Physics Students’ Innovation Readiness for Digital Learning within the University 4.0 Model: Essential Scientific and Pedagogical Elements That Cause the Educational Format to Evolve in the Context of Advanced Technology Trends

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Abstract: Students’ readiness for innovative educational formats is a determining factor that can affect the effectiveness of digital transformations in a higher education institution. Evaluation of students’ innovative readiness for the transition to the University 4.0 model can provide guidance on what actions and policies should be taken to achieve an educational institution’s digital transformation goals. This article aims to study the essential scientific and pedagogical elements that cause the educational format to evolve in the context of advanced technology trends and determine physics students’ innovation readiness for digital learning within the University 4.0 model. The survey was extended to the online forum University 4.0: Prospects for Modernising Approaches to Teaching Physics. The survey results showed the degree of readiness of physics students to implement digital approaches in teaching in four dimensions. Students had a high level of creativity and a positive attitude toward innovative educational activities (M = 3.89); they also had a high level of motivation for digital innovative training and sufficient knowledge of how the training will help them achieve their educational goals and professional and personal competence (M = 3.85); and they had a high level of digital literacy (M = 3.96). The scientific value of this article lies in demonstrating the developed methodology for determining and evaluating the degree of innovative readiness of students in the process of transition to a new educational format University 4.0. This methodology can be used in the process of developing an innovative strategy for organizing the educational process in the conditions of Industry 4.0 taking into account its challenges and opportunities.

Keywords: digital infrastructure; digital learning; digital literacy; digital transformation; Education 4.0; Industry 4.0

1. Introduction

The Industrial Revolution 4.0 is a collection of technologies that blur the boundaries between the physical, digital, and biological worlds and has a profound effect on all industries, resulting in the creation of products and services that enable human society to live a more fulfilling and prosperous life. Starting with factors such as knowledge, technological progress, labor productivity, the amount of wealth created, and ending with changes in the structure of administrative-institutional and managerial-administrative human capital, the Industrial Revolution 4.0 contributes to exponential development [1]. Globally, technological advancement is transforming people’s lives, the economy, industry, and jobs [2]. In today’s world, the emergence and development of new markets, industries, products, and professions occurs at a breakneck speed. The transformation of the economy, which produces results at the intersection of industries, is the primary catalyst for these processes.
It employs interdisciplinary knowledge, establishes cross-sectoral processes, develops infrastructure and digital platforms, and based on these, creates new market formats and models of market participant interaction. The world’s active information and technology advances present new challenges to all industries. The establishment of highly efficient intersectoral ecosystems and the transformation of economic agents’ interaction processes are two of them [3]. The expansion of technological advances in society’s socio-economic life affects the required skills and knowledge expected from human capital [4]. Educational institutions develop the human capital required by society and generate knowledge for innovation [5,6], bearing the responsibility for developing competent, innovative, competitive, and moral human capital to meet the needs of national economic systems [7]. In the long run, higher education is intended to serve as the foundation for developing and fully exploiting the nation’s intellectual potential. In this context, higher education institutions play a critical role in not only generating and communicating advanced knowledge but also in ensuring the reproduction of labor market-relevant competencies. The formation of research and innovative university models, which allows universities in the knowledge paradigm to perform their tasks more effectively, is one of the leading modern dimensions of higher education modernization. The formulation of tasks to strengthen the interaction between science and education is a distinguishing feature of these models [8].

Universities are critical components of innovation ecosystems. University involvement in cross-sectoral projects is also transforming and strengthening universities’ roles in the modern world of innovation, which is interdisciplinary [3]. Through partnerships that support research, marketing, personnel development, and entrepreneurship, the University 4.0 concept promotes the high-tech industry. Consequently, politicians and stakeholders should work together to promote modern universities as a hub for the development of intelligent, interconnected technologies and services that will lead to the long-term development of higher education that reflects contemporary challenges [9]. The organizational structure and values, in addition to the means, equipment, and motivation, are effective essentials in the process of implementing the University 4.0 concept. They should work collaboratively to advance flexible interaction with the internal and external educational spaces; decentralization of knowledge and its multiple dissemination; the creation and dissemination of the most elite meanings and knowledge; and academic, cultural, and social rationality [10].

