

IMPROVEMENT AND REDESIGN OF EDUCATIONAL PROGRAMS FOR TRAINING SPECIALISTS FOR INDUSTRY: CASE OF BACHELOR'S PROGRAM IN METALLURGY

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Purpose. The purpose of the study was to substantiate the possibility of improving the educational program for training bachelors in metallurgy through the analysis of global trends in the development of the metallurgical industry and the appropriate adaptation of the educational program components content in agreement with representatives of the industry employers.

Results. The directions of metallurgy development in the world and in Ukraine, which are determined by the refusal to use fossil fuels and the transition to alternative energy sources in order to reduce greenhouse gas (GHG) emissions, are considered. It is demonstrated that Ukraine's European integration course and support for the EU climate policy require urgent technical re-equipment of metallurgical enterprises, the introduction of resource-saving technologies with minimal GHG emissions, the transition to the production of iron and steel using hydrogen, etc. It is established that the specified restructuring of the industry requires adjustment of the content of specialists training for the relevant industries. It is shown that the corresponding adjustment of the educational program is most effective under the condition of close cooperation with representatives of the industry-employers.

Scientific novelty. Elements of a methodology for monitoring and adjusting the educational program for training specialists in higher education are proposed. The proposed approach is based on a combination of an analysis of the development trends of the relevant industry with the wishes of

industry representatives (employers) regarding the list, content, and scope of components of the relevant educational program.

Practical value. The proposed approach can be applied to improve any educational programs for training specialists for various industries and allows for effective monitoring in order to improve the quality of specialist training and maximise satisfaction of the employers and the labor market requirements.

Key words: green transition, greenhouse gases (GHG), innovative metallurgical technologies, sustainability, quality of higher education, monitoring and adjustment of learning content, redesigning educational programs.

1. Introduction

In March 2021, the Government of Ukraine approved the National Economic Strategy for the period until 2030 [1], which is based on an audit of the economy of Ukraine (analysis of the results of economic policy over the years of independence) and a vision for the development of the national economy with the definition of directions and strategic goals [2]. The following priorities have been identified as vectors of economic development for industry:

- creating a sustainable domestic demand for domestic industrial products;
- ensuring the Ukrainian industrial sector's access to global value chains, creating conditions for expanding exports of industrial products;
- strengthening the competitiveness of industrial products produced in Ukraine, introducing resource- and energy-efficient technologies;
- creating new production capacities by stimulating innovative activity of enterprises in all regions of the country using the competitive advantages of each of them.

Confirmation of the consistent actions of the Ukraine Government to implement legislative and political decisions on European integration is the “Action Plan to Implement the Recommendations of the European Commission Presented in the Progress Report of Ukraine within the Framework of the European Union Enlargement Package 2023”, approved by the relevant order [3].

In early July 2021, the European Commission presented a package of legislative initiatives “Fit for 55” to implement the European Green Deal and ensure a 55 % reduction in greenhouse gas emissions in EU countries by 2030 compared to 1990 levels. In essence, this is a set of proposals to revise and update EU legislation and introduce new initiatives to ensure that EU policy is in line with the climate goals agreed by the Council and the European Parliament [4; 5].

At the end of July 2021, the Cabinet of Ministers of Ukraine approved the Updated Nationally Determined Contribution of Ukraine to the Paris Agreement (NDC2), which declared a national target for reducing GHG emissions. By 2030, this reduction should be 65 % compared to 1990 [6]. The main measures included the modernisation of energy and industrial enterprises, the development of renewable energy sources, energy efficiency measures in all sectors of the economy from production, transportation to consumption, and others related to individual sectors of the economy and spheres of life [7].

The above-mentioned measures provide for a significant modernisation of existing and the introduction of new technological units and processes, including fundamentally new ones. Those based on other (alternative) energy sources, with a significant change in the course of the physical and chemical processes taking place, the energy and material balances of these processes, etc. Such changes must be taken into account in the content of educational programs for training specialists at universities. The corresponding modernisation of individual educational components in these programs should be carried out now so that graduates have the necessary competencies to work in new conditions. This is what prompted the authors, as those who ensure of the educational program quality (in our case, the bachelor's program in metallurgy) to constantly work on its improvement, including through the analysis of global trends in the development of the metallurgical industry. Accordingly, the main objective of this article is to highlight the experience of modernising the content of educational program components in accordance with modern trends in the economy, with the coordination of the proposed innovations with representatives of industry employers.

2. Review of literature

Ukraine's updated Nationally Determined Contribution to the Paris Agreement (NDC2) is a completely logical continuation of Ukraine's European integration course and support for the EU's climate policy. And it fully applies to metallurgy, as one of the basic industries of the state. But the reduction of GHG emissions in metallurgy cannot occur only at the request of the government – balanced and mutually agreed actions are needed both on the part of the state and on the part of enterprise owners, which would take into account all aspects, starting from the provision of raw materials and energy resources and ending with investments in the modernisation of metallurgical technologies and equipment.

But, as noted above, the European integration of Ukraine in general and its metallurgy in particular may be significantly hindered by climate issues, namely the volume of GHG emissions commitments that Ukraine will have to make in order to join the EU. To a large extent, the future of metallurgy in Ukraine will depend on this. Introduction of a carbon payment mechanism for importers to the EU (CBAM¹) may lead to the fact that the pig iron segment in the EU, in which Ukraine occupies about 50 %, may cease to exist and be replaced by hot-briquetted iron from the Middle East or Russia. This product is not yet produced in Ukraine. Along with the loss of 1.5 million tons of pig iron supplies, the CBAM could lead to the loss of an additional 1.6 million tons of rolled products and semi-finished products [8]. According to the European Business Association, the tax burden on Ukrainian producers will exceed 1 billion euros annually, taking into account the latest prices per ton of CO₂ emissions, which

¹CBAM – Carbon Border Adjustment Mechanism (*Engl.*) – a mechanism for regulating carbon emissions at the EU border, which is designed to prevent carbon pollution by charging EU importers for importing goods with a carbon footprint. On August 17, 2023, the European Commission adopted an implementing regulation, which introduced a transit period for the implementation of the CBAM (from 01.10.2023 to 31.12.2025).

are 84 euros, as well as imports of Ukrainian products from the EU. It is estimated that exporters of metallurgical products will pay an additional 961.3 million euros in carbon tax annually under the CBAM [9].

