IRSTI 14.27.09

10.51889/2959-5894.2024.87.3.024

Sh.Zh. Ramankulov[1*], N.P. Mussakhan[1], J.M. Bitibaeva[2], B.A. Kurbanbekov[1], D. Berdi[1]

[1] Khoja Ahmet Yassawi International Kazakh-Turkish University, Turkestan, Kazakhstan
[2] Abai Kazakh National Pedagogical University, Almaty, Kazakhstan
[*]*e-mail: Sherzod.ramankulov@ayu.edu.kz*

INTEGRATION OF EDUCATION, SCIENCE AND PRODUCTION: METHODOLOGICAL FEATURES OF STEM PRODUCT DEVELOPMENT

Abstract

The STEM-based laboratory is a module that combines elements of science, technology, engineering and mathematics from both a theoretical and practical point of view. In the educational process, this module examines the elements of problem-based learning to improve active learning and the learning process. In particular, teaching physics allows students to learn about digital engineering, work in educational and practical laboratories on their projects related to curricula, and improve their professional skills. This scientific study examines the methods of using the possibilities of the scientific environment and the integration of production in the development of the quality of education in physics educational programs. The purpose of this study is also to determine the impact of interdisciplinary STEM education on the labor market, factors determining the continuity of production and educational organizations. In the course of the study, multimethodic quantitative and qualitative research methods were used. A meta-analysis and systematic analysis of articles in highly regarded journals from Wos and Scopus sources was carried out. About 200 respondents participated in the quantitative data collection in the study. The STEM laboratories used the method of constructive research in order to combine physical knowledge with practice, to improve the work on the development of STEM products in scientific environments. The results of the study showed that the effective implementation of the links between the scientific environment and production in the educational process makes students competitive in the labor market. The research also revealed the technology of product development in the STEM laboratory and the methodological features of the use of products in the educational process. The results obtained correspond to global trends and have a positive impact on the development of scientific and technological trends in the country, the further development of the educational process, and the systematic formation of necessary 21st century skills among students.

Keywords: STEM education, continuity in education, STEM product, STEM laboratory, physics teaching, production.

Ш.Ж. Раманкулов[1], Н.П. Мұсахан[1], Ж.М. Битибаева[2], Б.А. Курбанбеков[1], Д. Берді[1]
[1] Қ.А.Ясауи атындағы Халықаралық қазақ-түрік Университеті, Түркістан қ., Қазақстан
[2]Абай атындағы Қазақ Ұлттық педагогикалық университеті, Алматы қ., Қазақстан

БІЛІМ, ҒЫЛЫМ ЖӘНЕ ӨНДІРІС ИНТЕГРАЦИЯСЫ: STEM ӨНІМДЕР ӘЗІРЛЕУДІҢ ӘДІСТЕМЕЛІК ЕРЕКШЕЛІКТЕРІ

Аңдатпа

STEM (Ғылым, Технология, Инженерия және Математика) негізіндегі зертхана - ғылым, технология, инженерия және математика элементтерін теориялық және практикалық тұрғыдан біріктіретін модуль болып табылады. Білім беру үдерісінде бұл модуль белсенді оқыту мен оқу үдерісін жақсарту үшін проблемаға бағытталған оқыту элементтерінде қарастырады. Әсіресе, физиканы оқытуда білім алушыларға цифрлық инжиниринг мәселелерін үйретуге, олардың оқу жоспарларымен байланысты өз жобалары бойынша оқу-практикалық зертханаларда жұмыс істеуге және өздерінің кәсіби дағдыларын жетілдіруге мүмкіндік береді. Бұл ғылыми зерттеуде физика білім беру бағдарламалары бойынша білім беру сапасын дамытуда ғылыми ортаның мүмкіндіктерін пайдалану және өндірісті интеграциялау әдістері қарастырылады. Сондай-ақ, бұл зерттеудің мақсаты - пәнаралық STEM білім берудің еңбек нарығына әсерін, өндіріс пен білім беру ұйымдарының сабақтастығын

