International Journal of Research in E-learning
Vol. 4 (2), 2018, pp. 45–59

DOI 10.31261/IJREL.2018.4.2.04

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Influence of University Innovative Educational Environment on the Development of Digital STEM Competences

Abstract

The article deals with the problem of the influence of the innovative educational environment of the university on the development of digital STEM competences in the process of training teachers of the new formation. It is determined that the innovative educational environment of the university consists of organisational, educational, methodological, and technological and information resources, the purpose of which is to create conditions for the development of digital STEM competences of teachers. The main aspects of introduction and development of STEM education in different countries of the world are analysed. Particular attention is paid to the functioning of the STEM Centre, which is the basis of the innovative educational environment of the pedagogical university. The practical experience in introduction of STEM education at Ternopil Volodymyr Hnatiuk National Pedagogical University is summarised. The peculiarities of the influence of the innovative educational environment of the university on the development of digital STEM competences are explored.

K e y w o r d s: STEM education, digital STEM competences, innovative educational environment, project-based learning, research

Introduction

Many countries in the world, including developed economies such as those of the United States and the European Union (EU), transform their education systems in order to be competitive in the age of innovation (Schleigh, Bossé, & Lee, 2011; Williams, 2011). Innovation is largely dependent on advances in science, technology, engineering, and mathematics. More and more jobs in all sectors of the economy require STEM knowledge, which goes beyond training for specific jobs. STEM education is aimed at developing deep mathematical and scientific knowledge, as well as developing a way of thinking and reasoning. STEM education promotes the development of creative skills and critical thinking that young people can use in all areas of their lives (Morze, Smyrnova-Trybulska, Kommers, Gladun, & Zuziak, 2017).

Ukrainian students should also be competitive on the labour market of the 21st century. Reforms taking place in the sphere of education of Ukraine contribute to this. The implementation and development of STEM education is especially important today. Within the framework of STEM education, interdisciplinary curricula are introduced, students' knowledge of STEM subjects and STEM professions increases, STEM courses are provided for students, and students are trained for successful post-school employment and education. At the same time, at each stage, this system develops students' ability to do research, work analytically, experiment, and think critically; it combines school and out-of-school opportunities and teaching methods (LaForce, Noble, King, Century, Blackwell, Holt, Ibrahim, & Loo, 2016).

The analysis of pedagogical literature shows the interest of scientists in various aspects of STEM education. Taking into account that STEM education is one of the most important directions of reforming Ukrainian education, it is worth highlighting some aspects of its implementation in the educational process.

Integrative STEM Education

In the scientific literature, researchers (Sarıer, 2010; Schleigh, Bossé, & Lee, 2011) distinguish five aspects of STEM education.

1. STEM education is focusing on challenges and problems. At STEM lessons, students are faced with real social, economic, and environmental issues and seek solutions.
2. STEM lessons focus on the engineering design process. STEM education provides a flexible design process. In this process, students determine the

problem, conduct preliminary research, put forward a few ideas for their solutions, develop and create a prototype, and then test it, evaluate it, and implement it. STEM lessons provide student teams with opportunities to conduct their research based on their own ideas, test different approaches, make mistakes, discuss them and learn from them, and carry out further research. Their focus is on finding solutions.

3. STEM education immerses students in a practical inquiry and open study. The students' work is practical and collective, and their decisions are coordinated. Students communicate, exchange ideas, and, if necessary, upgrade their prototypes. They control their own ideas and conduct their own research.
4. STEM education involves students in productive collaborative work. They need help from teachers to work together as a productive team. This becomes possible if all the teachers at school work together and meet students' expectations.
5. STEM education integrates math and science. It is necessary to create plans for joint work of teachers of various subjects. Using knowledge from various subjects during lessons will teach students to understand that combining mathematics and other sciences can solve important life problems. This will increase interest in mathematics and science. The art teacher should be drawn to such lessons as well, since art plays an important role in the development of a practice-oriented project, enhancing its attractiveness, design, and demand.

In order to integrate mathematics and science, M. Sencer Corlu, Robert M. Capraro, and Mary M. Capraro (2014) suggested the STEM education model. According to it, for the successful transition from the traditional to the integrated model of education, emphasis is placed on the importance of integrated study of disciplines and on the interaction between teachers and students. This model involves a systematic approach to the study of natural and mathematical disciplines, and promotes the development of innovation, the implementation of creative potential of the individual, and its pre-professional education.

