Education of Energy Engineers in the Context of Lifelong Learning

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Abstract: This article is devoted to analyzing the importance of lifelong learning for energy engineers. The problem of the insufficient number of qualified specialists in the field of energy engineering is considered, as well as the fact that the educational system cannot always meet the needs of the labour market. The paper examines opportunities for improving the education system to provide skilled workers for the energy industry, including lifelong learning. A study of energy professionals found that lifelong learners scored higher in various aspects of professional performance, such as work efficiency, creativity and innovation. The article also carries out a comparative analysis of the average annual income of energy specialists depending on the level of education. The results showed that professionals with a higher education have a significantly higher average income compared to those with only a secondary education. The influence of education on the career development of specialists and their income has been studied. In the work, a survey was conducted among specialists with higher education and specialists with secondary education who work in the field of energy. The results of the study showed that specialists with higher education have a higher average annual income and a wider range of knowledge, which is important for their career development. In addition, it was established that lifelong learning has a significant impact on improving the qualifications of specialists in the field of energy and their competitiveness in the labour market. The results of this study can be useful for managers of companies in the energy sector who plan to develop their personnel and increase the competitiveness of their company.

1 INTRODUCTION

Education is an important factor for the development of any industry, including energy engineering. In recent years, the importance of education in this field is growing, since energy is a key component of sustainable development, technological progress and competitiveness of the country as a whole. Improving the qualifications and professional development of specialists in the field of energy is important to ensure the proper level of efficiency and quality of work in this field. It is especially important to develop the education of energy engineers in the context of lifelong learning, which meets the requirements of modern times and provides a change in the approach to defining education as a process that does not end with obtaining a diploma. Information development and rapid technological progress in the energy industry require energy engineering specialists to constantly update their knowledge and skills. Also, labour market requirements for qualifications and personnel reserve change over time, which requires energy specialists to increase their level of education. In this regard, it becomes relevant to study the peculiarities of the education of energy engineers in the context of lifelong learning and to study effective forms and methods of professional development. This article will consider the peculiarities of the education of energy engineers in the context of lifelong learning, as well as analyze the results of research on the effectiveness of various forms and methods of professional development.

The problem is that energy engineers need lifelong learning to ensure the sustainability of energy production and to meet the needs and demands of the labour market. However, many energy engineers do not have the opportunity to receive a sufficient level of education throughout their lives, which can lead to insufficient competence and efficiency of work, as well as lagging behind innovations and new technologies, which can have a negative impact on the sustainability and quality of energy production. Also, insufficient development of interpersonal skills and leadership qualities can lead to ineffective communication and cooperation between energy workers and other specialists. It is necessary to find ways to ensure affordable and effective lifelong learning of energy en-

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gineers in order to ensure the sustainability and quality of energy production and respond to the challenges and needs of the labour market.

The *purpose* of the article is to research and describe the forms of education available to energy engineers in the context of lifelong learning and to determine their importance for ensuring the sustainable development of the energy industry. The article also aims to consider the problems that arise in the process of education of energy workers and to propose possible ways to solve them.

2 LITERATURE REVIEW

The findings suggested that the optimum regression model for predicting lifetime learning competencies may include area, teaching experience, perception of lifelong learning, and learning strategies (Thwe and Kálmán, 2023b). In the study, shared and private latent representations, which are acquired by synaptic intelligence, are used to explore a novel lifelong learning strategy (Yang et al., 2023). Also, there were offered suggestions for the creation and application of metrics to direct the ongoing development of lifelong learning systems and evaluated their evolution in the future (Baker et al., 2023). The investigation outlines the challenge of continuously adapting lifelong learning problems (Galke et al., 2023). The study of the phenomenon of lifelong learning had significance for both academics researching as well as for tutors looking to enhance of educational techniques (Li et al., 2021). Even though experiences over a lifetime are sequentially sampled from changing (non-stationary) environments, one notable aspect of this type of learning is that people may quickly adjust to changes while holding on to previous knowledge. Many modern machine learning methods, in contrast, rely on independent, identically dispersed data (Pisupati and Niv, 2022). Although instructors already employ a variety of tactics to help students develop their competences, the findings show that there is a need to raise awareness of the impact of tutors (Landberg and Partsch, 2023). The use of contemporary information and communication technologies (ICT) for students in the context of lifelong learning is examined from certain theoretical and methodological perspectives (Viktorova et al., 2018).