The above-mentioned aspects of the “green transition”, which Ukraine has already de facto joined by having received the status of candidate for EU membership on June 23, 2022, provide for specific steps to implement the national goal of reducing GHG emissions, including in the metallurgical industry. For metallurgists, this means, first of all, technical re-equipment and an accelerated transition to technological production chains that have a significantly smaller “carbon footprint”. As already noted, this is not only a question of meeting the requirements of the time, but also a question of the existence of Ukrainian metallurgy as an industry, for which the slogan “modernise or lose” is becoming increasingly relevant on the agenda. Modernisation and “greening” of metallurgical technologies require colossal investments, which are difficult to count on in conditions of martial law, but are quite possible during recovery.

As researchers note, in particular [10], the metallurgical industry is the most energy-intensive sector of production, consuming 5 % of the total global energy consumption and emitting 4–5 % of the total global anthropogenic CO₂ emissions. Therefore, it is important for this industry to achieve the highest possible energy efficiency and compensate for CO₂ emissions. To determine ways to increase the overall efficiency of metallurgical production from the point of view of modern low-carbon technologies, the authors focus on the following aspects:

- use of waste heat energy released from different sources during the production of iron and steel;
- comparison of possible routes for the production of iron and steel in order to analyse energy consumption and the impact of CO₂ emissions from different sources of production processes and routes;
- Carbon Capture and Storage (CCS) technology;
- water use and wastewater management;
- analysis of sources of uncontrolled CO₂ emissions.

The analysis of total emissions for each of the metallurgical processes conducted by the authors [11] showed that global steel production resulted in 147 billion tons of CO₂ emissions from 1900 to 2015, which is 9 % of global greenhouse gas emissions for this period. The largest contribution (about 50 %) to total emissions, caused mainly by the use of carbon as a fuel and as a reducing agent, belongs to the production of pig iron. Steelmaking in total emitted 33 Gt CO₂-eq, of which about half is from the open-hearth furnace. Despite the significantly lower carbon intensity, the steel finishing stage added 27 Gt CO₂-eq, mainly due to large production flows.

The results of the analysis of advanced solutions of the world’s leading metallurgical companies to reduce carbon emissions in metallurgy show that in the coming years we will observe the development and implementation of technologies that contribute to resource efficiency and encourage a greater level of circularity of materials; the implementation of promising options for the transition to metallurgy with

minimal GHG emissions, such as CCS and the transition to hydrogen-based steel production.

Examples include flagship projects from ArcelorMittal, such as XCarb™, Torero (conversion of biomass into biochar to replace coal use in the blast furnace) and Carbalyst (capture of carbon-rich blast furnace exhaust gases and their conversion into bioethanol), innovative DRI production projects and others [12]. No less ambitious are the plans of another powerful player in the steel market, the Indian company Tata Steel, which, like ArcelorMittal, has production facilities in the EU countries. Thus, Tata Steel UK is implementing several projects aimed at reducing CO₂ emissions as part of the movement to 2050 with a neutral steel emission, and the plant in the Netherlands is already one of the most efficient steel producers in the world in terms of CO₂ emissions and has declared its ambitions to reduce its emissions by 5 million tons per year (35–40 %) by 2030. To achieve this, various technological options have been explored, including CO₂ capture and storage, as well as a hydrogen route for steel production – Tata Steel Netherlands has already found the first customer for its green steel after the plant in IJmuiden switches to hydrogen-based steel production [13].

Leading Japanese metallurgical companies are also making significant efforts to achieve the ambitious goal of zero CO₂ emissions in metallurgy by 2050, using all possible means, including promoting a sharp reduction in CO₂ emissions from blast furnaces through the COURSE50 project and ferrocoke plus CCS technologies, developing super-innovative technologies such as expanded scrap utilisation, waste heat utilisation, biomass utilisation, and many others [14].

In December 2020, the South Korean government unveiled its 2050 carbon neutrality strategy, setting a goal of reducing greenhouse gas emissions by 24.4 % by 2030 below 2017 levels of 536 million tons of CO₂-eq, and a vision of carbon neutrality by 2050 [15]. In line with the strategy, POSCO Steel Corporation, South Korea's largest steelmaker, has pledged to reduce CO₂ emissions by 20 % in the near term by 2030, by 50 % on average by 2040, and long-term carbon neutrality could be achieved by 2050. South Korea's low-carbon transition mainly focuses on the application of new technologies such as hydrogen-based direct reduction steelmaking and CCS technology, improving energy efficiency, including upgrading the technical level and promoting smart factories using Industry 4.0 technologies, promoting a circular economy by reusing more steel scrap, increasing the use of low-carbon fuels, mainly replacing fossil fuels with renewable sources, and expanding the use of “green” electricity.

In June 2021, the German government adopted a new federal climate protection law, increasing the target for reducing GHG emissions by 2030 from 55 % to 65 % compared to 1990 levels and setting a new intermediate target of 88 % reduction by 2040 [16]. The German government's goal is to create a strong, internationally competitive and climate-neutral metallurgical industry, a net-neutral steel industry and, preferably, a carbon-free steel industry by 2050. The goals will be achieved by

implementing appropriate technologies such as the use of hydrogen instead of coke, CCS, and scrap-based steel production in combination with electric arc furnaces (Scrap/EAF). The Scarp/EAF route will provide 30 % of Germany's crude steel production, a share that could be further increased, but will be limited by the availability of steel scrap.

The National Hydrogen Strategy adopted by the German government deserves special attention [17]. According to it, "green hydrogen" produced from renewable energy sources can offer opportunities for climate action in energy-intensive sectors where there are no technological alternatives or more effective solutions for decarbonisation, especially in the metallurgical industry. Within the framework of the infrastructure projects H2Giga, H2Mare and TransHyDE, the German government, together with representatives of the research and industry, is setting up the future of Germany's energy supply with environmentally friendly hydrogen. Hydrogen is already being used in steel production in Germany, for example at ThyssenKrupp AG, one of Europe's leading steel groups [18].

According to the authors, the use of "green" hydrogen can be an effective solution for the Ukrainian metallurgy, where relevant projects could be implemented. One such project could be the injection of hydrogen into a blast furnace, for example, by adding it to pulverised coal fuel (PCF) at those enterprises where this technology is used [19]. Several years ago, it was reported that the above-mentioned metallurgical company ThyssenKrupp Steel Europe had begun a series of tests at its plant in Duisburg, in which part of the volume of pulverised coal fuel was replaced with hydrogen. The company planned at that time to gradually expand the use of hydrogen for all 28 lances of one of the blast furnaces, and from 2022 for three other blast furnaces. After the conversion of the blast furnaces, the company plans to create large direct reduction plants from the mid-2020s, which will then operate on gases containing hydrogen. The sponge iron produced in these plants will initially be melted in existing blast furnaces, but in the long term will be processed into crude steel in electric arc furnaces using renewable energy sources [20; 21].

