

Factors Determining the Development of Engineering Education in the Labor Market and the Real Sector of the Economy of the East Kazakhstan Region

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ABSTRACT

Engineering education is undergoing a profound transformation driven by rapid technological advancement, industrial digitalization, and the global transition to Industry 4.0. In Kazakhstan, as in many post-Soviet economies, engineering programs face mounting pressure to align with labor market demands and contribute to regional development. Yet a persistent gap remains between graduate competencies and employer expectations in the real sector. This study investigates the key factors shaping engineering education in the East Kazakhstan Region, with a focus on aligning educational outcomes with labor market needs. Universities and industrial enterprises are considered core stakeholders. The research aims to identify the root causes of competency mismatches, assess the adaptability of higher education to industrial transformation, and offer practical recommendations for improvement. A mixed-methods design was employed, combining a structured stakeholder survey ($n = 146$), expert validation, policy analysis, and a review of secondary data. Internal consistency was confirmed using Cronbach's Alpha ($\alpha = 0.91$), and exploratory factor analysis (EFA) in Jamovi identified two principal components accounting for over 70% of the variance. Key findings point to limited university-industry collaboration, outdated curricula, and inadequate career guidance systems as the main barriers. The study concludes with strategic recommendations to strengthen the capacity of regional universities to produce graduates who are better equipped for Industry 4.0.

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INTRODUCTION

Modern industry is undergoing rapid and significant transformation. Since all production processes, regardless of their level of automation, depend on human input, even minor technological changes require updated skills and workforce adaptation. As a result, engineering education has become a strategic driver of the national economy. In Kazakhstan, enhancing the quality of engineering education is closely linked to addressing socio-economic challenges and supporting long-term development. Reflecting this priority, the national education policy of the Republic of Kazakhstan places strong emphasis on advancing engineering training. It sets clear goals for developing modern competencies that prepare graduates to solve real industrial problems and contribute to the sustainable growth of regional economies.

The Concept for the Development of Higher Education and Science of the Republic of Kazakhstan for 2023–2029 outlines strategic priorities for modernizing and innovating the higher education system (Kozybayev University, 2023). Special attention is given to regional universities, traditionally located in the country's industrial areas. These institutions are expected to ensure academic excellence, address technological and scientific challenges, and facilitate the transfer of innovation to the real sector. As regional development becomes a central focus of national economic and investment policy, aligning the mission of regional universities with this agenda is increasingly important. In response, the Ministry of Science and Higher Education has launched modernization initiatives aimed at strengthening the role of regional universities in developing human capital and technological capacity. However, despite these policy-level efforts, significant implementation challenges persist, particularly in aligning educational outcomes with labor market needs.

In the East Kazakhstan Region and across the Republic of Kazakhstan, ongoing efforts to raise household incomes by 2025 have placed new demands on the national workforce development system. Educational institutions, governments, and private-sector stakeholders are expected to revise their approaches to vocational guidance and human capital development. Identifying high-demand occupations and forecasting future skill needs aligned with regional labor market trends is a particular focus.

However, a significant challenge remains: a persistent mismatch between the competencies of engineering graduates and the expectations of employers in the real sector. Graduates often lack adequate preparation in key areas such as technological innovation, applied research, and interdisciplinary problem-solving. If unaddressed, this gap could weaken national human capital and threaten the region's long-term economic competitiveness.

The sustainable development of regional economies increasingly depends on the advancement of engineering education, which requires ongoing improvements in both quality and global competitiveness. In academic discourse, there is growing agreement that rethinking engineering education frameworks is essential for driving innovation, supporting economic transformation, and tackling today's societal challenges. While traditionally associated with product development, engineers in fact contribute across a wide range of activities, including system design, implementation, debugging, programming, and applied research. As an inherently interdisciplinary profession, engineering combines creative and technical expertise. Throughout history, figures like Archimedes, Leonardo da Vinci, Nikola Tesla, and Henry Ford have exemplified the transformative power of engineering in shaping society and advancing technology.

Within the higher education system, educators, researchers, students, and graduates have become key drivers of societal progress (Leifler & Dahlin, 2020; Nazarova, 2018; Thinakaran & Chuprat, 2022). Today, engineering education plays a central role in this transformation by integrating advanced innovations and technologies that fuel economic and industrial growth. It supports a shift from problem identification to solution implementation, adopting a forward-looking approach that anticipates future challenges and shapes development trajectories (McGowan & Bell, 2020). Engineers' professional strengths, particularly systems thinking, intellectual discipline, and technical expertise, enable them to contribute meaningfully across diverse sectors, not just in technology. As a result, there is an increasing need to cultivate a large pool of

technically proficient professionals and to promote technological literacy throughout society. These efforts are vital not only for creating engineering innovations but also for ensuring their successful adoption, thereby fostering a nationally grounded scientific and engineering elite (Pokholkov, 2012).