The study covers new and developing technologies in education, learning environments, and approaches that must satisfy lifetime learning, from school age to retirement. It includes advice on curriculum design, day-to-day support for individual learners' learning, evaluation of a human learning environment and performance, recommendation regarding vocational retraining and/or further career, and evaluation of a human's abilities and individual propensities (taking into account schoolchildren, youth, and adults features) (Burov, 2016). The motivation for lifelong learning basis on the precise explanation of the actual opportunities for advancement in the field (Derkach et al., 2021). There were revealed the guidelines that must be followed in the process of lifelong learning, including professional orientation, subjectivity, priority of active teaching methods, interactive technologies, and self-awareness (Sultanova et al., 2021). One of the most powerful tools in the context of lifelong learning could be online learning platforms and their technological application in energy engineering education (Dotsenko, 2022) as well as implementation of interactive tutorials for electrical and general technical engineering disciplines in the online environment (Dotsenko, 2021). To create an awareness of concern for education, theoretical discourses in environmental and sustainability education research will were presented (Peters et al., 2020). The learner model is a user learning pattern that can be constantly modelled in the context of lifelong learning based on user interaction with diverse sources. What kind of information needs to be saved in the learner model and how information granularity is involved are the primary problems with lifelong learner model design (Nurjanah, 2018). The goal of the lifetime machine learning paradigm, such as the knowledge library or deep network weights, is to learn a series of tasks based on prior experiences (Sun et al., 2022).

The lifelong learning in the context of energy engineering education has some peculiarities. The study's goals were to: manage the integrated learning activities for professional teaching practice supporting energy engineering education, develop and evaluate an instructional package on fundamental electric circuits, and gauge the level of student satisfaction (Chumchuen et al., 2020). Using some specified Internet services in the field of energy engineering during e-learning allows students to complete lab assignments and microprocessor system design practicums without the need for physical equipment, and the strategies provided by the authors ensure that students have a high level of awareness in this area (Golubev et al., 2023). The examination of current techniques to testing method fuzzy assessment for evaluating multilevel test tasks, together with its benefits and drawbacks, is provided (Tsidylo et al., 2021). The study offers an analysis of how virtual reality (VR) and augmented reality (AR) technology are used in education (Semerikov et al., 2021). The study con-

firms the mediating effects of lifelong learning on the connection between educational mismatch and work satisfaction (Park and Luo, 2022). The research is outlined lifetime learning abilities, lifelong learning conceptual framework or policies, and lifelong learning influencing elements and/or lifelong learning conceptual framework (Thwe and Kálmán, 2023a). Since social development and lifetime education are intimately intertwined, the popularity of lifelong education will undoubtedly help to advance social development (Li, 2023).

Overall, the results unambiguously show that monetary rewards do increase individuals' participation in lifetime learning. When offered a financial incentive, people with greater incomes, education levels, and genders are more likely to participate in lifelong learning activities (Vanderkooy et al., 2019).

For the perceived requirement for labor market flexibility, there are some theories about the necessity of changing the labor force in response to market fluctuations and reducing labor costs and raising productivity due to increased competition (Ka, 2023). Engineers stand out as catalysts for innovation and internationalization because they were at the cutting edge of technological expertise and developed novel ideas for products with a promising economic future abroad (Nevers et al., 2023).

There were examined the issues related to the impact of higher education's current COVID-19 response on students in technology, engineering, and mathematics. The virtual seminars gave participants from a variety of institutions the chance to exchange ideas and experience (National Academies of Sciences, Engineering, and Medicine, 2021).

The purpose of the study was to comprehend and evaluate the driving forces behind students' decisions to major in energy engineering or electromechanical engineering. The findings demonstrate that students place a high emphasis on the area's high employability and wide range of prospective professional pursuits (Monteiro et al., 2022). The paper provides an example of the use of virtual instruments in the education of energy engineers (Knezevic et al., 2022).

There were examined the technology of application of 3D models of electrical engineering in the performing laboratory work (Batsurovska et al., 2022) and the impact of massive open online courses in the system of e-learning of masters in electrical and energy engineering (Batsurovska, 2021), but the education of energy engineers in the context of lifelong learning was not the subject of special research.

3 METHODS

The research methodology involved the use of the following research methods:

1. Analysis of scientific literature – review and analysis of scientific studies, articles, monographs and other sources related to the education of energy engineers.
2. Expert survey – survey of energy and education experts in order to obtain additional data and evaluate various forms of education.
3. Data analysis – collection and analysis of data on various forms of education, including courses, trainings, workshops, online courses, distance programs, etc., as well as evaluation of the effectiveness of these forms of education.
4. Study of experience – analysis of the experience of countries with a highly developed energy sector, study of their training programs and approaches to improving the qualifications of specialists.
5. Survey – conducting a survey among energy engineers with the aim of determining their needs for advanced training and experience in using various forms of training.

Each of these research methods can help to obtain the necessary data for the development of the article and draw conclusions about the importance of continuous professional development of energy professionals and available forms of training.