A prominent place in this model belongs to a well-educated and experienced teacher with strong skills to interact with other subject teachers, students, and parents. Such a teacher must understand the importance of integrated pedagogical education programmes, and have expert knowledge from the main subject area and working knowledge in other areas (Corlu, R. Capraro, & M. Capraro, 2014; Williams, 2011).

Implementation of STEM disciplines is required depending on the level of development of the innovative educational environment of the educational institution. Under the innovative educational environment of the university, we will understand organisational, educational, methodological, technological, and informational resources, the purpose of which is to create conditions for the development of digital STEM competences of teachers.

The purpose of this article is to consider the problem of the influence of the innovative educational environment of the university on the development of digital STEM competences in the process of training teachers of the new formation.

Implementation of STEM Education at Ternopil Volodymyr Hnatiuk National Pedagogical University

The policy of coordination between school and university will improve the quality of pedagogical education at the initial stages of the implementation of STEM education. Such coordination activity can be carried out in two directions: programmes for training of future teachers and teachers' qualification upgrading. Teacher training programmes developed in tandem with school curricula will facilitate the teachers' acquisition of the necessary knowledge and experience in the educational environment of a modern school where the principles of STEM education are implemented (Sanders, 2009).

The implementation of the principles of STEM education at Ternopil Volodymyr Hnatiuk National Pedagogical University succeeded in providing:

- integration of the best STEM educational practices of domestic and foreign experience;
- development of new teaching materials (interdisciplinary programmes) in educational institutions; and
- encouragement of students of the pedagogical university to study STEM subjects.

The STEM Centre, which is the basis of the University's innovative educational environment, has been operating in Ternopil Volodymyr Hnatiuk National Pedagogical University – at the Faculty of Physics and Mathematics – for three years. The scientific and technical activity of STEM Centre is carried out with the participation of scientific and pedagogical staff of the Department of Computer Science and Teaching Techniques. Teachers of the Department provide educational services in the field of STEM to students and teachers.

The aim of the STEM Centre as an innovative educational environment of the University is to create organisational and pedagogical conditions for advanced scientific and technical youth education in accordance with the priority directions for science and technology development, and to form the competences that determine the competitiveness of the individual in the labour market. The profile of the educational activities of the STEM Centre of the University determines the following areas of STEM education: IT, robotics, virtual reality, Internet of things, 3D modelling, and 3D printing.

This profile is provided by the availability of the appropriate equipment: LEGO construction toys, robotic systems, models, measuring complexes and sensors, 3D printers, computers, digital projectors, projection screens, interactive whiteboards, document cameras, etc. High-tech equipment helps students in designing and researching, modelling various processes and phenomena, and mastering new transdisciplinary knowledge consciously and qualitatively.

The activities of the STEM Centre are based on pilot-oriented project-based learning aimed at in-depth study of specialised disciplines and the acquisition of digital STEM competences required for experimental, design, and inventive activities.

The STEM Centre activity forms STEM competence of students, and they acquire knowledge in many disciplines and learn skills in using interdisciplinary approaches to solve real-life problems (Balyk, Barna, Shmyger, & Oleksiuk, 2018).

The transition to the competence model of STEM education at Ternopil Volodymyr Hnatiuk National Pedagogical University is based on the application of the following methodological approaches:

- shifting in emphasis in educational activities from narrow-subject to common didactics;
- setting a new goal in the pedagogical process;
- updating the structure and content of curricula, courses, and specialised courses;
- introducing competence-oriented forms and teaching methods;
- assessing learning outcomes in terms of competences;
- introducing innovative teaching technologies (case-study technologies, interactive methods of group training, problem-oriented techniques for developing critical and system thinking, etc.); and
- creating pedagogical conditions for gaining experience of project activity and start-ups development.

The STEM Centre provides education based on the principles of differentiated and individual approaches to learning, taking into account age, individual abilities, interests, likes, abilities, and health status of children and young people, using different organisational forms of work.

A special form of pervasive STEM education are integrated lessons aimed at establishing inter-subject relationships and contributing to the formation of a holistic, systematic outlook. Integrated classes are conducted by combining similar topics of several educational subjects or forming individual ones. The basis of the effectiveness of such classes is a clear definition of their purpose and plan.