Other hydrogen projects that could be implemented by national steel companies include direct iron reduction based on "green" hydrogen, natural gas – DRI with CCS and a traditional blast furnace (BF) or liquid phase reduction (SR) with partial replacement of coal with biomass and using CCS, direct iron ore electrolysis and others (see Table 2).

Fossil fuel-based direct reduction (DR) (using natural gas or gasified coal) is already used in industry, and global DRI production reached 120 million tons in 2021. However, to be successful, it is necessary to overcome not only the technical complexity of switching to a clean H₂ fuel, but also the economic challenge of significantly expanding capacity to switch to a near-zero H₂-DRI-EAF route. Water electrolysis for H₂ production requires huge amounts of renewable energy, the supply of which is often variable and intermittent. In addition, for the most common DR technologies in industry, the MIDREX shaft furnace or HYL-Energiron, the iron ore

supply must meet strict quality requirements to maintain steel quality and pig iron and steel production productivity [22].

In the authors' opinion, the considered (and numerous other) trends in the development of ferrous metallurgy require highly qualified specialists with appropriate knowledge and competences for their implementation and development. Since Ukrainian metallurgical companies are traditional and quite noticeable players in the European and international markets, the problem of training these specialists is also relevant in Ukraine, especially for regions with a developed metallurgical industry.

3. Methodology

This study was conducted on the example of Ukrainian State University of Science and Technologies. The Nikopol faculty of the university, which the authors represent, has been training bachelors in several specialties since its establishment (1998), including the field of knowledge 13-Mechanical Engineering specialty 136 Metallurgy (G10). Most graduates of the faculty after graduation are employed at metallurgical enterprises of the city of Nikopol and the region, specialising in the production of pipes and ferroalloys. Specialists are trained according to the relevant educational and professional program (EPP), which was developed on the basis of the higher education standard approved and put into effect by the order of the Ministry of Education and Science of Ukraine dated 04.10.2018 No. 1072 [23]. Educational programs that were developed and accredited by other metallurgical universities were also taken into account. The relevant recommendations of the Ministry of Education and Science of Ukraine on the development of educational programs and general recommendations on the formulation of competencies provided by the Tuning project were also taken into account [24]. In 2021–2024, with the direct participation of the authors, the EPP was updated to the current version [25].

This study used the following scientific methods: observation, analysis, comparison, synthesis. The results of the survey “EPP through the eyes of employers” were also used, which is part of the annual EPP monitoring procedure. This survey was attended by 21 representatives from 9 of the most powerful metallurgical enterprises in the city of Nikopol. Among the respondents were heads of human resources departments, deputy heads of enterprises for human resources management, and human resources staff (responsible for training, briefings, etc.). Because of the martial law and the fact that the Nikopol district is an area where fighting is happening, this survey was done online using Google Forms.

One of the important tasks of improving the educational program is to provide relevant and reliable data on the formation of relevant program competencies and program learning outcomes proposed by the higher education standard and additional ones defined by the educational institution and employers. In order to have such data, it is desirable to have a valid methodology (procedure) for their receipt and interpretation. One of the key components of such a procedure is the monitoring of the educational program, the content of which currently does not have a clear description, as was shown by the authors in [26]. Nevertheless, monitoring in this context should

include the following main stages:

- planned and repeated data collection;
- analysis and interpretation of the collected data;
- reporting on the results of monitoring;
- recommendations for actions (which usually include monitoring reporting);
- taking measures and reviewing actions.

The above monitoring stages fully comply with the principles laid down in the well-known Shewhart-Deming cycle (study or check in Figure 1). This cycle, often abbreviated as PDCA, can be considered a quality assurance procedure (industry does not matter). For the education sector, it is a procedure for ensuring the quality of education (educational services).

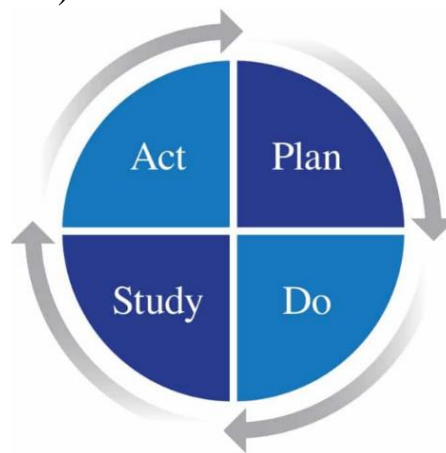


Figure 1. Shewhart-Deming Cycle (PDCA)

Source: image from the Deming Institute website [27].

An important addition to the standard procedure (Figure 1) is the consideration of the content and quality of the basic education of education seekers. The experience of the faculty, highlighted in [28], shows that this aspect is no less important for achieving the goals declared in the EPP, mentioned earlier.

In accordance with the above principles, the faculty also provides constant feedback with employers in the region. Thanks to this, the faculty receives feedback on the quality of training of specialists and proposals for improving the content of educational programs. These proposals are taken into account to improve the educational process, including by adjusting its content (introduction of additional professional and elective components of the EPP, redistribution of hours for studying individual disciplines, organisation of practice at enterprises, etc.).

4. Results and discussion

4.1. Analysis of trends in the development of ferrous metallurgy. According to analysts, before the war, despite constant import restrictions, the share of Ukrainian MMC sales to the EU was about 35 %, compared to 20 % on the domestic market [29]. Since 2022, after the start of large-scale aggression, trade integration between Ukraine and the EU has significantly increased, especially after the suspension of protective import quotas and anti-dumping measures by the EU for Ukrainian metallurgical products in June 2022 [30; 31]. It is obvious that after the start of the war, the EU

became the main export market for Ukrainian metallurgists: over 80 % of the metal products produced in 2023–2024 were supplied to the European Union countries. Among the importing countries: Poland (40.1 %), Bulgaria (14.6 %), Italy (7 %), Spain (6.8 %), Romania (4.5 %) [32].

According to many experts, the main obstacles to the “greening” of the mining and metallurgical complex (MMC) of Ukraine are its rather high dependence on exports, which is why we have a low level of HVA and a significant share of semi-finished products. Thus, according to the GMK Center, the share of high-margin products in the MMC in 2019 was only 32 % [33].