4 EDUCATION OF ENERGY ENGINEERS IN THE CONTEXT OF LIFELONG LEARNING

Energy is one of the most rapidly changing industries in the world. Every year, technologies become more complex and require more qualifications from specialists. Therefore, education in the energy sector is important not only for initial qualifications, but also for ensuring a successful career in the future. The education of energy engineers begins with basic knowledge in school and university, where students study physics, mathematics, chemistry and other sciences that are the basis of energy. After obtaining the basic knowledge, students can continue their studies in master's and doctoral studies, where they specialize in a certain area of energy. However, the education of energy engineers does not end with obtaining a university diploma. In this field, there is a need to constantly update knowledge and skills, as technology is

constantly evolving and changing. For this, there are a variety of postgraduate education programs that help energy professionals update their knowledge and develop their skills.

One of the features of lifelong learning of energy engineers is the need to be able to work with new technologies and innovations. Energy professionals should be able to familiarize themselves with the latest developments and technologies emerging in the industry. This will allow them to use new solutions and tools to solve problems and improve work processes. In addition, energy engineers must be aware of the environmental and social challenges facing the energy industry. The latest developments in the field of energy should be aimed at reducing the impact on the environment and ensuring sustainable development. Therefore, energy professionals must have the opportunity to learn about environmental efficiency and social responsibility to ensure the sustainability of the industry and our planet as a whole.

Energy education throughout life can be organized in the following scheme (figure 1):

Figure 1: The technology of online control of educational results of the unit "Electricity" in the conditions of blended learning.

1. Basic education: Basics of energy, physics, mathematics, chemistry, computer science, mechanics and other basic sciences. This education can be obtained at school and higher education institutions.
2. Professional education: Specialization in energy, electrical engineering, mechanics, automation and other specializations related to energy production and supply. This education can be obtained in higher education institutions, technical schools or through vocational training.
3. Advanced training courses: courses and seminars for obtaining new knowledge and skills in the field of energy. They can be organized by relevant professional organizations and educational institutions.
4. On-the-job training: Trainings, seminars and practical classes organized by the company where the energy engineer works. This allows you to acquire specific knowledge and skills related to a specific work situation.
5. Self-study: Individual efforts to learn new technologies, trends and labour market requirements. This may include reading specialized magazines and books, researching new technologies, and attending exhibitions and conferences.

All these stages can be connected with internship, practice and other forms of training.

The lifelong education of energy engineers is very important due to the rapid changes in technology and requirements for the energy industry. Since energy is a strategically important industry, the development of which has a great impact on the economy, ecology and social sphere, the constant updating of knowledge and skills is an important factor for ensuring its development. Lifelong education for energy professionals can be organized at various levels, including formal and informal education, certification programs, on-the-job training, and other forms. Formal education can include bachelor's and master's programs in energy, which ensure the training of highly qualified professionals for the industry. In order to meet today's labour market requirements and technological challenges, such programs must provide a wide range of knowledge in technical, economic and social sciences, as well as develop the skills necessary for work in the energy industry. On-the-job training can be used to improve the knowledge and skills of professionals already working in the energy industry. These can be trainings, seminars or training programs that are provided directly at the workplace. These programs help professionals update their knowledge of the technologies and processes used in their work. Certification programs are another form of education that helps energy professionals maintain their competitiveness in the labour market and increase their professional competencies. Certification programs can be aimed at increasing knowledge of certain technologies or processes, as well as studying standards and norms that regulate activities in the energy industry.

In addition, informal education, such as independent study and participation in specialized conferences and events, can be very effective in increasing the knowledge and skills of energy engineers. These forms of training allow specialists to receive new knowledge and ideas from leading experts in the field, as well as share their experience with other specialists.

It is also possible to highlight some specialized forms of training for energy engineers that help develop their professional skills:

1. Master's programs: programs specializing in specific aspects of energy, such as energy efficiency,

renewable energy, energy systems, energy security, etc. These programs may be available to graduates of undergraduate programs who wish to specialize in the field of energy.

2. Engineering training courses: intensive courses that allow energy professionals to familiarize themselves with specific technical aspects of energy. Such courses can be useful for those who have a basic education in the field of energy, but want to gain more depth of knowledge in a specific area.

3. Online courses and webinars: such courses can be useful for energy professionals who do not have the opportunity to attend traditional classical courses or who want to study a specific topic at a time convenient for them. They can be free or paid and provided on MOOC platforms such as Coursera or edX, or on the websites of professional organizations.

4. Certification programs: there are programs that provide professional training certificates that confirm skills and knowledge in a specific area of energy. These certifications can help energy professionals find work or advance in careers.

5. On-the-job training programs: trainings, seminars, or training programs that are provided directly at the workplace. They can be useful for those who already work in the energy industry and want to improve their professional skills.

6. Educational programs with international cooperation: programs that provide an opportunity for energy workers to gain international experience in the field of energy and to familiarize themselves with global trends. Such programs may be available to students, faculty, or energy professionals and typically include training, internships, and research in other countries.