анықтайтын факторларды айқындау болып табылады. Зерттеу барысында мультиметодикалы сандық және сапалық зерттеу әдістері қолданылды. Wos және Scopus дереккөздеріндегі жоғары рейтингті журналдарда орын алған мақалаларға мета-анализ және систематикалық талдау жүргізілді. Сандық деректерді жинауда зерттеуге 200-ге жуық респондент қатысты. STEM зертханаларда физикалық білімді практикамен ұштастыру, ғылыми ортада STEM өнімдерді әзірлеу жұмыстарын жақсарту мақсатында сындарлы зерттеу әдісі қолданылды. Зерттеу нәтижелері білім беру үдерісінде ғылыми орта және өндіріс байланысын тиімді іске асырудың еңбек нарығында білім алушыларды бәсекеге қабілетті болатындығын көрсетті. Сондай-ақ, зерттеу барысында STEM зертханасында өнімдер әзірлеудің технологиясы мен өнімдерді оқу үдерісінде қолданудың әдістемелік ерекшеліктері айқындалды. Алынған нәтижелер әлемдік трендтерге сәйкес келеді және еліміздегі ғылыми-технологиялық бағыттың дамуына, білім беру үдерісін одан әрі дамытуға, білім алушыларды 21 ғасырдағы қажетті дағдыларының жүйелі қалыптасуына оң әсер етеді.

Түйін сөздер: STEM білім, білім берудегі сабақтастық, STEM өнімі, STEM зертхана, физиканы оқыту, өндіріс.

Ш.Ж. Раманкулов[1], Н.П. Мусахан[1], Ж.М. Битибаева[2], Б.А. Курбанбеков[1], Д. Берди[1]
[1] Международный казахско-турецкий Университет имени Х.А.Ясави, Туркестан, Казахстан
[2]Казахский Национальный педагогический университет имени Абая, Алматы, Казахстан.

ИНТЕГРАЦИЯ ОБРАЗОВАНИЯ, НАУКИ И ПРОИЗВОДСТВА: МЕТОДИЧЕСКИЕ ОСОБЕННОСТИ РАЗРАБОТКИ ПРОДУКТОВ STEM

Аннотация

Лаборатория на основе STEM-это модуль, который сочетает в себе элементы науки, технологий, инженерии и математики как с теоретической, так и с практической точки зрения. В образовательном процессе этот модуль рассматривает элементы проблемно-ориентированного обучения для улучшения активного обучения и учебного процесса. В частности, преподавание физики позволяет обучающимся обучаться вопросам цифрового инжиниринга, работать в учебно-практических лабораториях над своими проектами, связанными с учебными планами, и совершенствовать свои профессиональные навыки. В данном научном исследовании рассматриваются методы использования возможностей научной среды и интеграции производства в развитии качества образования по образовательным программам физики. Также целью данного исследования является определение влияния междисциплинарного STEM-образования на рынок труда, факторов, определяющих преемственность производства и образовательных организаций. В ходе исследования были использованы мультиметодические количественные и качественные методы исследования. Был проведен метаанализ и систематический анализ статей в высоко оцененных журналах из источников Wos и Scopus. В количественном сборе данных в исследовании приняли участие около 200 респондентов. В лабораториях STEM применялся метод конструктивных исследований с целью сочетания физических знаний с практикой, улучшения работы по разработке продуктов STEM в научных средах. Результаты исследования показали, что эффективная реализация связей научной среды и производства в образовательном процессе делает обучающихся конкурентоспособными на рынке труда. Также в ходе исследования были выявлены технология разработки продукции в лаборатории STEM и методические особенности применения продукции в учебном процессе. Полученные результаты соответствуют мировым трендам и положительно влияют на развитие научно-технологического направления в стране, дальнейшее развитие образовательного процесса, системное формирование у обучающихся необходимых навыков 21 века.

Ключевые слова: STEM образование, преемственность в образовании, STEM продукт, STEM лаборатория, преподавание физики, производство.

Main provisions

A promising research idea is to establish the continuity of STEM education as a new way to develop employment opportunities for students in natural sciences, starting from school, through planned cooperation at the University and industry levels. We refer to the new scientific problems of introducing STEM design into educational processes on the basis of interdisciplinary continuity, assessing the impact on the development of industrial industries, combining knowledge within the walls of schools and universities with science and industry.

As a result of the study, the level of exchange of knowledge at the enterprise and educational institutions and contacts between the scientific environment and industry was assessed. The methodological features of the development of products and their use in the educational process in the STEM laboratory were identified. The conclusion of the study showed the importance of implementing the continuity of the STEM education model.