Building on these perspectives, both foreign and domestic research in engineering education has concentrated on several key areas. International studies have addressed the development of industry-aligned technical curricula (Koehn, 1999), the integration of emerging technologies and design-oriented approaches (Hernández-de-Menéndez & Morales-Menéndez, 2019), outcome-based assessments of engineering programs (Yi et al., 2017), and the creation of educational standards (Cooklev, 2010). Further research has focused on evolving pedagogical models, shifting educational goals, and systemic reforms in engineering education (Crawley et al., 2014; Kuznecov, 2012). In parallel, other studies have sought to define the core competencies essential for modern engineers (Prihod'Ko & Solovyev, 2015; Rudskoj, 2015). Many scholars have drawn attention to a persistent issue: the growing gap between the fast pace of technological advancement in industry and the relatively static intellectual and methodological frameworks of traditional university programs (Gladkikh, 2005; Satymbekova et al., 2014; Sobolev, 2018).

Despite the acknowledged importance of engineering education, the higher education sector is often criticized for its limited ability to keep pace with rapid socio-technological change (Berge et al., 2018; Carberry & Baker, 2018). Labor market stakeholders argue that universities adapt too slowly to real-world demands, producing graduates who frequently lack the competencies necessary for effective integration into industrial settings (Eberhard et al., 2017). As a result, engineering education often falls short of the expectations of high-tech industries striving for global competitiveness (Pokholkov, 2021).

This study is based on the premise that the sustainable development of regional economies and, more broadly, national technological advancement is strongly influenced by the number and quality of engineering graduates. Using the East Kazakhstan Region as a case study, the research examines the structural and institutional factors shaping engineering education and its alignment with labor market and industrial needs.

The primary objective is to identify and analyze the key drivers influencing the development of engineering education in the East Kazakhstan Region, with a particular focus on aligning educational outcomes with labor market requirements. The study also offers evidence-based recommendations to improve the responsiveness of engineering programs to industrial transformation under Industry 4.0 and to support regional economic growth.

RESEARCH METHODS

The theoretical foundation of this study was established through a structured review of scholarly literature related to engineering education and labor market demands. This involved the systematic search, classification, and evaluation of academic publications. Complementing the theoretical component, the empirical base of the research includes the analysis of more than a dozen national policy documents, reports, and strategic presentations. Key among these are the National Project “Quality Education: Educated Nation”, the National Project “Technological Leap through Digitization, Science, and Innovation”, and the Concept for the Development of Higher Education and Science of the Republic of Kazakhstan for 2023–2029.

A comprehensive methodological approach was applied, combining literature review, policy analysis, and both primary and secondary data collection. This integrated framework provided a robust basis for examining the alignment between engineering education outcomes and labor market needs within the context of Kazakhstan’s ongoing digital and economic transformation.

Primary data were collected via a structured survey, a widely accepted method for capturing stakeholder perspectives on complex socio-economic issues (Groves et al., 2009; Dillman et al., 2014). The survey assessed regional demand for engineering personnel and identified key factors affecting the quality of engineering education amid the transition to Industry 4.0. To ensure internal consistency, Cronbach's Alpha was calculated, yielding a high reliability coefficient ($\alpha = 0.91$), which indicates excellent coherence among items (George & Mallery, 2019). Prior to exploratory factor analysis (EFA), the dataset's suitability was confirmed using the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's Test of Sphericity. The KMO value of 0.84 indicated meritorious sampling adequacy, and Bartlett's test was statistically significant ($\chi^2 = 564.21$, $df = 120$, $p < 0.001$), validating the use of EFA (Field, 2013). The EFA was conducted using Jamovi software, chosen for its open-source framework, user-friendly interface, and integrated analytical tools. Two principal components were extracted, accounting for over 70% of the total variance. These components formed a reliable basis for the interpretation presented in the results and discussion sections.

The target population comprised key stakeholders from the East Kazakhstan Region, specifically representatives of industrial enterprises, university faculty, and engineering students. A purposive sampling strategy was employed during field visits to universities and enterprises to ensure the inclusion of participants with relevant expertise and experience. The selection prioritized institutions and companies directly engaged in the engineering sector of East Kazakhstan. Industrial enterprises were drawn from strategically significant sectors, including metallurgy, mechanical engineering, and energy, while universities with accredited engineering programs were targeted to ensure academic relevance. In total, 146 respondents participated in the survey. The questionnaire was developed based on an extensive review of academic literature and policy frameworks, with content validity verified through expert evaluation by professionals from both academia and industry.

Secondary data analysis formed a central component of the desk research phase. Quantitative data were primarily sourced from the "Taldau" information-analytical system maintained by the Bureau of National Statistics under the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan (Bureau of National Statistics, 2023). The analysis employed core descriptive economic techniques to identify and interpret regional economic trends (Gujarati & Porter, 2009; Wooldridge, 2020). These included comparative analysis, the transformation of absolute values into relative indicators, and the calculation of average values. Additionally, the study incorporated findings from the 2023–2025 Workforce Demand Analysis, a large-scale employer survey encompassing 51,200 companies, conducted by the Ministry of Labor in collaboration with the National Chamber of Entrepreneurs "Atameken."

To strengthen the validity and reliability of the research, a triangulation approach was employed by integrating three complementary data sources: (i) a structured stakeholder survey (primary data), (ii) content analysis of strategic policy documents (such as national projects and education strategies), and (iii) official statistical data from the Bureau of National Statistics. This methodological triangulation not only enhanced the study's robustness but also enriched the interpretive depth by situating quantitative reliability tests (e.g., Cronbach's Alpha, EFA) within a broader contextual framework.

