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**«КӨЛІК ЖӘНЕ ЭНЕРГЕТИКАНЫҢ ӨЗЕКТІ МӘСЕЛЕЛЕРІ:  
ИННОВАЦИЯЛЫҚ ШЕШУ ТӘСІЛДЕРІ» XIV ХАЛЫҚАРАЛЫҚ  
ҒЫЛЫМИ-ТӘЖІРИБЕЛІК КОНФЕРЕНЦИЯСЫНЫҢ  
БАЯНДАМАЛАР ЖИНАҒЫ**

**СБОРНИК МАТЕРИАЛОВ  
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Полученное значение коэффициента термоЭДС рассчитанного по формуле, приблизительно одинаковы для всех значений температуры ( $\alpha_{ср}=0,7824\text{мВ/}^{\circ}\text{C}$ ). Коэффициент термоЭДС дает возможность определять температуру любого исследуемого вещества.

Проведенные экспериментальные работы, показывают, определение коэффициента термоЭДС, иногда ее называют коэффициентом Зеебека, что коэффициент численно равен величине термоэдс, возникающей в данной цепи при разности температур спаев  $\Delta t=1\text{К}$ . Определение коэффициента термоЭДС нам позволило сразу определить разности температур в нашем случае комнатной и рабочей температуры [10].

Разработанный прибор позволяет по характеру изменения тепловых потерь и температуры грунта над обследуемыми теплосетями оперативно и с незначительными затратами определять места утечек теплоносителя в окружающую среду, а также своевременно определять участки теплопроводов с неудовлетворительным состоянием их теплоизоляционных и ограждающих конструкций.

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#### MODERN TECHNOLOGIES IN THERMAL POWER ENGINEERING EDUCATION IN KAZAKHSTAN

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*Abstract.* Казахстанское инженерное образование на примере теплоэнергетики рассматривается. Несколько подходов из мировой практики анализируются для внедрения в Казахстане. Проблемы оценины, решения предложены.

*Key words:* Thermal power engineering, engineering education, STEM, CDIO, KOSEN.

## **Introduction**

Modern thermal power engineering in Kazakhstan remains the basis of the energy system, as it continues to use fossil fuels (primarily coal). Coal has a part approximately 60% in Kazakhstan's power generation. Decarbonization and achieving carbon neutrality are key global priorities. Higher education in the thermal power sector must move beyond traditional lecture models and prepare graduates for success future activity in modern engineering challenges: integrating renewable energy sources, intelligent systems, and optimizing efficiency and safety. Practically oriented technologies such as STEM (science-technology-engineering-mathematics), CDIO (Conceive-Design-Implement-Operate), KOSEN (Japanese-style of engineering education), and new tools such as digital twins (DT) and virtual reality (VR) simulators address these needs by emphasizing practical, interdisciplinary, and life-long learning. This publication assesses technologies for implementation in Kazakhstan power sector of higher education.

### **Progressive educational technologies in thermal power engineering sector**

**STEM: Project-based integration.** STEM brings together science, technology, engineering, and mathematics through real problem solving, fostering systems thinking and creativity. For the power sector, it facilitates the development of new hybrid systems (RES + Fossil fuels) and any energy modules. For example, [1] describes the integration of engineering design processes in a STEM laboratory for teaching renewable energy, which significantly improves students thinking skills. This approach is comprehensive and corresponds to the traditional thinking of an engineer as a person with knowledge of the natural sciences (mathematics, physics, chemistry etc.). [1] recommends STEM for Rankine Cycle efficiency analysis. A global labor market analysis emphasizes the role of STEM in addressing the skills shortage in the energy sector: academic, industrial, and entrepreneurial competencies are critical for the transition from carbon to renewable energy in Europe (by example of solar energy) [2]. In the United States, the 2018 Federal STEM Strategic Plan documented an increase in the number of STEM degrees awarded since 2000 in the energy sector [3].

**CDIO: Competence during the lifecycle of complex systems.** CDIO builds education around the complete product/system lifecycle – Conceive (needs identification), Design (planning), Implement (creation/testing), and Operate (maintenance/development) – integrating technical foundations. This framework was first developed at MIT and Swedish universities in the early 2000s. An excellent example from the thermal power engineering sector comes from Siberian Federal University (Russia, 2014): students completed individual projects on “Microthermal Power Plants” based on the Rankine Cycle. The quantitative results were impressive: the number of student publications and participation in research competitions multiplied. These achievements were the result of partnerships with industry and the integration of thermodynamics (natural sciences) and IT into projects. The authors of the publication [4] concluded that CDIO shortens the onboarding period and develops critical competencies for thermal power engineers.