Introduction

The joint utilisation of the potential of stakeholders and thus the integration of education, science and production is of great importance for economic, social, scientific and technological success. Intensive development of information flow provides situations based on inter-subject links in society. Consequently, the integration processes between learning and production activities in the scientific environment are effective and accelerate scientific and technological progress. It will also be possible to rationally use the potential of science and higher education in the world community and in the country [1].

STEM education allows to build a successful career in the future by meeting today's technological and scientific demands. As STEM education aims to strengthen connections between disciplines, gaining new ideas and advances in the field provides students with a wide range of opportunities. The work of several academics who have studied the impact of interdisciplinary STEM education on the labour market through meta-analyses of articles that have occurred in highly ranked journals in recent years can be taken as a basis.

A.T.Akcan, B.Yıldırım, A.R.Karataş and M.Yılmaz determine the impact of interdisciplinary STEM education on the labour market from the teachers' point of view using survey and interview methods among teachers considering the conditions of interdisciplinary STEM education [2]. By increasing the number of students with STEM education in the United States, the demand for STEM education in the labour market has increased [3]. Cooperation between universities and manufacturing companies in the USA and European countries ensures the quality of the education system in the country and sustainable development of the country. Kazakhstan, along with developed countries, contributes to the preservation of economic stability of the country through the implementation of joint projects between higher education institutions, research institutes and large manufacturing companies.

The continuity between education, scientific environment and production as one of the most important factors of sustainable development of each country allows to introduce innovations, develop new technologies and improve the efficiency of the economy in any sector [4].

Integration processes, such as training of future specialists in physics, joint research with academia in the field of advanced training and retraining of specialists, implementation of research developments, cover a wide range of spheres of activity. Technological development not only affects various spheres of society, but also contributes to the production, economic aspects, contributes to the quality of life, and increases labour productivity. STEM education has been promoted all over the world to create a science, technology, engineering and maths literate society. Therefore, the idea of interdisciplinary STEM education has started to be considered. This concept plays an important role in today's education system.

Based on our preliminary research, we consider it appropriate to implement the process of creating STEM-labs, preparing products and introducing them into the teaching process of physics educational programmes. This is because physics is an experimental science that studies nature. Given that physics has a high potential for interdisciplinary integration, we see that STEM has more opportunities to achieve new creative innovations by developing products in laboratories.

Scientific works by H.Gerde, G.Bingham, M.Kung, A.Pikus and H.Etchison consider the impact of STEM labs on improving the quality of teacher-student interactions and science experiences. Special attention was paid to the role and effectiveness of STEM labs in the professional development of scientists, teachers [5]. In the article, N.Huri and M.Karpudewan evaluate the effectiveness of integrated STEM lab activities to improve middle school students' understanding of the phenomenon

of electrolysis. The article discusses the features of STEM lab activities in chemistry teaching and its impact on students' academic achievement [6]. The research of M.Estes, J.Liu, K.Reedy proves the effectiveness of using problem-based learning method in STEM labs. The results of this study show that students can improve their research skills, teamwork skills and overall academic achievement [7].

In a research article, W.Kadir, I.Mustapha and N.Abdullah investigate the effect of STEM-based interactive physics laboratory module on learners' understanding of physics and performance, employment. The paper examines the learners' participation in the learning process and the effect of interactive laboratory practices on their level of understanding. The results of the study showed that the level of physics understanding of the learners in the experimental group who used the STEM laboratory module was significantly higher than that of the control group. The interactive laboratory module increased the learners' interest and aroused their interest in the subject.

From the above studies, we can observe that STEM labs can effectively integrate education, research and industrial integration through product development. However, according to the topic of the current study, there is insufficient research on interdisciplinary STEM education, the effectiveness of the education system, and the preparation of labour market-ready professionals. Specifically, interdisciplinary STEM argues that education causes shortages in educational resources, teacher training and qualifications, job shortages, and difficulties in absorbing new technologies. The first step towards meeting these needs, along with the effective implementation of academic disciplines in the training of STEM professionals in interdisciplinary STEM education, is to determine its impact on the labour market.

Consequently, in accordance with the purpose of our study, it is relevant to determine the impact of interdisciplinary STEM education on the labour market, factors determining the continuity of production and educational organizations.