In addition, an expert validation process was implemented to ensure the content validity of the survey instrument. A panel comprising academic scholars and industry practitioners reviewed the questionnaire to assess its clarity, relevance, and comprehensiveness with regard to the competencies required in contemporary engineering education. Their feedback informed the refinement of survey items prior to data collection, ensuring alignment with the practical needs of Industry 4.0.

Finally, the abstract-logical method was applied as a general analytical framework, facilitating theoretical generalization and the synthesis of findings across empirical, statistical, and documentary sources.

RESULTS AND DISCUSSION

From an economic point of view, humanity is making a civilizational transition from one technological mode to another. At the new stage of production force development, economic efficiency is determined primarily using highly qualified personnel, new knowledge, technologies, and management methods. These factors help to ensure the relevance of education to the needs of the labor market and contribute to the continuous professional development of engineers.

The Main Indicators of the Labor Market

Human resources are one of the main factors of the economy and dominate innovation and information structures. This factor influences the formation of a new quality economy. It contributes to economic growth by ensuring an adequate supply of labor resources and helps address the mismatch between supply and demand in local markets.

The demographic situation of the region over the past 10 years has been characterized by negative dynamics. The annual decline was, on average, from 0.07% to 0.65%, with small intermediate positive indicators in 2014-2016. According to official statistics, the total labor force in the East Kazakhstan region is decreasing. In 2021, the labor force amounted to 701,813 people, a decrease of 6% compared with 2012 (Fig 1). The unemployment rate in 2021 returned to the indicators of 2019, decreasing by 0.1% compared with the same period in 2020. Migration processes probably influenced the decline in the total number of employed people in East Kazakhstan – the number of residents in the region decreased by 7.3 thousand people last year.

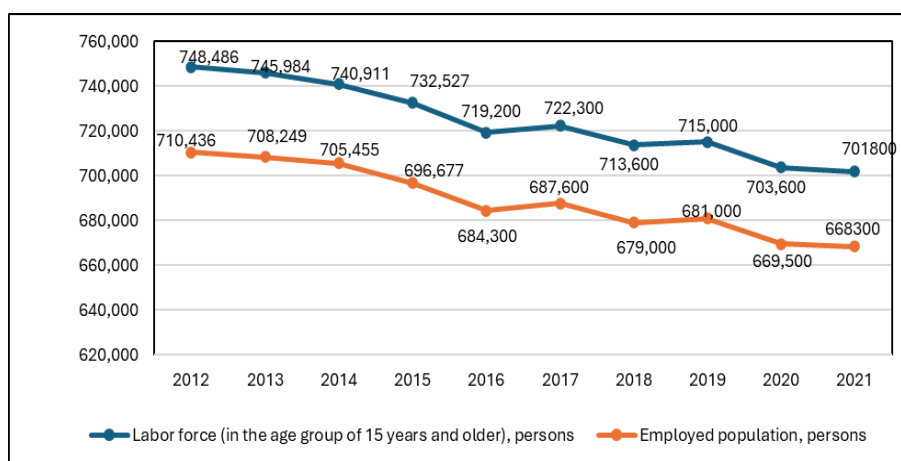


Fig. 1. The level of the economically active population and the level of the employed population of East Kazakhstan region.

The predominant portion of wage labor, approximately 70%, typically comprises employees within organizations. As of 2021, East Kazakhstan had 193 thousand sole proprietors, marking a decrease of 40 thousand compared to 2012 (Fig 2). The average value of the share of the employed population of the East Kazakhstan region by type of economic activity in the period from 2014 to 2021 is presented in Table 1 (Bureau of National Statistics, 2023). The majority of the employed population works in agriculture, forestry, and fisheries – 17.30%, in second place, wholesale and retail trade – 17.28%, in third, education, and in fourth place, manufacturing – 10.07%. The number of vacant jobs by 2022 in the East Kazakhstan region was 3,472. According to this indicator, East Kazakhstan ranks fifth in terms of regional context.

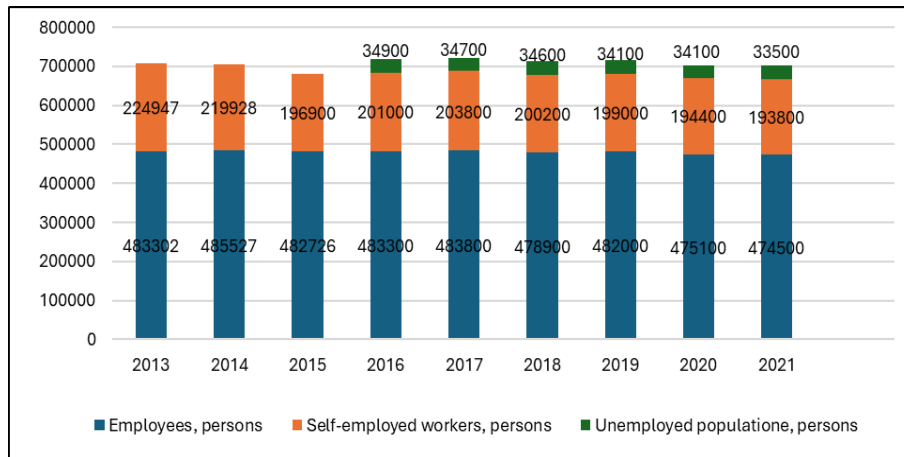


Fig. 2. Dynamics of the employed population in the East Kazakhstan region from 2013 to 2021.

