

# Human Capital and Digital Education in Kazakhstan's Oil and Gas Sector

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**ABSTRACT:** The purpose of the study is to identify patterns of human capital development in the oil and gas region of Western Kazakhstan and to assess the adaptive potential of educational programs of technical universities in the context of the transformation of industry competencies. The paper uses methods of comparative and correlation analysis, SWOT assessment of educational programs, content analysis of labor market data and expert interviews with representatives of industry enterprises. The results of the study indicate that the share of programs focused on the development of digital and environmental competencies is less than 35%. According to employers, graduates' qualifications do not fully meet modern production requirements. At the same time, there is a positive trend in the development of the areas of "digital engineering" and "automation of technological processes". The identified trends reflect not only structural changes in the field of education, but also deeper institutional shifts related to the digitalization of the economy. This contradiction between the supply and demand of personnel is due to the slow updating of educational standards and insufficient involvement of business in the development of training programs. The constructed model of the relationship between the level of digitalization of education and the quality of human capital made it possible to identify priority development trajectories until 2035: robotic systems, data management, energy-efficient technologies and sustainable production. The scientific novelty of the research lies in the proposal of an integrative model for analyzing the human capital of the oil and gas region, taking into account the digitalization of education and the sectoral characteristics of the regional labor market

The results of the study can serve as a basis for the development of transformational models of engineering education in other resource regions of Central Asia.

**Keywords:** human capital; labor market; digital transformation; new professions; modernization of the personnel training system.

## I. INTRODUCTION

The modern global economy is undergoing profound transformations related to the transition to digital technologies, "green" energy and a new architecture of human resources. Human capital comes to the fore a set of knowledge, competencies, skills and innovative potential that determine a society's ability to adapt to technological and social changes [1, 2]. For resource-based economies, where the oil and gas industry plays a key role, human capital becomes not only a factor of economic growth, but also a condition for the sustainable development of regions in the long term. In Kazakhstan, the formation of human capital in oil and gas regions is of particular importance. Western Kazakhstan accounts for the bulk of oil and gas production, the largest fields (Tengiz, Karachaganak, Kashagan) and the leading industrial centers Atyrau, Aktobe, Aktau and Uralsk. At the same time, the region is facing a contradiction: on the one hand, there is a growing need for a new generation of engineering and technical personnel capable of working with automated systems, data analysis and digital technologies; On the other hand, there remains a structural discrepancy between the demands of enterprises and the training system [3, 4]. It should be emphasized that the transformation of competencies in the oil and gas industry requires not only the modernization of educational standards, but also a revision of the very logic of interaction between universities and business.

The competencies of the oil and gas industry are rapidly transforming. If mechanical and mining skills were key in the early 2000s, today digital engineering solutions, environmental management, industrial analytics, and project management in the field of sustainable development are coming to the fore [5]. By adopting the Digital Kazakhstan strategy and the industrialization program until 2030, Kazakhstan has identified a priority for the transition to a knowledge economy. However, the staffing base, especially in the regions, does not yet fully reflect these changes [6]. Modern concepts of human capital include not only knowledge and skills, but also psychological stability, motivation, and professional well-being of education and science workers. Psychological and pedagogical conditions for the prevention of burnout among teachers of technical universities are an important element of the sustainable development of the region's human resources potential. Systematic activity in these areas reduces the degree of professional stress, prevents the development of emotional exhaustion and professional deformation, and increases the level of engagement and job satisfaction. Together, these measures contribute to the preservation and strengthening of human capital in the field of higher education in the region, ensuring the sustainable development of human resources and improving the quality of training specialists for the main sectors of the economy [7-9].

Thus, the relevance is due to the need for a systematic analysis of the mechanisms of formation and development of human capital in the oil and gas region, taking into account digitalization, innovative transformations and regional characteristics of the labor market. The research is based on the theory of human capital, the concept of a "learning organization" [10], the competence approach model [11]), as well as the principles of scenario forecasting of regional development [12]. The work takes into account the provisions of the theory of innovation systems [13] and the model of the "triple helix" of interaction between universities, business and the state [14], which allows us to consider education as a driver of the formation of human capital and the innovative potential of the region. The empirical base of the study includes: statistical data from the Ministry of Labor and Social Protection of the Population of the Republic of Kazakhstan, the Ministry of Science and Higher Education of the Republic of Kazakhstan for 2018-2024; analytical reports from international organizations (OECD, World Bank, WEF, Deloitte, IFC); results of content analysis of educational programs of three leading technical universities in Western Kazakhstan:

Atyrau University of Petroleum West Kazakhstan Technical University, Aktobe Regional University; interviews with representatives of HR services of oil and gas sector enterprises.

The problem of the shortage of qualified specialists in the oil and gas industry of Western Kazakhstan is systemic. According to the Ministry of Labor of the Republic of Kazakhstan, more than 60% of graduates of technical specialties are not employed in the profile in the first year after graduation. The main reasons are outdated curriculum content, weak integration of digital disciplines, and limited participation of employers in the formation of educational standards. There remains a significant gap between the regions in terms of human capital, while in Atyrau and Aktau the share of specialists with engineering education and experience in digital systems exceeds 20%, in Aktobe and Uralsk this figure is below 10%. Such differences create a risk of concentration of human resources and increase territorial imbalances in the development of the region [15]. Despite the growing body of research on human capital development, existing studies predominantly focus on national-level indicators or individual labor market outcomes, often without accounting for regional specificity in resource-dependent economies. Moreover, the digitalization of technical education is rarely integrated into analytical frameworks assessing human capital in oil and gas regions. As a result, there is a lack of multilevel, region-specific models that explicitly link education digitalization, institutional coordination, and regional labor market dynamics. This research addresses this gap by proposing an integrated analytical framework tailored to the oil and gas regions of Western Kazakhstan.

Unlike existing approaches that treat human capital primarily as an individual attribute, this study conceptualizes human capital as a systemic outcome shaped by digital infrastructure, institutional interaction, and regional industrial specialization. Digitalization fundamentally reshapes human capital logic by transforming skill formation processes, accelerating knowledge renewal, and increasing workforce adaptability in technology-intensive oil and gas regions.

The purpose of the study is to comprehensively analyze the dynamics of human capital development in the oil and gas region of Western Kazakhstan, assess the compliance of educational programs with industry requirements and develop recommendations for improving the effectiveness of personnel training. To achieve this goal, the study solves the following tasks: to assess the current state of human capital and the labor market in the region; to compare the structure of educational programs of technical universities with modern professional standards; identify the factors influencing the development of human capital in the context of digitalization; create scenario forecasts of staffing needs until 2035; develop practical recommendations for universities, government agencies and employers.

The scientific significance of the study lies in the fact that for the first time a model for analyzing the human capital of the oil and gas region is proposed, based on an interdisciplinary approach a combination of economic, educational and technological parameters. The practical value lies in the possibility of applying the developed provisions in the strategic planning of personnel policy, the modernization of educational standards and the formation of regional sustainable development programs. The research results can be used in the development of government strategies in the field of education and employment, the formation of partnerships between universities and enterprises, as well as in the creation of digital platforms for monitoring competencies. This will ensure that professional training is synchronized with the real needs of the oil and gas industry and accelerate the region's integration into the knowledge economy. Thus, the further presentation of the work is devoted to the disclosure of the theoretical and methodological foundations of the study, the description of the empirical base and the analysis of the results obtained. The formulation of the research hypotheses is grounded in established theoretical frameworks. Human capital theory explains the role of education and competencies as key drivers of productivity and employment outcomes. Endogenous growth theory [16] emphasizes knowledge and innovation as internal sources of regional economic development. In addition, the Triple Helix model highlights the systemic interaction between universities, industry, and government, which is particularly important for resource-based regions. These theoretical perspectives provide the conceptual foundation for the hypotheses formulated in this study.

Despite the growing body of research on human capital and regional development, existing studies predominantly focus either on national-level indicators or on isolated institutional dimensions. There

remains a lack of region-specific, multilevel analyses that explicitly integrate the digitalization of education into human capital assessment, particularly in resource-dependent oil and gas economies. Despite extensive research on human capital development, existing studies predominantly address national-level dynamics or focus on isolated institutional factors without considering regional specificity. In particular, oil and gas regions remain underrepresented in empirical research, despite their structural dependence on technical education systems and rapid technological transformation. Moreover, the role of education digitalization as a mediating mechanism between institutional quality and labor market outcomes has not been sufficiently explored. This study addresses this scientific gap by proposing a region-specific, multilevel analytical framework that captures the interaction between digitalization, institutional coordination, and human capital outcomes in oil and gas regions.

The aim of this study is to analyze the dynamics of human capital development in the oil and gas region of Western Kazakhstan by integrating educational digitalization indicators into a multilevel analytical framework. The objectives of the study include: (i) assessing regional labor market trends; (ii) evaluating the digitalization of technical education programs; (iii) identifying institutional factors influencing human capital outcomes; and (iv) developing scenario-based forecasts for human capital development. The scientific contribution of this research lies in the development of a region-specific, multilevel model that explicitly links education digitalization, institutional coordination, and labor market outcomes in a resource-dependent economy.

The scientific novelty of this study lies in the development of a region-specific, multilevel analytical framework for assessing human capital in oil and gas regions. Unlike previous studies that predominantly examine human capital at a single level or focus on national indicators, this research integrates education digitalization indicators into a three-level model encompassing individual, institutional, and regional dimensions. The proposed framework explicitly accounts for the structural characteristics of resource-dependent economies and demonstrates how digital transformation of technical education reshapes human capital development in oil and gas regions of Kazakhstan.

## II. LITERATURE REVIEW

The concept of human capital, firmly rooted in the economic theory of the 20<sup>th</sup> century, reflects the qualitative characteristics of labor resources that determine their ability to create economic and social value. In the classical works of T. Schultz [17] and G. Becker, human capital is interpreted as a set of knowledge, skills and abilities acquired through education, professional training and experience. These authors have shown that investments in humans bring returns comparable to investments in physical capital. At the next stage of the concept's development, within the framework of the endogenous theory of growth [18], human capital is considered as an independent factor of economic development. Unlike classical models, where knowledge was an external element, the endogenous paradigm asserts that it is the internal processes of competence accumulation that form long-term growth trajectories. This theoretical shift has played a key role in shaping the modern understanding of human capital as a dynamic, reproducible resource that depends on the institutional environment.

Modern research [19] highlights that in the 21st century, human capital goes beyond a narrow economic understanding and includes digital, creative and environmental competencies. In the context of the transition to the fourth industrial revolution, the ability of the workforce to adapt to technological changes is becoming the main predictor of the competitiveness of national economies. This adaptive component of human capital determines the success of commodity-oriented countries seeking economic diversification. For Kazakhstan, especially for its western regions, this trend is of strategic importance. The oil and gas industry remains systemically important, but its sustainability increasingly depends on human capital capable of integrating engineering, digital and ESG knowledge. Thus, the classical theory of human capital is complemented by the context of digitalization, global energy shifts and regional specifics of resource economies. Summarizing the key stages of the concept's development, we will consider the main approaches to the study of human capital (Table 1).