East Kazakhstan Technical University (EKTU) became the first institution in Central Asia to adopt the CDIO format into a number of engineering education programs [5]. At the national level, the Concept for the development of engineering education for 2023–2029 [6] adopted a three-level CDIO model, prioritizing green energy, dual education, and industry co-financing for funding programs, including thermal power engineering.

**KOSEN: Japanese-style of engineering education.** The Japanese approach is based on "Kohza" workshops—small research groups led by professors with open access for students, graduate, and PhD students etc. The technology emphasizes teamwork and practical skills such as metalworking, welding, and turning, which facilitates understanding of many devices, because of students are able to manufacture the same device or its component parts themselves “by hand”. The KOSEN system is a Japanese version of STEM. Using JICA grants, the system is being expanded to developing countries such as Kazakhstan, Malaysia, and Egypt. It includes group research in laboratories funded by industry. Unlike Western courses, it develops "ningen ryoku" (human skills) through workshop work. Energy is studied as the basic science of energy conversion [7]. Cutting-edge research in the energy sector is also being conducted around hydrogen.

**New technologies: digital twins and virtual reality simulators.** In addition to basic technologies, digital twins and virtual reality can facilitate low-cost training. Digital twins enable real-time simulation of thermal power plants for design, maintenance, and operator training, especially in emergency situations [8–10].

**Kazakhstan's content of educational technologies.** Kazakhstan's thermal power engineering programs (e.g., ENU, AUES universities) have traditionally focused on equipment and operational processes, but are facing the need for modernization in the context of the energy transition. The Higher Education Development Concept for 2023–2029 explicitly links CDIO/STEM with green technologies and a practical focus [6, 9]. Currently, the implementation of these technologies remains in its starting stages [5, 10].

Table 1 - Comparison of modern technologies of engineering education according to the thermal power engineering

Technologies	Main focus	Advantages	Implementation in Kazakhstan (energy sector)
STEM	Interdisciplinary Projects	Heat transfer prototypes, renewable hybrids, systems thinking	Initial implementation stage at universities [9]
CDIO	Life Cycle (Design-Operation)	Design, construction, and testing of a micropower plant (Rankin cycle)	Implemented at VKTU. Reflected in the National Concept 2023–29 [5,6]
KOSEN	Laboratory Group Research and Industry Liaison	Energy conversion experiments, teamwork	Engineering training through JICA grants [7]
DT/VR	Real-Time Virtual Simulation	Safe emergency preparedness	Initial implementation stage [10]

Common advantages can be identified: all models promote effective training that bridges the gap between theory and practice, improves employability, and supports the concept of sustainable development. The CDIO and KOSEN models excel in the STEM context of traditional fossil-fuel-based energy, while the STEM and DT models emphasize innovation for Kazakhstan's energy transition.

### Conclusion

The main challenges to the direct implementation of these technologies are:

- Mentality. For example, “the Japanese style” implies discipline and an even division of responsibilities with minimal (even absence) management.
- Traditions of the power sector in Kazakhstan. For example, a sudden transition away from coal-fired power generation will inevitably lead to the impoverishment of entire regions in Kazakhstan, such as the Karaganda and Ekibastuz regions. There are also doubts about the reliability of renewable energy sources.
- Mistrust of new technologies. Senior lectures/professors have concerns about virtual systems – how closely do they replicate real-industry conditions?

To address these gaps, the following solutions are proposed:

1. Applying CDIO-STEM-KOSEN models to individual disciplines, rather than entire educational programs. The authors of this publication plan to integrate STEM or KOSEN into the "Renewable Energy Systems Design" discipline. Testing the technology in one discipline will provide experience for further implementation.

2. KOSEN-type laboratory projects, supported by JICA scholarship programs, will enhance the inventive capacity of heat engineering students.

3. Virtual twins are particularly suitable for developing skills in emergency situations at thermal power plants. Moreover, young people (students) are interested in such training technologies.

4. Hybrid solutions are possible. Combinations of CDIO-STEM-KOSEN can be used temporarily or partially, depending on the circumstances.

STEM, CDIO, KOSEN, and DT/VR together offer proven, practical paths to modernizing engineering education, including in the field of thermal power engineering. Kazakhstan's Concept for 2023–2029 provides a timely legal framework. These approaches will enable increased efficiency in the thermal power sector and a partial energy transition.

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