The SWOT analysis of the metallurgical industry of Ukraine, carried out by the authors and briefly presented in Figure 2, allows for a more objective assessment of the situation in the domestic MMC and an assessment of possible risks associated with reducing of GHG emissions.



Figure 2. SWOT analysis of the metallurgical industry of Ukraine

Sources: authors’ analysis (summary) using separate data from [34].

Equally important is the existing level of technologies used and the associated GHG emissions (Figure 3). In this context, the need to discontinue open-hearth steel production and replace it with more modern ones is obvious for Ukrainian metallurgy. According to statistics, about a quarter of the steel volume in Ukraine is currently produced in this way (Table 1).

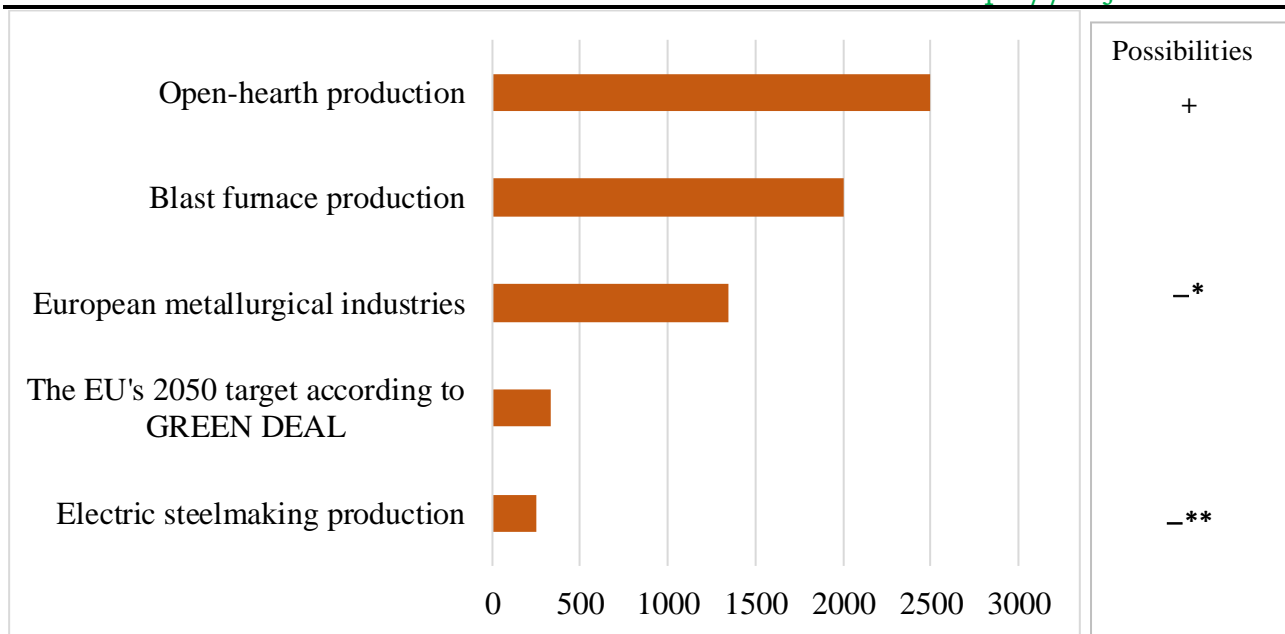


Figure 3. CO₂ emission level, kg/ton of steel and possibilities for its reduction (+) at metallurgical enterprises of Ukraine

Notes. * – some reduction in CO₂ emissions is possible through the use of hydrogen as an additional fuel (in the long term – due to the decommissioning of units /blast furnaces/);

** – has minimal CO₂ emissions and can be an alternative to blast furnace production through the introduction of iron ore metallisation technologies and/or if sufficient scrap is available.

Source: [35] with notes from the authors.

Table 1

Crude steel production by process in the 10 largest producing countries and in Ukraine, 2023

Countries	Steel production, million tons	Including by processes, % of total		
		Oxygen	Elektric	Other
<i>Total in the world</i>	1892.2	71.1	28.6	0.3
China	1019.1	90.1	9.9	-
India	140.8	43.6	56.4	-
Japan	87.0	73.8	26.2	-
United States	81.4	31.7	68.3	-
russia	76.0	65.1	32.0	2.9
South Korea	66.7	70.5	29.5	-
Germany	35.4	72.3	27.7	-
Turkey	33.7	28.4	71.6	-
Brazil	31.8	76.2	22.5	1.3
Iran	31.0	7.9	92.1	-
...
<i>Ukraine</i>	6.2	48.1	12.3	39.6*

Note. * – open-hearth method.

Source: [8] with authors' design (layout).

The currently existing ways of producing steel, both traditional and alternative, not involving the use of the blast furnace process, are shown in Table 2.

Table 2

Technological schemes of the main routes for the production of iron and steel

Raw materials	Preparation process	Product for processing	Unit 1	Unit 2	Final product	CO ₂ emissions (kg/t of Crude steel)
Classic schemes (routes)						
BF / BOF – blast furnace / oxygen converter (71.1% of world steel production)						
Iron ore	Pelletisation	Pellets	Blast furnace (BF)	Basic oxygen furnace (BOF)	Crude steel	1500...1800 (for present BF)
	Sinter production	Sinter				
Coal	Coking	Coke				
	Grinding	Pulverised coal	1300...1700 (for advanced BF)			
Steel Scrap / EAF – (28.6% of world steel production)*						
Steel scrap	–			Electric arc furnace (EAF)	Crude steel	300...600
Modern direct iron production processes						
DRI / EAF – “direct reduction of iron” route – the product (direct reduction iron) is a raw material for steelmaking in an EAF**						
Iron ore	Direct reduction	Direct reduced iron (DRI)	–	Electric arc furnace (EAF)	Crude steel	700...1300
Natural gas						
Iron ore	Direct reduction	Direct reduced iron (DRI)	–	Electric arc furnace (EAF)	Crude steel	2300...3000
Coal						
SRI / Converter – “direct” iron/pig production processes (HIsarna, COREX, FINEX etc.)						
Iron ore	Smelting reduction	Smelting reduced iron (SRI)	–	Converter	Crude steel	N/A
Natural gas						

Notes. * – limited by scrap availability; ** – limited by low cost DRI availability.

Source: authors’ design and estimated data from [36] (in the column on the right).