The use of the leading principle of STEM education, that is, integration (interdisciplinary, transdisciplinary) makes it possible to modernise methodological foundations, content, and volume of educational material and to apply modern technologies during education process in order to form competences on a qualitatively new level.

In order to involve students in practical activities at the STEM Centre, organisational forms and teaching methods, as well as methods of educational interaction were expanded. For better acquisition of learning material and formation of digital STEM competences, we conduct tours, quests, contests, festivals, hackathons, trainings, and seminars.

In addition to traditional intellectual events (contests, tournaments), the STEM Centre plans to conduct scientific-educational events, STEM weeks, scientific picnics, festivals on robotics, and maker fairs. The STEM Centre also organises and holds events for vocational guidance (trainings, excursions) of students concerning a conscious choice of future profession, taking into account the regional characteristics of the labour market. Examples are: STEM-creaton regional festival, STEM-spring all-Ukrainian festival, Day of Science, Visiting TNPU, Class Idea festival of startups, the all-Ukrainian festival of innovations, winter and summer STEM-schools.

An effective tool for the development of digital STEM competences is a project activity that changes the emphasis of learning activities. The acquisition of knowledge, skills, and abilities that – in the global information environment – are losing their relevance cannot be a goal in itself, while the research skills and practical experience gained in the process of project activity will promote acceleration of adaptation of young people to a changing social and economic life.

Implementation of educational projects involves an integrated research and creative activity of students, aimed at obtaining independent results under the teacher guidance. In the process of studying various courses and specialised courses, students develop training projects based on the system of integrated tasks simulated from real life situations.

The teacher manages such activities, encourages students to search; he helps in determining the goals and objectives of the project, advisory methods or techniques of the research, and in information seeking to solve certain educational and cognitive tasks. Students themselves choose the form of presentation and defend the received results. Evaluation of the project activity is carried out individually.

During the execution of educational projects, a number of different levels of didactic, educational, and developmental tasks are solved: new knowledge, abilities, and skills are acquired; motivation and cognitive interests are developed; the abilities to independently navigate the information space, express one's own judgments, and identify competence are formed. The design work contributes to the formation of STEM competences (Shmyger & Balyk, 2017), and allows passing the technological algorithm from the problem's discovery, or the origin of the idea, to the creation of a commercial product – a startup, as well as learning to present it to potential investors. Ultimately, this will contribute to changing the value priorities and ideological position of youth in the direction of the formation of responsible and socially active social behaviour.

In the educational process, the teachers of the Department of Computer Science and Teaching Techniques of Ternopil Volodymyr Hnatiuk National Pedagogical University test different types of projects: project-task, project-discipline, and project-start-up. Here are some examples of the projects:

- study with pleasure,
- STEM projects,
- technologies of a successful personality development,
- make the city better,
- development of the project and social management system,
- development of media resources for the creation of an open co-learning centre for the promotion of the ideas of the Ukrainian Charter of the Free Person,
- development of innovative educational projects based on the concept of the New Ukrainian School, and
- innovative approaches to the use of ICT and competence education in the conditions of the New Ukrainian School.

Let us place greater focus on the implementation of the educational project "Development of innovative educational projects based on the principles of the New Ukrainian school," which started in 2017. As a result of it, more than two hundred portfolios of integrated educational projects were developed and performed by undergraduates of all specialties of the University for primary and secondary school teachers.

The current vector of the innovative educational environment of the University is the organisation of the educational process as an integral part of the entire educational process and orientation, primarily, on universal human values. One of such innovative projects in the social sphere, which implements the innovative function of the University for the creation of new social and humanitarian practices, was the project to popularise the ideas of the Ukrainian Charter of the Free Person.

Future teachers created methodological support with media to promote ten Charter novels and their practical use with education and training aim in educational institutions, as well as for public community activities in Ukraine.

Research Results

In our opinion, the key to the development of digital STEM competences was the impact of the University's innovative educational environment and the activities of the STEM Centre. In 2017/2018, a poll was conducted to determine the factors of the University's innovative educational environment that have the greatest impact on the development of digital STEM competences for preservice teachers.

The survey involved 138 students of the third year of the Faculty of Physics and Mathematics and the Faculty of Chemistry and Biology. The questionnaire offered to evaluate the components of the innovative educational environment of the university on a 5-point scale and to determine the importance of the development of each component on a 3-point scale: 1 – low, 2 – medium, and 3 – high.