**Table 1.** Main approaches to human capital research.

Approach	Studies	The conceptual essence	Significance for research	Limitations
Economic theory of human capital	Becker, Schultz	Human capital is the result of investments in education that increase productivity.	It allows us to evaluate the effectiveness of investments in personnel training.	It does not sufficiently take into account the institutional and regional context.
Endogenous growth theory	Romer, Lucas	Accumulation of knowledge and innovations creates internal sources of development.	Explains the role of education in shaping the region's innovative potential.	Difficult to apply to resource-based economies.
The concept of a learning organization	Argyris & Schön	Organizations develop through training and adaptation.	Describes the mechanisms for developing competencies in universities and companies.	It takes little account of the role of the state and the external environment.
The Triple Helix model	Etzkowitz & Leydesdorff	Universities, businesses, and the government are creating an innovative ecosystem.	Provides an institutional framework for analyzing human capital.	Requires a high level of cross-sectoral coordination.
Theory of regional innovation systems	Cooke, Lundvall	The development of regions is determined by innovative infrastructure and knowledge.	Takes into account spatial differences in human capital levels.	Needs detailed regional data.
Digital and ESG paradigms	WEF, Deloitte	New technologies and sustainable development are shaping the competencies of the future.	Defines the directions of modernization of education.	At risk of rapid obsolescence of technological requirements.

Source: compiled by the authors based on data from the OECD, WEF, and Deloitte.

A comparative analysis of the approaches shows that each of the presented approaches reveals the nature and role of human capital in its own way, but none of them provides an exhaustive explanation of the processes of its formation and use in the context of a resource-oriented and simultaneously digitalizing economy of Kazakhstan. First, the economic theory of human capital (Becker, Schultz) laid the foundation for analyzing the relationship between education and labor productivity. Its key contribution is the recognition of human investment as a source of economic growth. However, this theory does not take into account institutional and spatial differences, which limits its applicability to the regional level of analysis, especially in oil and gas territories, where access to educational opportunities and innovations is heterogeneous. Secondly, the endogenous theory of growth (Romer, Lucas) focuses on the accumulation of knowledge as an internal factor of development. This approach is particularly valuable in exploring the role of education and innovation in the sustainable growth of regions. However, in an economy dominated by raw materials industries, the potential for endogenous growth is often limited by structural dependence on external investment and technology. Thirdly, the concept of a learning organization shifts attention from the macro level to the organizational one, revealing the mechanisms of self-learning and adaptation of enterprises and universities.

This area is of practical importance for Kazakhstan, as it describes how educational institutions and companies in the oil and gas sector can increase their resilience and flexibility in the face of digital transformation. Fourth, the triple helix model demonstrates the need to integrate three key actor's universities, business, and government. This approach allows us to consider human capital as a result of

systemic interaction, and not just as an individual characteristic. However, the implementation of this model in Kazakhstan requires an increased level of intersectoral coordination and institutional maturity. Fifth, the theory of regional innovation systems (Cooke, Lundvall) introduces a spatial dimension of analysis, explaining why regions with comparable resources and infrastructure show different dynamics of human capital development. This approach is important for understanding the regional specifics of Western Kazakhstan, where the concentration of innovation activity and the skill level of personnel vary between regions.

Despite the growing body of literature on human capital development, several important gaps remain. Existing studies predominantly focus on national-level indicators, single institutional dimensions, or generalized labor market outcomes, often without accounting for regional specificity in resource-dependent economies. Moreover, the digitalization of technical education is rarely integrated into human capital assessment frameworks, particularly in the context of oil and gas regions. There is a lack of multilevel, region-specific models that explicitly link education digitalization, institutional coordination, and labor market outcomes. This study addresses these gaps by proposing an integrated analytical framework tailored to oil and gas regions, with empirical evidence from Western Kazakhstan.

Finally, the digital and ESG paradigms (WEF, Deloitte) form the modern trend in the development of human capital theory. They emphasize the need to integrate digital competencies, environmental responsibility, and principles of sustainable development into the education and training system. These approaches ensure the relevance of the analysis in the context of global technological and climatic changes. Thus, the comparative analysis shows that a comprehensive study of the human capital of the oil and gas region of Kazakhstan requires the integration of several theoretical frameworks. Only the combination of economic, institutional, organizational and digital logic makes it possible to reveal the multidimensional nature of human capital and assess its impact on the innovative development of the region. Based on the above, in the framework of this study, it is advisable to rely on a combination of classical and modern theoretical approaches that provide a systematic understanding of human capital in the context of the transformation of the oil and gas economy. The next section will substantiate the choice of these methodological foundations as the most relevant for analyzing the relationship between education, innovation and regional development in Western Kazakhstan.

The choice of the methodological framework of the study is conditioned by the need for a comprehensive analysis of the interrelationships between education, the labor market and the innovative development of the oil and gas region. First, the economic theory of human capital (Becker, Schultz) forms the foundation for assessing the return on investment in education and identifying structural imbalances. In the context of Kazakhstan, this approach makes it possible to analyze the effectiveness of engineering training and the degree to which educational programs meet business requirements. Secondly, the endogenous theory of growth (Romer, Lucas) expands the understanding of the role of knowledge as an internal source of innovation. For Western Kazakhstan, where large companies with foreign capital dominate, but the potential for local innovation is limited, this theory provides a key to understanding the barriers to sustainable development. Thirdly, the concept of a learning organization allows us to consider universities and oil and gas companies as interconnected learning systems capable of self-renewal. The application of this concept is especially important when analyzing the flexibility of educational programs and the ability of enterprises to form their own personnel trajectories.

Fourthly, the triple helix model sets a systematic format for interaction between universities, business and the state, which is especially important for Kazakhstan, where such coordination is still fragmentary. Finally, the theory of regional innovation systems (Cooke, Lundvall) makes it possible to explain the differences between the oil and gas centers of Western Kazakhstan Atyrau, Aktau, Aktobe and Uralsk through the prism of heterogeneity of knowledge and innovation infrastructure. The modern oil and gas sector faces a number of specific challenges that have a significant impact on the development of human capital and the efficiency of the regions: Lack of digital competencies despite the active introduction of digital technologies and process automation, most specialists lack the skills to work with modern IT systems,

analytics platforms and industrial digital tools. This reduces the competitiveness of the regional workforce and limits the ability of enterprises to innovate;

The increasing demands on environmental and social responsibility of companies create new standards of work. Regional enterprises should adapt processes and prepare employees for new tasks related to environmental monitoring, safety and sustainable development. The remoteness of some oil and gas regions from major centers and the uneven distribution of educational and infrastructural resources create additional barriers to the formation of qualified human capital. Differences in the level of digitalization, access to education and jobs exacerbate socio-economic imbalances. These challenges underscore the need for an integrated approach to human capital development that takes into account not only traditional educational and organizational aspects, but also digital competence, sustainable development, and regional specificities.

Analytical generalization and synthesis of concepts Modern research highlights the need to move from linear models of human capital to networked and adaptive ones, where the key element is the interaction of actors the state, business, universities and society. The triple helix model organically combines investment and institutional aspects, demonstrating that the sustainable development of the region is impossible without the synergy of educational and innovation systems. Of particular importance is the digital and ESG paradigm, which forms a new dimension of human capital the digital-intellectual potential. This category reflects the integration of technological and ethical competencies, which is especially important for the oil and gas sector, which is under pressure from decarbonization and digital trends. Thus, it can be assumed that in the oil and gas regions of Kazakhstan, the development of human capital is not so much a consequence of investments as a result of the quality of interaction between institutions, their ability to adapt to external challenges and maintain innovative dynamics.

Formulation of the research model and hypotheses Based on the theoretical framework, a three-level model of human capital in the oil and gas region is proposed (Figure 1). The structure of the proposed analytical model is grounded in established theoretical frameworks. Human capital theory informs the individual level of the model, where competencies, qualifications, and digital skills determine employment and productivity outcomes. The institutional level is based on the Triple Helix model, emphasizing the role of universities, industry, and government interaction in shaping educational quality and workforce relevance. The regional level draws on the theory of regional innovation systems [20], which explains how spatial concentration of knowledge, infrastructure, and institutional coordination influences human capital development in oil and gas regions.

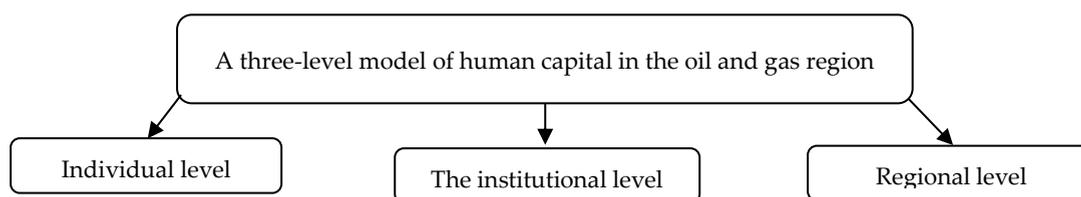


FIGURE 1. Analytical three-level model of human capital development in the oil and gas region.

The three-level framework presented in Figure 1 is specifically designed to reflect the structural characteristics of oil and gas regions. At the individual level, the model captures the competencies, digital skills, and employment outcomes of graduates. The institutional level reflects the role of universities as key actors in shaping human capital through educational programs, digital infrastructure, and industry collaboration. At the regional level, the model incorporates labor market conditions, industrial specialization, and policy environment. Such regions are characterized by high capital intensity, strong institutional coordination, and a high dependence on regional infrastructure and resource-based industries. Therefore, a multilevel analytical approach is required to adequately capture the complexity of human capital formation in oil and gas regions.

The proposed analytical framework is based on explicit causal pathways linking digitalization, institutional quality, and human capital outcomes. Digitalization of technical education enhances the content, delivery methods, and relevance of educational programs, which directly improves the quality of training. Improved program quality leads to higher levels of graduate competencies, digital skills, and adaptability to technological change. These individual-level outcomes translate into improved employment prospects and labor productivity, which, at the regional level, contribute to the accumulation and effective utilization of human capital in oil and gas regions.

The model specifies the directional relationships between key variables across individual, institutional, and regional levels. At the institutional level, the digitalization of educational programs, measured by the Index of Digitalization of Technical Education (ICTE), influences the formation of graduate competencies at the individual level. These competencies, in turn, directly affect labor market outcomes, including employment, adaptability, and productivity. At the regional level, aggregated labor market outcomes contribute to overall human capital development in the oil and gas region.

Institutional coordination between universities, industry, and government, conceptualized through the Triple Helix framework, acts as a moderating mechanism that strengthens the relationship between education digitalization and labor market outcomes by enhancing feedback loops and increasing the effectiveness of human capital development processes.

- Individual level: competencies, qualifications, digital literacy, innovativeness;
- Institutional level: the quality of educational programs, forms of partnership between universities and businesses;
- Regional level: investments in education, innovation clusters, digitalization of the economy.