It should be noted that the Steel Scrap/EAF, DRI/EAF and SRI/Converter routes using electricity and natural gas (or hydrogen) are the most acceptable in terms of CO₂ emissions per ton of steel. But the situation in Ukrainian ferrous metallurgy as of today is such that only one route can provide real production volumes – Steel Scrap/EAF, and then only at individual enterprises. The DRI/EAF and SRI/Converter routes are promising, but in Ukraine these technologies are not yet developed, although there are plans to build the necessary capacities. It should be expected that under the pressure of EU requirements (through SVAM) these technologies can be implemented “on a turnkey basis” in the very near future, although they will require large amounts of investment. In conclusion, today there is already an obvious need for training specialists who are familiar with such technologies and could work in new conditions.

4.2. Improving the educational program for training bachelors in metallurgy.

Taking into account the researched trends in the development of ferrous metallurgy, the quality assurance group initiated changes to the content and structure of individual educational components of the EPP, such as “Fundamentals of Metallurgy”, “Heat

Engineering”, “Fundamentals of Ecology”, which will be discussed further. But the list of educational components remained without significant changes and allows you to form all the competencies provided for by the current standard of higher education in the specialty “Metallurgy” and achieve the corresponding program learning outcomes. This can be evidenced to some extent by the successful defense of bachelor’s final qualification theses in 2022–2024, the results of the latest accreditation of the program (2024), and the results of a survey of key stakeholders, in particular employers (Table 3).

Table 3

**Distribution of answers to one of the questions of the questionnaire
“EPP Metallurgy through the eyes of employers” in 2023–2024**

No.	Questions	Distribution of responses (%) on a scale from 5 to 2, where 5 is very good, 2 is very bad*			
		5	4	3	2
1	Level of basic and professional knowledge and skills	100	-	-	-
2	Ability to apply knowledge in practice	80	20	-	-
3	Ability to work in a team	80	20	-	-
4	Ability for self-improvement and desire to develop	70	30	-	-
5	Ability to take initiative	60	40	-	-
6	Ability to communicate and find common ground	80	20	-	-
7	Information technology skills	100	-	-	-

Note. *rounded to whole numbers.

Source: based on the results of a survey of employers (processed by the authors).

As the authors previously emphasised [24], one of the main factors ensuring the competitiveness of the faculty (university) in the market of educational services and its graduates in the labor market is the constant transformation of the content of specialist training in accordance with the requirements of employers. In the aforementioned EPP Metallurgy, its developers introduced additional Program Learning Outcomes (PLO25... PLO28), which take into account individual comments of employers, considered in the work [37]:

PLO25. Ability to take the initiative and make proposals for improving individual links and production technologies, ensuring product quality and proper working conditions. Skills and understanding of the need for constant self-improvement.

PLO26. Comprehensive awareness and understanding of the psychological aspects of organising the work of a team, methods of managerial influence of a grassroots leader (site foreman, foreman).

PLO27. Understanding of general issues of organising production on a site and managing a production site, issues of organising workers' labor.

PLO28. Comprehensive awareness of the quality indicators of final products (depending on the production profile), the influence of technological production factors on them and control methods. Comprehensive awareness of the quality management systems and product certification operating at enterprises according to national and international standards.

But neither among them, nor among the program learning outcomes

corresponding to individual professional areas (PLO29... PLO53), are there any that would clearly formulate the ability of a metallurgical specialist to comprehensively analyse the possibilities of modernising certain technological processes, taking into account the requirements of reducing GHG emissions and transitioning to modern low-carbon technologies that would meet the requirements of Ukraine's national goal of reducing emissions and the European Green Deal, which were discussed at the beginning. In our opinion, this is currently a shortcoming that needs to be eliminated.

The importance of training specialists to ensure a green transition is emphasised by all authoritative institutions, starting with the European Commission [38] and ending with the equally respected Organization for Economic Co-operation and Development (OECD), European Investment Bank, International Labor Organization (ILO) etc. [39–42]. Among the recommendations of the aforementioned organisations, a document from the ILO is noteworthy, which states, in particular, that in many developed countries that have committed to achieving climate goals to reduce GHG emissions, there is a significant growing demand for the skills necessary to green the economy. This in turn encourages the development of skills development strategies, technical and vocational education and training policies. It is noted that many diplomas and certificates now include awareness-raising on issues related to environmental sustainability, and some have undergone more advanced and specific adaptation to the methods, knowledge and skills needed for the ecological transition. 27 countries have adopted regulations on renewable energy and energy efficiency, including regulations on the qualification, certification of skills and/or training of specialists. These regulations usually concern specific professions, such as energy auditors, inspectors, assessors, energy managers, installers and operators of equipment and buildings [39].

The same document notes that one of the policy instruments for raising environmental awareness is the inclusion of “basic skills” in education systems at all levels. Here, basic skills are non-professional and non-technical competencies that are necessary for performing work and which, in the context of the green transition, include environmental awareness and the willingness to learn everything related to reducing GHG emissions. It also notes that in many countries, environmental legislation reforms introduced since 2010, especially in the areas of energy, construction and waste management, have led to the establishment or revision of professional qualification standards. It is emphasised that in the long term, it is very important to include the acquisition of skills for the green transition in the formal education system with subsequent implementation at the levels of college degrees, bachelor's, master's, PhD and postgraduate studies at universities.

Analysis of general and professional competencies of EPP Metallurgy showed that the existing list is quite sufficient for the formal formation of the proposed program learning outcome. But, in order for its formation to be possible not only on paper, an important condition is to make appropriate adjustments to the work programs of educational disciplines (educational components of EPP), both mandatory and elective. These adjustments should concern both fundamental disciplines (physics, chemistry,

physical chemistry, electrical engineering, heat engineering), and others that form the key professional competencies of bachelors in metallurgy, including competencies in the field of using secondary energy resources, analysing energy consumption and the impact of CO₂ emissions from various sources of production processes and routes, CCS, water use and wastewater management, identifying sources of uncontrolled emissions of CO₂ and other greenhouse gases. In addition to the above, it is highly advisable to conduct an additional survey of key employers – partners of the faculty – regarding the inclusion in the EPP Metallurgy of the specifics of certain enterprises and their chosen production modernisation strategy, taking into account European integration processes and adaptation to EU requirements regarding greenhouse gas emissions.

As an example, we can cite fragments of the content of work programs for individual disciplines of the EPP Metallurgy (2024 year of development), which focus on the issues that were mentioned (Table 4).

