

The Technological Aspect of the SMART-TNPU Ecosystem

Halyna R. Henseruk¹, Bogdan B. Buyak¹, Halina I. Falfushynska¹, Nadiia R. Balyk¹ and Serhii V. Martyniuk¹

¹ Ternopil Volodymyr Hnatiuk National Pedagogical University, 2 M. Kryvonosa str., Ternopil, 46027, Ukraine

Abstract

Facing novel challenges, we have proposed the innovative-digitalized educational-scientific ecosystem "SMART-TNPU" which was invented at Ternopil Volodymyr Hnatiuk National Pedagogical University (TNPU). The particular traits of the "SMART-TNPU" are its interactivity and opportunity for close interplay between different structural components. The ecosystem "SMART-TNPU" composes from several structural components namely technology, education, science, administration, management and marketing which are permanently cooperate and being coordinated by each other. The technological aspect plays an important role in the implementation of the SMART-TNPU ecosystem. The experience of TNPU IT infrastructure development, local and cloud digital space, as well as the evolution of SMART-TNPU ecosystem performance have been described. The peculiarities of the development of the digital educational environment of TNPU as an important component of the ecosystem "SMART-TNPU" in the context of the development of digital competence of students and academic staff have been analyzed. The organizational component (structural centers and laboratories; corporate standards); content component (educational and methodological aspect); and monitoring component pertain to constituents of the digital educational environment. One of the results of "Digital Science" and "Digital Management" intercommunication is modern and prospective degree programs (e.g. BA program "Game study"). One of the more significant findings to emerge from this study is that only essential collaboration and interplay between all structural components of Smart-University ecosystem with deep involvement of human resources within University developmental Strategy could provide visible way to success.

Keywords

Ecosystem, SMART-TNPU, digital technologies, components, digital educational environment.

1. Introduction

The development of the Internet, means of communication, digitalization of everyday life requires the transformation of the information society into a smart one, which is now called the Smart-society. Smart-society requires an improvement of all aspects of human life using digital technologies in various fields. Smart-society is a new quality of social life. Thanks to digital technologies and high-quality Internet provision, there is a constant and high-quality collaboration of all interested participants in this process. Such changes should in the long run improve potential and perspective socio-economic, socio-political educational and scientific relations.

Smart-technologies have led to the development of mobility in education, science, social sphere, economy and other spheres of employment [1]. The introduction of digital technologies requires changes in the functioning and methods of interaction and communication, including the institution of

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EMAIL: genseruk@tnpu.edu.ua (H. R. Henseruk); Buyak.Bogdan@tnpu.edu.ua (B. B. Buyak); falfushynska@tnpu.edu.ua (H. I. Falfushynska); nadbal@tnpu.edu.ua (N. R. Balyk); sergmart65@tnpu.edu.ua (S. V. Martyniuk)
ORCID: 0000-0002-5156-7280 (H. R. Henseruk); 0000-0003-1496-7573 (B. B. Buyak); 0000-0003-3058-4919 (H. I. Falfushynska); 0000-0002-3121-7005 (N. R. Balyk); 0000-0002-5611-3317 (S. V. Martyniuk)



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higher education. Today, it is not enough for universities to simply position themselves as digital. Responding to the main challenges of the digital transformation of education and science, they must become "smart" through the interaction of all intellectual systems of the academic community, which ensures the development of quality education and science.

The total preparation of participants in digitalization to master the elements of digital culture of modern life is relevant in this context. The educational institutions should promote the development of the potential of educational and scientific systems aimed at shaping the demand for general and specialized digital skills. Learning these skills and their development throughout life, as well as the development of digital competence of all participants in the educational and scientific process, will be more comfortable in the functioning of Smart-University.

2. Methods of Research

In our study we used a set of theoretical and empirical methods, including methods of comparative analysis of scientific sources to determine the state of the research problem; synthesis; generalization; systematization of the best practices of foreign and domestic specialists on the development of the model of Smart-University, Smart-education, Smart-learning.