The model assumes that the consistency of these levels is a key condition for the sustainable development of human capital. Based on this, hypotheses are formulated: **H1**. The higher the level of digitalization of the educational programs of technical universities, the higher the rate of human capital development in the oil and gas region. **H2**. The degree of integration of universities, business and the state positively correlate with the compliance of graduates' competencies with the requirements of the industry. **H3**. The development of human capital is determined not only by the volume of investments, but also by the institutional maturity and degree of digitalization of regional innovation systems. The review showed that the evolution of the concept of human capital reflects the transition from an economic to an institutional and innovative understanding. The synthesis of economic, educational and digital factors is becoming crucial for the resource regions of Kazakhstan. The integration of these elements can provide not only quantitative, but also qualitative renewal of human capital, ensuring sustainable growth and innovative adaptation of the oil and gas complex.

### III. DATA AND METHODOLOGY

This study employs a mixed-methods research design combining quantitative and qualitative approaches. The quantitative component is based on cross-sectional regional and institutional data for the period 2018–2024, while the qualitative component relies on expert interviews and content analysis. This design enables methodological triangulation and enhances the robustness of the findings. The study follows a mixed-methods research design combining cross-sectional quantitative analysis of regional and educational indicators (2018–2024) with qualitative expert interviews to ensure methodological triangulation.

Research design and conceptual foundations. The methodological design of this study is based on an interdisciplinary approach that integrates economic, educational, and institutional dimensions of human capital analysis. This integration allows competencies to be examined not as a linear process of knowledge accumulation, but as a systemic outcome of a regional ecosystem that includes education, the labor market, innovation environment, and public policy. The study assumes that the quality of human capital depends not only on the level of education, but also on the effectiveness of cooperation between universities, enterprises, and government agencies. Accordingly, the dynamics of human capital in the oil and gas sector

are considered as a function of institutional coordination and the system's capacity to adapt to technological change. Methodologically, the analysis relies on several complementary theoretical approaches reflecting different analytical levels.

- The theory of human capital explains the economic efficiency of investments in education and training, allowing measuring the return on educational investments in the form of productivity and income growth.
- Endogenous growth theory [21] focuses on knowledge and innovation as internal sources of regional development, which is especially important for Western Kazakhstan, where key growth drivers are formed not from outside, and as a result of the accumulation of competencies within the region.
- The concept of a learning organization considers universities and industrial enterprises as self-developing structures capable of constantly updating competencies under the influence of technological changes [22].
- The Triple Helix model reveals the interaction between universities, business and the state as a mechanism for the formation of an innovative environment and human resources.
- The approach of regional innovation systems allows taking into account spatial differences in knowledge accumulation and explains why certain regions have a concentration of competencies and a higher level of innovation activity. These approaches are not applied in isolation, but are integrated into a single analytical framework, which provides a comprehensive perception of the processes of human capital formation.
- Modern empirical research in the oil and gas industry [23, 24] confirms the need to integrate economic, managerial and educational factors in assessing human capital development, emphasizing the relevance of institutional and digital components.

## 1. THE APPROACHES ENSURE SYSTEMATIC ANALYSIS OF HUMAN CAPITAL FORMATION

In oil and gas regions with a high industry concentration, isolated econometric models are insufficient. They are unable to take into account the institutional, cultural and technological features of the industry. The theory of human capital makes it possible to identify quantitative relationships between investments in education and labor productivity growth. The endogenous growth theory explains how the accumulation of knowledge and innovation helps to reduce the region's dependence on external factors and diversify the economy. The concept of a learning organization and the triple helix model make it possible to consider the personnel training process as a continuous feedback loop between universities and industry. And the innovation systems approach expands the analysis by taking into account spatial differences, institutional barriers, and social capital.

These theoretical frameworks form the methodological framework of the study, providing the opportunity to interpret human capital as a multilevel system from individual competencies to institutional structures. This approach allows not only to assess the current state, but also to identify the factors determining the sustainability of the region's human resources potential in the long term. The combination of these theoretical frameworks makes it possible to move from a conceptual level to an empirical analysis. Consequently, the research methodology is focused not only on verifying statistical relationships, but also on identifying the institutional mechanisms through which human capital is formed. This approach provides a holistic view of the problem from macroeconomic patterns to practical tools of regional policy.

## 2. THE EMPIRICAL STUDY IS STRUCTURED INTO THREE ANALYTICAL BLOCKS

### 2.1. Statistical and documentary sources

The empirical part of the study is based on the analysis of quantitative and qualitative data for the period 2018-2024, which provides an opportunity to track the medium-term dynamics of human capital transformation in the context of digitalization and industrial modernization. The main sources of information were: Ministry of Labor and Social Protection of the Population of the Republic of Kazakhstan employment indicators, structure of demand for specialists, level of professional inconsistencies; Ministry of Science and Higher Education of the Republic of Kazakhstan data on educational programs, admission and graduation rates, the proportion of technical specialties, the availability of dual and practice-oriented education; Bureau of National Statistics of the Republic of Kazakhstan macroeconomic indicators (regional GRP, labor

productivity, investments in human capital, employment by industry); International sources (OECD, World Bank, WEF, Deloitte, PwC Kazakhstan) indices of competitiveness, digital readiness and innovation activity. To ensure comparability, all quantitative data has been normalized and adjusted to constant prices in 2023. The use of standardized z-indicators made it possible to eliminate regional scale differences and identify real development trends. The set of selected methods reflects the multilevel structure of the research objectives, from identifying statistical dependencies to interpreting institutional mechanisms for the development of human capital.

For international comparisons, only harmonized indicators provided by OECD, World Bank, and WEF were used, ensuring comparability across countries despite differences in national statistical definitions. In total, the analysis includes more than 250 indicators for four regions of Western Kazakhstan (Atyrau, Mangystau, Aktobe and West Kazakhstan regions), which ensured the representativeness and reliability of the conclusions. A sensitivity analysis was conducted by varying the weights of ICTE components within reasonable ranges, confirming the stability of the correlation results.

**Table 2.** Summary of data sources, indicators, and units of analysis.

Data source	Indicator	Years	Unit of analysis
Ministry of Labor and Social Protection of the Population of the Republic of Kazakhstan	Graduate employment rate, labor market indicators	2018–2024	Region (Western Kazakhstan)
Ministry of Science and Higher Education of the Republic of Kazakhstan	Enrollment data, number of graduates, educational programs	2018–2024	University / Region
OECD	Human capital and education indicators	2018–2024	Country / Region
World Bank	Labor market and innovation indicators	2018–2024	Country
World Economic Forum	Digital skills and innovation indicators	2018–2024	Country
University official websites and curricula	Digitalization level of educational programs (ICTE components)	2018–2024	University
Expert interviews	Qualitative assessments (SWOT)	2023–2024	Organization

Note: Index of Curriculum Technological Embeddedness (ICTE).

All data sources used in the study are publicly available, except for expert interview materials, which were collected in accordance with ethical research standards.

### 2.2. Content analysis of educational programs

The study pays special attention to the educational programs of technical universities in Western Kazakhstan, as they form the basis of the human resource potential of the oil and gas industry. The analysis covered 72 bachelor's and master's degree programs from three leading universities in the region: Atyrau University of Oil and Gas named after S. Utebayev (Atyrau Oil and Gas University named after S. Utebayev); West Kazakhstan Technical University named after Zhangir Khan University; Aktobe Regional University named after K. Zhubanov (Zhubanov University). Each program was analyzed according to five criteria (Figure 2).

Figure 2 shows that according to criteria such as the proportion of disciplines related to digital and engineering technologies (automation, AI, data analysis); the presence of ESG components and elements of sustainable development; the amount of practical training (internships, laboratory modules, dual training); the participation of employers in the development of curricula; interdisciplinarity and connection with

international educational standards. In addition, the analysis took into account the availability of modules aimed at developing mentoring skills, managerial and communication competencies that enhance the integration of young professionals into the professional environment. Based on the analysis, the Index of Digitalization of Technical Education (ICTE) was created, which quantifies the degree of adaptation of universities to the requirements of Industry 4.0. This index was subsequently used for correlation analysis with the indicators of graduate employment and labor productivity in the region. The content analysis was conducted using a structured coding procedure. Each educational program was independently reviewed based on predefined criteria related to digitalization, ESG integration, practical training, employer involvement, and interdisciplinarity. For each criterion, binary and ordinal codes were assigned depending on the presence and depth of relevant modules in the curriculum. To ensure consistency, coding guidelines were developed prior to the analysis, and ambiguous cases were jointly discussed by the authors. The resulting codes were aggregated to construct the ICTE index, allowing for comparability across universities and regions.

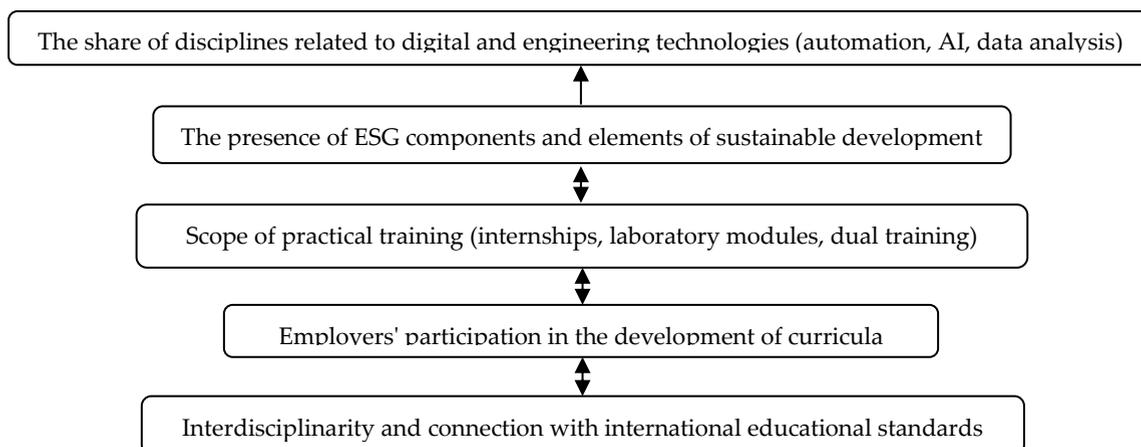


FIGURE 2. Criteria for oil and gas research programs at major universities in western Kazakhstan.

The ICTE index was constructed using content analysis of university curricula and official program documentation, focusing on digital, technological, and ESG-related components. The coding process was conducted independently by two researchers, with discrepancies resolved through discussion to ensure consistency. This approach ensured the reliability and comparability of the ICTE values across institutions.

### 2.3. Expert interviews

To supplement the statistical data and obtain qualitative interpretations, 15 semi-structured interviews were conducted with representatives of industry, the academic community, and government agencies. The interview results were used in the verification of quantitative data. The sample included heads of HR services of oil and gas companies, heads of departments, directors of career departments and experts in the field of regional policy. The interview analysis was conducted using the methods of thematic coding and content analysis. As a result, the authors identified the key categories: (i) institutional barriers to interaction between universities and enterprises; (ii) insufficient integration of digital modules into educational programs; (iii) lack of new generation engineering competencies; (iv) limited involvement of business in the development of curricula; (v) weak correlation between academic and practical skills of graduates. The interviews confirmed the existence of a systemic gap between the structure of personnel training and the demands of the industry, which made it possible to clarify the interpretation of quantitative results and form a more complete picture of the state of the region's human capital. The sample size was considered sufficient to

achieve thematic saturation, as recurring patterns and consistent expert positions emerged across interviews from different institutional groups.