Table 4

Fragments of work programs of academic disciplines with topics related to green metallurgy issues

Section names	Topic content (fragments)
<i>Discipline “Fundamentals of Ecology”</i>	
<i>Chapter 3. Anthropogenic load on the environment. Problems of environmental protection and resource conservation in metallurgy</i>	<p><i>Resource conservation and environmental protection problems in metallurgy</i></p> <p>Protection of air and water basins at metallurgical enterprises. Ferrous metallurgy and problems of reducing emissions of “greenhouse gases”. Equipment of sinter plants, ferroalloy, electric steelmaking, rolling (pipe) shops from the point of view of environmental impact</p> <p><i>Environmental management and legal aspects of environmental protection. Modern environmental standards of activity, including international ones</i></p> <p>Basic principles of environmental management. Legal aspects of environmental protection, state supervision over compliance with environmental legislation. Modern environmental standards of activity, including international ones. Ukraine’s tasks in the field of ecology in the light of European integration processes</p>
<i>Discipline “Heat Engineering”</i>	
<i>Section 1. Main types of natural and artificial fuels and energy carriers, main energy characteristics of fuels and features of use in production</i>	<p><i>Modern renewable energy and alternative fuels</i></p> <p>Fuel as a significant component of the cost of production and its competitiveness. Renewable energy sources – solar, wind, etc. Green energy, technologies for obtaining and using hydrogen in metallurgy. Opportunities and limitations for the use of green energy</p>
<i>Discipline “Fundamentals of Metallurgy”</i>	
<i>Chapter 12. New Materials and Metallurgical Technologies</i>	<p><i>Modern technologies and global trends in the development of metallurgy</i></p> <p>Carbon-free economy, green energy and green production. Use of hydrogen in metallurgical processes. Technologies for obtaining raw materials with a high degree of metallisation (HBI, DRI) and its further processing into steel. Technologies for obtaining high-quality metal. Combined processes and casting and rolling complexes. Additive manufacturing technologies</p>

Source: developed by the authors.

It should be noted that despite the obvious relevance of the changes made to the work programs of educational disciplines, these changes must be coordinated with key stakeholders, primarily employers. In the work [43] it is emphasised that “... there are certain discrepancies between the ideas of employers and higher education institutions about the necessary competencies of a future specialist. Periodic discussion with employers of the current educational program or its elements helps to make the necessary adjustments in a timely manner”. The authors of the work [44] express the same opinion, noting that “... a higher education institution should analyse the information received and identify common and conflicting needs of stakeholders”. While fully agreeing with the opinions of the authors of the aforementioned works, it should be noted that these works do not provide practical examples of the implementation of the proposals made.

The Nikopol Faculty, represented by the authors of this article, constantly cooperates with all employers in the region, the results of this cooperation have been repeatedly covered at international conferences and in scientific journals [24; 28; 37; 45; 46]. The adjustments made by the authors in 2024 to the EPP Metallurgy and to the content of the working curricula of the disciplines (see Table 3) were agreed upon by the authors with specialists from metallurgical enterprises – employers for graduates of the faculty. For example, one of the reviews states: “... We consider the appearance of an additional section 12 – New materials and metallurgical technologies to be very useful. It is desirable that this section contain information about modern metallurgical processes and general trends in the development of modern metallurgical science and practice” [47].

Taking into account the above, it is considered appropriate to supplement the EPP Metallurgy with at least one additional program learning outcome in the section “Additional program learning outcomes defined by the educational institution and employers” of the following content:

PLO_Comprehensive awareness of the green transition, means of reducing carbon emissions and their impact on the competitiveness of the final product (depending on the production profile), the impact of technological factors of production and control methods. Comprehensive awareness of current environmental standards and product certification according to national and international standards in the field of production and product ecology.

5. Conclusions

This study substantiated the possibility of improving the educational program for training bachelors in metallurgy by analysing global trends in the development of the metallurgical industry and correspondingly adapting the content of the educational program components in agreement with representatives of industry employers. European integration processes in Ukraine, part of which is the implementation of European legislation, in particular, on the implementation of the national goal of reducing greenhouse gas emissions, including in the metallurgical industry, require changes to existing educational programs. The experience of redesigning the EPP

Metallurgy, which is presented in this article, shows the possibility and feasibility of the corresponding update. The main source of information for updating educational programs should be the systematic scientific work of teaching staff, tracking the main trends in the development of industry and specific technologies and equipment. An important condition in this case is the coordination of adjustments to the EPP with the main employers – partners of the faculty to take into account the specifics of a particular enterprise and its chosen strategy for modernisation of production. This will allow graduates of the faculty to have additional modern competencies, and industrial enterprises – specialists who are familiar with the technologies that are components of the so-called “green” metallurgy. This will contribute to Ukraine’s rapid transition to carbon-neutral technologies and thus meet sustainable development goals.

According to the authors, a significant result of the presented work and another component of its scientific value is the confirmation of the importance of graduates having socio-communicative skills (so-called “soft” skills), as evidenced by a survey of employers. Along with the requirement for an appropriate level of professional knowledge and skills, mastery of information technologies, employers want to see in workers the ability to work in a team, the ability to self-improvement, and the ability to show initiative. We believe that when modernising educational programs, this aspect also deserves attention.

6. Limitations and future research

The conducted research has certain limitations in terms of conclusions regarding the formation of key competencies and program learning outcomes in students under the modernised educational program, since students under this EPP are still studying. An important point is that despite the participation of employers in coordinating the content of the EPP, additional research is needed on the formation of key program learning outcomes, including that proposed by the authors as a result of this research. The prospects for further research on the topic of the article, unfortunately, largely depend on the situation in the economy of Ukraine as a whole, and in metallurgy in particular due to military actions that have not yet been stopped. This also causes some uncertainty regarding the further vectors of development of domestic metallurgy, the possibility of its modernisation and attracting investments for the introduction of new technologies. Nevertheless, the approach proposed by the authors to adjust (or redesign) the EPP can be used to update and modernise the content of specialist training in higher educational institutions, but taking into account the specifics of specific fields of knowledge and specialties.

References

1. Cabinet of Ministers of Ukraine (2021). On the approval of the National Economic Strategy for the period until 2030. Available at: <https://www.kmu.gov.ua/npas/pro-zatverdzhennya-nacionalnoyi-eko-a179>.
2. National Economic Strategy 2030 (n.d.) Available at: <https://nes2030.org.ua/#rec246061582>.
3. Verkhovna Rada of Ukraine (2024). On approval of the action plan for

implementing the recommendations of the European Commission presented in the Progress Report on Ukraine within the framework of the 2023 European Union Enlargement Package. Available at: <https://zakon.rada.gov.ua/laws/show/133-2024-%D1%80#Text>.

