further initiatives aimed at developing the HES sector have been targeted by the idea of internationalization and the creation of an educational hub in Central Asia. The Strategic Plan to develop the higher education sector by 2029 was introduced, which required several targeted activities and policy changes. Overall, they have contributed to the development of science, resulting in an increase in publication activity, increased mobility of scientists, and improved research capacity within the country. In particular, Figure 4 illustrates the surge in publications in Kazakhstan from under 1000 in 2014 to over 5000 in 2024. Lovakov and Yudkevich (2021) has identified the peculiarities of the contribution of transition countries to the overall publication output. Noting that, from the former Soviet countries, only a few contribute to global science on a larger scale.

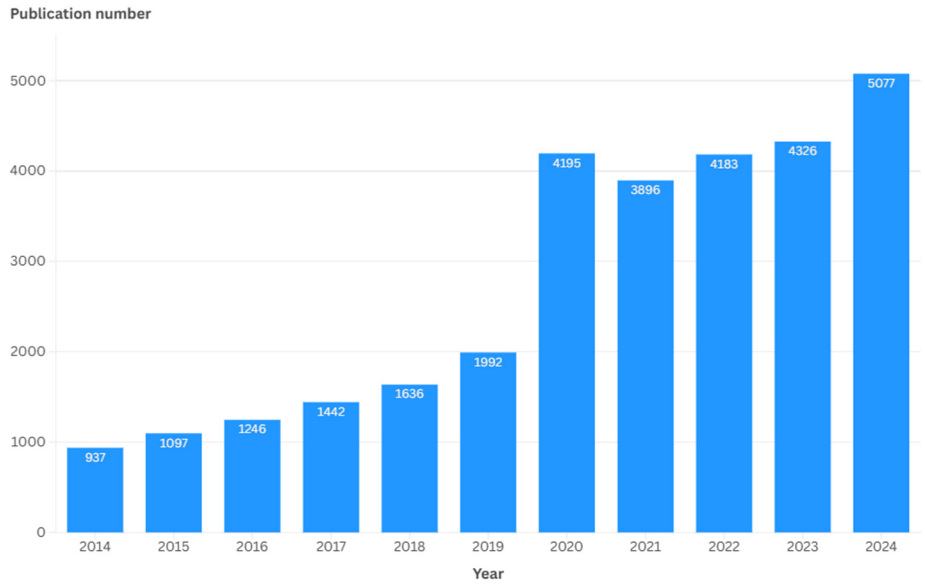


Figure 4. The dynamics of publication activity of Kazakhstan in 2014–2024.

4.1.3. Institutional Research Funding and Commercialization

Research infrastructure, as a core element of a national innovation system, not only relies on macro-level R&D investment but also requires policy support, education and training mechanisms, and institutional arrangements for research funding and results transformation (OECD, 2019). We systematically examined the paths, achievements, and challenges of Kazakhstan in improving its scientific capabilities over the past decade based on this internationally recognized evaluation framework.

In 2023, Kazakhstan demonstrated a structured and multi-channel approach to scientific funding, encompassing both program-targeted financing and grant financing. A total of eight program-targeted financing competitions were initiated by various ministries, with 285 applications submitted, out of which 116 (40.7%) received funding. In parallel, over 3100 applications were submitted for grant financing competitions, with 32.8% receiving funding.

Additionally, the Science Fund launched specialized grants for commercialization-oriented R&D projects, approving 32.6% of the applications. Across both funding schemes, a significant share of the supported projects focused on fundamental research, with some emphasis on applied outcomes. By the end of 2023, 106 program-targeted financing programs and 527 grant financing projects had been completed, resulting in 1696 scientific publications (including 528 indexed in Scopus and Web of Science), 155 intellectual property registrations, and 260 instances of practical implementation. These data highlight Kazakhstan's increasing institutional support for scientific advancement, reflected in competitive funding mechanisms and growing emphasis on research output and commercialization.

Based on data we collected from 31,676 Kazakhstani publications and more than 24 million global records indexed in Web of Science from 2014 to 2024, we created Figure 5 to compare Kazakhstan's publications with the global average, distributed by fields of science. Notably, Kazakhstan's research output is primarily concentrated in the natural sciences (53.8%) and engineering (28.3%), which are higher than the global averages of 48.1% and 25.9%, respectively. This trend shows that the national research focus is closely aligned with the fields of technology and basic sciences, reflecting the country's industrial background and strategic focus on engineering-oriented development. In contrast, medicine only accounts for 12.3% of Kazakhstan's publications, compared to 28.6% globally. Similarly, social science publications are 12.5% in Kazakhstan and slightly lower than globally (16.4%). Despite Kazakhstan having similar proportions in agricultural sciences and humanities, the overall share of these fields is quite low, around 3–5%. These gaps suggest that these fields of science receive lower institutional investment and fewer research projects, and the disciplinary imbalance may limit opportunities for interdisciplinary collaboration, thereby reducing Kazakhstan's visibility in global scientific networks.