### 3. METHODS OF DATA PROCESSING AND ANALYSIS

The research is based on a combination of quantitative and qualitative methods, which made it possible to ensure both statistical reliability and meaningful depth of analysis.

- Comparative analysis was used to identify differences between the regions of Western Kazakhstan in terms of skill levels, employment, and digitalization of education. To achieve the objectives of the study, a set of complementary methods was used to ensure quantitative accuracy and qualitative interpretation of the results obtained.
- Correlation analysis was used to determine statistically significant links between the level of digitalization of educational programs (according to the ICTE index) and graduate employment rates.

To examine the relationships between digitalization indicators, the ICTE index, and labor market outcomes, correlation analysis was conducted using the Pearson correlation coefficient. The analysis focused on identifying linear associations between the level of digitalization of educational programs and graduate employment rates in the oil and gas region. The inclusion of digitalization and ESG-related modules in the analytical framework is methodologically justified by the structural transformation of the oil and gas sector. Digital competencies are increasingly critical due to the adoption of Industry 4.0 technologies, automation, and data-driven production processes. At the same time, ESG requirements shape workforce demand through environmental regulation, occupational safety standards, and corporate sustainability strategies. In oil and gas regions, these factors directly influence the content and quality of technical education programs, making digitalization and ESG integration essential components of human capital development.

- SWOT analysis allowed us to systematize the strengths and weaknesses of the regional personnel training system, identifying key opportunities and threats associated with technological transformations.

The qualitative component of the study was implemented through expert interviews and SWOT analysis to systematize the strengths and weaknesses of the regional personnel training system, as well as to identify key opportunities and threats associated with technological transformation. The expert study involved 15 specialists representing HR departments of oil and gas companies, management of technical universities, and regional education authorities. Experts were selected using purposive sampling based on professional experience (at least seven years), involvement in workforce development or educational program implementation, and direct interaction with the regional labor market. The SWOT analysis was conducted in a qualitative format using semi-structured interviews and a unified interview guide to ensure consistency and reproducibility. Expert assessments were grouped into thematic categories and aggregated using frequency-based thematic analysis, which made it possible to identify stable and recurring expert positions. The qualitative findings were used to complement and validate the results of the quantitative analysis.

- The content analysis of educational programs and interviews provided a qualitative interpretation of the revealed patterns.
- Scenario forecasting methods were used to model possible trajectories of human capital development in the region until 2035, taking into account the level of digital integration, innovation activity and coordination between actors. To ensure the reliability of the results, methodological triangulation was used a comparison of conclusions obtained by different methods and from different sources. This made it possible to minimize sampling errors and ensure the stability of data interpretation. Multiple linear regression was used to assess the impact of factors (financing, employer participation, and the level of digitalization) on employment rates. Statistical data processing was performed using the SPSS Statistics 27 and Stata 17 packages, and visualization was performed in Microsoft Power BI and Excel. Such a toolkit ensured reproducibility of the results and the possibility of constructing visual comparative diagrams.

Scenario forecasting was applied to model alternative trajectories of human capital development in the oil and gas region until 2035. Three scenarios were constructed: baseline, optimistic, and inertial. The baseline scenario assumes the preservation of current trends in educational modernization and employer involvement. The optimistic scenario reflects an increase in investment in education, deeper integration of

digital technologies, and strengthened university–industry cooperation. The inertial scenario is based on minimal institutional changes and slow adaptation of educational programs to technological requirements. The scenarios were compared using key indicators of human capital development, including graduate employment rates, digital competence levels, and regional labor market balance.

The study has a number of limitations. First, some of the statistical data for individual regions is presented with a time lag, which may affect the accuracy of inter-regional comparisons. Secondly, the index of digitalization of educational programs ICTE is based on a content analysis of curricula, which implies an element of subjective interpretation. Finally, expert interviews, although they provide deep qualitative insights, do not fully reflect the position of all industry participants. These limitations do not reduce the reliability of the results, but set the direction for further research. Thus, the research methodology combines macroeconomic, institutional and educational levels of analysis, providing a holistic understanding of the dynamics of human capital in the oil and gas region. A systematic approach based on a combination of the theory of human capital, the triple helix model and the principles of a learning organization allowed us to consider human capital not only as a result of educational processes, but also as a strategic resource for regional development. The data obtained and the applied methods form the basis for the subsequent analytical section, which will provide an empirical justification for the relationship between the quality of educational programs, the structure of the labor market and the prospects for the development of human capital in Western Kazakhstan in the context of digitalization and energy transition. A comprehensive combination of quantitative and qualitative methods makes it possible to adequately assess the complex nature of human capital in the oil and gas sector. Such a methodology makes it possible not only to describe the current state, but also to form practical guidelines for the modernization of the educational and innovation policy of the region. The presented methodological and empirical foundations provide a solid foundation for analyzing the dynamics of human capital in the oil and gas region of Western Kazakhstan. The following section presents the results of modeling and statistical evaluation of the relationships between education, employment and innovation.

The analysis of empirical data has shown that the human capital of the oil and gas region of Western Kazakhstan is in the stage of deep transformation. Despite positive quantitative trends, growth in employment, productivity, and employer participation, qualitative aspects related to digital and engineering competencies are still being formed unevenly [25]. As a result, there is a contradiction between the dynamics of the labor market and the speed of adaptation of the educational system. For a comprehensive assessment of these processes, a multi-level analysis was conducted, including comparative, correlation, institutional and forecast components, which allowed us to identify not only current trends, but also factors determining the potential for human capital development on the horizon until 2030 [26]. To identify regional features, we will analyze the dynamics of human capital and the labor market. in the oil and gas region of Western Kazakhstan for 2018-2024 (Table 3).

**Table 3.** General dynamics of human capital and labor market in western Kazakhstan for 2018-2024.

Indicator	2018	2020	2022	2024
Share of employees in the oil and gas sector, % of total employment	28,4	30,1	31,7	32,5
Unemployment rate among graduates of technical universities, %	14,6	13,2	11,4	10,1
Average labor productivity, thousand tenge/person	13 250	14 180	15 820	17 450
Share of graduates employed in their field, %	47,3	51,8	57,4	63,2
Level of employer participation in educational programs, %	18,2	24,5	29,1	36,8

Source: compiled by the authors on the basis of data from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms, the Ministry of Labor and Social Protection, the Ministry of Education and Science of the Republic of Kazakhstan.

There is a steady positive trend in most indicators, which indicates a gradual strengthening of the region's human resources potential. The increase in labor productivity (+31.7%) is mainly due to technological modernization of enterprises and an increase in the number of specialists with technical education [27]. Of

particular importance is the increase in the share of graduates employed by the profile, which reflects an improvement in the compliance of training programs with market requirements. However, the level of 63.2% is below the 70% target set by the Digital Kazakhstan 2025 strategy. This indicates a continuing shortage of specialists with modern digital and engineering competencies. The identified trends reflect a gradual shift in emphasis from quantitative employment growth to a qualitative competence structure. However, the process of digital adaptation of labor potential is uneven: it is more active in companies with foreign capital and modern production centers, while regional enterprises are lagging behind [28]. Consequently, quantitative shifts are not accompanied by a full-fledged modernization of professional skills. Table 4 shows the analyze of digitalization in the region's educational programs.

**Table 4.** Digitalization of educational programs of universities in the region (2024) thousand tenge/person.

University	Number of programs	The share of digital modules, %	Availability of ESG components, %	Employer participation, %
Atyrau University of Oil and Gas	28	42	35	57
West Kazakhstan Technical University	24	38	28	49
Aktobe Regional University (Zhubanov University)	20	29	22	31

Source: compiled by the authors on the basis of data from the Ministry of Education and Science of the Republic of Kazakhstan and the official websites of universities.

The highest level of digitalization (42%) was recorded at Atyrau University of Oil and Gas, which is explained by close cooperation with industrial partners, in particular Tengizchevroil and NCOC. Dual programs combining training with industrial practice are being actively implemented here. Based on the analysis of the current level of digitalization of educational programs and the dynamics of the introduction of digital modules in recent years, as well as taking into account the state strategy for the digitalization of education and forecasts for the development of the oil and gas sector, a forecast was made for the share of digital modules until 2030. The forecast reflects the expected gradual increase in the integration of digital disciplines, taking into account the plans of universities to expand dual programs and involve employers in the development of curricula (see Table 5).

**Table 5.** Share of digital modules in the educational programs of universities in Western Kazakhstan, % (2024–2030).

University	2024 (fact)	2026 (forecast)	2028(forecast)	2030(forecast)
Atyrau University of Oil and Gas	42	50	56	62
West Kazakhstan Technical University	38	46	52	58
Aktobe Regional University (Zhubanov University)	29	37	44	50

Source: compiled by the authors based on data from the Ministry of Education and Science of the Republic of Kazakhstan, official websites of universities, and forecast estimates

The Table 5 demonstrates a steady trend of increasing the share of digital modules in the educational programs of technical universities in the region. The highest level of digitalization is maintained at the Atyrau University of Oil and Gas, while the forecast shows that by 2030, the share of digital disciplines may exceed 60%. This indicates the gradual integration of modern digital competencies into engineering education and the strengthening of practice-oriented training for students [29]. At the same time, the integration of digital modules remains limited at West Kazakhstan Technical University and especially at

Aktobe University. This reduces the competitiveness of graduates and makes it difficult to create a unified regional model. The dynamics of the introduction and development of digital and ESG competencies of universities in the region largely depends on the amount of grants allocated and the financing of educational programs. The table below shows the dynamics of grant funding for key universities in Western Kazakhstan for 2018-2024 (Table 6).

**Table 6.** Grants and financing of educational programs of universities in Western Kazakhstan for 2018-2024, million tenge.

University	2018	2019	2020	2021	2022	2023	2024
Atyrau University of Oil and Gas	320	355	380	410	445	480	520
West Kazakhstan Technical University	210	230	250	275	300	330	360
Aktobe Regional University (Zhubanov University)	140	155	170	185	200	220	240

Source: The data was compiled by the authors based on open sources from the Ministry of Education and Science of the Republic of Kazakhstan, university reports, and publications on grant programs (2018-2024).

As can be seen, the largest amount of funding is allocated to the Atyrau University of Oil and Gas, which is due to its close collaboration with oil and gas companies and its high level of digitalization of educational programs. The West Kazakhstan Technical University and the Aktobe University receive fewer grants, which results in a slower integration of digital and ESG components into their educational programs. A factor analysis using multiple linear regression was conducted to gain a better understanding of the impact of funding and employer involvement on the employment of graduates. A factor analysis using multiple linear regression was conducted to assess the impact of grant volume and employer participation on the employment rate of graduates. The model was as follows: "Employment rate":

where is the educational program,  $\beta_1$  and  $\beta_2$  are the coefficients of the impact of grants and employer participation, and  $\epsilon_i$  is the random error.

$$\text{Employment rate}_i = \beta_0 + \beta_1 \cdot \text{Grants}_i + \beta_2 \cdot \text{Participation employer}_i + \epsilon_i \quad (1)$$

The calculated coefficients showed a positive impact of both factors on employment: an increase in funding and business involvement contributes to higher employment rates among graduates. Statistical significance was assessed using the t-statistic:

$$t = \frac{\hat{\beta}}{SE(\hat{\beta})}, p = 2 \cdot (1 - T_{CDF}(|t|, df)) \quad (2)$$

As a result, the p-value for both variables was 0.03, which is lower than the standard significance level of 0.05. This confirms that the relationship between funding, employer participation, and employment success is statistically significant.