4. European Commission Official Portal (n.d.). *The European Green Deal. Striving to be the first climate-neutral continent*. Available at: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en.

5. Fit for 55. Available at: <https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition>.

6. Government Portal (n.d.). The government approved Ukraine's climate policy goals until 2030. Available at: <https://www.kmu.gov.ua/news/uryad-shvaliv-ciliklimatichnoyi-politiki-ukrayini-do-2030-roku>.

7. Ministry of Environmental Protection and Natural Resources of Ukraine (2021). *Analytical review of Ukraine's updated nationally determined contribution to the Paris Agreement*. Available at: <https://mepr.gov.ua/wp-content/uploads/2023/07/Analitichnyj-oglyad-NVV-lypen-2021.pdf>.

8. World Steel Association (n.d.). *World Steel in Figures 2024*. Available at: <https://worldsteel.org/steel-topics/statistics/world-steel-in-figures-2024>.

9. Boiko O. *Ukrainian exporters to pay more than € 1 billion in carbon tax to the EU under the CBAM*. Available at: <https://eba.com.ua/en/ponad-1-mlrd-yevropodatku-na-vuglets-shhoroku-splachuvatymut-ukrayinski-eksportery-v-yes-v-ramkah-svam>.

10. Quader, M. A., Ahmed, S., Ghazilla, R. A. R., Ahmed, S., & Dahari, M. (2015). A comprehensive review on energy efficient CO₂ breakthrough technologies for sustainable green iron and steel manufacturing. *Renewable and Sustainable Energy Reviews*, 50, 594–614. <https://doi.org/10.1016/j.rser.2015.05.026>.

11. Wang, P., Ryberg, M., Yang, Y., Feng, K., Kara, S., Hauschild, M., & Chen, W.-Q. (2021). Efficiency stagnation in global steel production urges joint supply- and demand-side mitigation efforts. *Nature Communications*, 12, 2066. <https://doi.org/10.1038/s41467-021-22245-6>.

12. ArcelorMittal (n.d.). *ArcelorMittal launches XCarb™, signalling its commitment to producing carbon neutral steel*. Available at: <https://corporate.arcelormittal.com/media/press-releases/arcelormittal-launches-xcarb-signalling-its-commitment-to-producing-carbon-neutral-steel#%E3%80%91>.

13. Tata Steel (n.d.). *Forging sustainable steel. How tata steel became a worldsteel sustainability champion*. Available at: <https://www.tata.com/newsroom/business/tata-steel-sustainable-aalingana>.

14. The Japan Iron and Steel Federation (n.d.). *Climate change policy*. Available at: <https://www.jisf.or.jp/en/activity/climate/index.html>.

15. UNFCCC (2020). *2050 carbon neutral strategy of the Republic of Korea. Towards a sustainable and green society*. Available at:

https://unfccc.int/sites/default/files/resource/LTS1_RKorea.pdf.

16. Press and Information Office of the Federal Government of Germany (2021). *Climate Change Act. Intergenerational contract for the climate*. Available at: <https://www.bundesregierung.de/breg-en/service/archive/climate-change-act-2021-1936846>.

17. Federal Ministry for Economic Affairs and Climate Action of Germany (2023). *National Hydrogen Strategy Update. NHS 2023*. Berlin. Available at: https://www.bundeswirtschaftsministerium.de/Redaktion/EN/Publikationen/Energie/national-hydrogen-strategy-update.pdf?__blob=publicationFile&v=3.

18. Thyssenkrupp (n.d.). *Green hydrogen and its derivatives*. Available at: <https://www.thyssenkrupp.com/en/stories/sustainability-and-climate-protection/green-hydrogen-and-its-derivatives>.

19. Andrukh, Ye. O., & Stupak, Yu. O. (2020). On the prospects of using hydrogen as a fuel substitute and reducer in ferrous metallurgy. *Proceeding of II All-Ukrainian Conference of Young Scientists “Young Scientists 2020 – from theory to practice”* (December 17, 2020). Dnipro. Available at: <https://nmetau.edu.ua/file/min-2020-elver.pdf>.

20. Elektrovesti.net (2019). *ThyssenKrupp starts using hydrogen in steel production*. Available at: https://elektrovesti.net/68338_thyssenkrupp-nachal-ispolzovat-vodorod-v-proizvodstve-stali.

21. Mazengarb, M. (2019). Another nail in coal’s coffin? German steel furnace runs on renewable hydrogen in world first. *Renew Economy*. Available at: <https://reneweconomy.com.au/another-nail-in-coals-coffin-german-steel-furnace-runs-on-renewable-hydrogen-in-world-first-55906>.

22. Devlin, A., Kossen, J., Goldie-Jones, H., & Yang, A. (2023). Global green hydrogen-based steel opportunities surrounding high quality renewable energy and iron ore deposits. *Nature Communications*, 14, 2578. <https://doi.org/10.1038/s41467-023-38123-2>.

23. Ministry of Education and Science of Ukraine (2018). Ukrainian higher education standard for the first (bachelor’s) level in the field of knowledge 13-Mechanical Engineering, specialisation 136-Metallurgy. Available at: <https://mon.gov.ua/storage/app/media/vishcha-osvita/zatverdzeni%20standarty/12/21/136-Metalurhiya-bakalavr.pdf>.

24. Khokhlova, T. S., Stupak, Yu. O., Soloviova, I. A., Horobets, A. P., & Revenko, O. O. (2021). Regarding the participation of employers in improving the content of specialist training at universities. *Proceedings of the IV International Conference “Innovative technologies in science and education. European experience”* (December 6–8, 2021). Helsinki–Dnipro. Available at: <https://crust.ust.edu.ua/server/api/core/bitstreams/9b7969e0-5500-4d92-be12-03bc885e2b59/content>.

25. Dnipro Metallurgical Institute of Ukrainian State University of Science and Technologies (2025). *Educational and professional programme “Metallurgy” of the*

first (bachelor's) level of higher education in the speciality 136 Metallurgy. Available at: <https://nmetau.edu.ua/ua/mdiv/i2062/p4331>.

26. Balakin, V. F., & Stupak, Yu. O. (2024). Experience in monitoring the educational programme for training specialists in the field of metallurgy (based on the example of the Metallurgy educational programme of the Nikopol Faculty of UDUNT). *Proceedings of the XVIII International Conference "Strategy of Quality in Industry and Education"* (3–6 June, 2024). Varna–Dnipro. Available at: https://nmetau.edu.ua/file/balakin-stupak-varna-2024-stor_142_187.pdf.