In addition, in the course of the study we determine the solution of the following research questions:

- Which possibilities are there to combine physical knowledge with practice in STEM laboratories, to improve the work on development of STEM products in scientific circles?
- What is the connection of effective implementation of scientific environment and production links in the educational process with the competitiveness of students on the labour market?
- What is the technology of product development in STEM-labs and methodological peculiarities of product application in the educational process?

These research questions are distinguished by their novelty from a scientific and methodological point of view. Therefore, the determination of the solution of the tasks set in accordance with the purpose of the study is an urgent problem of our time.

Research methodology

The study used Multimethod Research (Multimethod Research), which allows us to expand the depth and scope of the subject, compare data from different data sources, and integrate results using multiple methods and approaches simultaneously. Scientific articles were collected via Elsevier's Mendeley software (https://www.mendeley.com/search/) and meta-analysed. More than 150 scientific articles were identified using the keywords «STEM education», «continuity in education», «STEM product', «STEM laboratory», «physics teaching», «manufacturing». They were selected according to different criteria. A systematic analysis was made of 12 recent articles that formed the basis of the research topic. Conclusions were obtained on the advanced technological educational resources and research findings used in the research papers of the research scholars. In the meta-analysis of qualitative studies, in line with our research topic, we have taken as a basis the research papers of N.Tenti et al. [9], D.Suciana et al. [10]. A 15-question survey was developed via Google Forms. The survey questions focused on demonstrating participant information (anonymised), STEM knowledge, employment impact, skills and career opportunities, suggestions and conclusions covering 5 sections. The survey was randomly administered to employees in STEM fields. General information about the survey participants is summarised in Table 1.

Table 1. Information about survey participants

Category	*Number*	*Percentage (%)*	*Total*
Employee	*120*	*60%*	*200 (100%)*
Unemployed	*20*	*10%*	
Student	*50*	*25%*	
Other	*10*	*5%*	
Gender	*Female (115)*	*57,5%*	
	Male (85)	*42,5%*	

Let's list the main questions in accordance with the 3rd, 4th and 5th sections contained in the structure of the questionnaire:

- Did STEM education help you get a job?
- Do you think employers value candidates with STEM education more?
- What skills gained during STEM education were most useful in the workplace?
- Do you think STEM education increases career opportunities?
- How important are the skills learned during STEM education in your current workplace?
- What, in your opinion, are the main advantages of STEM education in the labor market?
- What difficulties did you face with getting a job or STEM education in the workplace?
- How important do you think it is to exchange experience in industrial places to achieve success in STEM education?

Google went to the "answers" button at the top of the form and received a brief summary of the answers. Graphs of the answers given to each question and individual answers of each respondent were discussed. In the preparation of technology for creating products in the STEM laboratory, the method of modeling 3D-printing, digital design methods for engineering and technical objects were used. We used the design method in the development of 3-dimensional graphics of the necessary equipment based on new software.

Results of the study

The results obtained from scientific papers on the topic of research on the world stage show that people with STEM education are more likely to find work. At the same time, domestic scientists believe that Interdisciplinary STEM education will strengthen scientific and innovative potential, comprehensively train future specialists, and allow students to project thinking, connecting the acquired knowledge with the environment. Although Interdisciplinary STEM education plays an important role in providing professions, improving the education system, it is obvious that it allows systematic search work to solve some difficulties in the direction of Education. Interdisciplinary STEM education trains students in their practical application by deepening innovative, scientific and technical knowledge. Researchers show that STEM makes a significant contribution in education through the use of industrial actors, in economic growth, in increasing interest in STEM, in empowering young people. However, there is also the unevenness of STEM education according to the type and nature of jobs in the labor market. There is an increasing need for professionals in the STEM field, such as physicists and computer science specialists. This further strengthens the link between STEM education and employment. Thus, Interdisciplinary STEM education can contribute more to the economy (Figure 1).

Integration of the scientific environment and production in the training of future specialists in the educational programmes of physics in universities affects the development of innovations and new technologies, as well as the sustainable development of the economy. The methods of integration of production into the educational and scientific environment for training future specialists allow to introduce new knowledge and technologies, new innovations. Therefore, analysing scientific and methodological literature and regulatory documents, we propose to use several methods of production integration (Table 2).