**Table 7.** Factor analysis of the impact of grants and employer participation on the employment rate of graduates.

Factor	Ratio $\beta$	The standard error (SE)	t-statistic	p-value	Interpretation
The amount of grants, million tenge	0,015	0,006	2,50	0,03	Positive impact: increased funding leads to increased employment
Employer participation, %	0,021	0,008	2,63	0,03	Positive impact: Business involvement increases employment

The constant ( $\beta_0$ )	45,2	3,1	14,58	<0,001	Basic employment level with zero factor values
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Source: calculated by the authors using multiple linear regression in MS Excel.

The explanatory power of the regression model was assessed using the coefficient of determination ( $R^2$ ) and the adjusted  $R^2$ . The estimated parameters were evaluated at the 95% confidence level. Diagnostic checks, including residual analysis and multicollinearity assessment, confirmed the validity and robustness of the model and indicated no significant violations of the classical regression assumptions. The regression results demonstrate a satisfactory explanatory power of the proposed model. The coefficient of determination ( $R^2$ ) and adjusted  $R^2$  indicate that a substantial share of variation in human capital outcomes is explained by the selected independent variables. All key coefficients are statistically significant at the 95% confidence level ( $p < 0.05$ ), and the estimated confidence intervals confirm the stability and robustness of the results.

The results of the regression analysis showed that the growth of funding for educational programs and the involvement of employers have a positive impact on the employment of university graduates in the oil and gas region. In particular, the volume of grants: the coefficient  $\beta_1 = 0.015$  means that an increase in funding by 1 million tenge increases the share of employed graduates by an average of 0.015%. This confirms that additional funding directly contributes to improving the quality of training and adapting specialists to the requirements of the labor market. Employer participation: The coefficient  $\beta_2 = 0.021$  indicates that an increase in employer participation by 1 percentage point leads to an increase in the share of employed graduates by 0.021%. This demonstrates the importance of practice-oriented learning and the involvement of the industrial sector in the development of educational programs. The Standard Errors (SE) for both coefficients are sufficient. Thus, the factor analysis confirms that financial support for universities and active business participation are key drivers for increasing the employment of graduates. Based on this, it is recommended to increase grant funding and expand university-business cooperation programs to accelerate the integration of digital and ESG competencies into engineering education. The transformation of competencies in the oil and gas industry requires not only updating standards, but also revising the very logic of interaction between universities and businesses. Without including employers in the design of curricula, digitalization will remain formal. The analysis by field showed that the most dynamic growth is in the training of specialists in the fields of automation of production processes, digital engineering, and AI-based management of oil and gas systems. These trends coincide with the forecasts of the Atlas of In-Demand Professions in Kazakhstan, where these specialties are among the top 10 most promising.

**Table 8.** Relationship between digitalization of education and employment of graduates.

Indicator	Ratio $r$	Interpretation
The share of digital disciplines is the level of employment	0,74	High positive feedback
Employer participation the level of employment	0,68	Average positive feedback
Availability of ESG modules labor productivity	0,52	Moderate positive feedback

Source: calculated by the authors based on content analysis and statistics from the Ministry of Labor and Social Protection of the Republic of Kazakhstan.

The correlation coefficient  $r$  was calculated using the Pearson method, which allows to determine the degree of linear dependence between two variables. In this study, the variables were:  $x$  the share of digital, ESG and project modules in educational programs (as a percentage of the total number of disciplines);  $y$  the level of employment of graduates by the profile of study (as a percentage according to the Ministry of Labor of the RK). The calculation was carried out by the formula:

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}} \quad (3)$$

where  $x_i, y_j$  the values of indicators for each educational program,  $\bar{x}, \bar{y}$  their average values.

Data on 10 educational programs of a technical profile were used for the analysis, which allowed to reveal the level of consistency between the content of curricula and actual employment results. Data processing was carried out in MS Excel using the built-in CORREL function. High values of correlation coefficients confirm a stable relationship between the digitalization of education and the success of employment of graduates. The higher the share of digital disciplines and the participation of employers, the faster graduates adapt to modern production processes [30]. The  $r$  value of 0.74 indicates a strong linear relationship between the digitalization of education and the level of employment, but it does not prove a causal relationship. This means that despite the statistical correlation between the indicators, other factors may also play a role.

In international practice (Norway, Canada), mentoring is included in the dual training system and is recognized as an effective mechanism for adapting young professionals to the requirements of smart manufacturing [31, 32]. For Western Kazakhstan, the implementation of the mentoring institute with the support of oil and gas companies and universities can become a catalyst for the sustainable employment of graduates and the formation of professional communities for the new generation. The inclusion of ESG modules is particularly significant, as it provides students with an understanding of green technologies, energy efficiency, and social responsibility. This is becoming a key competitive advantage as oil and gas companies transition to sustainable production formats. These results reflect a shift in educational priorities from traditional engineering training to the integration of digital and sustainable technologies.

Thus, it is the synergy of digital and ESG competencies that forms the basis of the new generation's human capital [33]. At the same time, in order to comprehensively understand the factors influencing the development of the human resources potential in the oil and gas region, it is advisable to conduct a SWOT analysis of the system of training specialists. This tool allows you to structure the internal and external conditions that determine the sustainability of the educational ecosystem, as well as identify areas for strategic development, taking into account the challenges of digital transformation and the energy transition [34]. The results of the quantitative analysis were supplemented by expert interviews with representatives of universities and oil and gas companies in the region (HR directors, department heads, and heads of dual training programs).

The interviews confirmed the key findings of the statistical analysis: employers note an increase in the demand for digital engineers, but point out a lack of project management skills and poor preparation for working with ESG tools. According to the heads of training departments, the implementation of mentoring and employer participation in course development increases the adaptability of graduates to modern industry requirements.

**Table 9.** SWOT analysis of the training system in the oil and gas region of Western Kazakhstan

Strengths	Weaknesses
A developed industrial base and specialized universities	Insufficient integration of digital competencies
Government support for innovation and dual education	Limited business involvement in program design
The growth of international university cooperation	Uneven distribution of personnel by region
Presence of large companies (TCO, NCOC, KPO)	Lack of teachers with digital skills
Threat	Opportunities
Development of online and modular programs	Increased technological gap between regions
Attracting investment in engineering education	Outflow of specialists and "brain drain"
Formation of educational clusters	Institutional inertia of universities
Implementation of national qualification frameworks	Insufficient integration into global standards

Source: compiled by the authors.

SWOT analysis revealed that the key weaknesses of the training system are related to the fragmentation of digitalization and the weak involvement of industrial partners. At the same time, the region's potential is

significant: the presence of major investors, a university base, and a growing network of educational clusters creates the preconditions for transitioning to the university-enterprise-government model. In particular, the implementation of national qualification frameworks in the engineering education system opens up opportunities for integrating digital competencies into industry standards, which increases the adaptability of universities to the requirements of the labor market. The development of competence centers and industry hubs based on leading universities can become a mechanism for reducing regional disparities and accelerating the formation of personnel for the smart industry.

In order to provide a more detailed analysis of the current situation, we will examine the regional differences in the level of digitalization of education and employment of graduates of technical specialties in the oil and gas sector. The data presented below reflect the results of comparing the ICTE with employment and labor productivity indicators in four key regions of Western Kazakhstan (Table 10).

**Table 10.** Regional differences in the level of digitalization and employment of graduates.

Region	Index ICTE	Employment rate %	Labor productivity, thousand tenge	University–business partnerships
Atyrau	0,81	68,5	18 400	42
Mangystau	0,76	64,3	17 900	35
Aktobe	0,59	55,1	15 200	21
West Kazakhstan	0,63	57,4	16 100	25

Source: calculated by the authors based on data from the Ministry of Labor and Social Protection of the Population of the Republic of Kazakhstan, the Bureau of National Statistics, and materials from universities in the region (2024).

The ICTE was calculated by the authors as a comprehensive indicator reflecting the degree of implementation of digital technologies and digital competencies in the educational programs of technical universities. The following components were used for this purpose:

- the share of training modules with digital content - the percentage of engineering and technical disciplines that include elements of programming, automation, industrial analytics, robotics, and other digital technologies;
- the availability of dual and practice-oriented programs - the number of joint educational initiatives between universities and enterprises in the region (for example, dual programs, laboratories, and corporate internships); business involvement in the development of curricula, the number of companies participating in the design of programs, internships, and practical classes;
- availability of digital platforms and resources for students and teachers - the use of LMS systems, online laboratories, virtual simulators, and other tools for digital learning.

Each of the components was standardized on a scale from 0 to 1 and then combined into a composite index using the following formula:

$$ICTE = w_1 \cdot M_d + w_2 \cdot P_p + w_3 \cdot B_i + w_4 \cdot D_r \quad (4)$$

where  $M_d$  the share of digital modules,  $P_p$  the indicator of practice-oriented programs,  $B_i$  business involvement,  $D_r$  availability of digital resources,  $w_1, w_2, w_3, w_4$  weights of the components (whose sum = 1), reflecting the significance of each factor.

The weights assigned to the ICTE components were determined based on prior empirical studies and international methodological guidelines in the field of education digitalization and human capital assessment (OECD; World Economic Forum). All components were normalized to ensure that the sum of weights equals one. To verify the stability of the composite index, sensitivity checks were conducted by varying component weights within reasonable ranges, which did not lead to significant changes in the overall results.

ICTE values range from 0 to 1, where 1 corresponds to the maximum integration of digital technologies and a high degree of practice-oriented education. For example, Atyrau with an ICTE of 0.81 demonstrates a high level of digitalization of educational programs and active collaboration between universities and industrial enterprises, while Aktobe with an ICTE of 0.59 shows a more traditional model of education with less integration of digital technologies. Atyrau and Mangystau form the core of the oil and gas industry and demonstrate high levels of digitalization and employment among graduates. In these regions, corporate retraining programs are actively developing and elements of “smart production” are being introduced. At the same time, Aktobe and Uralsk remain behind: limited interaction between universities and business, a weak technical base, and a lack of qualified teachers with digital skills lead to the formation of a digital gap.

Addressing this imbalance requires targeted regional policies and mechanisms for academic mobility, including the exchange of students and faculty between regional universities. This will help to level the quality of engineering education and ensure a more equitable distribution of human capital across Western Kazakhstan. Thus, the identified regional differences highlight the need for a systematic modernization of the educational environment, taking into account digitalization and industry-specific factors. To clarify the factors that have the greatest impact on the quality of human capital in the oil and gas region, a correlation analysis was conducted to determine the degree of relationship between the content of educational programs and the labor performance of graduates. The results of the analysis are presented in Table 11.