Table 1. The share of the employed population of East Kazakhstan region by types of economic activity (average value for the period 2014-2021)

Type of economic activity	Share in %
Agriculture, forestry, and fisheries	17.30
Mining and quarrying	3.54
Manufacturing industry	10.07
Supply of electricity, gas, steam, hot water, and air-conditioned	1.70
Water supply; waste collection, treatment, and disposal, pollution elimination activities	0.93
Construction	5.06
Wholesale and retail trade; repair of cars, motorcycles	17.28
Transportation and warehousing	6.27
Provision of accommodation and catering services	2.48
Information and communication	1.53
Financial and insurance activities	1.57
Real estate transactions	1.21
Professional and scientific, and technical activities	1.77
Administrative and support services activities	1.84
Public administration and defense; compulsory social security	7.49
Education	10.45
Public health and social services	5.68
Art, entertainment, and recreation	1.07
Provision of other types of services	2.77

The expected need for personnel for 2022 - 2024 in the East Kazakhstan Region is 1,756 people. According to this indicator, East Kazakhstan ranks fifth in terms of regional context. Industries need workers most of all: i) manufacturing (304 people), ii) agriculture (294 people), and iii) construction (289 people). The lowest demand is observed in the following industries: i) art and entertainment – 4 people; ii) information and communication – 7 people; and iii) real estate transactions – 15 people.

Despite positive aspects, the persistence of negative trends driven by internal and external threats may lead to a deterioration of the socio-economic situation in the East Kazakhstan region. Additionally, a growing number of pensioners combined with a reduced workforce may further exacerbate the pension fund deficit. A possible decline in the standard of living of the population under the influence of the ongoing

global systemic crisis, coupled with a decrease in aggregate demand for goods and services, will restrain economic growth.

To solve this problem, it is necessary to constantly increase the number of high-tech jobs. This initiative is inextricably linked to scientific and technical activities, as well as professional training. This will increase the productivity of public labor in the region, thereby solving the problem of reducing the number of labor resources and increasing the collection of taxes and contributions to the pension fund. As a result, there are additional opportunities to finance social programs.

Basic Data of the Real Sector of the Region's Economy

The volume of the gross regional product (GRP) of the region in 2021 amounted to 5063.7 billion tenge and has grown 1.6 times over a past 5 years. The share of the GRP of the East Kazakhstan Region to the GDP of the Republic of Kazakhstan (82.2 trillion tenge) was 6.16% (Fig 3).

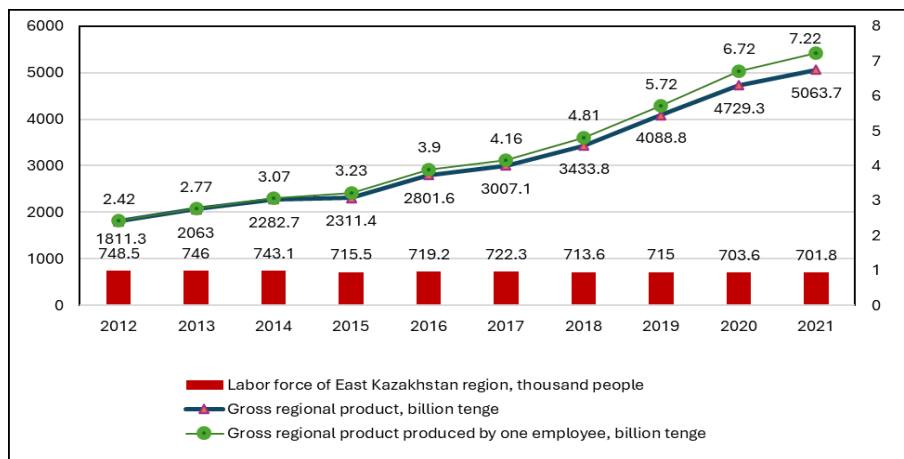


Fig. 3. Gross regional product of East Kazakhstan region in dynamics for 2012 - 2021.

The average annual GRP growth rate of the East Kazakhstan region is 113.6%, but the average annual inflation in the East Kazakhstan region is 7.4%; hence, the growth rate of the real GRP is approximately 105%. The enlarged GRP of East Kazakhstan consists of GVA according to the type of economic activity and net taxes. From 2010 to 2021, the share of net taxes in GRP has not changed, amounting to 5.3% in the GRP of the East Kazakhstan region, and, accordingly, the share of gross value added (GVA) in the GRP of the East Kazakhstan region (94.7%) has not changed. Value added includes labor costs, depreciation, and profits. The largest share in the East Kazakhstan Region's GVA is accounted for by the industry. Thus, in 2010, the share of the industry's GVA was 29.3%, and in 2021, it was 35.5%. The largest GVA is created in the manufacturing industry; thus, workers in this area and owners of manufacturing enterprises receive maximum income. During the review period, the contribution of industries such as agriculture, forestry and fisheries, construction, education, and healthcare to the formation of the East Kazakhstan Region's GVA increased. The contribution of other types of economic activity to the GRP of the East Kazakhstan region has decreased (Table 2) (Bureau of National Statistics, 2023).