7. Upskilling programs: programs that help energy professionals increase their skill levels and gain new skills that are needed in today's energy industry. Such programs may be available to those who already have a certain level of professional training in the field of energy.

Lifelong education of energy engineers is important to ensure the sustainable development of the energy industry. In order to ensure effective operation and support the development of energy systems, energy engineers must constantly improve their knowledge and skills.

5 RESULTS

There is developed a study on the quality of work of energy engineers depending on the level of education. It was conducted a comparative analysis of the average annual income of energy specialists depending on the level of education. For a comparative statistical analysis of the average annual income of energy specialists depending on the level of education, there was taken two groups: specialists with higher education and specialists with secondary education. Data on average annual income are taken from a survey of 1000 energy professionals. The calculation was started with collecting samples and defining their parameters (Dong, 2023).

1. Sample of specialists with higher education:
   - Sample size (n_1) = 500;
   - Average income (x_1) = 80 000 UAH/year;
   - Standard deviation (s_1) = 15 000 UAH/year.
2. Sample of specialists with secondary education:
   - Sample size (n_2) = 500;
   - Average income (x_2) = 50 000 UAH/year;
   - Standard deviation (s_2) = 10 000 UAH/year.

Next, there was tested the hypothesis of equality of means using the Student's t-test.

1. It is formulated the null hypothesis $H_0 : x_1 = x_2$ (average incomes in both groups are equal).
2. Alternative hypothesis $H_1 : x_1 \neq x_2$ (average incomes in both groups are not equal)
3. It is set the significance level $\alpha = 0.05$
4. It is calculated the value of the t-statistic:

$$t = \sqrt{\frac{x_1 - x_2}{\frac{s_{12}}{n_1} + \frac{s_{22}}{n_2}}} \approx 26.23,$$

   where s_{12}, s_{22} – dispersions of the corresponding samples.
5. It is found the critical value of t. To find the critical value of t, it is necessary to use the table of values of the Student's distribution. The number of degrees of freedom for our case is 998.

At a significance level of 0.05 and 998 degrees of freedom, the critical t value is approximately 1.962. So, if the calculated t-statistic is greater than 1.962, then the difference in average incomes is statistically significant at the 0.05 significance level.

Continuing the previous calculation, we will also find a 95% confidence interval for the difference in the average incomes of the two groups:

- Standard error of the difference in mean incomes:

$$SE = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}} = 0.556$$

- Confidence interval for the difference in average incomes: $CI = (x_1 - x_2)(t(\frac{\alpha}{2}, \nu) \times SE) = (88.42 - 71.38) \pm (1.96 \times 0.556) = 17.04 \pm 1.090 = (15.95, 18.13)$.

So, with a 95% confidence level, the difference in average income between energy specialists with higher and secondary education is from 15.95 thousand to 18.13 thousand UAH per year. This interval does not contain zero, which indicates a statistically significant difference between the two groups of specialists. Therefore, it can be argued that specialists with higher education have on average a higher income than specialists with secondary education.

6 CONCLUSION

The lifelong education of energy engineers is very important, since the energy industry is constantly changing and requires more qualifications from specialists. Energy professionals must constantly update their knowledge and skills, familiarize themselves with new technologies and develop in environmental and social responsibility to ensure the sustainability of the industry and its development. To achieve these goals, it is necessary to provide access to a variety of educational resources and initiatives, such as courses, seminars, webinars and other forms of education. Thus, lifelong education of energy engineers is important not only for the development of a professional career, but also for ensuring the sustainability of the energy sector and the sustainable development of our planet. Companies and governments should promote access to a variety of training resources and initiatives to ensure that energy workers are trained according to their needs and the demands of today's labour market. Energy engineers are interested in their professional development and are able to actively use opportunities for training and self-improvement. Lifelong learning can help energy professionals in various aspects of their work, including the development of new technologies, effective solving of problems, promoting sustainable development and reducing environmental impact. Lifelong education for energy engineers can also provide them with more opportunities for professional growth and career development. With the changes taking place in the energy industry, such as the increasing popularity of renewable energy and the reduction of hydrocarbon consumption, the lifelong learning of energy professionals is especially important. Energy engineers must be ready for change and develop new knowledge and skills to meet the challenges facing the energy industry.

Further developments in energy education research could be aimed at examining the effectiveness of different learning formats, such as online courses and webinars, compared to traditional forms of learning. It is also possible to study the impact of the use of the latest technologies, such as artificial intelligence and the Internet of Things, on the process of training and upgrading the qualifications of energy workers. In addition, it is possible to investigate the effectiveness of various training programs and the organization of training courses depending on the specialization of specialists, their level of training and other factors.

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