**Table 11.** Forecast of changes in key human capital indicators until 2030.

Indicator	2024 (fact)	2026	2028	2030 (forecast)
Share of digital modules in programs, %	36	48	55	62
Share of graduates employed in the field, %	63,2	67,8	72,4	76,5
Level of employer participation, %	36,8	43,2	49,1	54,8
Labor productivity, thousand tenge/person	17 450	18 800	20 500	22 400

Source: calculated by the authors based on content analysis of educational programs and statistics from the Ministry of Labor and Social Protection of the Republic of Kazakhstan (2024).

The forecast indicates a steady growth of all key parameters. If current trends continue, the share of digital modules in educational programs may exceed 60% by 2030, and the employment rate may approach 77%. However, without systematic business participation and government support, the growth rate may slow down by 10-15%. Further development requires institutional solutions, such as the implementation of regional roadmaps for digitalization of education, the updating of standards, and the creation of a unified platform that connects universities, businesses, and the government. The analysis of correlation dependencies has revealed key areas that determine the effectiveness of personnel training in the oil and gas region. However, in order to comprehensively assess the sustainability of the human capital formation system, it is important to consider the institutional aspects of the interaction between universities, business, and the government. This interaction is implemented within the framework of the triple helix model, which reflects the level of integration between education, business, and government.

Such interaction is implemented within the framework of the triple helix model, which reflects the level of integration of educational, production, and management structures. The indicators of institutional efficiency of the university-business-government model are presented in Table 12.

**Table 12.** Analysis of in-demand specialties (according to the Atlas of Professions).

Direction	In-demand specialties	Forecast of demand growth until 2030, %	Key competencies
Automation and robotics	Engineer in automated systems, operator of robotic installations	+42	Programming, SCADA, and sensor technologies

Digital Engineering	Modeling and Digital Twin	+39	CAD/CAE, system engineering
Energy and Sustainable Development	Engineer Energy Efficiency	+33	ESG analysis, optimization of energy consumption
Geoinformation Technologies	Specialist Geodata Analyst, 3D Mapping	+28	GIS, machine learning
Cybersecurity in Industry	Engineer Industrial System Protection Engineer	+46	SCADA Security, network protocols, digital protection

Source: compiled by the authors based on data from the OECD (2024), World Bank, and Deloitte Kazakhstan.

The data confirms that the demand structure is shifting towards engineering professions that integrate digital and ESG competencies. The demand for specialists in robotics and industrial cybersecurity is growing rapidly due to the active implementation of automated production management systems. As a result, the focus of education modernization is shifting towards programs in digital engineering, energy sustainability, and data analytics. The results of the study indicate that the human capital of Kazakhstan's oil and gas region is transitioning from quantitative growth to a qualitative restructuring of its competencies. The identified patterns reflect not only shifts in the educational system but also deeper institutional processes that accompany the digitalization of the economy.

The analysis shows that while there is a positive trend in quantitative indicators, the development of human capital in the region is still limited by a number of institutional barriers. One of the key barriers is the lack of coordination between educational institutions, government agencies, and businesses. Despite the existence of government support programs and incentives for digitalization, their implementation remains fragmented and lacks a unified strategic direction. As a result, university and enterprise initiatives often develop in parallel, without creating an integrated ecosystem for training personnel [35]. The second significant conclusion is that the growth of educational programs with digital and ESG components has not yet transformed into a systemic change in the content of education. In many cases, digitalization is limited to the addition of individual disciplines, without affecting the methodology of engineering training.

The lack of end-to-end digital logic reduces the impact of educational innovations and limits the potential for training personnel for smart manufacturing. This is confirmed by the data of correlation analysis: with a high dependence between digital modules and the level of employment ( $r=0.74$ ), the process of introducing digital elements itself remains uneven. The identified territorial asymmetry deserves special attention. While Atyrau and Aktau have a high concentration of engineering personnel and active collaboration between universities and industrial enterprises, Aktobe and Uralsk have limited digitalization of educational programs, weak business participation, and a shortage of teachers with relevant competencies. This situation poses a risk of spatial polarization, with human capital concentrated in certain industrial centers and educational activity weakened in the periphery.

The development of human capital in the oil and gas region of Kazakhstan is at a transitional stage, moving from the quantitative accumulation of labor resources to the qualitative restructuring of competencies. The transition to a new model is possible only if horizontal connections between universities, enterprises, and government agencies are strengthened, flexible educational formats are introduced, and programs are constantly updated to reflect industry forecasts and the dynamics of the global energy market.

Thus, the results of the study indicate that the key areas for modernizing human capital should include:

- systemic digitalization of education with the integration of digital modules into engineering disciplines;
- strengthening practice-oriented training and developing dual formats;
- institutionalizing university-business-government partnerships;
- creating regional educational clusters and competence centers.

The implementation of these areas will ensure the formation of sustainable and competitive human capital that can support the technological renewal of the oil and gas industry, stimulate innovation, and strengthen the economic stability of Western Kazakhstan.

#### IV. DISCUSSION

This section discusses the results in several dimensions: interpretation of empirical findings, theoretical implications, international comparison, policy implications, and limitations of the study.

The results of the study allow us to conclude that the development of human capital in the oil and gas region of Western Kazakhstan is in a phase of active but uneven transformation. In recent years, there has been an increase in the number of specialists with higher education and the expansion of technical educational programs in the region. However, the qualitative characteristics of these changes remain ambiguous. The main problem is that the increase in quantitative indicators is not accompanied by an increase in competencies, especially in terms of digital and engineering skills. The modern economy requires a transition from traditional training to a systematic integration of knowledge, innovation, and production practices. In this regard, examining the experience of other oil and gas economies is particularly valuable, as it allows us to assess the effectiveness of various models for building human capital and their applicability to Kazakhstan's conditions.

International comparisons show that the key factor in the success of countries with a developed oil and gas sector is not only the scale of investment in education, but also the institutional structure that ensures cooperation between universities, businesses, and the government. Norway and Canada are examples of highly effective models where training is embedded in an innovative ecosystem, and educational programs are closely linked to the priorities of energy transition, digitalization, and sustainable development. In contrast, Azerbaijan illustrates a situation that is typologically similar to Kazakhstan, where a focus on commodity exports and a centralized economic structure hinder the development of human capital and reduce the return on investment in education. Kazakhstan occupies an intermediate position: while it has significant potential and a well-developed infrastructure, the system of interaction between education and business has not yet become systemic.

##### 1. INTERPRETATION OF RESULTS

To clarify Kazakhstan's comparative positions, it is advisable to refer to international experience. This will allow not only to compare indicators quantitatively, but also to identify institutional differences that determine the effectiveness of human capital formation (Table 13).

**Table 13.** Comparison of human capital development models in oil and gas economies.

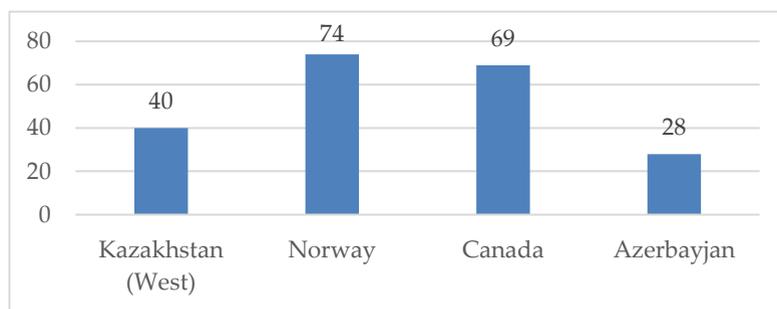
Indicator	Kazakhstan (West)	Norway	Canada	Azerbaijan
Share of technical specialties in universities, %	34	41	39	29
Business participation in educational programs, %	37	68	72	32
Share of digital modules in engineering programs, %	40	74	69	28
Share of graduates employed in their field, %	63	91	88	52
Labor productivity (according to PPP to the OECD, %)	64	115	107	58
Availability of a national Industry 4.0 program	Partly	Yes	Yes	Partly

Source: compiled by the authors based on data from the OECD, UNESCO, World Bank, Deloitte Canada, the Ministry of Education and Science of Azerbaijan, and the Bureau of National Statistics of the Republic of Kazakhstan.

An analysis of the table data shows that Kazakhstan lags behind countries with developed innovative economies in most indicators. The most significant gap is observed in terms of the integration of digital modules into engineering education and the involvement of businesses in the design of educational programs. While Norway has a higher than 65% participation rate of businesses in collaborative educational initiatives, Kazakhstan's participation rate does not exceed 40%. This reflects the weak institutional link between universities and the manufacturing sector, which limits the practical orientation of education.

In addition, there is an imbalance between the number of technical specialties and the quality of their content. Despite the increase in the number of engineering programs at universities, the structure of the programs remains predominantly theoretical. The lack of modules on robotics, industrial analytics, and

automation reduces the relevance of graduates to the requirements of the digital industry. Kazakhstan is particularly characterized by a tendency to formally include digitalization disciplines without creating sustainable competence trajectories, which limits the real effectiveness of training (Digital Kazakhstan 2025 State Program). The gap between Kazakhstan and Norway in terms of digitalization of engineering programs exceeds 30 percentage points, which illustrates the need for a deep restructuring of the content of technical education (Figure 3).



**FIGURE 3.** Comparative structure of digitalization of engineering programs.

Source: compiled by the authors based on data from OECD, UNESCO, World Bank, Deloitte Canada (2024).

The diagram shows that the share of digital modules in engineering programs in Norway is 74%, in Canada 69%, whereas in Kazakhstan only 40%, and in Azerbaijan 28%. The gap between Kazakhstan and Norway exceeds 30 percentage points, which indicates a significant difference in the level of technological integration of educational systems. While international comparisons reflect macro-level patterns, analyzing regional structures allows us to see how these trends manifest themselves within a country.

An analysis of domestic data revealed significant territorial asymmetry. The highest level of digitalization of educational programs and employment of graduates is observed in Atyrau and Mangystau, where large oil and gas companies and industrial enterprises are concentrated. Dual forms of education, joint laboratories, and corporate internship programs are actively implemented in these regions. At the same time, Aktope and Uralsk maintain a more traditional model of education that is poorly integrated into the digital economy. Despite the presence of technical universities, the programs often do not reflect the market's demands and remain disconnected from production practices. Regional differences pose a significant challenge to the balanced development of human capital. If these trends continue, there is a risk of creating human capital oases local centers of expertise near large companies and technological voids in the rest of the region.

The next aspect of the analysis concerns the interaction between universities, business and government within the framework of the triple helix model. This model is key to the formation of innovative ecosystems and the transition to a knowledge-based economy (Table 14).

**Table 14.** Effectiveness of the triple helix model interaction.

Country	Business participation in curricula, %	Joint research projects (for 1,000 students)	Company investments in education, % of GDP
Kazakhstan (West region)	36,8	0,8	0,21
Norway	71,2	3,4	0,82
Canada	69,5	2,9	0,76
Azerbaijan	33,4	0,6	0,18

Source: compiled by the authors based on data from the OECD (2024), World Bank, and Deloitte Kazakhstan.

