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Advanced Engineering Schools as Strategic Actors in the National Innovation System: Institutional Roles, Structural Interactions, and Contributions to Sustainable Development Goals (SDGs)

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ABSTRACT

This article examines Advanced Engineering Schools (AES) as strategic actors within the National Innovation System (NIS) in the context of post-industrial development and ongoing technological transformation. The study addresses the need to enhance the effectiveness of AES in strengthening technological sovereignty and supporting innovation-driven economic growth under conditions of global uncertainty. A conceptual and analytical research design is employed, applying institutional, administrative, systems, and ontological approaches to analyze the structural position and functional roles of AES within the NIS. The analysis shows that AES contributes to innovation system transformation through customized research activities, applied innovation development, and creativity-oriented engineering education, while simultaneously engaging in cooperative and competitive relationships with other NIS actors. These interactions generate systemic synergies that improve innovation performance. The study demonstrates the relevance of AES to the achievement of Sustainable Development Goals (SDGs). The article contributes theoretical insights and practical implications for innovation policy and strategic planning.

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1. INTRODUCTION

In the context of post-industrial development and the emergence of a new technological paradigm, national innovation systems (NIS) play a decisive role in determining a country's capacity for sustainable economic growth and technological competitiveness. Innovation is no longer limited to isolated technological advances but has become a systemic process involving interactions among universities, research institutions, industry, and government actors. Scholars emphasize that innovation increasingly affects all spheres of economic and social life, requiring institutional structures capable of integrating scientific knowledge, technological development, and human capital formation into coherent innovation ecosystems (Magrupova *et al*., 2021). Within this framework, universities are expected to move beyond traditional educational functions and actively contribute to innovation-driven development through research, technology transfer, and strategic partnerships.

Despite the recognized importance of universities within innovation systems, previous studies indicate that higher education institutions have often faced structural and financial constraints that limit their engagement in large-scale, breakthrough research and innovation projects, particularly in the early twenty-first century. In response, many countries have introduced targeted institutional mechanisms to strengthen the role of universities in national innovation agendas. In Russia, this policy shift has been formalized through the federal project "Priority 2030," which promotes the establishment of Advanced Engineering Schools (AES) within leading technical and polytechnic universities. AES are designed as specialized organizational units intended to enhance technological sovereignty, accelerate scientific and technological progress, and align engineering education more closely with the needs of the real economy (Neretin & Ilyina, 2024; Popova, 2024). However, the conceptual distinction between AES and previously existing scientific or educational schools remains insufficiently clarified in the literature, and their systemic role within the NIS is still underexplored (Aetdinova, 2024).

Existing research on national innovation systems has largely focused on conceptual frameworks, institutional configurations, and methodological approaches for analyzing innovation dynamics at national and sectoral levels (Ashurov, 2023; Belomestnov, 2019). At the same time, studies addressing competence centers, think tanks, and specialized innovation institutions highlight the growing importance of organizational forms that facilitate cooperation, competition, and knowledge diffusion within innovation ecosystems (Savage, 2015; Ivchenkova, 2019; Gurtov & Stasevich, 2020). Nevertheless, limited attention has been given to Advanced Engineering Schools as distinct institutional actors within the NIS, particularly regarding their interaction mechanisms with other innovation system elements and their potential contribution to sustainable development through education, innovation, and partnership-building.

Against this background, this study aims to analyze Advanced Engineering Schools as structural and institutional elements of the National Innovation System. The article seeks to examine the roles, functions, and interaction mechanisms of AES within the NIS and to assess their contribution to innovation system transformation and sustainable development, with particular relevance to SDG 4 (Quality Education), SDG 9 (Industry, Innovation and Infrastructure), and SDG 17 (Partnerships for the Goals). By addressing these issues, the study contributes to a clearer conceptualization of AES and provides analytical foundations for innovation policy design and strategic planning in national innovation systems.