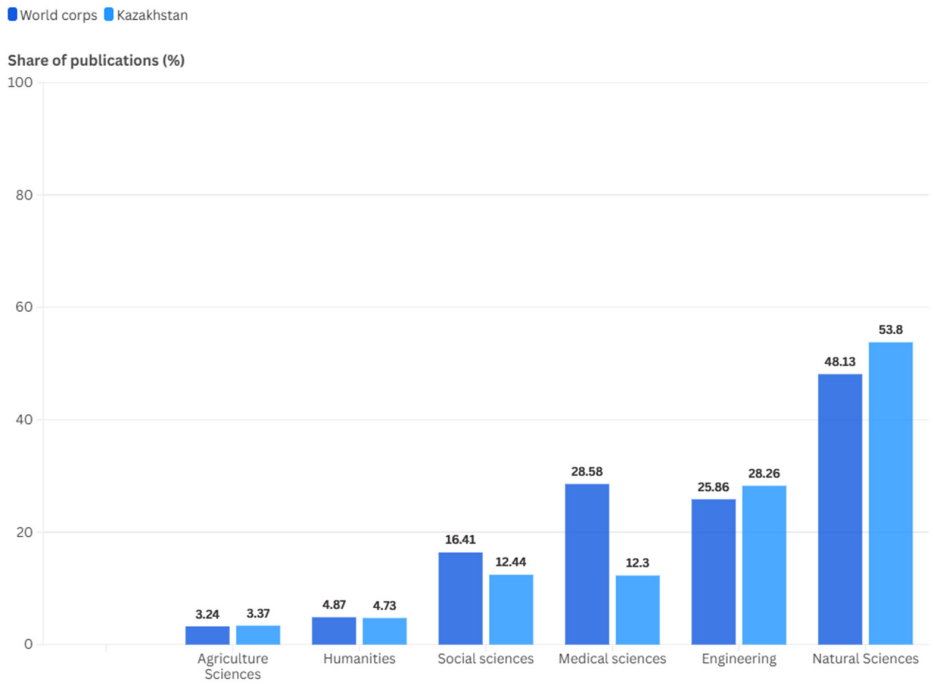


Figure 5. Structure of Kazakhstan's publications by fields of science aggregated for 2014–2024.

4.2. Network Analysis: Global and Kazakhstani Research Trends in HES

We analyze the results of the scientometric evaluation following the "top-down" and "bottom-up" models (Sabatier, 1986). The "top-down" approach emphasizes promoting reform through central-level policy design and institutional reform. At the same time, the "bottom-up" model suggests that reforms should concentrate on practical innovation, local adaptability, and user participation. The analysis is divided into two parts: the first analyzes the global literature, and the second examines the literature specific to Kazakhstan. Within these two parts, for clarity of the analysis, we divided the scientometric clusters into two groups based on Sabatier's theoretical framework (Imperial, 2021). The first group of clusters, following the "top-down" approach, implies the reforms with institutional construction and policy orientation. The second group of clusters, following the "bottom-up" approach, focuses on technology integration, sustainable development, and educational innovation. We address our RQ-2 with this analysis.

4.2.1. Network Visualization of the Global Trends in HES

Figure 6 presents a network visualization of global research trends related to national projects focused on strengthening educational and research capacity. This visualization was created using VOSviewer Version 1.6.20, drawing on patterns of keyword co-occurrence within the Scopus database. Only 78 keywords that appeared at least 27 times in the dataset were included in this analysis. In this map, each node represents a distinct keyword, and the size of the node corresponds to its frequency of occurrence in the dataset. Links between nodes indicate how often the keywords appear together in the same articles, while colors denote clusters of thematically related terms.

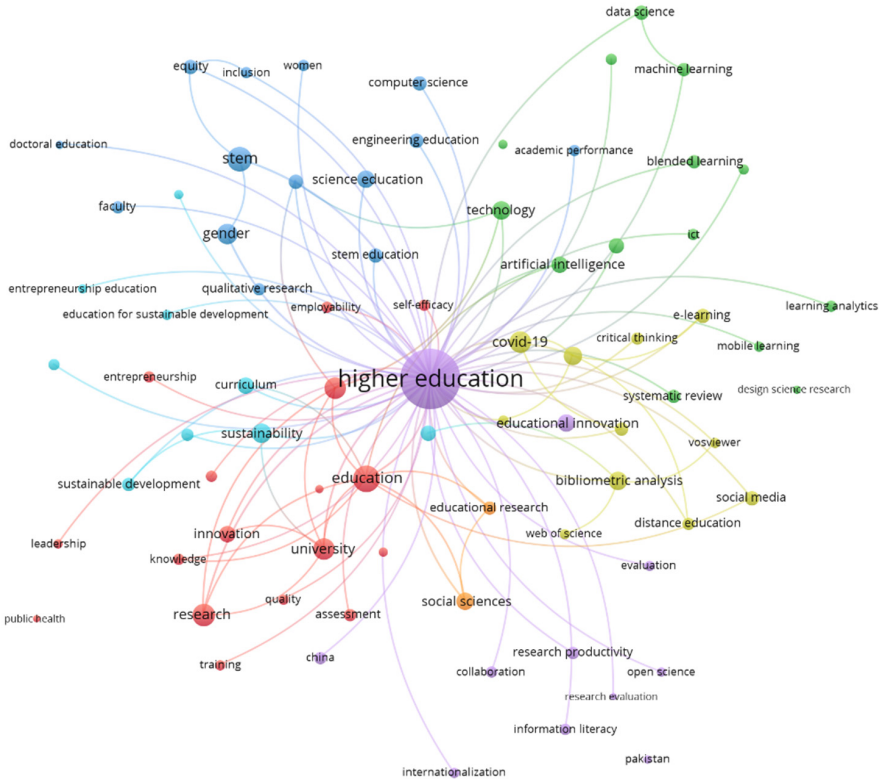


Figure 6. Network of the global literature on HES.

Notably, higher education is at the center of the network, suggesting its vital role in national efforts to build HES capacity. It is closely linked to broader concepts, including education, universities, research, STEM, sustainability, and innovation. Following our approach, we grouped this map into two major cluster groups.