In 2021, industry occupies a large share in GRP with the volume of output of 1698643.9 million tenge (33.55%), wholesale and retail trade are in second place - 626589.8 million tenge (12.37%), agriculture, forestry, and fisheries are in third place - 517445.5 million tenge (10.22%).

The structure of production volumes (performance of works, provision of services) for the period from 2012 to 2021 has changed due to an increase in the share of industry by 7.6 percentage points, construction by 1.5 percentage points, and agriculture by 1.5 percentage points. The shares of trade, transport, and communication have decreased. The highest average annual growth rate of production volumes (works and services) was observed in the construction sector, where the average annual growth rate of the volume of work performed was 112.88%. To calculate the real growth rates, the method of leveling the initial points of analysis was applied, and the effect of inflation on this indicator was leveled (Table 3) (Bureau of National Statistics, 2023).

Table 2. The share of the employed population of East Kazakhstan region by types of economic activity (average value for the period 2014-2021)

GRP elements	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Agriculture, forestry, and fisheries	9.4	9.4	8.7	9.6	8.6	9.0	9.1	9.0	9.6	10.2
Mining and quarrying	3.7	5.0	6.0	7.1	6.7	8.6	9.9	12.0	11.5	10.7
Manufacturing industry	23.1	21.2	22.1	19.6	24.6	21.1	22.9	21.9	22.3	20.8
Supply of electricity, gas, steam, hot water, and air-conditioned	1.6	1.6	1.7	2.5	2.5	2.4	2.2	1.8	1.7	1.9
Water supply; waste collection, treatment, and disposal, pollution elimination activities	0.3	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.2
Construction	4.6	5.1	5.1	5.1	6.1	5.6	5.3	5.2	6.3	6.3
Wholesale and retail trade; repair of cars, motorcycles	14.7	14.4	14.8	13.9	12.2	12.1	12.4	13.0	14.1	12.4
Transportation and warehousing	7.7	8.3	7.4	9.0	8.2	10.4	9.9	8.7	6.4	6.1
Provision of accommodation and catering services	1.1	1.1	1.1	1.1	0.9	0.7	0.8	0.8	0.6	0.6
Information and communication	0.9	1.0	1.0	1.0	0.8	0.7	0.7	0.6	0.6	0.6
Financial and insurance activities	1.3	1.6	1.8	2.1	2.1	2.1	1.7	1.6	1.5	1.4
Real estate transactions	10.1	9.1	8.3	9.4	8.0	7.7	6.0	5.2	6.0	7.0
Professional and scientific, and technical activities	2.5	2.0	1.9	2.1	2.4	2.1	2.4	2.1	1.8	2.0
Administrative and support services activities	1.5	1.3	1.4	1.4	1.4	1.0	0.9	0.9	1.1	1.5
Public administration and defense; compulsory social security	3.5	3.7	3.6	3.6	3.2	3.1	2.7	3.0	2.9	3.1
Education	3.7	3.4	3.3	3.3	3.1	3.0	2.9	2.9	4.0	4.2
Public health and social services	2.8	2.8	2.8	2.2	2.2	2.9	2.7	2.9	2.6	3.0
Art, entertainment, and recreation	0.5	0.6	0.6	0.6	0.7	0.8	0.6	0.5	0.5	0.5
Provision of other types of services	1.5	1.7	2.3	1.3	0.9	1.1	0.8	1.1	1.2	2.2
Total GVA, million tenge	94.4	93.7	94.1	95.4	94.6	94.6	94.1	93.6	94.8	94.7
Net taxes on products in the production account, million tenge	5.6	6.3	5.9	4.6	5.4	5.4	5.9	6.4	5.2	5.3
Gross regional product, million tenge	100	100	100	100	100	100	100	100	100	100

Since the East Kazakhstan region is an industrial region, the volume of industrial production increases 2.8 times during the period under review. If we consider the index of the physical volume of industrial products in % compared to the previous year, the dynamics in 2021 decreased by 1% compared to 2020 (Table 3).

The volume of industrial production in the region in 2021 amounted to 2763.4 billion tenge, including 1966.4 billion tenge - manufacturing industry, whose share in total industrial production was 71%, mining industry - 23.6%, electricity - 4.5%, water supply - 0.06% (Fig 4).

The average annual increase in the volume of industrial production (works and services) in the East Kazakhstan region was 4.93%. The East Kazakhstan Region industry includes mining, manufacturing, supply of various types of energy, water supply, collection, treatment, and disposal of waste. From 2010 to 2021, the sectoral structure of the East Kazakhstan region's industry has shifted towards increasing the share of the mining industry, owing to a decrease in the share of manufacturing, energy supply, and water supply. Thus, the East Kazakhstan region's economy continues to be predominantly poverty-oriented despite a significant average annual increase in manufacturing output of 6.18%. The largest share in the volume of production of industrial products of the mining industry is occupied by metallurgical production - 75%.