2. METHOD

This study adopts a conceptual and analytical research design aimed at examining the role of AES as structural and institutional elements of the NIS in the context of post-industrial development. Given the systemic, multi-actor, and non-empirical nature of the research object, the study does not employ statistical or experimental methods but instead relies on qualitative analytical approaches commonly used in innovation system and institutional research (Belomestnov, 2019; Ashurov, 2023).

The methodological framework integrates several complementary approaches. First, the institutional approach is applied to analyze AES as innovation-related institutions, understood as systems of stable relationships among actors involved in research, education, and innovation activities. This approach allows examination of how AES interact with other NIS elements, including universities, research institutes, competence centers, and industry partners, through cooperation and competition mechanisms (Belomestnov, 2019). Second, the administrative and organizational approach is used to examine the structural positioning of AES within universities and the broader NIS. This approach focuses on AES as organizational units established within the framework of state innovation policy, particularly the federal "Priority 2030" project, and assesses their functions in relation to governance structures, policy objectives, and technological sovereignty goals (Neretin & Ilyina, 2024; Popova, 2024).

Third, the systems approach is employed to conceptualize the NIS and AES as complex hierarchical systems characterized by multiple levels of interaction, feedback, and functional differentiation. This approach enables analysis of AES influence on NIS transformation processes by examining interconnections among system elements, innovation flows, and coordination mechanisms across research, innovation, and educational domains. Fourth, the ontological approach is applied to compare and structure key concepts related to innovation activities, innovation objects, and stages of innovation development within the NIS. This approach facilitates clarification of the conceptual boundaries between AES and other innovation actors and supports the development of analytical representations of AES functions and roles within the NIS.

In addition, situational and behavioral approaches are used to analyze the innovation behavior of AES and other NIS actors under changing technological and geopolitical conditions. Within the situational approach, innovation processes are examined as combinations of system states, available managerial decisions, and their potential effectiveness, allowing assessment of alternative development trajectories for AES within the NIS (Ashurov, 2023). Data for the analysis consist of peer-reviewed academic literature, policy documents, and analytical studies on national innovation systems, advanced engineering education, and institutional innovation mechanisms. The study employs comparative analysis, logical reasoning, and synthesis to integrate findings from these sources. The methodological combination applied in this research ensures analytical robustness and provides a comprehensive basis for examining AES contributions to innovation system transformation and sustainable development, particularly in relation to SDG 4 (Quality Education), SDG 9 (Industry, Innovation and Infrastructure), and SDG 17 (Partnerships for the Goals).

3. RESULTS AND DISCUSSION

The analysis of AES as elements of the NIS indicates that their emergence represents not merely an organizational reform within higher education but a structural transformation of

innovation governance in the post-industrial economy (Ashurov, 2023). Unlike traditional university faculties or isolated research units, AES are designed as innovation-oriented institutional actors that integrate education, applied research, and technological development within a unified organizational framework. This integration enables AES to operate simultaneously as knowledge producers, innovation intermediaries, and facilitators of cooperation between academia, industry, and the state (Belomestnov, 2019).

From a systems perspective, the positioning of AES within the NIS highlights its role as a hybrid institution located at the intersection of multiple innovation subsystems (Magrupova *et al*., 2021). On the one hand, AES remains structurally embedded within universities and inherits academic norms related to education and research. On the other hand, they are oriented toward solving applied technological problems defined by industrial partners and national innovation priorities established through state policy instruments such as the "Priority 2030" project (Neretin & Ilyina, 2024). This dual positioning enables AES to bridge structural gaps that traditionally existed between fundamental research institutions and industrial enterprises, thereby reducing fragmentation within the NIS and improving coordination among heterogeneous innovation actors (Ashurov, 2023). The analysis further shows that AES influences the NIS through both cooperative and competitive mechanisms. Cooperation is expressed through joint research projects, shared innovation infrastructure, co-supervision of graduate students, and participation in interdisciplinary innovation consortia (Gurtov & Stasevich, 2020). At the same time, AES may compete with existing research institutes, competence centers, and analytical organizations for access to funding, highly qualified personnel, and strategic influence within innovation networks (Ivchenkova, 2019). Importantly, this coexistence of cooperation and competition does not undermine the functioning of the NIS; rather, it stimulates innovation dynamics by encouraging specialization, efficiency, and differentiation of institutional roles, which is consistent with contemporary innovation ecosystem theory (Savage, 2015). The structural role of AES within the NIS becomes more explicit when its interactions with other key innovation system elements are systematically examined. These interactions define the functional boundaries of AES activities and shape their contribution to innovation system transformation. To clarify these relationships, the position of AES relative to major NIS actors is summarized in **Table 1**.