3. Analysis of latest research and publications

Problems of design and development of Smart-Universities, Smart-learning environments, Smart-digital pedagogy, Smart-learning are topics of various international and domestic studies. These issues are included in the institutional programs and strategic plans of measures, projects and initiatives of different countries.

The Digital Education Action Plan (2021-2027) outlines the European Commission's vision for quality and affordable digital education in Europe. The new Action Plan has two strategic priorities, including promoting the development of a highly efficient digital education ecosystem. To solve this problem the following points are necessary [2].

Roth-Berghofer interprets Smart-University as "a platform that receives and provides basic data to manage the analysis and improvement of the teaching and learning environment" [3]. A Smart-University must have tools that meet the European Qualification Framework for Educational Profiles, including curricula and professional courses that meet the standards of the scientific and professional communities [4].

The role and functions of Smart-University for Smart-city are considered in the research of Nuzzaci, A. & La Vecchia, L. [5]. In their opinion, the educational environment of Smart-University provides an opportunity to significantly increase the academic results of students.

The ways to develop a university learning environment for Smart-education are considered in the studies of Morze, N., Smyrnova-Trybulska, E. & Glazunova, O. [6]. In their opinion, the digital learning environment is the next stage of the e-learning environment and virtual learning environment [7]. Hamayseh, Y., Mardini, W., Aljawarneh, S. & Yassein, M. outline the proposals for integrating Internet technologies into the Smart-University Campus [8]. Smart-campus is a new paradigm of thinking regarding the holistic intellectual environment of the campus. It covers e-learning, social networking and communications for collaboration, environmental friendliness and the sustainability of digital technology collaboration with intelligent management systems [9].

According to experts, digital technologies are widely used in universities. However, in addition to Smart-education, other aspects need to be considered, such as IT infrastructure, management of institution of higher education, e-learning management, communication, social interaction, data storage and security [4].

Spivakovskiy, O., Vinnyk, M. & Tarasich, Y. proper construction of the IT infrastructure of the university affects the improvement of quantitative and qualitative indicators of administrative and educational processes, increasing the status of the institution.

Smart-University is a concept that includes a comprehensive modernization of all educational processes [11].

The Kwok and Hui study describes the role of an e-portfolio for smart lifelong learning. It helps students to plan their lifelong learning and professional development course [12].

Despite some publications in the field, the question of whether technology can solve the problems of Smart-University development is not considered in detail.

4. Results of Research

The transformation of a traditional university into a Smart-University is one of the current trends in the modernization of higher education. Training a new generation of professionals who are successful and competent to work in the digital society is important in today's university. We understand Smart as a property of the system, which is manifested in interaction with the outside world and gives the system the ability to: immediate response to changes around; defining goals and mobilizing resources to effectively achieve a quality result; prompt adaptation to constantly transforming conditions; independent development and self-control, coordination for the sake of integration.

Smart-University is a university where the integration of technological innovations and the Internet can provide a new quality of educational and scientific processes, learning results, scientific, innovative, educational, social and other activities.

The Ternopil Volodymyr Hnatiuk National Pedagogical University (TNPU) has created and is developing an innovative digitalized educational and scientific ecosystem "SMART-TNPU", which includes 5 philosophical interrelated factors of development: Technology, Social, Access, Regulated, Mobile.

TNPU is an open academic community. The activity of the university is determined by its social orientation, the degree of its academic mobility, openness and accessibility.

The SMART-TNPU ecosystem is divided into profile clusters: technologies; education; science; management and marketing. Synergy of educational and scientific processes is important in the implementation of the SMART-TNPU ecosystem (Figure 1).



Figure 1: Structural elements of the SMART-TNPU ecosystem

In the context of our study, we will focus on the justification of the technological aspect of the development and implementation of the ecosystem "SMART-TNPU".

