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University 4.0 concept: educational and scientific policies, innovative development of vocational education and training

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The paper aims to generalize theoretical and practical aspects of educational and scientific policies and management of the vocational education innovative development within a University 4.0 model. The study of the University 4.0 continuum in this paper is based on a systematic approach. Our research content and construct validity, and reliability of its results were analyzed at the stage of developing a University 4.0 scale of environments using the SPSS (Statistical Package for the Social Sciences) and LISREL (Linear Structural Relations) software packages. Based on an explanatory factor analysis we developed a three-dimensional indicative scale of environments for an innovative entrepreneurial university. The efficient and reliable tool which is offered for assessing the internal environments of an innovative entrepreneurial university and its activities as a University 4.0 type is scaling. By scaling the University 4.0 environments our universities could succeed in upgrading their innovative entrepreneurial characteristics aimed to benefit their students, government agencies, and the entire economy at the macro level.

KEYWORDS

e-learning, vocational education, University 4.0, digital economy, integration processes, key competencies

1. Introduction

One of the challenges often encountered in the digitalization of higher education is the transformation of Universities 4.0 associated with Industry 4.0. The adaptation of the workforce, which will be most affected by the Industry 4.0 process, and its preparation for new competency needs will be largely performed by universities and research centers. The assessment of the research (Aladyshkin et al., 2020; Gresse von Wangenheim et al., 2021; Rocha et al., 2022) that will be conducted within this program in a wide range (not only in engineering but also in social sciences, medicine, and even law) will accelerate the process of integrating Industry 4.0 in universities. Thus, with the changing aims and learning outcomes of competency-based academic programs, it is natural to expect the industry to impact educational programs and methods.

As a competition requirement, government authorities are concerned about the role of universities in entrepreneurship. The scientific and educational policy of the state provides significant support and assistance to universities in this area (Bodunkova and Chernaya, 2012).

In special literature (Shahroom and Hussin, 2018; Gresse von Wangenheim et al., 2021; Wessels and van Wyck, 2022), it is noted that universities have recently put forward their innovative entrepreneurial university feature in marketing activities, one of the forms of such activity is e-learning (Suprunenko and Masyuk, 2020). However, the following question arises to what extent students, who are the real target group of universities, are accounted for in the university entrepreneurship ecosystem? Methods of evaluating and measuring the university as an innovative entrepreneurial university have become the subject under study in higher education (Guerrero-Sosa et al., 2019; Cai and Ahmad, 2021; Gasanov, 2021). To address these issues, internal environment of innovative entrepreneurial universities and their activities are required to be evaluated by their student bodies, the concepts of Industry 4.0 and University 4.0 being taken into account. Relying on the benefits of actively digitalizing environment, universities, though, are facing pressure to change organization of their tangible and intangible assets or physical and non-physical properties. The system of domestic higher education in the late 20th and early 21st centuries entered a series of dynamic transformations, and the modernization and reformation of universities continue to the present. The presence of market orientation and pronounced competition characterizes the current educational reality. Innovative organizations of higher education are acutely faced with issues of identity and positioning, which in turn produces dilemmas of established academic values formed in the industrial era, with the needs of an information (post-industrial) society. Developed countries are actively accelerating the transition of the information society to the cognitive (knowledge society), where Universities 4.0 are not only on the frontier of change but also cultivate productive socially significant values (Shtykhno et al., 2022). "The role of the higher education system is strengthening on a global scale to ensure the sustainable development of the state and its competitiveness. These requirements have led to the problem of flexibility and adaptability of the management system of Russian universities since the current management structure is characterized in most cases by a rigid vertical and high inertia" (Dovbysh, 2021, p. 2).

Management of universities in the Russian Federation is conducted following the state policy on higher education; its priorities are fixed in key laws, national projects, and development programs (Ministry of Science and Higher Education of the Russian Federation, 2021; Russian Federation, 2021a). The domestic legislator clearly formulates the demand for self-sufficiency of Universities 4.0 and the achievement of highly qualified innovative results. Over the past decade, the Government of the Russian Federation has implemented programs to create national research and federal universities in this direction. Project 5-100 (2021) continued the universities' optimization vector to increase the competitiveness of leading Russian universities among the world's leading scientific-educational centers (SEC). These programs demonstrate the efficiency and significantly increase the scientific and innovative potential of domestic universities. The directions for the development of universities for 2021–2030 have been formed by the state program of strategic academic leadership named Priority 2030 (Russian Federation, 2021b).