Table 3. Structure of the main types of economic activity in 2010 and 2021

Main types of economic activity	2010	2021
	%	
Agriculture, forestry, and fisheries	12.06	13.62
Industry	35.16	42.80
Construction	4.46	6.23
Trading	40.48	31.15
Transport	7.23	5.87
Connection	0.60	0.33

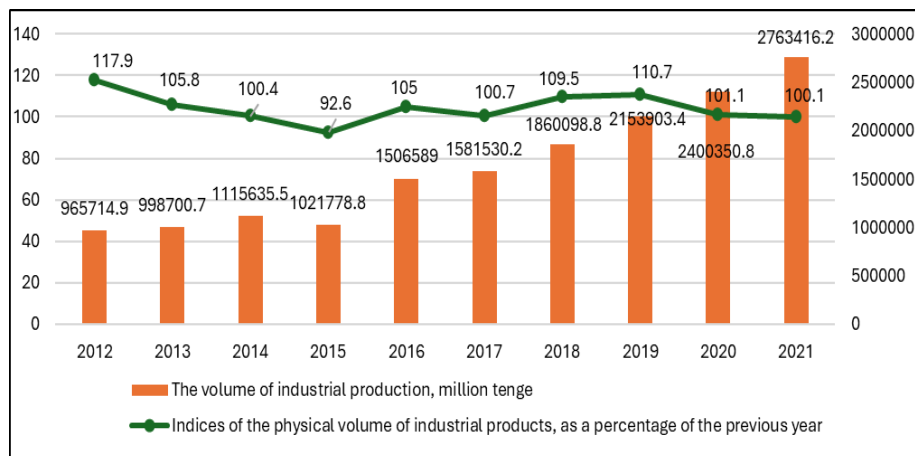


Fig. 4. Dynamics of industrial production in value terms and indices of the physical volume of industrial products.

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Indicators of Personnel Training at the Regional Level

Gross enrollment in higher education in the East Kazakhstan region over the past 10 years shows positive growth dynamics, with slight declines in 2013 and 2014. On average, the gross coverage of higher education in the East Kazakhstan region for the analyzed period was 51.54%, which was 4.56% lower than

that in the republic (56.10%) (Fig 5).

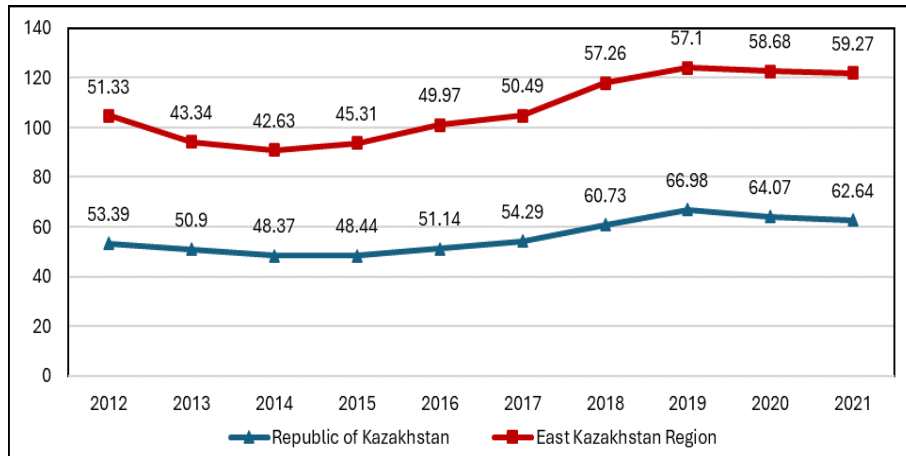


Fig. 5. Gross coverage of higher education in East Kazakhstan region (%).

At the beginning of the 2020-2021 academic year, there were seven independent higher educational institutions in the East Kazakhstan region, four of them were non-state (Fig 6). Enrollment in higher and postgraduate educational institutions in the region witnessed an increase of 107 students compared to the preceding academic year, reaching a total of 32.2 thousand individuals, with females constituting 18.3 thousand, or 56.8%. 55.7% of the student population was enrolled in state education institutions.

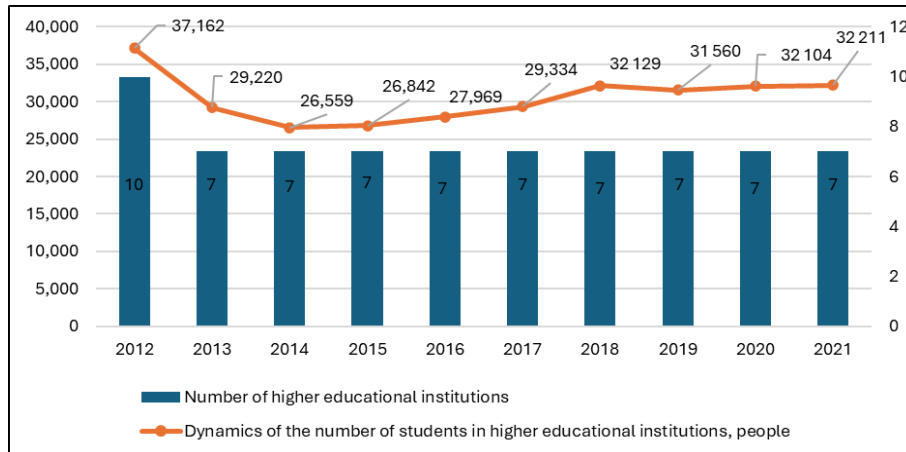


Fig. 6. Dynamics of the number of higher educational institutions and their number of students in them according to the East Kazakhstan region.