Table 1. Position of advanced engineering schools within the national innovation system.

NIS Element	Core Function	Interaction with AES	Dominant Relationship Mode
Universities	Education and fundamental research	Organizational integration and joint programs	Cooperation
Research Institutes	Fundamental and applied research	Knowledge transfer and joint R&D	Cooperation
Competence Centers	Applied innovation and skills development	Project coordination and specialization	Cooperation/ Competition
Industrial Enterprises	Commercialization and production	Joint innovation projects and technology testing	Partnership
Analytical Centers	Policy and technology analysis	Overlapping analytical functions	Competition

As shown in **Table 1**, AES occupies a central and integrative position within the NIS. Their strongest cooperative relationships are observed with universities and research institutes, where AES functions as a platform for transforming fundamental knowledge into applied technological solutions (Belomestnov, 2019). At the same time, interactions with competence

centers and analytical organizations often involve competitive elements, particularly in areas related to project leadership, analytical expertise, and access to innovation funding (Ivchenkova, 2019). These competitive interactions remain embedded within a broader cooperative framework shaped by national innovation policy objectives and institutional coordination mechanisms (Neretin & Ilyina, 2024).

A key result of the analysis is the identification of three core functional domains through which AES contributes to NIS transformation: customized research, applied innovation development, and creativity-oriented engineering education. Customized research refers to the orientation of AES scientific activities toward solving concrete technological problems defined by industrial demand and strategic state priorities. Unlike traditional academic research, which often prioritizes disciplinary advancement, customized research within AES is problem-driven and outcome-oriented, increasing the relevance of research outputs and accelerating their diffusion into innovation processes. Applied innovation development constitutes the second functional domain of AES activities. In this domain, AES serves as a site for the development, testing, and refinement of technological solutions, prototypes, and engineering systems. The close integration of research, education, and innovation within AES enables rapid feedback loops between theoretical knowledge and practical application, thereby reducing the time required for transitioning from concept to implementation. This structural feature strengthens the technological capabilities of the national economy and supports industrial modernization in line with long-term innovation strategies.

The third functional domain, creativity-oriented engineering education, represents a distinctive contribution of AES to the NIS. Educational models implemented within AES emphasize project-based learning, interdisciplinary collaboration, and sustained interaction with industrial partners (Aetdinova, 2024). Through these approaches, AES contributes to the formation of a creative engineering workforce capable of operating in complex and uncertain innovation environments. This function directly supports human capital development and aligns with global priorities related to quality education and lifelong learning. From a sustainable development perspective, the functional roles of AES correspond closely with several Sustainable Development Goals. By strengthening advanced engineering education and innovation competencies, AES contributes to SDG 4 (Quality Education). Through applied research and technological development, they support SDG 9 (Industry, Innovation and Infrastructure). Furthermore, the emphasis on collaboration with industry, research institutions, and government actors reflects the principles of SDG 17 (Partnerships for the Goals) (Kickbusch & Hanefeld, 2017). These contributions are embedded in the institutional logic of AES and reinforce their relevance within national and global innovation agendas.

The analysis also indicates that AES possesses significant potential to influence regional innovation development. In regions where AES actively engages with local industries and public authorities, it can function as an innovation anchor within regional or interregional clusters, enhancing knowledge diffusion and supporting regional economic resilience. However, realizing this potential requires strategic alignment between AES objectives, regional development strategies, and national innovation policy frameworks. Beyond their structural positioning, the effectiveness of AES within the NIS depends on how coherently their internal functions are aligned with broader innovation system objectives. The analysis indicates that AES effectiveness is not determined by the volume of activities alone, but by the degree of functional integration among research, innovation, education, and partnership-building processes. In this regard, AES differs fundamentally from traditional university units, which often operate these functions in parallel rather than as an integrated system.