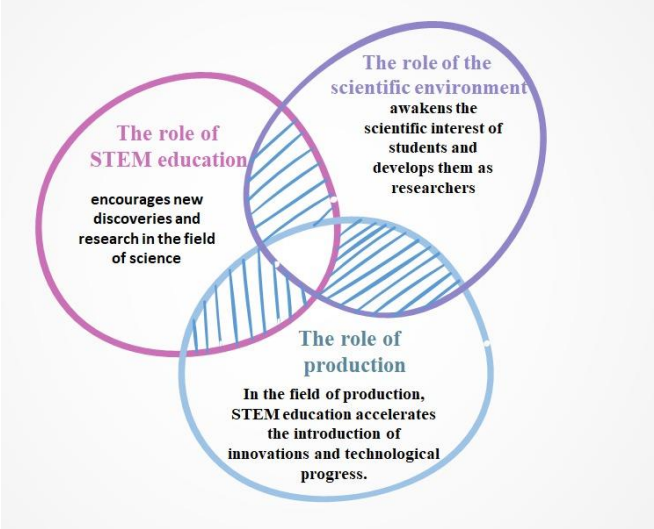

Figure 1. Continuity in the direction of education, scientific environment and production in the field of STEM

Table 2. Methods of integrating production into the educational and scientific environment for the training of future specialists

p/c	*Integration of production in education and science*	*Description*
1	*Research and development work in higher educational institutions.*	*Organization and conduct of joint research projects between higher educational institutions and industrial organizations. This method allows to develop new technologies, improve production processes in the country.*
2	*Increase of places of production practice and creation of innovation centers.*	*For future specialists it is necessary to choose the right places of industrial practice. This allows students to gain work experience in specific production conditions. Innovation centres at universities create conditions for students and researchers to work closely with production companies.*
3	*Integration of educational programs. Implementation of dual-degree and vocational training programs.*	*The introduction of dual degree programmes, vocational training programmes based on agreements between higher education institutions and production companies will help to gain industrial experience during the training period, improve the qualifications of the workforce and increase the efficiency of production activities.*
4	*Creation of technoparks. Centralization of the use of laboratory and production facilities.*	*The creation of technoparks at universities allows start-ups, research groups and production companies to jointly develop and introduce new technologies into production. The efficiency of resource utilisation is increased through the use of laboratory and production facilities.*
5	*Organization and holding of seminars and conferences.*	*By bringing together the scientific and industrial community through the organisation of joint seminars and conferences, it is possible to develop the potential of students and researchers.*
6	*Obtaining patents, copyright certificates and licenses. Implementation of pilot projects.*	*New technologies developed in higher education institutions contribute to the scientific, technical and economic development of the country through the introduction of licensing and commercialisation mechanisms in production companies and joint implementation of pilot projects.*

We opened a educational laboratory «STEM and Creativity» as methods of integration of scientific environment and production as part of educational programmes for training future specialists in physics. The educational laboratory is equipped with modern equipment and is focused on the

development and implementation of innovative products. The students of the Physics educational programme work together with researchers in the teaching-lab to develop and implement various products in the educational process. STEM product development in this teaching lab is done by integrating educational, research and industrial processes. All resources and tools necessary for the development of innovative products and technologies are available in these laboratories (Fig.2).

Figure 2. STEM products developed in the laboratory

The strategic goal of the educational laboratory «STEM and Creativity» is to create a modern digital educational environment, to realise the effectiveness of interdisciplinary teaching of physics, to develop STEM products and evaluate their effectiveness in the educational process, to develop engineering activities of students, to promote the development of science and technology in the country through commercialisation of the created products, to improve economic efficiency.

On what topic exactly the work in the laboratory will be carried out depends on the STEM and creative methodology. As a rule, such laboratories are used in Physics in order to develop practical skills and increase creative abilities. Training laboratories have the opportunity to develop products in such key areas as" energy conversion and energy sources"," robotics and automation elements"," electric and magnetic fields"," optics and light phenomena"," mechanics and laws of motion"," 3D-modeling and engineering projects".