Let us consider the results of the survey conducted concerning the importance of developing the hardware, organisational, methodological, and software components of the university's innovative educational environment for the development of digital STEM competences of students at Ternopil Volodymyr Hnatiuk National Pedagogical University (Figures 1–4).

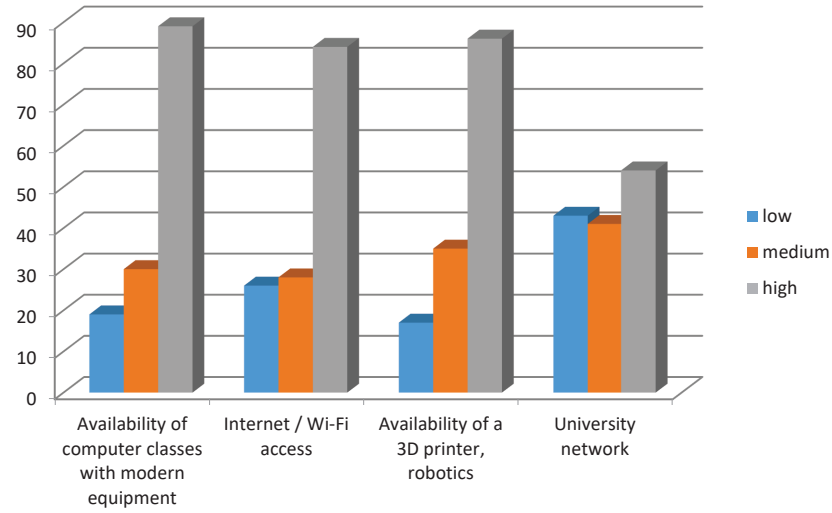

Figure 1. Results of the study of the importance of the hardware component of the university's innovative educational environment in the context of the development of digital STEM competences.

Source: Own work.

Concerning the hardware component, such indicators as availability of a 3D printer, robotics, and other equipment of the STEM Centre (65%), modern computer classes (61%), high-speed Internet (62%), and developed university computer network (39%) are the most significant (the importance of the component on a 3-point scale is high) for development of the digital STEM competences of students. A small percentage of university network component can be explained by the fact that there is a sufficient number of students possessing gadgets with Internet access.

In recent years, the University has been actively introducing non-formal education (training sessions, workshops, seminars, webinars, round tables, conferences, contests, internships). Therefore, 63% of students (the importance of development of a component on a 3-point scale is high) noted it as a factor that

greatly influenced the development of their digital STEM competences. It can be summarised that in the framework of the innovative educational environment of the university, formal and non-formal education of future teachers complement each other, compensating for disadvantages of these types of education.

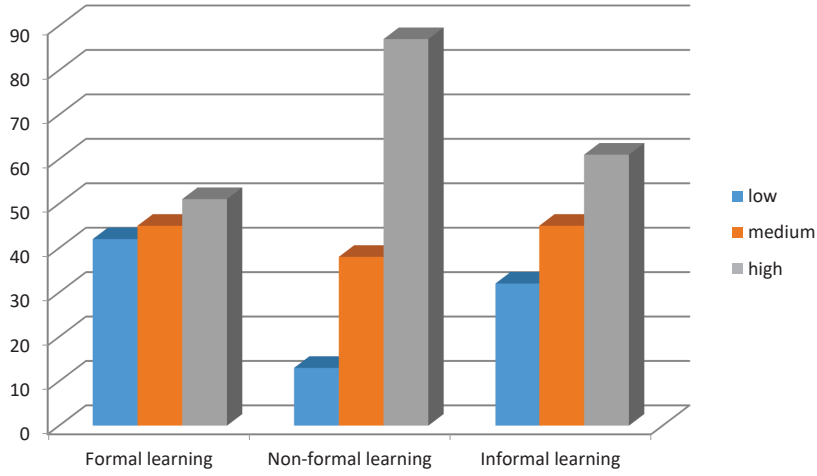

Figure 2. Results of the study of the importance of the organisational component of the university's innovative educational environment in the context of the development of digital STEM competences.

S o u r c e : Own work.