4.1. IT infrastructure and technologies of the "SMART-TNPU" ecosystem

Technology is ensured by the inclusion in the architecture of the solution of both application and special software, virtualization of platforms, services and resources; modularity, scalability, use of open software interfaces, the ability to develop and supplement functionality by third-party developers.

The formation of the "SMART-TNPU" Concept can be traced from the late 90s of the last century to the present. This project systematically demonstrates the consistent progress of TNPU to create a quality digital educational environment.

An important factor in the design and development of the ecosystem "SMART-TNPU" is the availability of modern IT infrastructure, which has a systemic nature and includes technical, software and information, organizational and methodological levels.

The computerization department is responsible for the architecture, principles of construction and maintenance of the IT infrastructure of the "SMART-TNPU" ecosystem. In 1999, one of the first in Ukraine, the computerization department of TNPU designed and laid a fiber-optic network that united all the administrative buildings and dormitories of the university. The basis of the university's IT infrastructure is a structured cabling system with subsystems of external, internal highways, switching equipment at system nodes and network equipment for direct connection of user workstations.

The local area network connects the administrative buildings of the university and dormitories (Figure 2). The IT infrastructure of the "SMART-TNPU" ecosystem is very extensive due to the large internal architecture of the buildings, their location and remoteness. Therefore, high-speed fiber-optic communication channels are used to connect all remote buildings. Subsequently, an internal network and an electronic management system were implemented on its basis (2000-2005).

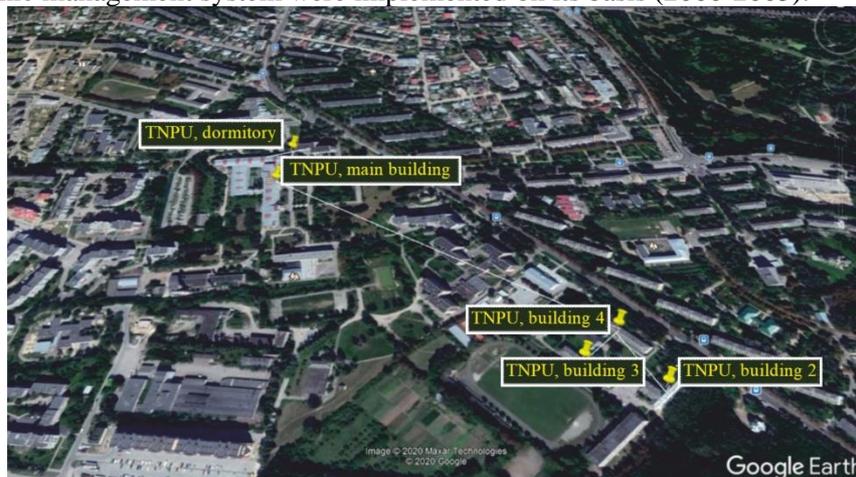


Figure 2: Local area network of the "SMART-TNPU" ecosystem

Installed computers and servers work exclusively on licensed software from MicroSoft, UA Budget and have certificates of conformity according to UKRSEPRO. Workstations based on computers, netbooks, nettops with the provision of access rights to information flows within a single information system are synchronized in the network using Active Directory (AD).

It is important in the functioning of the "SMART-TNPU" ecosystem to support the smooth operation of its IT infrastructure. At the university all important communication nodes are equipped with power supplies of different power depending on the available switching equipment.

Access to the Internet is arranged by two Internet providers. This made it possible to qualitatively organize the process of combined (blended) learning with elements of distance education in a pandemic. The connection of the corporate network to the global data network of the Internet is carried out by channels with a fiber-optic cable with a speed of 1 GB/s. The TNPU's high-speed Internet access makes it possible to improve the quality of services related to the widespread use of the World Wide Web by users, teleconferencing using streaming audio and video, providing appropriate conditions for connection to external electronic resources, online and blended learning. Four channels are permanently connected to ensure the smooth operation of the Internet. The university organizes wireless Wi-Fi access (90% of the area of education buildings) and round-the-clock access to electronic resources of TNPU.