In 2021, 9.6 thousand students were enrolled in higher and postgraduate education institutions, which is 6.0% more than that in 2020 and 15.7% more than that in 2012. The admission of students to state educational institutions increased by 3.7% and that of private institutions increased by 8.6% (Fig 7). According to the State Department of Education of the East Kazakhstan region, about 50% of school graduates from the East Kazakhstan region attend universities in the region.

The dynamics of the number of students studying under state educational grants and paid educational services in organizations of higher and postgraduate education (OHPE) in the East Kazakhstan Region have shown positive growth over the past two years (2020 and 2021). The growth rate was 0.04% for students under the state educational grant and 7.99% for students at the expense of the population funds (for a fee). As for the total number of students receiving education at the expense of state educational grants, it was 10.6 thousand people, or 33.1%, studying on a paid basis – 21.5 thousand people (66.9%). The dynamics of graduates from public and private higher education institutions in the areas of training are shown in Table 4 (Bureau of National Statistics, 2023).

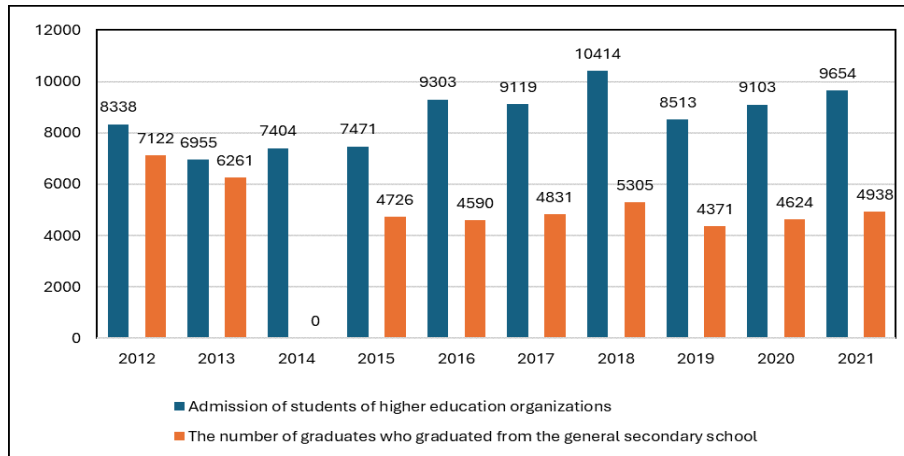


Fig. 7. Graduation from secondary schools and admission to universities in the East Kazakhstan region.

Data on the graduation of specialists in the areas of training in 2020 and 2021 in the East Kazakhstan region show an increase in the number of graduates in all areas of training, except 6B03 "Social Sciences, journalism, and computer science. According to data from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, more graduates are registered in the Pedagogical Sciences, Engineering, Manufacturing and Construction industries, and healthcare.

Table 4. Dynamics of specialist output in the areas of training

Areas of training	2020	2021
6B01 Pedagogical sciences	2166	3768
6B02 Arts and humanities	131	234
6B03 Social sciences, journalism and computer science	1250	1208
6B04 Business, management and law	1424	2257
6B05 Natural sciences, mathematics and statistics	106	281
6B06 Information and communication technologies	6	488
6B07 Engineering, manufacturing and construction industries	1777	3368
6B08 Agriculture and bioresources	191	378
6B09 Veterinary medicine	108	1185
6B10 Health and social security	1205	2572
6B11 Services	182	425
6B12 National security and military affairs	0	41

The increase in the number of state educational orders for technical areas has made engineering education more accessible but has reduced its status, since often the technical direction is chosen as an

additional alternative, according to the residual principle. In many technical areas, students qualify for a state grant of 50 points, while in some areas, grants are not mastered at all. An insufficient professional orientation leads to the choice of other directions. The status of an engineer is declining in general; this fact is confirmed by the research "Career Guidance in Kazakhstan".

With Jamovi software, we conducted a reliability and factor analysis of the factors identified as influencing the quality of engineering education in East Kazakhstan. A structured stakeholder survey involving 146 respondents (including university faculty members, students, and employees of industrial enterprises) served as the empirical basis.

Internal consistency of each factor was assessed using Cronbach's Alpha, with all values exceeding the minimum acceptable threshold of 0.70, indicating good internal reliability (Tavakol & Dennick, 2011). To explore the underlying structure and confirm the factor composition, Principal Component Analysis (PCA) with Varimax rotation was performed. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy exceeded 0.70, and Bartlett's Test of Sphericity was significant at $p < 0.001$, confirming the suitability of the data for factor analysis.

Table 5 presents the results of the analysis, including factor loadings for individual items, Cronbach's Alpha coefficients, and the percentage of explained variance for each component.

Table 5. Factor analysis and reliability results

Factor	Description	Cronbach's Alpha	Factor loading (EFA)	Explained variance (%)
Outdated teaching methodologies	Focus on factual knowledge, lack of practical and independent learning skills	0.875	0.812	18.5
Outmoded infrastructure	University facilities lag behind those of regional industries	0.881	0.827	19.2
Poor organization of practical training	Insufficient enterprise participation, lack of university funding	0.89	0.846	17.8
Limited access to advanced learning	Lack of opportunities for lifelong learning and gamification	0.887	0.834	17.5

The results confirm the multidimensional structure of the challenges in engineering education. Each factor demonstrated satisfactory internal consistency and contributed significantly to the overall explained variance (cumulative 78.3%). The strongest loadings were observed for infrastructure-related issues and outdated teaching methods, reflecting critical weaknesses in aligning educational programs with modern industrial requirements.