In addition to digital innovations in the field of education and scientific research, the current request of the University 4 is the development of commercialization of results, entrepreneurial activity, and communication with the real sector of the economy. These, in turn, oblige the university management not only to adjust the organizational structure, relying on the experience of the business community, but also to form new management principles that are understandable and acceptable both for commerce and for the academic sphere.

The modern world is represented by a complex integrative educational system that regularly generates new dilemmas, the solution of which is problematic using existing tools (Konstantinova et al., 2022). The growing global competition in the intellectual labor market and technologies requires qualitative changes in the content and methods of organizing the educational, research, financial, and economic activities of the university. However, such changes are only possible with relevant changes in the management system. These prompt University 4.0 to create a strategy for innovative development, test new management algorithms that should ensure sustainable development, and form competitive advantages and value of the university for society.

2. Materials and methods

The current paper aims to summarize what has been researched in relation to the scientific and educational policy and management of the innovative development of vocational education within the concept of University 4.0.

The research object was the educational ecosystems of the following universities: Vladivostok State Medical University (VSMU), Vladivostok; Vladivostok State University of Economics and Service (VSUES); Don State Technical University (DSTU), Rostov-on-Don; Plekhanov Russian University of Economics (Ivanovo branch, RUE), Ivanovo.

Monitoring of the activities of the research object was carried out based on the results of processing the 2021–2022 data questionnaires presented by the universities. Activities of Universities 4.0 was evaluated according to six parameters: (1) educational function; (2) research work; (3) socialization, reflecting the activities of the university in the social sphere; (4) internationalization or international practice; (5) brand; (6) digitalization, innovation, manufacturability of management, and commercialization. The method of forming the overall rating was a linear combination of particular parametric rankings, where each parametric index had its own weight coefficient. The methodology included an assessment of the university's activities in the Education segment (20%), the analysis of the University Research area (20%), the examination of the university's activities at the level of Social Environment (15%), and the definition of the effectiveness of the university in terms of Internationalization (15%). The methodology accumulated monitoring of the Innovations and Entrepreneurship of the University segment (15%) and the effectiveness of the university brand (15%).

We applied the MetALig methodology (Navodnov et al., 2019), which involved the study of University 4.0 systems, its educational and scientific policy, innovative development of vocational education, and training of Russian and foreign universities.

The MetALig methodology involved the following algorithm: the transition from places in the ratings of research objects to leagues; the use of the mathematical apparatus of convolutions; the intubation of weak bonds -Bn,m.

Each assessment matrix was quantitative in nature (place, score). Accordingly, all objects of the research were ranked in descending

order. Each rating was scaled into non-overlapping groups (quartiles) of SPSS (Statistical Package for the Social Sciences) and LISREL (Linear Structural Relations). As a result, the research object for each i-th rating fell into a specific group (1,2.3.4 quartile) and received a corresponding rating of Ai, Bi, Ci, or Di. If the university was not rated, then it received an Ei score (Figure 1; Bolotov et al., 2020).

The position of the research object among all 11 ratings considered is characterized by an eleven-dimensional vector of assessments (A, D, C, A, C, D, E, B).

Next, we used the so-called weak convolutions B 7,11. The essence of the procedure was to consider not all results of 11 ratings in the final assessment but only the 7 best (they can be individual for each university).

We used the provisions of the voting theory in small groups, including by de Borda (1784), Marie Jean Antoine Nicolas de Caritat, Marquis of Condorcet (Caritat and Marquis of Condorcet, 1785), and Simpson (1951). To transfer from a multi-criteria choice to a single-criteria problem, An analog of the de Borda method (de Borda, 1784) was used to move from a multi-criteria choice to a single-criteria problem. In the procedure by de Borda procedure, each element is assigned a rank. If there are k areas, then the first ordered area is assigned a rank equal to (k-1), the second (k-2), etc. The last object in the ordering of areas is assigned a rank equal to 0. The ranking of objects is built in descending order of the sum of ranks (Borda count). The best option is determined by the maximum value of Borda count, which is calculated as the sum of the ranks assigned to the areas (de Borda, 1784).