A system of server technologies has been created to support the vital functions of the "SMART-TNPU" ecosystem, manage users and save their data, organize access to databases, file servers, update anti-virus databases, software, and mail server. It allows you to scale and efficiently use server capacity.

SMART-TNPU implements a virtualization system. This helps to reduce the cost of the server part of the IT infrastructure with the ability to increase its efficiency and adaptability. The introduction of virtualization accelerates the deployment of academic loads, increases their productivity and availability, and provides automation of many processes. The university's IT infrastructure is becoming more manageable and economical.

It is important for the development of the "SMART-TNPU" ecosystem to build a unique system of protection against external interference and ensure its integrity. It contributes to the smooth and trouble-free operation of the university's electronic systems. TNPU has a anti-virus protection system.

The development of a single integrated IT infrastructure of the "SMART-TNPU" ecosystem required the use of software and hardware solutions (Figure 3).

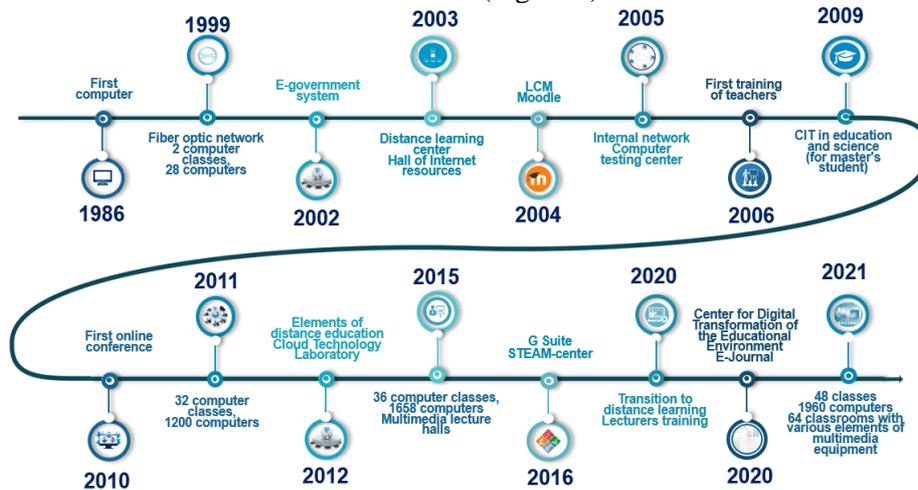


Figure 3: Evolution of the "SMART-TNPU" ecosystem

The "SMART-TNPU" ecosystem includes the following own structural components of digital control: University web-system; system "Science"; system "Learning", which includes planning and organization of the educational process, electronic journal of the academic group; system "E-learning"; system "Enrollee"; system "Library"; system "Accounting"; system "Personnel"; system "TNPU Campus".

The "SMART-TNPU" ecosystem includes a wide range of modern technologies that allow the most efficient use of hardware and software for management, decision-making, meeting the needs of the educational process. Technologies unite all digital components of Smart-University: provision of modern equipment, Internet and intranet, Wi-Fi, use of cloud technologies. This combination makes it possible to ensure the learning process regardless of the location of the student or lecturer (Figure 4).