One of the most significant findings of this study is that AES operates according to a concentration strategy, whereby resources, competencies, and managerial attention are deliberately focused on a limited number of priority innovation areas defined by national policy and industrial demand (Popova, 2024). Such strategic concentration enhances organizational coherence and reduces dispersion of effort, which is a common challenge in large universities. By concentrating on specific technological domains, AES can achieve greater depth of expertise, faster innovation cycles, and stronger alignment with industry needs. This concentration strategy is particularly evident in the functional differentiation of AES activities. Rather than treating education, research, and innovation as separate missions, AES embeds these functions within unified project-based frameworks. For example, research projects often serve simultaneously as educational platforms for students and as innovation vehicles for industrial partners. This multifunctionality increases the return on investment in innovation activities and strengthens feedback loops between knowledge generation and application (Aetdinova, 2024). As a result, AES contributes to the transformation of the NIS by promoting more integrated and adaptive innovation processes.

The functional roles of AES and their systemic contributions to NIS transformation can be analytically summarized across four interrelated domains: research, innovation, education, and partnership. These domains not only define AES activities but also link them to broader national and global development agendas. To clarify these relationships, the core functions of AES and their corresponding impacts on the NIS and Sustainable Development Goals are presented in **Table 2**.

Table 2. Functional roles of advanced engineering schools and their contributions to the national innovation system and SDGS.

AES Function	Core Characteristics	Contribution to NIS Transformation	Relevant SDGs
Research	Customized, problem-oriented scientific research	Accelerates knowledge-to-innovation transfer	SDG 9
Innovation	Development and testing of technologies and prototypes	Strengthens industrial innovation capacity	SDG 9
Education	Project-based, creativity-oriented engineering education	Develops advanced human capital	SDG 4
Partnership	Collaboration with industry, government, and research institutions	Enhances innovation ecosystems and networks	SDG 17

As illustrated in **Table 2**, the contribution of AES to sustainable development is multidimensional and embedded in its operational logic rather than treated as an external objective. Through advanced engineering education, AES directly supports SDG 4 by improving the quality, relevance, and innovation orientation of higher education. Their emphasis on applied research and technological development aligns with SDG 9 by fostering industrial innovation, upgrading infrastructure, and enhancing technological sovereignty. Furthermore, the partnership-oriented nature of AES activities reflects the principles of SDG 17, as AES actively facilitates cross-sectoral collaboration and knowledge exchange within innovation ecosystems (Kickbusch & Hanefeld, 2017).

Another important dimension of AES's influence on the NIS concerns its analytical and forecasting functions. The analysis indicates that successful AES increasingly perform not only technical and educational tasks but also analytical roles related to monitoring scientific and technological trends, assessing innovation risks, and formulating strategic recommendations for both institutional and policy-level decision-makers. These analytical capabilities are

essential for navigating the uncertainties associated with rapid technological change and geopolitical volatility. However, the development of such functions requires dedicated organizational structures and specialized competencies, which may not yet be fully institutionalized in all AES. From a governance perspective, the interaction between AES and other NIS elements highlights the importance of institutional coordination mechanisms. While AES benefits from a degree of organizational autonomy, its effectiveness depends on alignment with national innovation policies, regional development strategies, and sectoral priorities (Neretin & Ilyina, 2024). Insufficient coordination may lead to fragmentation, duplication of efforts, or misalignment between AES outputs and real economy needs. Therefore, the integration of AES into multi-level innovation governance frameworks remains a critical factor in maximizing their systemic impact.