Top-down structural reforms in the global context

This group of clusters encompasses key terms related to macro-level institutional construction, governance models, talent strategies, and research outputs. Purple, orange, red, and dark blue color-coded clusters characterize it.

The keywords within the purple cluster can be interpreted as those that reflect a global shift toward performance-oriented, collaborative, and transparent research ecosystems (Thibault et al., 2023). The most dominant terms in this cluster are research productivity and information literacy. These terms demonstrate an increasing emphasis on publications, citations, and institutional rankings. Moreover, this cluster emphasizes collaboration and internationalization, and this is linked to working with foreign nations to foster joint research and academic initiatives. The orange cluster addresses two main themes: social sciences and educational research. The connection between them reflects the importance of theory-driven, interdisciplinary inquiry in shaping educational policies, reform strategies, and institutional practices. While other clusters explore how to build research capacity through digitalization, STEM, or institutional reform, the orange cluster reminds us that sustainable change also requires rigorous, evidence-based understanding. The role of the social sciences here is to ask more profound questions about effectiveness, inclusion, and equity. Keywords in red, such as university, research, innovation, assessment, and leadership, suggest a focus on strengthening institutional governance and aligning academic systems with national development goals. Moreover, terms such as employability, self-efficacy, and entrepreneurship are receiving increasing attention in student outcomes and individual empowerment. For example, Römgens et al. (2020) analyze employability from research in higher education and workplace learning. Notably, the inclusion of public health as a thematic element reveals a broader shift in research priorities, reflecting that capacity building is no longer confined to academia but extends to pressing societal needs. The dark blue cluster is characterized by keywords such as STEM, science education, engineering education, and computer science, alongside terms related to gender, women, equity, and inclusion, suggesting that national projects are not only focused on expanding scientific fields but also on making them more accessible and inclusive. Terms such as faculty, doctoral education, and academic performance indicate efforts to improve the academic environment and enhance the quality of higher education. Qualitative research is increasingly showing interest in more diverse research methods, particularly in fields such as education and gender studies. Overall, this cluster suggests an integrated strategy for strengthening research capacity that advances technological innovation and promotes inclusivity within academic institutions.

Bottom-up innovation in global contexts

Figure 6 highlights the clusters that are related to technology integration and sustainable development in green, yellow, and light blue.

For example, the green cluster focuses on the role of emerging technologies such as artificial intelligence, data science, and ICT in reshaping research and education. It highlights a growing interest in intelligent systems for data-driven decision-making, personalized learning, and institutional efficiency (Bates et al., 2020; Singh et al., 2024). Other keywords, such as blended learning, mobile learning, and learning analytics, reflect a shift toward flexible, technology-enhanced learning models that gained prominence following the COVID-19 pandemic. The yellow cluster can be interpreted as reflecting how research communities responded to the rapid changes brought about by the COVID-19 pandemic. Two major themes of this cluster are related to bibliometric tools (VOSviewer, Web of Science, and bibliometric analysis) and reliance on e-learning, social media, and distance education. This reflects institutional challenges in adapting to the digital age and changing with the demands of current shifts.

Additionally, it is obvious that the light blue cluster centers on themes of sustainability and curriculum. Surrounded by keywords such as sustainable development and entrepreneurship education, this cluster reflects a strong alignment with global frameworks, particularly the UN's Sustainable Development Goals. This approach integrates environmental awareness, social responsibility, and long-term thinking into academic programs (Chang & Lien, 2020). The curriculum serves as a key connector, indicating that sustainability is being directly embedded into the learning process through interdisciplinary content and practical, problem-solving approaches (Avelar et al., 2023).

To summarize, the network visualization illustrates how global research on national projects in HES is shaped by a range of interconnected themes, including institutional reform and digital transformation, equity, sustainability, performance, and theory-driven inquiry. While each cluster highlights its area of focus, together, they offer a broad and nuanced picture of the role of HES in driving long-term social, scientific, and economic progress. These findings lay the groundwork for the following section, which examines key research trends in the local literature in Kazakhstan.

4.2.2. Network Visualization of the Kazakhstani Trends in HES

Figure 7 presents key themes and co-occurrence patterns identified through a network analysis of the literature focused on Kazakhstan. The keyword search initially showed 75 articles. From this corpus, this study selected keywords with a minimum occurrence of two times for further analysis. As with the analysis of global trends in HES presented above, we employed the same analytical approach for Kazakhstan in this section. That is, we interpreted the results through the lens of the "top-down" and "bottom-up" approach (Imperial, 2021; Sabatier, 1986). In the network, the two conceptual groups of clusters emerge: Kazakhstan and higher education. The themes in the top-down group of clusters, centered around the node Kazakhstan, reflect the broader policy-driven aspect of research development, highlighting priorities such as infrastructure, institutional capacity, and economic feasibility in Kazakhstan.