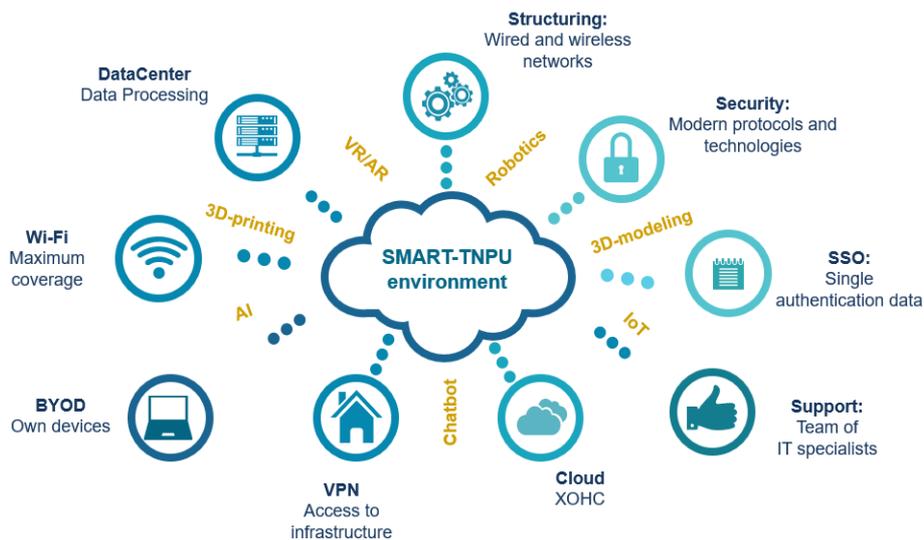


Figure 4: Technologies of the ecosystem "SMART-TNPU"

4.2. Smart-education and Smart-science

Smart-education today is an evolution in the digital world in the context of the internationalization of higher education. It aims to obtain qualitatively new educational, scientific, social and commercial results.

Important areas in the digital learning environment are: evolution of Smart-education; training of new generation specialists in the digital world; trends in the internationalization of education; evaluation of online courses; problems affecting the implementation of e-learning [13].

Smart-education is one of the clusters of digitalization of the university. Smart-education allows students to generate new knowledge and form the personality of a Smart-person who is well versed in digital technologies for searching, analyzing information and creating innovations [14]. Smart-education is not only a system of innovative technological solutions, but also a new philosophy of education.

In accordance with the trends that determine the development of the modern education system, TNPU has created and is developing a digital educational environment. It is based on the use of IT solutions and digital technologies. The design and operation of the digital educational environment of the ecosystem "SMART-TNPU" is implemented using a systems approach based on the approved concept [15].

The creation of the digital educational environment "SMART-TNPU" fully complies with the Concept of digital transformation of the Ministry of Education and Science of Ukraine, the concept of development of digital competencies and the Digital Agenda of Ukraine 2020 [16]. The model proposed by us can be successfully implemented in the activities of higher education institutions. We consider a wide range of open (educational public organizations) and secondary (university community) social groups, regardless of professional orientation, as the target audience.

The content component is considered in the context that led to the evolution of learning in TNPU from traditional to innovative — Smart-learning.

The introduction of various technologies and teaching methods into the educational process allowed to direct learning to the student, to adapt and meet his needs related to learning, and to make learning student-oriented [17]. In the "SMART-TNPU" ecosystem the technologies based on information and knowledge are transformed into technologies based on interaction, cooperation, and exchange of experience.

The TNPU Smart-lecturer constantly uses technological innovations and the Internet in the digital educational environment to achieve a new quality of the educational process that meets the requirements of the Smart-society (Figure 5).

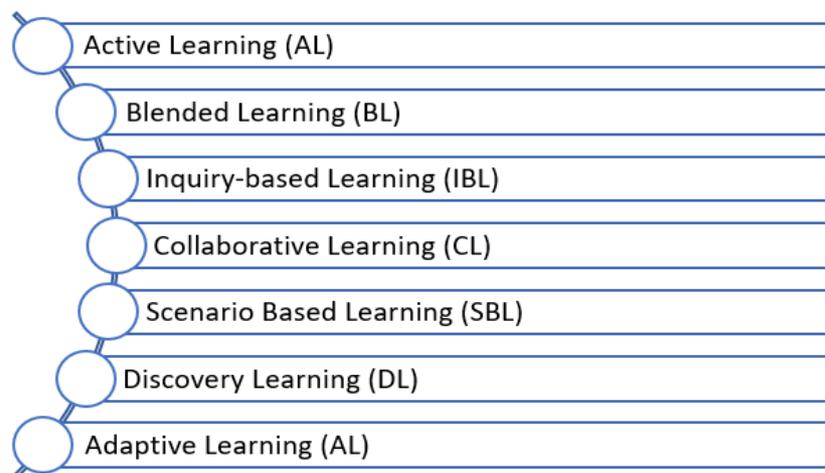


Figure 5: Educational concepts of the "SMART-TNPU" ecosystem

An important aspect in the evolution of the ecosystem "SMART-TNPU" is the introduction of e-learning in the educational process. Distance education in TNPU has been introduced since 2003 (the Distance Learning Center has been established).