This validated structure supports the robustness of the survey instrument and the empirical relevance of the identified factors. These findings offer a reliable analytical foundation for policy recommendations aimed at enhancing the responsiveness and quality of regional engineering education.

To further interpret the systemic position of engineering education in the East Kazakhstan Region, a SWOT analysis was conducted. SWOT (Strengths, Weaknesses, Opportunities, and Threats) is a strategic planning tool widely used in educational research to identify internal and external factors influencing institutional development (Dyson, 2004). This method allows for the synthesis of both quantitative results and qualitative insights obtained from stakeholder surveys and expert evaluations.

In this study, the SWOT framework was constructed based on the triangulation of three sources: (i) validated factors obtained through exploratory factor analysis, (ii) expert opinions and narrative responses from the survey, and (iii) regional socio-economic and policy documents. This approach ensured both analytical depth and contextual relevance. The results of the SWOT analysis are presented in Table 6.

The SWOT analysis confirms that while the region possesses considerable institutional and human potential such as well-established technical universities and applied science capabilities, it also faces

significant infrastructural and demographic constraints. These include outdated educational resources, limited regional attractiveness, and declining interest in engineering programs. Simultaneously, increased industry engagement and the demand for Industry 4.0 skills create favorable conditions for targeted educational reforms. The findings underline the necessity of a systemic policy response that builds on existing strengths and emerging opportunities while addressing structural vulnerabilities and risks.

Table 6. SWOT Analysis of Engineering Education in East Kazakhstan

Strengths: • The presence of historically established technical universities in industrial areas. • A tradition of practice-oriented training for engineers. • Potential for applied research development through collaboration with key enterprises. • Broad prospective student base.	Weaknesses: • Underdeveloped socio-economic conditions in the region. • Outdated infrastructure in technical universities. • Declining interest in engineering programs among applicants.
Opportunities: • Growing industry participation in the education sector. • Internationalization of academic standards. • Increased investment in university research infrastructure. • Rising demand for industry 4.0-aligned engineering skills.	Threats: • The outmigration of skilled labor to urban centers. • Aging faculty in regional universities. • Potential mismatch between global educational trends and local institutional capacities.

The evidence gathered in this study underscores the crucial role of engineering education in enabling the industrial transformation of the East Kazakhstan Region. The consistent feedback from business representatives, such as the finding that 35% of enterprises are planning modernization in line with Industry 4.0, indicates rising expectations for the quality and applicability of engineering graduates' skills. Simultaneously, the observed time lag of two to three years for graduates to integrate into the workforce highlights a misalignment between educational outcomes and labor market readiness. The validated factor structure and SWOT analysis confirm that systemic constraints such as outdated infrastructure, limited digital integration, and declining research capacity continue to hinder the region's potential for high-tech growth. As global and local trends reshape industrial development, the regional education system must accelerate its adaptation to remain competitive and capable of retaining talent. These insights offer a robust analytical foundation for policy interventions aimed at strengthening the education industry nexus in Kazakhstan's industrial heartland.

CONCLUSION

The findings of this study highlight the need for engineering education in the East Kazakhstan Region to adapt to rapid technological progress, digitalisation and labour market changes associated with Industry 4.0. Despite policy-level efforts, structural and systemic barriers, such as outdated infrastructure, insufficient integration between academia and industry, and misaligned curricula, continue to limit the responsiveness of higher education to regional economic demands. The persistent discrepancy between employer expectations and graduate competencies underscores the necessity for the targeted modernisation of engineering programmes and career guidance systems. Empirical data and stakeholder feedback suggest that improving the alignment of educational outcomes with labour market requirements requires a multifaceted approach involving strengthened cooperation between universities and enterprises, updated curricula reflecting digital and interdisciplinary competencies, and effective monitoring of demographic and employment trends. While this research provides a valuable foundation for policy and academic

interventions, it has limitations. The study does not fully capture broader socio-economic and institutional influences, nor does it include a detailed labour market forecast or programme-level analysis. Nevertheless, its integrative approach offers practical insights into how regional universities can enhance their capacity to prepare graduates for high-value employment and sustainable industrial growth. In the context of globalisation and the growing demand for skilled engineers, agile and forward-looking education systems will be required over the next decade to produce professionals who are equipped to navigate complex real-world challenges.

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CONFLICT OF INTEREST STATEMENT

All authors declare that they have no conflicts of interest.

AUTHORS' CONTRIBUTIONS

The authors confirm their contributions to the paper as follows: study conception and design by Oxana Denissova, Assiya Mashekenova; data collection by Oxana Denissova, Saltanat Suieubayeva, Alfiya Zakimova; analysis and interpretation of results by Oxana Denissova, Saltanat Suieubayeva, Assiya Mashekenova, Rajermani Thinakaran; draft manuscript preparation by Oxana Denissova, Nik Roselina Nik Roseley. All authors reviewed the results and approved the final version of the manuscript.

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