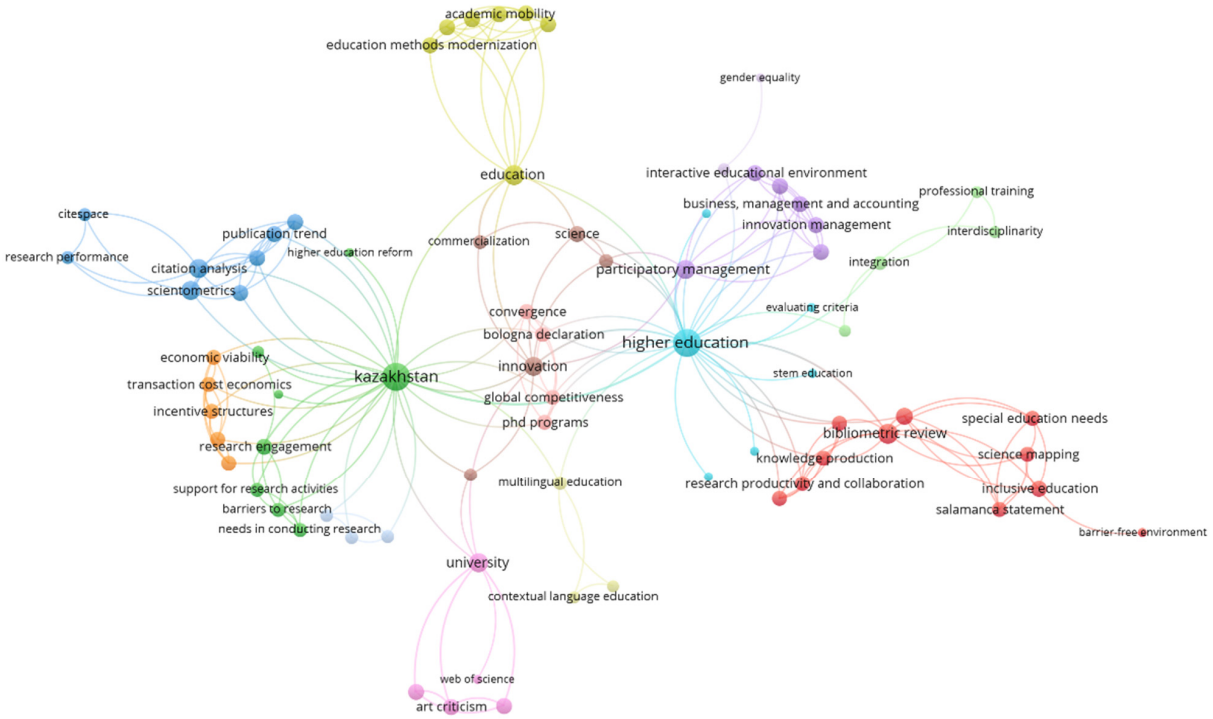


Figure 7. Network of the Kazakhstani literature on HES.

On the other hand, the themes in the bottom-up group, centered around the node Higher education, explain how these reforms are brought to practice through teaching, university governance, innovation, and efforts to make education more inclusive. Together, the clusters surrounding these two central nodes present a comprehensive picture of how Kazakhstan positions its HES. Next, we analyze the two groups in more detail.

Top-down structural reforms in Kazakhstan

The clusters directly connected to Kazakhstan underscore the state's central role in shaping the direction of research policy and educational reforms. The education cluster is linked to academic mobility, education methods modernization, and reflects the country's strategic interest in modernizing the national education system in alignment with international standards, encompassing both education and research (Gafu et al., 2024). The introduction of policies that support academic mobility, including student and faculty exchange programs, is a key factor in internationalization and integration into the global academic network. The reforms in teaching approaches and curriculum design are critical for further quality improvement and relevance.

The cluster with the themes around innovation reflects Kazakhstan's ambition to position itself as a knowledge-based economy. The nodes, such as science, commercialization, and convergence, highlight efforts to transform research into practical, market-driven outputs and to develop cross-sector collaborations. The Bologna Declaration and global competitiveness within the European Higher Education Framework give direction towards harmonization and quality assurance at the international level. The introduction of Ph.D. programs serves as an indicator to support advanced training and talent development in research.

Interestingly, the appearance of multilingual education and contextual language education adds a sociolinguistic dimension to this innovation narrative. These terms suggest that innovation in Kazakhstan is not just about scientific advancement, but also about embracing cultural and linguistic diversity in higher education—a reflection of Kazakhstan's post-Soviet identity and multiethnic composition. The university cluster encompasses the subtopics of Web of Science and art criticism, highlighting its focus on scientific excellence and cultural education. This emphasizes publications in international journals and the broader academic ecosystem where human values and human capital are at the core of creativity.

Finally, the research engagement cluster is one of the most practically oriented clusters. It includes terms like economic viability and transaction cost economics, suggesting that researchers and institutions operate within financial and structural constraints that impact their performance. Incentive structures and support for research activities reveal that national projects are being designed to address these barriers and to provide better frameworks for engagement. Moreover, nodes like barriers to research and needs in conducting research highlight persistent obstacles within the Kazakhstani research environment (Biloshchytskyi et al., 2024). Higher education reform serves as a cross-cutting theme in this cluster, connecting systemic weaknesses with broader transformation strategies. Additionally, the scientometrics cluster, with terms such as citation analysis, publication trend, and CiteSpace, reflects Kazakhstan's growing reliance on data-driven evaluation tools.

Bottom-up innovation in Kazakhstan

On the other side, the central node of Higher education links to the clusters, which reflect the themes of how reform efforts translate into academic practice, institutional culture, and societal responsiveness.

The cluster surrounding participatory management indicates a shift in Kazakhstan from traditional top-down governance models to more inclusive, collaborative, and decentralized approaches (Zhanbayev et al., 2020). Moreover, universities have become

more engaged in strategic planning, entrepreneurial initiatives, and performance-based administration. They are reflected in keywords such as innovation management, business management, and accounting. An interactive educational environment suggests pedagogical reforms aimed at increasing student engagement, collaboration, and active learning, which aligns with global trends in learner-centered education. Gender equality, meanwhile, adds a social justice dimension to this cluster, showing a growing awareness of diversity, representation, and equity within higher education governance and classroom dynamics.