The issues of transformation of technologies of electronic and distance learning into the practice of educational activity were gradually solved at the university.

Cloud technologies remain one of the most relevant trends of the decade. In 2015, TNPU was one of the first higher education institutions in Ukraine to join the G Suite for Education system. With the help of cloud services G Suite for Education the organization of network interaction between all participants of educational process during distance learning is carried out, education systems are created

that provide participants of educational process with conditions of realization of own individual trajectory of self-development.

In 2020, the university's educational and methodological department and the Center for Digital Transformation of the Educational Environment developed and implemented the project "TNPU E-Journal".

The implementation of the SMART-TNPU strategy required the development of information competence, and as of today — digital competence of lecturers and students. The professional development of the TNPU Smart-lecturer is successfully realized thanks to the synergy of numerous modern centers and laboratories created in the process of SMART-TNPU evolution (Figure 6).



Figure 6: Structural centers that ensure professional development of TNPU Smart-lecturer and Smart-student

For the effective digital transformation of the educational environment, the Center for Digital Transformation of the Educational Environment has been established at the university. The main purposes of the Center are the studying and implementation of strategies for the development of digital educational environment of the university, as one of the main components of SMART-TNPU; the development of digital competence of lecturers and students of the university, the organizational and methodological support in the integration of digital technologies in the educational process by university departments.

The key components of distance learning are communication and collaboration, digital content creation, problem solving. In this context, the Distance Learning Center together with the Center for Digital Transformation of the Educational Environment held seminars for university lecturers, which contributed to the study of the organization of the educational process in distance and blended learning. Non-formal education and academic mobility are also important aspects in the professional development of TNPU lecturers. In particular, in 2020 the lecturers had the opportunity to study for free at world universities on the international platform Coursera.

In accordance with today's requirements, implementing the provisions of the Concept of the New Ukrainian School on the importance of educating teachers-innovators who can change the world, develop the economy, compete in the labor market, learn throughout life, the first in Ukraine STEM-center was created at the Faculty of Physics and Mathematics in 2016 in the university structure in the context of the systematic implementation of the "SMART-TNPU" ecosystem. The STEM-center systematizes and accumulates the experience of successful educational STEM-practices.

It is important to train research practices and involve future professionals in real research and engineering university projects: "Smart Greenhouse", "Smart Home".

All components of the innovative educational ecosystem are aimed at integrating educational, scientific, innovative and social activities.

Smart-science is an important component of the "SMART-TNPU" ecosystem. In close cooperation with the community of the city and the region, with the participation of the Junior Academy of Sciences of Ukraine and the Science Center, university lecturers instill in pupils a love of science through the implementation of principles and methodological SMART-science techniques, generally accepted for the world community. As a result, the enrollee has a solid foundation for the formation of professional

competencies and soft skills. The concept of scientific and innovative ecosystem, which includes 5 consecutive steps, is taken as the basis of scientific activity at the university (Figure 7).