At present, the research group has launched several STEM research benches within the framework of the project. A telescope designed with the help of 3D printers and other equipment has been created. 3D model programmes on several physics topics have been created based on VR (virtual reality) technology. VR technology can be used to visualize and display complex phenomena in an understandable way in such topics of physics as mechanics, optics, electricity and magnetism, quantum physics, thermodynamics, astronomy, waves and vibrations, as well as the study of the Nano and microcosm. The developed products were implemented in the process of teaching special disciplines in physics educational programmes. The introduction of STEM products into the educational process was aimed at developing students' scientific and technical skills, increasing their ability to think innovatively and preparing them for specialities in demand in the future. The inclusion of content related to STEM subjects in the educational programme, i.e. the holistic integration of science, technology, engineering and mathematics, has enabled physics majors to be involved in projects that integrate several disciplines. Skills are taught in design and prototyping using 3D printers, resources needed for robotics, coding, engineering design and physics experiments. Consequently, integrating STEM education with academia and industry can encourage future professionals to innovate and develop new technologies. We also conducted a systematic analysis of the survey results in the course of the study, focused on identifying the impact of Interdisciplinary STEM education on the labor market, factors determining the continuity of production and educational organizations. The vast majority of participants were professionals over 30, 27.8% were between 22 and 25, and 22.2% were participants between the ages of 18 and 21. This survey was 57.5% women who expressed their views and 42.5% men who expressed interest in the survey.

On the question *«Do you have knowledge (concept/professional knowledge/interest) in the field of STEM (Science, Technology, Engineering, Mathematics)?»* 88.9% of the survey participants showed that they have STEM education, 11.1% do not have knowledge in this field of science. On the question

«Did STEM education help you get a job? If yes, how did STEM education affect you?» 50% of participants were able to get a job through STEM education, 33.3% were able to get a job partially, 16.7% were not able to get a job at all. According to the participants, we noticed that while STEM affects access to education, high technology and innovative jobs, according to some reviews, it is an improvement in professional skills. On the question *«Do you think employers value candidates with STEM education more?»* in the comments on the question, there was a positive answer that was in the lead, that is, 66.7% showed a high assessment of candidates with STEM education. And 27.8% of respondents said that sometimes, 5.6% of respondents said that they do not care about STEM education when applying for a job. On the question *«How important do you think it is to exchange experience in industrial settings to achieve success in STEM education?»* 61.1% of participants highly appreciated the importance of the exchange of experience, and 5.6% of participants noted the average level of importance. On the question *«How important do you think the continuity of school and higher education institutions is to achieve success in STEM?»* 55.6% of participants expressed their opinion that school and higher education institutions have a high degree of continuity for success in STEM, 33.9% said that it is moderately important, and 5.6% said that it is not important. For the question, *«What do you think are the barriers to becoming a qualified STEM professional?»* participants considered the lack of STEM specific disciplines, lack of qualified STEM professionals, teachers, and teachers to be a barrier. In addition, from the analysis of the survey participants' responses to other questions, conclusions were drawn on such topical issues as the great impact of STEM education on the labour market, training highly qualified specialists, stimulating innovation and technological development, ensuring economic growth and reducing unemployment. In addition, survey participants express confidence that STEM education will increase social equity and promote new occupations. Thus, it can be concluded that through STEM education it is possible to develop the labour market and improve the welfare of society as a whole.

Discussion

The results of our research determine the competitiveness of students in the labour market of interdisciplinary STEM education. The article by R.Kiselova and A.Gravite [11] examines STEM educational policies in Latvia and their impact on the labour market. Researchers through surveys and interviews analyse the reforms of Stem-direction in the Latvian education system and their impact on the economic development of the country. D.Bennett, E. Knight, A.Dockery and S. Bawa [12] discuss new pedagogical approaches to employability of STEM students using quantitative and qualitative methods in their research. The researchers‘ study identifies methods and strategies to enhance students’ preparation for the labour market. Our study aimed to identify the source of economic efficiency in the context of globalisation by incorporating new production processes in physics in combination with the labour market in STEM education. Globalisation and scientific innovation in STEM education, industrial continuity leads to renewal and openness of all spheres of life.

Conclusion

Consequently, STEM education has a serious impact on the modern labour market. Thanks to our multi-method quantitative and qualitative research methods, we were able to identify the factors determining the continuity of production and educational organisations, such as the improvement of highly qualified specialties and technical skills, the development of innovation potential, the creation of joint research centres, the renewal of educational programmes, the increase in sources of financial support and incentives, the build-up of technological infrastructure, the increase in strategic and strategic partnerships, the increase in the number of students, and the increase in the number of educational institutions. The implementation of the application of the results of this study on the example of teaching individual disciplines will allow creating a single educational space for engineering and technical creativity, programming, design and interdisciplinary experimentation, effectively implementing the joint activities of the school-university-industry association.