The integration cluster focuses on relevance and interdisciplinarity, linking academic programs to labor market needs and broader societal challenges. Keywords such as professional training, evaluation criteria, and interdisciplinarity highlight a commitment to functional, outcome-oriented education. Although a standalone term, STEM education, directly linked to higher education, represents a well-established priority in Kazakhstan's academic strategy. This suggests that investments in research capacity and curriculum reform are especially concentrated in these fields.

The bibliometric review cluster encompasses areas such as knowledge production, research productivity and collaboration, and science mapping, which indicate that Kazakhstan is actively monitoring and analyzing the performance of its academic institutions, aligning its education reforms with international research evaluation tools (Narbaev & Amirbekova, 2021). On the other hand, keywords such as special education needs, inclusive education, and barrier-free environment underscore a deep commitment to social inclusion and accessibility.

4.3. Temporal Analysis: Evolution of Research Trends in the HES Sector (2014–2024)

The temporal visualization shows a timeline of how research themes in Kazakhstan have evolved over the past decade (2014–2024) (Figure 8). As the colors in the figure transition from purple in 2014 to yellow in 2024, the map illustrates a clear shift from earlier structural reforms to a focus on performance evaluation, and, more recently, to themes such as inclusivity, internationalization, and digitalization. We identified three major phases, and the rationale for their division was in alignment with our findings from the content analysis and network visualization analysis presented in the previous sections. Respectively, the three phases are divided into the periods of 2014–2017, 2018–2021, and 2022–2024. Overall, we address our RQ-3 in this section.

4.3.1. Phase 1: Foundational Reforms and System Modernization (2014–2017)

The keywords in purple primarily reflect the themes of the foundational reforms. Core terms during this period include the modernization of education methods, research potential in higher education, state educational grants, and intellectual property. The keywords indicate that early national efforts focused on improving teaching methodology, enhancing research capacity, and establishing funding mechanisms. The implementation of the reforms aimed to align the education system with international standards. Meanwhile, other terms, such as post-Soviet transitioning society, multidimensional government reform initiatives, and higher education reform policy, also emerged. These findings suggest that early research was deeply engaged in redefining the state's role in shaping education policy. Overall, these terms indicate that, from 2014 to 2017, the focus was on laying the structural groundwork for research development and redefining academic identity in a transitioning society, which aligns with earlier studies (Amirbekova et al., 2022; Merrill, 2020).

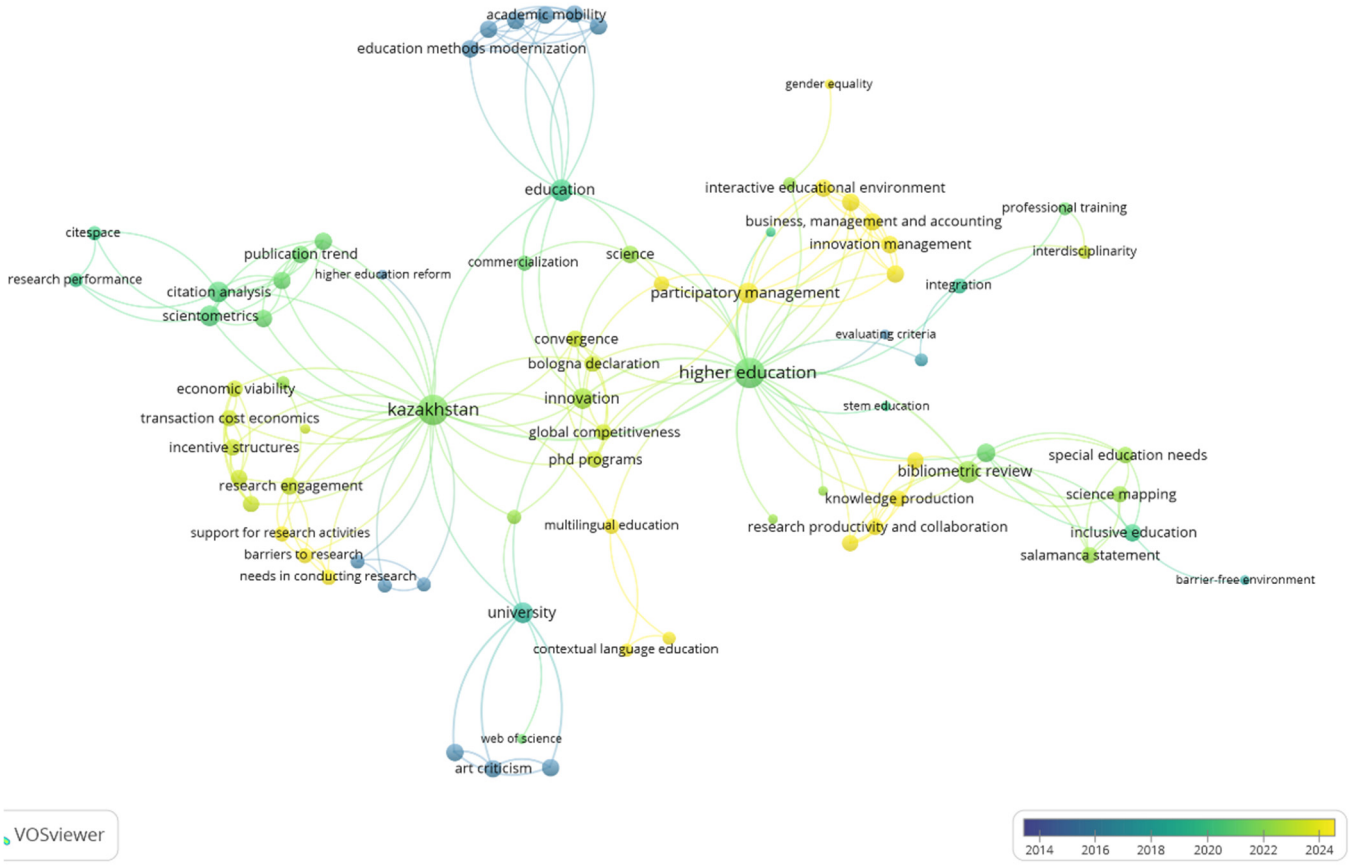


Figure 8. Thematic evolution of the Kazakhstan literature on HES (2014–2024).