The new ranking was based on the sum of the 7 best results. The value of Borda count in the case of 11 ratings could vary from 0 to 4*7 = 28. Those universities whose Borda count is equal to the maximum value of 28 make up the Premier League. The first league is universities whose Borda count is from 25 to 27, the second from 22 to 24, etc. In total, 10 leagues were divided into 4 zones (Table 1; Bolotov et al., 2020).

One should pay attention to the fact that the number of universities at the top could not coincide with the integer value; this is due to the fact that universities with the same Borda count could be included in the same league.

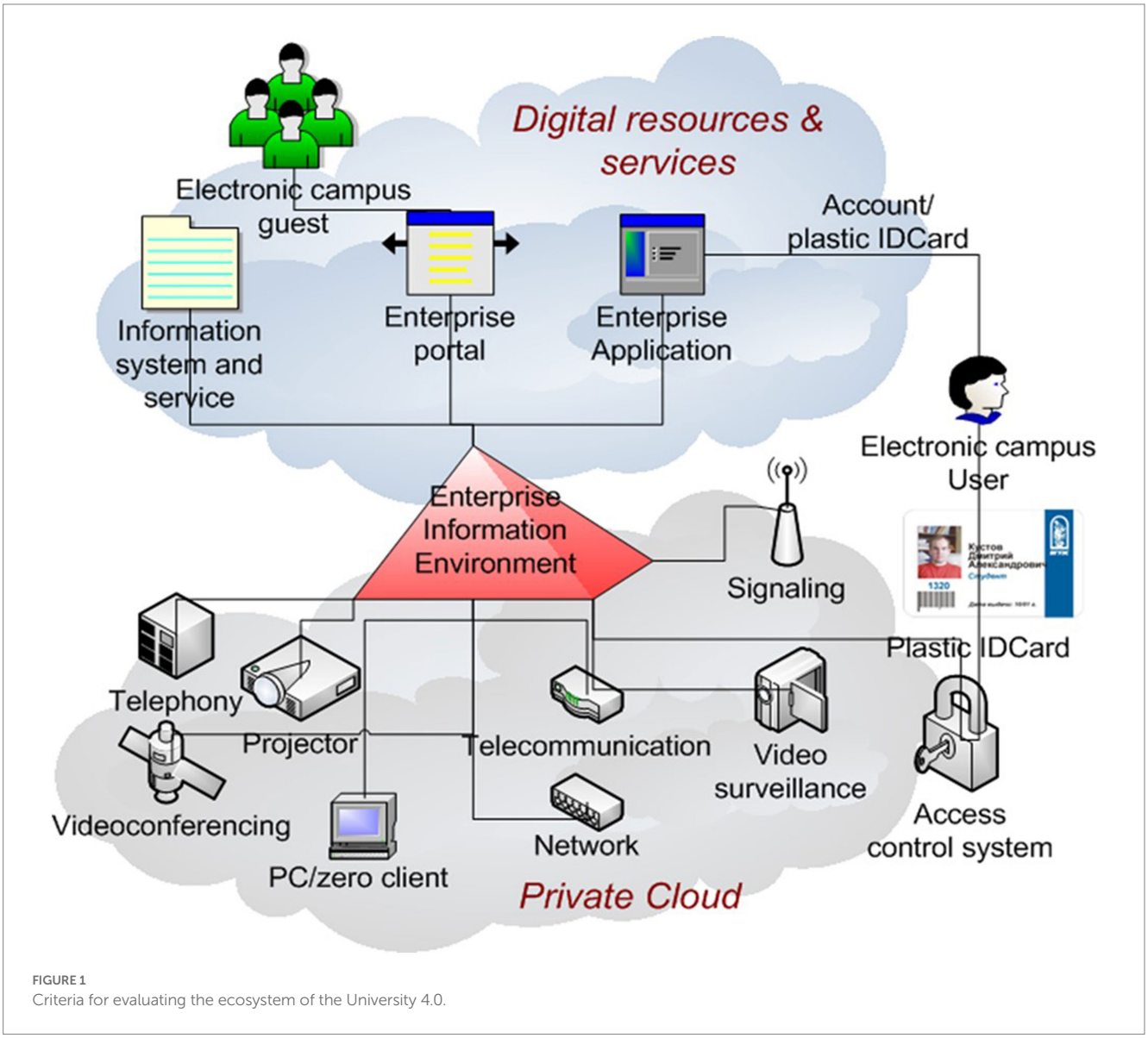

FIGURE 1
Criteria for evaluating the ecosystem of the University 4.0.

TABLE 1 Ranking of universities by leagues.

League	Borda count (for universities of culture and arts, physical culture, and sports)	Number of organizations	
Premier League	28 (16)	37	37
1 League	27, 26, 25 (15, 14)	77	114
2 League	24, 23, 22 (13, 12)	82	196
3 League	21, 20, 19 (11, 10)	100	296
4 League	18, 17, 16 (9, 8)	91	387
5 League	15, 14, 13 (7, 6)	93	480
6 League	12, 11, 10, 9 (5, 4)	95	575
7 League	8, 7, 6, 5 (3)	79	654
8 League	4, 3, 2	28	682
9 League	1, 0	12	694

Review of the literature is based on a systemic approach. Analysis of the content and construct validity, and reliability of results at the initial stage of building a University 4.0 scale of environment was carried out using the SPSS (Statistical Package for the Social Sciences) and LISREL (Linear Structural Relations) software. A three-dimensional scale for an innovative entrepreneurial university environment is based on the results of an explanatory factor analysis. This scale was found to be a valid and reliable measurement tool for evaluating internal environment and activities of innovative entrepreneurial universities. The University 4.0 environment scale, therefore, can be used as a driver in improving universities' entrepreneurship and innovations when targeting their students, governmental structures and the national economy.

2.1. Scientific and educational policy of University 4.0

Universities are not only a strategic educational resource, a kind of anchor, shaper, and innovator of nations; they also stimulate formulation and promotion of national ideas. They are a source of knowledge and an arena for developing understanding, and they provide a means to interpret and address the key issues of the time. Countries need universities to develop their own solutions to the problems and opportunities they face so that they