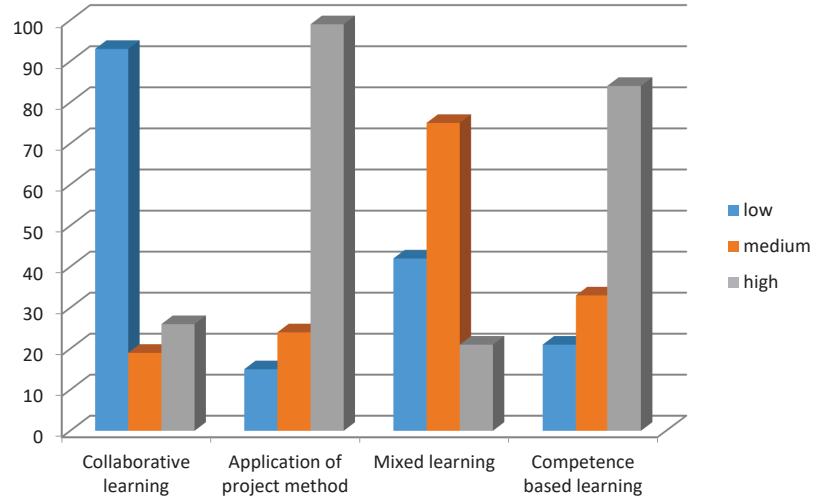

Figure 3. Results of the study of the importance of the methodical component of the university's innovative educational environment in the context of the development of digital STEM competences.

S o u r c e : Own work.

Among the teaching methods, students of Ternopil Volodymyr Hnatiuk National Pedagogical University have allocated project-based learning (72%) and competence-based learning (61%) as important ones (the importance of development of the component on a 3-point scale is high). Despite the high rates of project-based learning and competence-based learning, students (67%) still do not accept collaborative learning (the importance of development of the component on a 3-point scale is low).

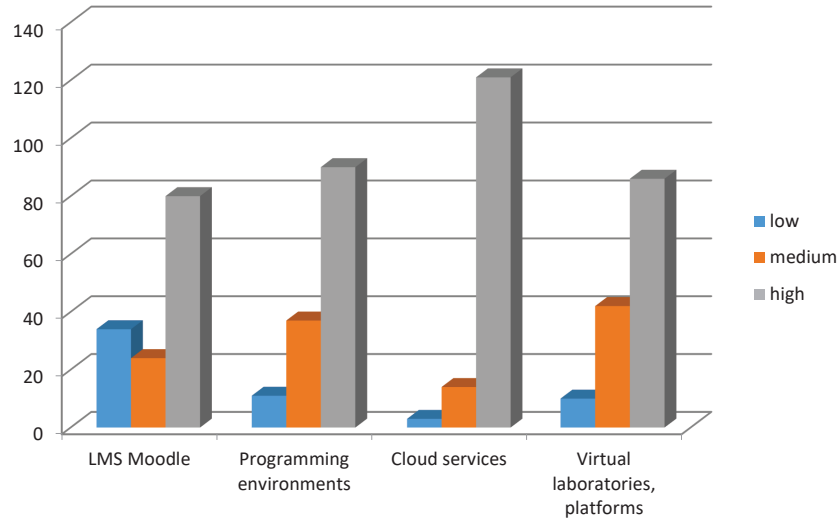

Figure 4. Results of the study of the importance of the programming component of the university's innovative educational environment in the context of the development of digital STEM competences.

S o u r c e : Own work.

Cloud computing (87%), programming environments (65%), virtual laboratories and platforms (62%) proved to be the most important concerning the software component of the programme (the importance of development of the component on a 3-point scale is high) for the development of digital STEM competences of students.

Modernisation of the software component enabled combining traditional and cloud-based learning tools, integrating cloud services (Google, Microsoft) into the IT infrastructure of the University, and organising training courses based on cloud platforms and cloud services.

In the learning process, we use cloud services for the development of creativity (Table 1), leadership and responsibility (Table 2), and problem solving (Table 3), but also for strengthening collaboration and team work (Table 4), and the development of effective communication (Table 5).

Digital Tools for STEM Competences Development

Table 1.
Digital tools for development of creativity

Creativity – an innovative mindset	
Easely	creating posters and infographics
Prezi	online presentation tool
Dumpr	creating photo collages by templates
BannerSnack	creating banners
EnjoyPic	creating combined images with photos and applying animations
Photosynth	creating three-dimensional modelling of photo panoramas

S o u r c e: Own work.

Table 2.
Digital tools for development of leadership and responsibility

Leadership and responsibility – initiative and awareness of personal responsibility	
Google Apps	organising collective work by creating a joint document or presentation
Facebook	moderating a thematic group in a social network, communicating with readers
Trello	effective management of own tasks and tasks of members of a team (group, project)
Blog	keeping an online diary, covering the news and own vision, and sharing thoughts on a topic

S o u r c e: Own work.