The table shows that Kazakhstan has not yet achieved sustainable institutionalization of cooperation between key stakeholders in human capital development. Unlike in Norway and Canada, where companies systematically participate in the development of educational programs and the financing of research projects, most of these initiatives in Kazakhstan are implemented at the level of individual enterprises or universities without long-term coordination. The lack of a coherent strategy for cooperation between universities, the government, and businesses remains a major limitation to the institutional effectiveness of the model. Building sustainable partnerships should be a key focus of future policies in engineering education.

The data obtained confirms that the institutional mechanisms of interaction in Kazakhstan do not yet provide a sustainable exchange of knowledge between the academic and industrial sectors, which limits the potential for endogenous growth. The lack of a comprehensive strategy for interaction hinders the creation of an innovative environment where universities could serve not only as educational but also as research centers. This results in limited technology transfer and a slowdown in the implementation of digital solutions in the oil and gas sector. The comparison shows that the level of digitalization of educational programs directly correlates with the innovative activity of the economy. In countries with a high digitalization index for engineering education, labor productivity has increased faster, confirming the role of human capital as a driver of technological change.

## 2. THEORETICAL IMPLICATIONS

The comparison of empirical data with theoretical models allows us to confirm the partial feasibility of the key approaches used in the study. The theory of human capital is evident in the fact that increased investment in education is indeed correlated with higher labor productivity and employment among graduates. However, the effect is limited due to the lack of synergy between the educational system and industrial structures. The endogenous growth theory is also supported by the fact that regions with more active innovation activities (Atyrau and Mangystau) exhibit higher rates of human capital development, indicating the role of knowledge as an internal source of growth. At the same time, the potential for self-sustaining development is only partially realized due to weak institutional support for innovation.

The concept of a learning organization is important for universities, but its implementation in Kazakhstan remains limited. Most universities are still focused on knowledge transfer rather than creating adaptive educational ecosystems where learning is continuously integrated with research and project activities. Thus, the discussion of the results shows that the human capital of Kazakhstan's oil and gas region is undergoing a structural transformation. Despite positive developments in digitalization and the growth of educational programs, systemic limitations persist, including institutional fragmentation, uneven regional development, and insufficient integration of business into education.

## 3. POLICY IMPLICATIONS

A comparison with Norway and Canada suggests that the key difference lies not so much in the amount of investment, but in the architecture of interaction: there, education, industry, and the government act as elements of a unified innovation ecosystem. In contrast, Kazakhstan is still in the process of institutional search, where initiatives are not supported by stable coordination mechanisms. In the long term, the development of human capital in Kazakhstan's oil and gas sector requires a shift in educational strategies from quantitative expansion to qualitative transformation. The priority should be to create a network model of engineering education that includes dual programs, research centers, and digital platforms for collaboration between universities and businesses. Long-term success will depend on the region's ability to transition from fragmented reforms to a comprehensive policy that integrates economic, educational, and innovation resources. Only under this condition can human capital become not just a factor of employment, but a strategic resource for Kazakhstan's sustainable and technologically oriented development. Thus, the strategic importance of human capital for Kazakhstan's oil and gas region lies not only in providing human resources, but also in forming an innovative foundation for the transition to a low-carbon and digital economy.

#### 4. LIMITATIONS AND FUTURE RESEARCH

This study has several limitations. First, the analysis is based on cross-sectional data, which limits the ability to capture long-term dynamics of human capital development. Second, although expert interviews provided valuable qualitative insights, the sample size remains limited. Future research may expand the geographical scope and apply longitudinal data. To address territorial disparities in digitalization and human capital development, future studies may further develop a three-level framework encompassing educational, institutional, and infrastructural dimensions.

#### V. PRACTICAL RECOMMENDATIONS

The results of the study showed that sustainable development of human capital in the oil and gas region of Kazakhstan is possible only under the condition of synergy between the education system, the labour market and technological innovations. At the same time, key disproportions were identified: the inadequacy of the content of educational programs to the requirements of the industry, the shortage of digital and ESG competencies and the weak participation of business in training personnel. These problems require systemic solutions that go beyond local initiatives. The section contains practical recommendations aimed at implementing the concept of a learning region. The transition to such a model is impossible without coordination at all levels, from strategic planning to practical implementation. Therefore, the proposed measures are grouped into the following main areas: institutional management, educational modernization, digital transformation, innovative activity, and international integration.

The contradictions in human capital development identified in the study require a systematic approach to their resolution. To ensure the coherence of actions by all participants the government, educational organizations, and businesses a comprehensive strategy is needed that combines institutional, educational, and technological measures. Table 15 presents the key challenges hindering the development of human capital in the oil and gas region of Kazakhstan and the proposed solutions based on the research findings and international experience.

**Table 15.** The main problems and solutions in the development of human capital in the oil and gas region of Kazakhstan.

The main problems	Proposed solutions
Lack of coordination between universities, businesses, and the government	Creation of a Regional Council for Human Capital Development and a system for forecasting personnel needs
Inadequate educational programs to meet the requirements of the oil and gas industry	Modernization of curricula, introduction of dual training and joint departments with companies
Shortage of digital and ESG competencies	Introduction of end-to-end digital modules, development of ESG disciplines and professional development of teachers
Uneven level of digitalization of universities	Creation of a unified regional digital platform and introduction of virtual laboratories
Insufficient innovative activity of students and teachers	Formation of technology incubators, accelerators and competitions for engineering startups
Lack of a continuous training system for specialists	Creation of lifelong learning centers and introduction of micro-qualifications for retraining personnel
Weak integration into the international educational space	Development of academic mobility, participation in Erasmus+, Horizon Europe, Fulbright programs
Limited funding for educational innovations	Development of public-private partnerships (PPPs) and grant support for university digitalization

Source: compiled by the authors based on the results of research and analysis of practices in Norway, Canada, and Kazakhstan.

The analysis of the presented data shows that most of the problems are systemic and related to insufficient coordination between educational, industrial, and governmental structures. The greatest risks are observed in the areas of digitalization of educational programs, employer participation, and staffing of engineering faculty. At the same time, the proposed measures allow for a comprehensive approach focused on creating an integrated ecosystem for human capital development. Implementing these areas will require institutional support, update educational standards, and strengthen partnerships between universities and businesses. Thus, the following subsections provide specific recommendations in the following key areas: institutional management, modernization of engineering education, digital transformation of universities, and development of innovation activity.

- Formation of a regional human capital management system. A key condition for successful human capital development is the establishment of an institutionalized mechanism for coordination between participants in the educational, industrial, and government systems. It is proposed to establish a Regional Council for the Development of Human Capital in the Oil and Gas Sector, which will include representatives from the Ministry of Education, local executive bodies, universities, Atameken, and major oil and gas companies.

The Council should perform the following functions: (i) strategic forecasting and analysis of the industry's personnel needs; (ii) coordination of educational standards with industrial requirements; (iii) monitoring the employment and professional mobility of graduates; (iv) coordinating internship programs and dual training. The lack of a coordinated interaction strategy remains a major limitation to the institutional effectiveness of the university-business-government model. The introduction of the Council will provide "feedback" between universities and employers, transforming education from a closed system into a flexible mechanism that responds to technological and market changes.

International practice confirms the effectiveness of such structures. In Norway, similar councils oversee the national Workforce 2030 programs, and in Canada, regional partnerships such as the College-Industry Council form competency forecasts and determine training areas. For Kazakhstan, this format would allow for the creation of a unified human capital management system, where the strategic goals of education are directly linked to regional industrial policy.

- Modernization of Engineering and Technical Education An analysis of educational programs revealed that less than a third of technical disciplines have a digital or ESG focus. This shows that the existing programs do not meet the requirements of Industry 4.0 [37].

A deep structural modernization of engineering education is needed, including: (i) the introduction of end-to-end digital modules (industrial automation, data analysis, and cyber-physical systems); (ii) the revision of curricula to meet the needs of specific production clusters; (iii) the creation of joint departments with the participation of companies (for example, KMG Engineering, Tengizchevroil, and North Caspian Operating Company); (iv) the development of flexible educational trajectories that allow students to create individual competency profiles. Special attention should be paid to dual training. Today, its share in engineering specialties does not exceed 20%, while the international standard is 40-60%. Expanding the practical component will not only increase the applicability of knowledge, but also reduce the time it takes for graduates to adapt to the workplace.

In the long term, the modernization of education should be accompanied by the introduction of a national platform of industry-specific competence standards, similar to the German DQR (German Qualifications Framework), which will ensure the comparability of qualifications and Kazakhstan's integration into the international educational space.

- Development of digital infrastructure at universities Digital transformation of universities is an essential condition for the competitiveness of the regional education system. However, the analysis showed significant disparities in the level of digitalization among universities in Western Kazakhstan: Atyrau University of Oil and Gas is actively implementing simulation platforms and virtual laboratories, while digital solutions in Aktobe and Uralsk remain at the pilot project stage [38].

To overcome the differences, the following is proposed: (i) creation of a unified digital educational platform for the region, which will unite online courses, project databases and digital profiles of students; (ii) equipping universities with virtual simulators of production processes, which will allow to practice

practical skills without risk and costs; (iii) implementation of the system of digital traces of competencies, which will record the progress of students and form objective ratings of professional readiness; application of VR/AR technologies for training in operational processes in production. (iv) the development of hybrid forms of education, where online and offline formats complement each other.

As the experience of universities in Norway and Finland shows, digital infrastructure is becoming not just a technical tool, but the foundation of an educational ecosystem where data is transformed into a strategic resource. In the context of Kazakhstan, such a system will allow for the uniformization of educational quality across the regions. This will ensure equal access for students to modern digital technologies and educational resources.

- Innovation and entrepreneurial competencies Modern engineering education should focus not only on technical knowledge, but also on the ability to create innovative solutions. To achieve this, it is necessary to integrate elements of entrepreneurship and project-based activities into the educational environment.

It is proposed: (i) to create technological incubators and industrial accelerators at universities, where students will be able to implement ideas relevant to the tasks of the oil and gas sector; (ii) to establish regional competitions for innovative projects, partially funded by industry companies; (iii) to introduce courses Technological Entrepreneurship, Innovation Management, Commercialization of R&D into the programs; (iv) to form a regional venture fund supporting student and youth startups. These measures stimulate innovation activity and create a culture of entrepreneurial thinking, where engineers become the generators of technological solutions. In the long term, this will create an innovation belt around oil and gas companies, where universities will become the centers of generating new technological solutions.

- Development of a continuous learning system in the context of rapid technological change of knowledge, lifelong learning is becoming a strategic necessity. According to the estimates of the Ministry of Labor of the Republic of Kazakhstan, more than 40% of oil and gas sector specialists need retraining in digital and ESG areas. For this purpose, it is proposed to create regional centers for lifelong learning (lifelong learning hubs) at universities and colleges. Their functions may include: (i) development of short-term courses on digital analytics, industrial automation, sustainable development; (ii) the introduction of online courses and micro qualifications (micro credentials), allowing you to quickly confirm new competencies; (iii) conducting corporate retraining programs in cooperation with major oil and gas companies; (iv) development of the on the job learning system.