27. The Deming Institute (n.d.). *Enriching society through the Deming philosophy*. Available at: <https://deming.org/explore/pdsa>.

28. Khokhlova, T. S., Stupak, Yu. O., & Savchenko, H. H. (2020). Content and quality of basic education as an essential factor in the quality of professional training in a modern technical institution of higher education. *Educational Horizons*, 50(1), 190–200. <https://doi.org/10.15330/obrii.50.1.190-200>.

29. Glushchenko, A. (2023). How Ukrainian steel industry is integrating into EU. *GMK Center*. Available at: <https://gmk.center.ua/posts/shlyahi-ievrointegracii-ukrainskoi-metalurgii>.

30. Ahapova, V. (2023). Blocked logistics, global competition, and a threefold drop in exports. How the war changed Ukraine's metallurgy industry, which was the main source of foreign currency inflows. Research by Vox Ukraine. *Forbes Ukraine*. Available at: <https://forbes.ua/money/eksport-metaloproduktsii-vpav-utrichi-shcho-viyna-zminila-v-ukrainskikh-metalurgiv-yaki-davali-osnovnikh-pritok-valyuti-v-krainu-27062023-14446>.

31. DP «Derzhzovnishinform» (2023). *Forecast of steel production in Ukraine in 2023*. Available at: <https://dzi.gov.ua/press-centre/news/prognoz-vyrobnystva-stali-v-ukrayini-u-2023-rotsi>.

32. Sheiko, O. (2024). Difficult times for metallurgy. *Ekonomichna pravda*. Available at: <https://epravda.com.ua/columns/2024/02/16/710004>.

33. Hryhorenko, Yu. (2020). Iron vector: metallurgists must increase product margins. *GMK Center*. Available at: <https://gmk.center.ua/posts/zaloznij-vektor-metalurgi-majut-narostiti-marzhinalnist-produkcii>.

34. Holovko, I. (2021). Climate goals and Ukrainian industry: modernise or lose out. *Commons*. Available at: <https://commons.com.ua/uk/klimatichni-cili-ta-ukrayinska-promislovist>.

35. Ekonomichna Pravda (2021). *Green metallurgy: why no financial incentives for industrial decarbonisation are working in Ukraine*. Available at: <https://gmk.center.ua/posts/shlyahi-ievrointegracii-ukrainskoi-metalurgii>.

36. Gielen, D., Bennaceur, K., Kerr, T., Tam, C., Tanaka, K., Taylor, M., & Taylor, P. (2007). Tracking industrial energy efficiency and CO₂ emissions. International Energy Agency (IEA), OECD/IEA. Available at: https://www.researchgate.net/publication/279804486_IEA_Tracking_Industrial_Energy_Efficiency_and_CO2_Emissions.

37. Balakin, V. F., Khokhlova, T. S., Stupak, Yu. O., & Soloviova, I. A. (2022). Transforming the content of specialist training in line with employer demands as a necessary condition for the competitiveness of modern universities. *Proceedings of the V International Conference “Innovative technologies in science and education. European experience”* (November 29, 2022). Dnipro, Zhurfond. Available at: [https://drive.google.com/file/d/13VTOEPwGu8dRXhxjUvNVHMNMATWDq73V/v](https://drive.google.com/file/d/13VTOEPwGu8dRXhxjUvNVHMNMATWDq73V/view)
38. European Commission (2023). *Persistent lack of skilled workers could threaten EU clean energy transition*. Available at: https://cinea.ec.europa.eu/news-events/news/persistent-lack-skilled-workers-could-threaten-eu-clean-energy-transition-2023-12-06_en.
39. OECD (2023). *Assessing and anticipating skills for the green transition. Unlocking talent for a sustainable future*. Available at: <https://www.oecd-ilibrary.org/sites/374106af-en/index.html?itemId=/content/component/374106af-en>.
40. European Investment Bank (2023). *Skills shortage is delaying the green transition, EIB Municipality Survey shows*. Available at: <https://www.eib.org/en/press/all/2023-255-eib-unveils-2022-municipality-survey-findings-skills-shortage-is-delaying-the-green-transition>.
41. International Labour Organization (n.d.). *Skills for the green transition. World Employment and Social Outlook 2018*. Available at: <https://www.ilo.org/weso-greening/#Chapter-5>.
42. Huckstep, S., Kenny, C., & Dempster, H. (2022). *The green transition needs more skilled workers. Here’s how Europe could use migration to meet the demand*. Center for Global Development. Available at: <https://www.cgdev.org/blog/green-transition-needs-more-skilled-workers-heres-how-europe-could-use-migration-meet-demand>.
43. Bidenko, N. V., Ostapko, O. I., & Vatankha, T. V. (n.d.). Involvement of stakeholders in the preparation and improvement of the educational programme ‘Dentistry’ at the Bogomolets National Medical University. Available at: <http://ir.librarynmu.com/bitstream/123456789/6750/1/%D0%9C%D0%B0%D1%82%D0%B5%D1%80%D0%B0%D0%BB%D0%B8%20%281%29.pdf>.
44. Kryvoruchko, O. M., Kryvenko, L. F., & Femiak, O. A. (2024). Involvement of stakeholders in ensuring the quality of educational activities in higher education institutions. Materials of the III International Scientific and Methodological Conference “*Higher Education According to New Standards: Challenges in the Context of Digitalisation and Integration into the International Educational Space*” (April 4 2024). Kharkiv. Available at: <https://dspace.khadi.kharkov.ua/handle/123456789/22795>.
45. Dumenko, K. A., Esaulova, N. V., Sybeleva, T. N., Stupak, Yu. A., & Zynchenko, S. M. (2018). Metallurgical production at the European level: employer views on the qualifications (competences) of metallurgical graduates. *Materials of the XIV International Conference “Quality Strategy in Industry and Education”*, vol. I.

(June 4–7, 2018). Dnipro-Varna.

46. Balakin, V. F., Khokhlova, T. S., & Stupak, Yu. O. (2024). Interaction with employers as a factor in ensuring the relevance of the educational and professional training program. *Proceedings of the VII International Conference “Innovative technologies in science and education. European experience”* (December 23–25, 2024, Dnipro, Zhurfond. Available at: https://nmetau.edu.ua/file/-zbirnik-innovats-2024-isbn-na_sayt-1.pdf.

47. Kobliuk, S. (n.d.). *Feedback on the educational and professional programme “Metallurgy”*. Available at: https://nmetau.edu.ua/file/at_nzf-2024.pdf.