Table 3.
Digital tools to develop problem solving

Problem solving – will, awareness of the causes and consequences	
Bubells, Mind42	creating a map of knowledge with all possible options for solving the problem, thinking out the possible results of each solution
OneNote	writing down problems and tasks, adding decision ideas, and noting solved problems and tasks
Forum2x2	organising forums for communication and discussion
WebTalk, Skype	asking for help, talking and consulting with others

S o u r c e: Own work.

Table 4.
Digital tools for enhancing cooperation and teamwork

Cooperation and teamwork – abilities to plan activities collectively, work together, distribute roles and responsibilities, and focus on results	
Google Docs	creating and editing documents, spreadsheets, or presentations together; commenting and discussing created materials
Google Drive	saving documents, programmes, music, videos, photos in a shared repository; giving access to files to other users
Padlet	sharing reviews or suggestions on a shared board; printing text, drawing, embedding files, using full board for further work
Google groups	organising work with groups
Dreams Board	creating an informational virtual board (images, stickers, text)
Google calendar	creating a joint on-line organiser with a schedule of events, promptly updating information, conducting group correspondence on a certain topic

S o u r c e: Own work.

Table 5.
Digital tools for the development of effective communication

Effective communication – expressing and arguing opinion, possessing rhetorical skills, achieving communicative goals	
Skype, Viber	communicating and solving problems with people anywhere, regardless of their location; teaching and learning through online communication
Buzzumi, Speakplace	organising video communication, conferences, webinars, video interviews; creating and organising audio conferences
Google Forms	creating questionnaires and conducting online surveys to determine the needs or personal opinions of people; analysing the results of the surveys in the charts
Gmail, Outlook	communicating competently by e-mail, taking into account the ethics of communication; organising the contacts of people

S o u r c e: Own work.

Using the abovementioned cloud services made it possible for students to aggregate computing resources, increase the flexibility of their use, and create scalable repositories based on cloud computing.

Conclusions

The basis of the innovative educational environment at Ternopil Volodymyr Hnatiuk National Pedagogical University is the modern STEM Centre. Transition to STEM education competence model in Ternopil Volodymyr Hnatiuk National Pedagogical University is based primarily on creating conditions for teachers to gain experience of project activities.

The study revealed the factors that most contributed to the development of digital STEM competences in the pedagogical university: the availability of high-tech equipment STEM Centre; modern computer labs and high-speed Internet; advanced university computer network; virtual laboratories and platforms; programming environments and various cloud services; project-based learning and competence-based learning.

The results of the survey will enhance the effectiveness of the learning process and further development of teachers' digital STEM competences.

The prospect for further research is to develop educational strategies for the implementation of STEM education in the process of teachers' qualifications upgrading.

References

Balyk, N., Barna, O., Shmyger, G., & Oleksiuk, V. (2018). Proceedings from the *ICTERI 2018 – ICT in Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer*. Accessed 27 July 2018. Retrieved from http://ceur-ws.org/Vol-2104/paper_157.pdf.

Corlu, M., Capraro, R., & Capraro, M. (2014). Introducing STEM education: Implications for educating our teachers for in the age of innovation. *Education and Science*, *39*(171), 74–85.

LaForce, M., Noble, E., King, H., Century, J., Blackwell, C., Holt, S., Ibrahim, A., & Loo, S. (2016). The eight essential elements of inclusive STEM high schools. *International Journal of STEM Education*, *3*(1), 1–11.

Morze, N., Smyrnova-Trybulska, E., Kommers, P., Gladun, M., & Zuziak, W. (2017). Robotics in primary school in the opinion of prospective and in-service teachers. A comparison study. *International Journal of Continuing Engineering Education and Life-long Learning*, *27*(4), 318–338.

Sanders, M. (2009). STEM, STEM Education, STEMmania. *Technology Teacher*, *68*(4), 20–26.

Sarıer, Y. (2010). An evaluation of equal opportunities in education in the light of high school entrance exams (OKS-SBS) and PISA results. *Ahi Evran Üniversitesi Eğitim Fakültesi Dergisi*, *11*(3), 107–129.