The analysis also underscores the role of AES in regional innovation development. In regions characterized by industrial specialization or emerging technological clusters, AES can function as anchor institutions that stimulate local innovation ecosystems. By providing advanced training, supporting applied research, and facilitating industry–university collaboration, AES enhances regional absorptive capacity and contributes to balanced territorial development. This regional dimension of AES activities reinforces their relevance for inclusive and sustainable development within national economies. At the same time, several risks associated with the expanding role of AES must be acknowledged. One risk relates to potential institutional overload, as AES are expected to simultaneously deliver educational excellence, innovative outputs, analytical insights, and policy support. Without clear prioritization and performance evaluation criteria, this multiplicity of roles may undermine organizational effectiveness. Another risk concerns unequal development among AES, as variations in regional conditions, industrial partnerships, and institutional capacities may lead to asymmetric outcomes within the national innovation system.

To mitigate these risks, the findings suggest the need for continuous refinement of AES governance models, performance indicators, and strategic planning processes. In particular, evaluation frameworks should account not only for quantitative outputs, such as publications or patents, but also for qualitative contributions to innovation ecosystems, human capital development, and partnership-building. Such multidimensional evaluation approaches are consistent with contemporary perspectives on innovation system performance and sustainable development. In summary, the results of this study demonstrate that Advanced Engineering Schools constitute a distinctive and increasingly influential institutional element of the National Innovation System. Through integrated research, innovation, education, and partnership functions, AES contributes to innovation system transformation, technological sovereignty, and sustainable development. Their effectiveness, however, depends on strategic concentration, institutional coordination, and the development of analytical capacities. These findings provide a basis for further theoretical refinement and inform policy discussions on the role of specialized higher education institutions in national innovation systems.

5. CONCLUSION

This study has examined AES as a strategic institutional element of the NIS in the context of post-industrial development and technological transformation. The findings demonstrate that AES functions as a hybrid innovation actor that integrate education, applied research, innovation development, and partnership-building within a unified organizational framework. Through these integrated functions, AES contributes to reducing structural fragmentation

within the NIS, accelerating knowledge-to-innovation transfer, and strengthening technological sovereignty.

The analysis further shows that AES engages simultaneously in cooperative and competitive relationships with other NIS actors, generating dynamic interactions that enhance overall innovation system effectiveness. By adopting a concentration strategy focused on priority technological domains, AES improves organizational coherence and innovation outcomes. In addition, AES plays an important role in advancing Sustainable Development Goals, particularly SDG 4 (Quality Education), SDG 9 (Industry, Innovation and Infrastructure), and SDG 17 (Partnerships for the Goals).

The study contributes theoretically by conceptualizing AES as institutional innovation hubs and practically by providing analytical insights relevant for innovation policy design, strategic planning, and the governance of national innovation systems.

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

7. REFERENCES

Aetdinova, R. R. (2024). Advanced engineering school as an effective technology for training future engineers. *Scientific-Methodological Electronic Journal Concept*, *12*, 87–104.

Ashurov, M. S. (2023). National innovation system: Methodological aspects. *Economics and Entrepreneurship*, *158*(9), 408–415.

Belomestnov, V. G. (2019). Innovation economy of Russia: Institutional approach. *Problems of Modern Economy*, 72 (4), 30–34.

Gurtov, V. A., & Stasevich, A. V. (2020). Competence centers in the field of Arctic research. *Arctic and North*, *38*, 6–20.

Ivchenkova, M. S. (2019). Functioning of Russian "think tanks" in the information society. *Bulletin of the Institute of Sociology*, *10*(3), 151–164.

Kickbusch, I., & Hanefeld, J. (2017). Role for academic institutions and think tanks in speeding progress on SDGs. *BMJ*, *358*, j3519.

Magrupova, Z., Abdraimova, K., Tazhibekova, K., & Kocherbaeva, A. (2021). National innovation systems: Conceptual framework. *Proceedings of the University*, 85 (4), 252–256.

Neretin, D. A., & Ilyina, L. A. (2024). Federal project "Advanced Engineering Schools" as an element of training engineering personnel for Russia. *Science Alley*, 92 (5), 394–397.

Popova, A. V. (2024). Educational and technological sovereignty of Russia: On the question of revival of advanced engineering schools. *Theory of State and Law*, *40* (3), 105–116.

Savage, G. (2015). Think tanks, education and elite policy actors. *Australian Educational Researcher*, *43*, 35–53.