4.3.2. Phase 2: Capacity Building and Evaluation (2018–2021)

Between 2018 and 2021, Kazakhstan's higher education research landscape underwent reforms during its maturing phase, transitioning towards enhanced institutional performance and increased access to education. The temporal visualization demonstrates a transition from foundational reforms toward targeted capacity building (Figure 8). Core keywords such as university, integration, STEM education, inclusive education, and barrier-free environment highlight the growing complexity of Kazakhstan's educational goals. These terms indicate that the policy expanded by bridging and encouraging interdisciplinary and student-centered learning. Moreover, STEM education emphasizes the importance of training a highly skilled workforce, while inclusive education and a barrier-free environment underscore a growing commitment to equality and social inclusion. Evidence-based policy-making is supported through scientometric terms, including citation analysis, publication trends, research performance, CiteSpace, and Web of Science. We also notice that this phase is characterized by a data-driven culture of evaluation, where productivity is no longer viewed solely through publication volume, but also through indicators such as citation impact, journal quality, and collaborations.

4.3.3. Phase 3: Strategic Expansion, Inclusivity, and Globalization (2022–2024)

The light green and yellow color keywords in the temporal visualization represent this phase. It reflects a clear shift in Kazakhstan's research agenda toward global relevance, practical impact, and inclusive academic development. Several high-frequency clusters emerged during this phase, including science, commercialization, innovation, the Bologna Declaration, and global competitiveness, indicating Kazakhstan's strategic effort to position itself as a knowledge-based economy. These terms highlight efforts related to economic development, the Bologna process aimed at increasing competitiveness, and innovation-led

policies. Themes such as PhD programs, interactive educational environment, professional training, and interdisciplinarity suggest a continued focus on improving teaching and research infrastructure. Bibliometric review, knowledge production, research productivity, collaboration, and science mapping signal reliance on scientometric tools to evaluate institutional performance and inform policy decisions.

In summary, the entire temporal visualization reveals a clear trajectory in Kazakhstan's national discourse in HES, from foundational reforms (2014–2017) to capacity building and performance-oriented evaluation (2018–2021), and ultimately to a more mature and globally attuned research landscape (2022–2024).

5. Discussions

5.1. Insights from the Content Analysis

We discuss the main findings of the content analysis of Kazakhstan's science and innovation ecosystem from three perspectives, as recommended by the OECD: R&D investment, national higher education projects, and research output transformation at the institutional level. The analysis of the main results is provided in Section 4.1 (which addresses RQ-1).

First, from a macro perspective, R&D investment directly determines the scale and quality of scientific research. We can see that, although it shows an upward trend, it still accounts for only 0.14% of the country's GDP, which is far lower than that of major or developed economies, indicating a considerable gap. According to the OECD framework, sustained and adequate public investment is a key enabler of national research capacity and long-term innovation performance. Kazakhstan's relatively low investment level may restrict the improvement of research infrastructure and the development of high-level scientific research projects. It is urgent to enhance the country's overall innovation vitality by optimizing funding allocation and policy support.

Secondly, initiatives such as the implementation of the Bologna Process, the Bolashak scholarship program, and the establishment of NU are major flagship national projects in Kazakhstan. They have promoted the output of scientific research and international cooperation. On the one hand, they have improved the quality of talent and have provided institutional guarantees for these talents. They demonstrate an important bridge connecting national reforms in higher education and global research practices. This direction aligns with the OECD's emphasis on education policy and internationalization as essential drivers of national research excellence.

At last, Kazakhstan has established a competitive research grant system through multi-channel and multi-level funding, promoting the balanced development of both basic and applied research. At the same time, the intellectual property protection and industrialization of scientific research results have established a platform for enhancing the integrity of the innovation chain and its economic and social impact.

In summary, Kazakhstan has established an initial framework and foundation for building its scientific research capacity. However, it still needs to increase R&D investment to achieve substantial improvements in the quality of scientific research output and international competitiveness. Our findings from the content analysis provide both theoretical and practical insights for the development of Kazakhstan's future HES policies.

5.2. Comparative Network Analysis: Kazakhstani and Global Literature

The main findings of the scientometric analysis on the global and Kazakhstani academic literature related to national projects in HES suggest both alignment and divergence in the research discourse. Next, we interpret our main findings from Section 4.2 (which addresses RQ-2). This interpretation follows the top-down and bottom-up analytical framework introduced by Sabatier (1986), which we discussed earlier, enabling a clearer

understanding of the policy-centric versus practice-driven orientations reflected in the cluster results. Also, following the theories of (Bourdieu, 1988; Merton, 1973), we viewed HES institutions as strategic actors in national development and research policy formation.

At a broader level, both global and local studies emphasize the critical role of higher education, underscoring its strategic importance in driving knowledge-based development. Research themes such as digitalization, STEM development, inclusion, and the use of scientometric tools appear in both contexts. This indicates Kazakhstan's engagement with internationally recognized frameworks and priorities. The three decades of national policy reforms established consistent and solid principles for higher education standards, research practices, and involvement in the globalized HES space.