could participate with benefit and confidence in international scientific ecosystems (Petrichev et al., 2018). However, national universities do not and should not act alone. The 2030 Agenda and the Sustainable Development Goals represent the main international convention of the time and offer a positive step in recognizing the importance of higher education for individual and social development. However, they do not go far enough, especially in terms of countries seeking to grow prosperous economies and engaged societies. It is necessary to consider the national and international roles of universities, as well as the advantages or disadvantages of the internationalization of higher education and global conventions, such as the 2030 Agenda (Gasanov, 2021).

To date, there is a broad consensus in public science and education policy that globalization encourages countries and their governments to bring scientific truth into policy-making processes. However, many academics and policy analysts have also addressed the uncertainty and complexity of how scientific knowledge is used in policy-making processes (Aladyshkin et al., 2020; Bilyalova et al., 2020; Parreira do Amaral and Thompson, 2022; Prosalova et al., 2022). Table 2 presents the rating of the ecosystems of the research object (Bolotov et al., 2020).

According to Table 2, REU is included in the Premier League, DSTU and VSU in the 1st league, and TSMU in the 4th league.

The research objects promote the concept of *Phygital* (physical + digital) —the combination of the possibilities of digital technologies with the desire of people to communicate with each other in the physical world. This concept achieves a balance in which the university will teach students using the GiFlex model and real experience, human interaction, and physical self-expression, not limited exclusively to digital tools. VSU is the first university to create a balanced digital environment that takes into account the desire of people to communicate and express themselves. *HyFlex* (Hybrid + Flexible, hybridity + flexibility) is a learning model that combines elements of traditional learning (classroom classes) and online learning. It was first introduced into higher education in 2006 to give students a choice: to attend classes in the classroom or to study online; besides, they had an opportunity to switch from one to another at any time. The support of such a model requires different organization of the learning process, appropriate technical equipment, provision of training resources, and methodological readiness (Kryukov, 2022).