Therefore, given the high level of prospects for the results of the study, this circumstance makes a huge leap forward in the development of world and domestic science. The development of cooperation between education, the scientific community and industry will allow creating innovative processes, mastering engineering and technical education from an early age and solving problems up to employment, thereby improving the socio-economic situation of the country. Products created on the basis of the continuity of the Interdisciplinary STEM education model have a high practical value and a very wide level of readiness to be used by a large range of consumers through their commercialization. The results obtained in the course of our research on the example of teaching individual disciplines have a great impact on the development of the STEM industry in the country.

Acknowledgement

This research has been/was/is funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant AP22784343).

References

[1] Ayazhan, S., Tleubekovna, A. N., & Dinara, Z. (2022). Integration of science, education and production in the conditions of innovative development of Kazakhstan. Actual Problems in the System of Education: General Secondary Education Institution – Pre-University Training – Higher Education Institution, (2), 167–174. https://doi.org/10.18372/2786-5487.1.16595

[2] Akcan, A. T., Yıldırım, B., Karataş, A. R., & Yılmaz, M. (2023). Teachers' views on the effect of STEM education on the labor market. Frontiers in Psychology, 14. https://doi.org/10.3389/fpsyg.2023.1184730

[3] Salzman, H., & Lieff Benderly, B. (2019). STEM Performance and Supply: Assessing the Evidence for Education Policy. Journal of Science Education and Technology, 28(1), 9–25. https://doi.org/10.1007/s10956-018-9758-9

[4] Troshkova, E. V., Bezrukikh, J. A., Safronov, M. V., & Luk'ianova, A. A. (2023). Designing a new education ecosystem model for sustainable regional development using additive technologies. Advances in Business Marketing and Purchasing, 27, 101–109. https://doi.org/10.1108/S1069-096420230000027011

[5] Gerde, H. K., Bingham, G. E., Kung, M., Pikus, A. E., & Etchison, H. (2023). STEM Labs: A promising professional learning approach to promote teacher–child interaction quality and science and engineering practices. Early Education and Development, 34(5), 1147–1171. https://doi.org/10.1080/10409289.2022.2090775

[6] Huri, N. H. D., & Karpudewan, M. (2019). Evaluating the effectiveness of Integrated STEM-lab activities in improving secondary school students' understanding of electrolysis. Chemistry Education Research and Practice, 20(3), 495–508. https://doi.org/10.1039/c9rp00021f

[7] Estes, M. D., Liu, J., Zha, S., & Reedy, K. (2014). Designing for problem-based learning in a collaborative STEM lab: A case study. TechTrends, 58(6), 90–98. https://doi.org/10.1007/s11528-014-0808-8

[8] Kadir, W. N. H. W. A., Mustapha, I. R., & Abdullah, N. S. Y. (2021). The Effectiveness of a STEM-Based Physics Interactive Laboratory (I-LAB) Module for Form Four Physics Students. Review of International Geographical Education Online, 11(4), 1042–1049. https://doi.org/10.33403/rigeo.8006818

[9] Tenti, N. P., Asrizal, -, Murtiani, -, & Gusnedi, -. (2021). Meta-Analysis of The Effect of Integration Stem Education in a Various Learning Models on Student Physics Learning Outcomes. Pillar of physics education, 13(4), 520. https://doi.org/10.24036/10331171074

[10] Suciana, D., Hartinawati, Sausan, I., & Meliza. (2023). A Meta-Analysis Study: The Effect of Problem Based Learning Integrated with STEM on Learning Outcomes. European Journal of Education and Pedagogy, 4(2), 133–138. https://doi.org/10.24018/ejedu.2023.4.2.619

[11] Kiselova, R., & Gravite, A. (2017). STEM Education Policies and Their Impact on the Labour Market in Latvia. Bulgarian Comparative Education Society, 15, 108–114. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=ED574218&site=ehost-live

[12] Bennett, D., Knight, E., Dockery, A. M., & Bawa, S. (2020). Pedagogies for employability: understanding the needs of STEM students through a new approach to employability development. Higher Education Pedagogies, 5(1), 340–359. https://doi.org/10.1080/23752696.2020.1847162