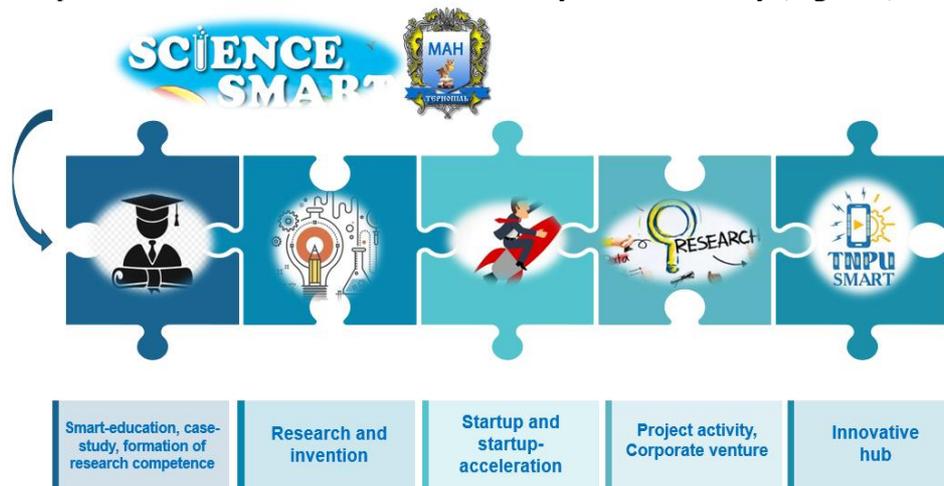


Figure 7: Scientific and innovative component of the ecosystem "SMART-TNPU"

At the first stage, the applicant of TNPU is trained and educated on the principles of the concept of Smart-education, actively uses the principles of problem-based learning, the case method, is involved in research work, including as a performer of scientific work of young scientists. The most successful applicants continue their education at 2-3 levels of higher education and in a team of experienced scientists perform researches that have regional, national and global significance. Today, TNPU organizes the work of an innovation hub, which will be a platform for the implementation of the most successful ideas and developments, the results of implemented projects in society, indirectly through cooperation with business, with the aim of its improvement and sustainable development.

4.3. Digital products

Digital technologies are changing the world so quickly that for a comfortable and safe life it requires completely new specialties and professions.

The results of the interaction between "Digital Science" and "Digital Management" of the "SMART-TNPU" ecosystem are modern and promising bachelor's degree programs — "Game study", "Digital Analytics", "Information Technology of the Internet of Things", "Physics and Robotics".

The educational program "Game study" for preparation of applicants for higher education of the first (bachelor's) level was launched in TNPU in June 2019. It is unique for the higher education institutions of Ukraine. Students of this specialty receive in-depth fundamental training in computer science, special and scientific-practical training taking into account the current state of digital technologies in the field of Game Studies. Graduates will be able to perform the functions of developers of computer programs (games), system administrators, game project managers, specialists in software development and testing (computer games), graphic designers, specialists in information technology and Game Studies, computer graphics and 3D-modeling, design and implementation of game technologies and data analysis tools.

All educational training programs are as close as possible to world educational standards. Graduates of these educational programs are in demand in the labor market.

5. Conclusions and recommendations for further research

"SMART-TNPU" is the innovative, digital, and educational ecosystem which serves for enhancement of quality of students' knowledge acquisition, increasing of efficiency of future teacher, as the specialist of novel era, training, and encourages the University mission realization. The particular traits of the "SMART-TNPU" are its interactivity and opportunity for close interplay between different structural components. The ecosystem "SMART-TNPU" composes from several structural components namely technology, education, science, administration, management and marketing which are

permanently cooperate and being coordinated by each other. One of the more significant findings to emerge from this study is that only essential collaboration and interplay between all structural components of Smart-University ecosystem with deep involvement of human resources within University developmental Strategy could provide visible way to success.

We see the prospect of further research in the construction of extranet networks, the introduction of IP-telephony, access to the international system Eduroam, modernization and development of computer technology, development of the actual software for digital transformation of the educational process. The broad introduction of chatbots and the use of augmented reality elements is important.

The next step is to optimize the internal quality monitoring system for certain indicators with visualized instant reports. It is also important to improve and fill the content of the university open course platform with the Coursera prototype, to develop and implement an online platform for exchanging ideas and achievements between lecturers of partner universities and their professional development, to initiate the creation of the regional Center for Digital Skills Certification together with the Ministry of Digital Transformation on the basis of TNPU.

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