However, distinct differences emerge in terms of focus and implementation. Global research tends to frame national projects through a diverse, interdisciplinary lens, blending theoretical insights, policy analysis, and practical innovation. It also places considerable emphasis on open science, collaboration, and methodological pluralism. In contrast, Kazakhstan's research discourse is more policy-oriented and state-driven, reflecting a top-down approach to system reforms. The findings from the analysis of the thematic clusters (Section 4.2.2) reveal a strong emphasis on infrastructure development, governance restructuring, economic viability, and institutional modernization, often shaped by Kazakhstan's unique socio-political transition from the Soviet model. This has been a pattern for transitional economies where, in order to adjust their internal systems, major policy changes had to be introduced.

Moreover, while global discourse increasingly centers around equity, sustainability, and pedagogical innovation (Section 4.2.1), Kazakhstan's literature highlights challenges related to research funding, language policy, internationalization, and structural barriers to research engagement (Section 4.2.2). The role of language is highlighted for its integration, academic mobility, and contribution to global knowledge. These differences reflect the contextual realities of a transitioning society still building institutional capacity and seeking its place within the global academic community.

In summary, Kazakhstan's national research agenda aligns with many global priorities but approaches them through a context-specific lens, striking a balance between international alignment and domestic reform goals. This comparison underscores the importance of adaptive strategies that consider local challenges while leveraging global best practices.

5.3. Thematic Evolution of the HES Sector

The results of the temporal visualization in Section 4.3 (which addresses RQ-3) show that Kazakhstan has experienced a significant phased transformation in its HES development over the past decade. We proposed the three phases as Phase 1: Foundational reforms and system modernization (2014–2017), Phase 2: Capacity building and evaluation (2018–2021), and Phase 3: Strategic expansion, inclusivity, and globalization (2022–2024).

In the initial stage (2014–2017), the country focused on promoting the modernization of education governance and the construction of research infrastructure, aiming to replace the former Soviet-style control system with a more autonomous and transparent higher education management mechanism. Against this background, Kazakhstan joined the Bologna Process in 2010, fully introducing the credit system (i.e., ECTS), the quality assurance system, and establishing a path for institutional integration with the European Higher Education Area. At the same time, the country continued to promote the Bolashak Scholarship Program to provide international talent for domestic universities and research institutions. Meanwhile, the establishment of NU has strengthened the comparability and international recognition of the education system. During this period, the core of policy promotion was to build the basic structure of HES through governance mechanism reform.

After entering the mid-term, in Phase 2 (2018–2021), the focus of research and policy gradually shifted to quality improvement and performance orientation. Kazakhstan accelerated the localization of the Bologna system, establishing a national academic certification system and a university ranking mechanism. These reforms promoted the linkage of HES and the labor market. More emphasis is placed on the autonomy of universities, financial transparency, and the in-depth development of institution-enterprise cooperation. In addition, the state encourages universities to establish curriculum systems centered on digital skills, STEM education, and social innovation, emphasizing the quantification and social adaptability of teaching outcomes.

In Phase 3 (2022–2024), the policy logic has further transitioned from efficiency orientation to strategic long-term planning. This means that the state is increasingly valuing the social and economic impact of scientific research results and promoting the connection between academic resources and industrial needs. A Western-style "research university" like NU has become a key carrier for policy experiments in HES in the country. At the same time, Kazakhstan actively integrates into the global education and research cooperation network, continues to optimize the doctoral education structure, and constructs international joint research platforms. In addition, during Phase 3, the importance of research productivity has increased, and researchers have begun to propose the necessity of research for the country, identifying obstacles and challenges to the development of scientific research, such as through an already established grant funding system. Notably, the policies in recent years have focused on both internal optimization and enhancing national competitiveness in the global context.

5.4. The Study Limitations

While our study offers meaningful insights into future policy and research developments in HES, several limitations should be acknowledged. We note that certain validity concerns remain to ensure transparency and scientific integrity.

For the content analysis, we used publicly available information and statistics. Other contextual data related to the financial and administrative aspects of these national projects is strictly prohibited.

Additionally, for the scientometric analysis, our study solely examined the literature records from Scopus, which may have led to the exclusion of relevant studies indexed elsewhere or published in languages other than English. Third, this study did not cover other forms of research output, such as patents, books, teaching manuals, or national funding for doctoral studies. This is particularly significant for countries with diverse publishing models; for example, in Latin America, where open-access publications and context-specific research outputs are more common but often underrepresented in Scopus. As a result, our scientometric analysis, which utilized Scopus due to its broader international coverage and compatibility with scientometric tools, may have overlooked important contributions to research capacity, especially in developing countries.

Another limitation is that the interpretation of the findings from the content and scientometric evaluations may carry a certain degree of subjectivity, specifically in the coding process, naming of cluster groups, and thematic phases, which may vary accordingly.

6. Conclusions

Our findings suggest that, while Kazakhstan aligns with global trends in the field (e.g., digitalization, scientometrics monitoring, and internationalization), these are achieved through a state-led, policy-driven approach shaped by its post-Soviet context and the transition processes it is going through. Additionally, the findings reveal a dual structure in Kazakhstan's HES sector, characterized by a strong top-down direction and increas-

ing institutional engagement. In terms of the thematic trends in the field, the country experienced a three-staged evolution: foundational reforms and system modernization (2014–2017), capacity building and evaluation (2018–2021), and, most recently, strategic expansion, inclusivity, and globalization (2022–2024). Throughout the analyzed period, low R&D intensity, disciplinary imbalances, and structural barriers still undermine desired development efforts in HES. These persistent obstacles reflect deeper structural and policy-level challenges that limit the ability to respond to the changes. A key issue lies in the lack of more effective coordination between national strategic goals and the actual implementation capabilities of HES institutions. In addition, the immaturity of the scientific research culture, unequal access to resources, and limited participation in international academic networks continue to slow the system's structural development.