While the evidence is highly cohesive in terms of advanced specialized knowledge, few scientists expect science and policy to perform the same functions and rationales. Moreover, the status and role of empirical data may differ in various policy projects depending on the areas of knowledge to which these projects belong and their political context.

Not surprisingly, therefore, that performance of expert groups in various areas of educational policy as well as findings and arguments provided by them have generated great interest among researchers (Barabanova et al., 2018; Burgos and Branch, 2021; Rackov et al., 2022).

2.2. Analysis of university management experience within the concept of University 4.0

In order to achieve what is called University 4.0, two conceptual models designated as macro and micro models are proposed as an institutional renewal plan (macro model) aligned with the stipulated 4IR (the fourth industrial revolution) requirements. The micro model suggests that teaching and learning can also bring economic and social benefits. Ideally, both models should be implemented simultaneously to provide optimal learning and training conditions for each graduate. While technology is the main driver and anchor of 4IR, some of the 4IR requirements can be met by the adaptive management and highly qualified teaching staff willing to understand the needs of current and future students (Wessels and van Wyck, 2022).

Thirty years of Tecnologico de Monterrey University experience in elaborating and implementing digital education programs for academic

TABLE 2 University 4.0 ecosystem of Russian universities.

Top (League)	Educational organization / Region	Rating score										
		1	2	3	4	5	6	7	8	9	10	11
Premier League	Plekhanov Russian University of Economics, Moscow	A	B	A	A	A	A	C	A	A	A	A
Top-100 1 league	Don State Technical University, Rostov Region	A	B	C	A	A	B	B	A	E	A	E
Top-100 1 league	Vladivostok State University of Economics and Service, Primorsky Krai	A	B	E	C	A	A	A	A	E	B	E
Top-400 4 league	Vladivostok State Medical University, Primorsky Krai	C	C	E	B	D	A	E	D	E	B	E

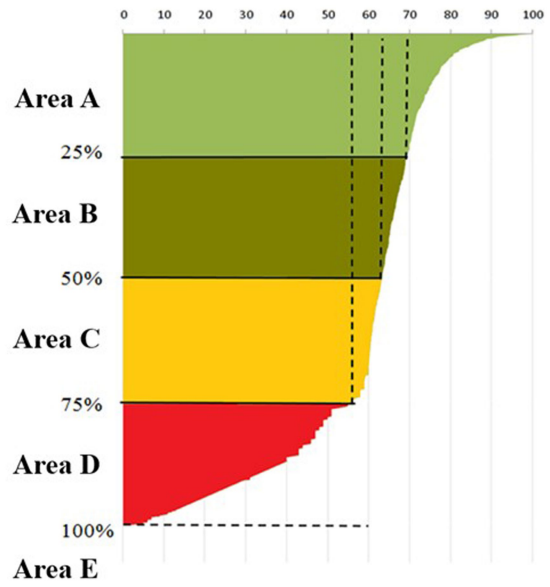

FIGURE 2
The infrastructure of the electronic campus of Vladivostok State University.

and continuing education, combined with modern advances in information and communication technologies (ICT) applied in the education sector, have contributed to the development and introduction of effective distance learning programs over the past few years. Some examples of the programs are as follows: (1) online graduate program (9,917 students); (2) courses based on flexible interactive technology and known as FIT courses (7,129 students); (3) online continuing education programs (73,943 students); (4) massive open online courses (MOOCs) (829,165 students); (5) telepresence courses (1,668 students); (6) hybrid-flexible model that was applied to ensure academic continuity at the Mexico City campus during an emergency caused by a strong earthquake in 2017 (8,472 students), etc. The experience gained in implementing these programs has been used to propose a new learning model that guaranteed academic continuity during the Covid-19 global health emergency in 2020–2021 (Molina et al., 2022).