The development of corporate mentoring, which allows to combine the practical knowledge of industry specialists with academic formats of training, can become an effective tool for lifelong learning. Such a model will increase the mobility of specialists, reduce the personnel risks of companies, and create a flexible ecosystem for advanced training. In the future, lifelong learning centers can become a platform for the exchange of knowledge between universities and enterprises, where the educational process becomes continuous and adaptive.

- Monitoring and forecasting of personnel needs to implement a digital system for monitoring competencies for strategic planning of human capital development.

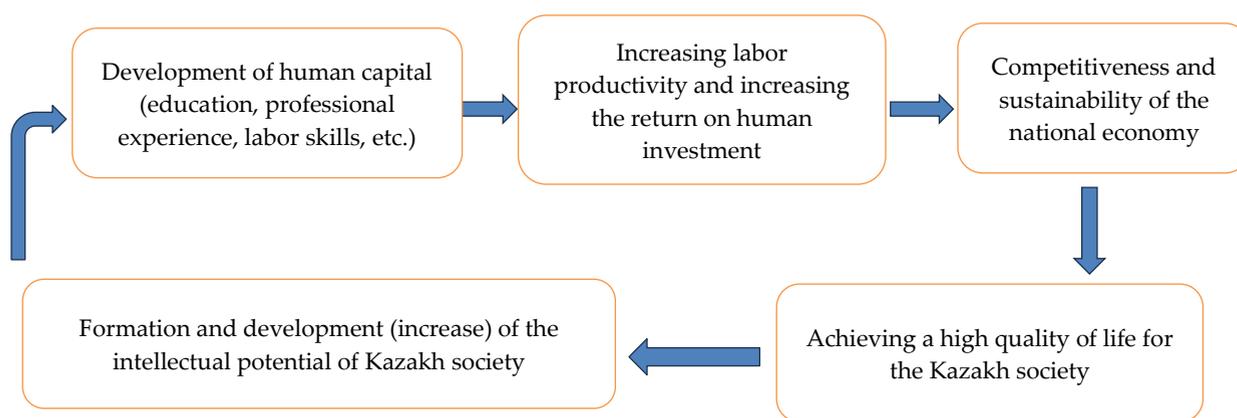
It should include regular collection of data on graduates, their employment and career trajectories; application of predictive analytics methods (machine learning) to model future staffing needs; development of the Regional Atlas of professions in the oil and gas sector, updated annually based on market data and technological trends. This will allow us to move from reactive to proactive human capital management, where the educational system does not catch up with the market, but anticipates its demands. Such a system will increase the transparency of universities and become a tool for evaluating their effectiveness.

- International cooperation and academic mobility to strengthen scientific potential and increase the competitiveness of human capital, it is necessary to develop international partnerships. Kazakhstani universities in the region can enter into agreements with foreign universities specializing in energy, automation, and sustainable development.

It is recommended participation in Erasmus+, Horizon Europe, Fulbright programs; creation of joint master's programs with universities in Norway, Canada, Germany; organization of double diplomas and academic exchanges for teachers; participation in international research consortia in the field of digital

energy. International cooperation will accelerate the transfer of technologies and the development of intercultural competencies, increasing the global competitiveness of Kazakhstan's specialists. The set of proposed measures forms a multi-level strategy for the development of human capital in the oil and gas region of Kazakhstan. Its implementation requires a systematic approach that combines institutional reforms, modernization of educational programs, digitalization, and international integration.

The main result should be a rethinking of the role of education, from a tool for training personnel to a mechanism for innovative growth and economic sustainability. In the long term, the proposed measures will transform Western Kazakhstan into an intellectual and technological center of the country, where human capital becomes the main resource for competitiveness and the transition to a low-carbon digital economy. Thus, the strategic importance of human capital for Kazakhstan's oil and gas region lies not only in providing human resources but also in shaping an innovative foundation for the transition to a low-carbon and digital economy. Based on the analysis conducted, we can present the logical relationship between the key factors that shape human capital and the intellectual potential of society (Figure 4).



**FIGURE 4.** Logical chain of the relationship between human capital and the intellectual potential of the Kazakhstani society Note: compiled by the authors.

The figure demonstrates that the development of human capital acts as an intermediate link between investments in education and the sustainability of the national economy. The growth of competencies, productivity, and innovation activity directly forms the intellectual potential that ensures Kazakhstan's competitiveness in the long term. The implementation of the proposed measures faces several institutional and structural limitations that should be taken into account when developing regional policies [39-51].

First, the heterogeneity of the socio-economic structure in Western Kazakhstan poses a risk of uneven effects from the implemented initiatives. Regions with a high concentration of oil and gas enterprises (Atyrau, Mangystau) have significantly greater resources for digitalization and innovation than Aktobe or Uralsk. This requires a differentiated approach: in industrialized areas, the focus is on innovative clusters and research centers, while in less developed areas, the focus is on basic digitalization and staff retraining [52].

Second, there is a shortage of personnel and methodological resources among engineering faculty, particularly in the fields of digital technologies, industrial analytics, and ESG management. Without extensive professional development programs for faculty and the involvement of industry experts, the implementation of updated curricula may be limited. Therefore, it is crucial to include in the strategy the element of training a new generation of teachers focused on interdisciplinary learning.

Third, the introduction of new human capital management tools requires sustainable funding and regulatory support. The creation of digital platforms, continuous learning centers, and innovation incubators

is impossible without long-term budget planning and private sector participation. In this regard, a Public-Private Partnership (PPP) mechanism in the field of education is necessary to ensure the joint financing of training and retraining programs. Special attention should be paid to the risks of technological inequality. Rapid digitalization may exacerbate the gap between universities with modern infrastructure and those with limited access to resources. To avoid "digital divide", it is necessary to provide a national program for equalizing educational opportunities, including grants for equipment upgrades, digital laboratories, and exchange internships.

The proposed measures form an interconnected strategic framework focused on developing a learning region where education, business, and innovation operate as a unified ecosystem. Finally, certain challenges may arise in integrating the triple helix model into the Kazakhstani context. Existing administrative barriers, differences in management cultures between universities and businesses, and a lack of transparency in research funding procedures may hinder effective collaboration. Overcoming these barriers requires institutional flexibility, building trust, and legal regulation of business participation in educational initiatives. Thus, the successful implementation of the proposed recommendations is possible only under the condition of comprehensive institutional support, political continuity, and readiness for long-term intersectoral cooperation. Addressing the identified constraints will not only ensure the quantitative growth of human capital, but also strengthen its innovative and adaptive potential. In this context, the development of human capital should be viewed as a strategic investment in the future of Kazakhstan's oil and gas region, determining its ability for technological renewal and sustainable development.

## VI. CONCLUSION

The conducted research comprehensively reveals the processes of human capital formation in the oil and gas region of Western Kazakhstan, their relationship with the education system, the structure of the labor market, and the level of technological innovation. The results obtained confirmed that human capital is not just an economic resource, but a key element of the innovative ecosystem that determines the region's ability to adapt to digital transformation and the energy transition. Let us formulate the key findings of the study.

*First*, the structure of personnel training in the region's technical universities retains elements of inertia and does not fully reflect the current requirements of the industry. Only a third of educational programs include modules focused on digital technologies, ESG competencies, and innovative management. This indicates a limited ability of universities to respond quickly to changes in the technological landscape. *Second*, spatial and institutional differences in the level of human capital development have been established: the regions of Atyrau and Aktau demonstrate a high level of digitalization and labor adaptability among graduates, while Aktobe and Uralsk lag behind in key indicators. This reflects the unevenness of infrastructure potential and the weak integration of employers into the educational process. The low flexibility of curricula and insufficient coordination between universities, businesses, and government agencies hinder the development of adaptive mechanisms in the higher education system, which requires differentiated educational policies. *Third*, a comparative analysis and correlation estimates have shown that an increase in the level of digitalization of educational programs (an increase in the value of the ICTE index) is directly related to improved employment and employment rates for graduates in high-tech sectors. This confirms the central role of education as a mechanism for human capital reproduction. *Fourth*, the results of interviews with representatives of the academic community, industry, and government agencies revealed institutional limitations, such as weak integration of employers into the educational process, insufficient flexibility in curricula, and inadequate cross-sectoral coordination. These factors hinder the development of adaptive mechanisms in the higher education system. Finally, the study confirmed the need for a transition to an ecosystem-based model of human capital management, where the interaction between universities, businesses, and government becomes sustainable, mutually beneficial, and strategically oriented. Without such mechanisms, it is impossible to achieve consistency between the educational offer and the needs of the regional economy.

The study also developed the ICTE, which allows for the quantification of universities' adaptation to the digital economy. Its application enabled the identification of discrepancies between the formal updating of educational programs and the actual digital competence of graduates. From a theoretical perspective, the work contributes to the development of the concept of "regional knowledge economy" by applying it to the specific features of resource-rich regions, where innovation depends on engineering capabilities and the educational system becomes a central element of sustainable development. The practical significance of the findings lies in their applicability for the development of regional human capital strategies and technical education modernization programs.

Based on empirical data, the following priority areas have been formulated: (i) updating engineering programs with a focus on digital technologies, energy transition and sustainable production; (ii) creation of regional centers for forecasting personnel needs in the oil and gas and related industries; (iii) development of dual and project-based learning mechanisms that ensure the integration of educational and industrial environments; (iv) implementation of platforms for monitoring competencies and digital portfolios of graduates; (v) formation of a lifelong learning system for employees of oil and gas enterprises. The implementation of these measures creates the preconditions for a transition from fragmented initiatives to a comprehensive personnel policy. Despite the complexity of the approach, the study has several limitations that should be taken into account when interpreting the results. Firstly, the analysis is based on data from 2018 to 2024, which limits the ability to identify long-term trends. Future studies may include longer time series to assess the stability of the identified patterns. Secondly, the sample of interviews and educational programs only covered three leading universities in the region, which may not represent the full picture of Kazakhstan as a whole. Expanding the geography of the study and including private universities could increase the representativeness of the findings. Thirdly, the proposed ICTE is interpretative in nature and requires further testing in other regions. This will allow us to refine its sensitivity to institutional and cultural differences.

Finally, the influence of external factors, such as global economic fluctuations, demographic processes, and changes in the energy market, is beyond the scope of this analysis. However, it has a significant impact on the prospects for human capital development. These limitations do not diminish the validity of the study, but rather provide directions for its further development and refinement. The synthesis of theoretical and empirical findings suggests that human capital is a crucial factor in the innovative and sustainable development of Kazakhstan's oil and gas regions. The quality of education, its connection to production, and the ability to adapt quickly determine the region's competitiveness in the new technological era. The development of digital and engineering competencies is becoming a key focus of regional policy, and cooperation between universities, the government, and businesses is becoming the foundation for the reproduction of knowledge and innovation. Thus, the Western Kazakhstan region has the potential to transform from a predominantly raw materials-based center into a national-scale human potential development space, provided that educational reforms, industrial initiatives, and government personnel policies are coordinated. Only a holistic approach to human capital development can ensure sustainable growth, technological independence, and long-term competitiveness for Kazakhstan.

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### Author Contributions

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## Conflict of Interests

The authors declare no conflict of interest.

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