The main takeaways include the low R&D investment, at 0.14% of GDP, which is far below global standards and limits scientific infrastructure and research development. The policy reforms in HES had a positive impact; national programs, such as the Bologna process, Bolashak Scholarship, and NU, were instrumental in enhancing talent quality and linking Kazakhstan to the global academic landscape. Lastly, innovations in HES were developing; the government introduced a competitive grant system and research commercialization, which established a strong connection between research and socio-economic outcomes.

We restate the contributions of this study. The research established a baseline for understanding Kazakhstan's national research ecosystem using the OECD framework and identified both achievements and systemic weaknesses. It also emphasized urgent policy directions, particularly increased R&D investment and smarter funding allocation. Additionally, the case of Kazakhstan in our study can serve as an exemplary model for similar countries undergoing a transition in their HES sector.

The following policy recommendations can enhance the effectiveness of the HES sector. The funding mechanisms should be made more transparent and equitable, ensuring inclusivity across academic disciplines and supporting open-access research infrastructure. Additionally, higher education institutions should shift from quantity-based to impact-based research evaluations, invest in researcher training, and foster international and industry collaboration. This will help close the gap between the expected outcomes of implementing national projects in HES and their actual outcomes. Also, future policy directions can be structured around strengthening institutional capacity, enhancing funding mechanisms, fostering international collaboration, and aligning more closely with global academic and research trends.

We also suggest that future research could build on our findings by involving a wider range of databases, multilingual literature, and inclusion criteria, using complementary metrics such as Altmetrics or qualitative assessments. Future studies in other emerging countries can evaluate the impact of national initiatives on HES and overall research productivity. A comparative analysis between two or more countries can be conducted in this area, considering different socio-political contexts.

Our findings provide valuable insights that can be applied beyond the domestic context to enrich broader regional discussions. This can be particularly useful for transition economies undergoing systemic reforms in the HES sector. First, Kazakhstan's three-phase evolution (the foundational reforms, capacity building, and strategic globalization) provides a practical roadmap for other post-Soviet or transitioning nations seeking to modernize their HES. This sequential approach highlights the importance of establishing institutional autonomy before introducing performance metrics, prioritizing foundational governance reforms over global expansion, and aligning policy initiatives with clear, time-bound developmental objectives. Second, the country's dual emphasis on domestic institutional

restructuring and international alignment (e.g., through the Bologna process and research university models) reflects the challenge faced by many transition economies: how to maintain national priorities while participating in a globalized academic environment. This, for example, encompasses the importance of maintaining context-sensitive policies while adopting global standards, as well as the need to preserve language identity while promoting international research cooperation. Third, Kazakhstan's state-centric, top-down policy model resonates with other developing countries that lack a strong private research sector. We note that government reforms can be essential in the early stages of system transformation in HES. This, for example, includes the potential of major projects (e.g., the Bolashak scholarship, NU) to catalyze institutional excellence and build reputational capital.

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Abbreviations

The following abbreviations are used in this manuscript:

ECTS	European Credit Transfer and Accumulation System
GDP	Gross Domestic Product
GERD	Gross Domestic Expenditure on Research and Development
HES	Higher education and science
NU	Nazarbayev University
OECD	Organization for Economic Cooperation and Development
STEM	Science, Technology, Engineering, and Mathematics
R&D	Research and development
UNESCO	United Nations Educational, Scientific and Cultural Organization

Appendix A

Table A1 presents the coding framework for the content analysis part of this study. The coding to review the selected articles was performed manually using four thematic categories: National R&D strategy, Higher education reform programs, Institutional research support, and Research capacity and output. The explanation of the coding approach is given in Section 3.2.

Table A2 presents the results of coding by the three researchers (co-authors) for one article from the dataset.

Table A3 presents the intercoder agreement results for the whole dataset. The results were calculated using Krippendorff's Alpha indicator based on independent coding by the three researchers (co-authors).

Table A1. A coding scheme for the content analysis.

Main Category (Codes)	Subcategories	Description
1. National R&D strategy (Code 1)	R&D investment, GDP share, policy priorities, international comparisons	Analysis of Kazakhstan's R&D spending trends and alignment with global benchmarks
2. Higher education reform programs (Code 2)	Bolashak Program, Bologna Process, Nazarbayev University, strategic plans	Evaluation of key national programs aiming to reform and internationalize higher education
3. Institutional research support (Code 3)	Grant funding, commercialization of research, government programs	Assessment of institutional funding mechanisms and translation of research into practice
4. Research capacity and output (Code 4)	Publication output, international collaboration, research mobility, field distribution	Measurement of research productivity, scientific capacity, and contribution to global science

Table A2. A code of one sample article from the dataset.

Coder	Researcher 1	Researcher 2	Researcher 3	Agreement
Code 1	✓	✓	✓	Yes
Code 2	✓	✗	✓	No
Code 3	✓	✓	✓	Yes
Code 4	✓	✓	✓	Yes

Note: a symbol ✓ means that a reviewed article contains coded information; a symbol means ✗ that a reviewed article does not contain coded information.

Table A3. The intercoder agreement results for the coded thematic categories.

Code	Krippendorff's Alpha	Interpretation
Code 1	0.82	Strong Agreement
Code 2	0.73	Acceptable Agreement
Code 3	0.79	Acceptable Agreement
Code 4	0.83	Strong Agreement

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