Schleigh, S., Bossé, M., & Lee, T. (2011). Redefining curriculum integration and professional development: In-service teachers as agents of change. *Current Issues in Education*, *14*(3), 1–14.

Shmyger, G. & Balyk, N. (2017). Formation of digital competencies in the process of changing educational paradigm from e-learning to smart-learning at pedagogical university. In E. Smyrnova-Trybulska (Ed.), *Effective development of teachers' skills in the area of ICT and e-learning*, Monograph, Vol. 9 (pp. 483–497). Katowice–Cieszyn: University of Silesia Press.

Williams, J. (2011). STEM education: Proceed with caution. *Design and Technology Education*, *1*(16), 26–35.

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Wpływ uniwersyteckiego innowacyjnego środowiska edukacyjnego na rozwój cyfrowych kompetencji STEM

Streszczenie

Artykuł dotyczy kwestii wpływu uniwersyteckiego innowacyjnego środowiska edukacyjnego na rozwijanie cyfrowych kompetencji STEM (kompetencji cyfrowych z zakresu nauki, technologii, inżynierii i matematyki) w procesie szkolenia nowego pokolenia nauczycieli. Określono, że innowacyjne środowisko edukacyjne uniwersytetu składa się z zasobów organizacyjnych, edukacyjnych, metodologicznych, technologicznych i informacyjnych. Celem takiego środowiska jest rozwój cyfrowych kompetencji STEM u nauczycieli. Zanalizowano główne aspekty wprowadzenia i rozwoju kompetencji STEM w edukacji w różnych krajach świata. Zwrócono szczególną uwagę na funkcjonowanie centrum STEM, które jest podstawą innowacyjnego środowiska edukacyjnego uniwersytetu pedagogicznego. Dokonano podsumowania praktycznego doświadczenia we wprowadzaniu edukacji o profilu naukowym, technicznym, inżynieryjnym i matematycznym (STEM) na Narodowym Uniwersytecie Pedagogicznym im. Wołodymyra Hnatiuka w Tarnopolu na Ukrainie. Zbadano szczególne aspekty wpływu innowacyjnego środowiska edukacyjnego Uniwersytetu na rozwój cyfrowych kompetencji STEM.

Słowa kluczowe: edukacja STEM, cyfrowe kompetencje STEM, innowacyjne środowisko edukacyjne, uczenie się metodą projektów, badania

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Влияние инновационной образовательной среды университета на развитие STEM компетенций в области цифровых технологий

Аннотация

В статье рассматривается проблема влияния инновационной образовательной среды университета на развитие цифровых компетенций STEM в процессе подготовки преподавателей для нового образования. Определено, что инновационная образовательная среда университета состоит из организационных, образовательных, методических, технологических и информационных ресурсов, целью которых является создание условий для развития цифровых STEM компетенций преподавателей. Анализируются основные аспекты внедрения и развития обучения STEM в разных странах мира. Особое внимание уделяется функционированию центра

STEM, который является основой инновационной образовательной среды педагогического университета. Обобщен практический опыт внедрения STEM-образования в Тернопольском национальном педагогическом университете имени В. Н. Гнатюка. Рассмотрены особенности влияния инновационной образовательной среды университета на развитие цифровых компетенций STEM.

Ключевые слова: STEM образование, цифровые STEM компетенции, инновационная образовательная среда, проектное обучение, исследования

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Influencia de entornos educativos universitarios innovadores en el desarrollo de competencias digitales innovadoras

Resumen

El artículo aborda la influencia de entornos educativos universitarios innovadores en el desarrollo de competencias digitales STEM en la formación del profesorado. Se determina que un entorno educativo innovador en la universidad consiste en recursos organizativos, educativos, metodológicos, tecnológicos e informativos, cuyo objetivo es crear un contexto apropiado para el desarrollo de las competencias digitales de los docentes. Se analizan los principales aspectos de la implementación y el desarrollo de la educación STEM en diferentes países del mundo. Se presta especial atención al funcionamiento del centro STEM, que es la base del entorno educativo innovador de la universidad pedagógica. Además, se resume la experiencia llevada a cabo en Volodymyr Hnatiuk Ternopil National Pedagogical University con competencias STEM. Se exploran las peculiaridades de la influencia del entorno educativo innovador de la universidad en el desarrollo de las competencias STEM.

Palabras clave: educación STEM, competencias digitales STEM, entorno educativo innovador, aprendizaje basado en proyectos, investigación