Let us consider the concept and model of a Russian digital university. The activities of the Industrial University of Tyumen (Tyumen, Russia) are an example of ongoing research arising from the specifics of software and hardware solutions that allow the implementation of a strategic project for the development of intelligent technologies. The main idea of the project is to turn the University into the Center for initiative aimed to develop and realize decisions on effective management of urban and environment resources in the Tyumen region (Russia). The tasks of the strategic project are as follows: (1) development and introduction of software and hardware solutions; (2) organization of consulting; and (3) expertise of regional projects for the development of intelligent technologies. In addition, it helps the Industrial University of Tyumen build a reputation as a regional leader in Smart-City, IoT, IIoT, and Big Data areas. The University thereby can be involved in solving the complex issues of effective city management in collaboration with local communities and experts. Besides, the strategic project paves the way for the elaboration of educational programs and training based on programs that form specific skills for the implementation of intelligent technologies (Lin et al., 2022). Tyumen Industrial University is a vivid, but not the only example of a university making the transition to University 4.0. A similar vector of development was chosen by other Russian universities, including Vladivostok State University, Pacific State Medical University, Don State Technical University, Russian University of Economics. G.V. Plekhanov, whose representatives are the authors of the article.

One of the examples is the electronic campus of Vladivostok State University, the infrastructure of which is shown in Figure 2 (Kryukov and Shakhgeldyan, 2013).

The campus, which is currently the central place of higher education for most students, will be complemented (but not replaced) by the integration of digital technologies in management and learning. The base of these changes is the concept of virtualization of both labor and student learning. Virtualization is directly used in mobility, i.e., relying on modern interaction methods, it is possible to improve the qualifications of employees and students to expand the educational experience through online courses of other universities. This is an argument in favor of the following thesis: "Learn and develop where you live" —what is the point of leaving and enrolling Higher School

of Economics (HSE) or Ural Federal University (UrFU) if soon 50% of their disciplines will be online and students will never see the leading professors? It is possible to enroll in VSUES while staying in Vladivostok and take courses in HSE and other leading universities (Kryukov, 2022).

As a result of the implementation of the strategy at DSTU, an adaptive digital management environment based on data will be created by 2025 and by 2030 —a super service for seamless communication between the university and stakeholders on basic business processes. These measures will significantly reduce costs, increase the speed of implementation of basic processes, and improve the quality of services provided and the attractiveness of the university.

The considered research objects are engaged in the following areas of activity: (1) development of a single digital ecosystem of the University 4.0; (2) introduction of digital services in educational and administrative processes; (3) realization of research and applied work in the field of artificial intelligence, including machine vision and VR/AR technologies; (4) attraction and development of interaction with external partner organizations (Rostelecom, Yandex, VK Group, RT-Capital, Capital Group, Glosav, Academy IT, Romir Research Holding, INTECH, etc.); (5) conclusion of cooperation agreements with key departments: Federation of Computer Sports of Russia, Innovation Agency (Moscow), Chamber of Commerce and Industry, Russian eSports Student League, Moscow eSports, School eSports League, Cyber School, Agency for the Development of Computer and other sports.

3. Conclusion

It is reasonable to state that the current period of socio-economic development of society is aimed at the ontogenesis of key trends in the development of scientific and educational policy and management of the innovative development of vocational education within the University 4.0 strategy. Practical benefits of our research lie in the fact that it gives a possibility to evaluate transformation of higher education at large and of universities in particular, all the changes in the status of universities and high risks in conducting scientific research and practical experiments being considered. Hence, the University 4.0 model can be characterized as a transition of educational process from confrontation to partner communication, penetration of Big Data, implementation on multi-format open educational platforms, combination of new and classical forms of learning, and transformation of traditional classrooms into the open space system (Open Space Learning). In the near future the world will evidently witness dynamic development of such educational methods as using personal devices for self-directed learning or individual devices during training, mobile tracking, accommodation of the flipped classroom, mobile and flexible gadgets in educating, adaptive learning on digital platforms, and further accumulation and development of online resources and the Internet of things.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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