Higher education 4.0 is a pioneering period that responds to the needs of modern society. Students should possess sufficient pioneering abilities to adapt to society’s rapidly changing environment, which rewards the persistence of knowledge. The Industrial Revolution 4.0’s process of digital transformation of higher education institutions has created critical tasks for the effective deployment of a digital university (University 4.0) [11]. Education 4.0 demonstrates how to integrate technological advancements (3D printing, augmented reality, virtual reality, cloud computing, holograms, biometrics, multi-touch LCD, Internet of Things, artificial intelligence, big data, QR code) to achieve educational goals. Innovative digital solutions are being implemented by educational organizations that seek to respond effectively to the growing social need to improve, optimize, and personalize large-scale education in the context of Industry 4.0. Education 4.0 promotes alignment between education and Industry 4.0, propelling educational institutions onto technological and pedagogical transformation trajectories [12]. University 4.0 is a collaborative effort to integrate intelligent technologies, intelligent functions, intelligent software and hardware systems, intelligent pedagogy, intelligent curricula, intelligent learning, academic analytics, and diverse fields of computer science and computer engineering [13]. Through the use of Industry 4.0 technologies in the educational environment, innovative education aims to improve the educational and pedagogical process while also democratizing access to quality education [14].

In the face of modern technological trends, an integrated approach to education system transformation necessitates the close collaboration of all participants in the educational process. It is possible to create a high-quality effective educational space for a new generation by focusing on the priority of innovative changes and promoting the development of
digital citizenship among teachers and students, making it the backbone of the university’s educational policy. This, in turn, will help the educational institution stay up to date, giving students the modern education they need to be successful in the future. Designing, developing, and utilizing a contemporary digital educational environment is the optimal path to digital maturity for all its participants [15].

When teaching in the context of digital educational transformations, a competent approach to teaching alters pedagogical principles and assigns new responsibilities to teachers and students. Throughout Industry 4.0’s intensive development of digital technologies, information and digital competencies take precedence over other key competencies, manifesting themselves in the following functions:

- The ability to use available information and digital tools to obtain, process, distribute, and store necessary information;
- The ability to systematize and summaries information found online;
- The ability to extract objective information in a dynamic and contradictory hypertext environment;
- The ability to create information bases from various sources and evaluate facts and statements;
- The ability to manage the multimedia flow using information filters and agents;
- The ability to create a personal information strategy and implement a portfolio approach with a choice of delivery sources and mechanisms [16].

The ability to effectively implement innovative professional activities is made possible by having a high level of digital competence. Furthermore, it enables people to better understand the motivations for professional and personal development, to be open to new information, to learn quickly and effectively, to conduct research, and to generate new ideas [17].

Basic digital literacy skills and the ability to use digital educational tools are essential for today’s students. Educational organizations should be infrastructurally and intellectually prepared to provide educational experiences under the conditions required by the digital University 4.0 concept [18]. Teachers can use the benefits of digital learning to help students gain knowledge, apply it, improve skills, and achieve good academic results if they understand the level of students’ readiness for it. Students’ readiness for digital learning can be assessed in five areas: motivation, technological capabilities, possession of online learning tools or equipment, online learning benefits, and self-education skills [19].

Since the conditions of the digital University 4.0 concept require a high level of infrastructural and intellectual readiness of the participants in the educational process, assessing the degree of innovative readiness of students is a necessary and important act in the process of developing a digital transformation strategy. Assessment of students’ innovative readiness for the University 4.0 model can provide insight into the measures and policies that should be implemented to accomplish an educational institution’s digital transformation goals. In this regard, the purpose of this article is to investigate the essential scientific and pedagogical elements that cause the educational format to evolve in the context of advanced technology trends, and to determine physics students’ innovation readiness for digital learning within the University 4.0 model. The following tasks were assigned to accomplish this:

- Study the evolutionary trends of the university format and substantiate the need for the digital transformation of approaches to vocational training in the relationship between the concepts of the Industrial Revolution 4.0 and Education 4.0;
- Conduct a survey aimed at studying the extent to which physics students are ready to embrace digital approaches in learning to the extent of the online forum University 4.0: Prospects for Modernising Approaches to Teaching Physics, which was attended by 84 students from 3 universities of Kazakhstan;
- Determine the extent to which physics students are ready for digital educational experience in terms of personal creativity and attitude to innovative educational activities;
- Determine the extent to which physics students are ready for digital educational experience in terms of their motivation for digital educational activities and understanding the benefits that digital learning can bring them;
- Determine the extent to which physics students are ready for digital educational experience in terms of ownership of digital learning tools or equipment and access to technological infrastructure educational opportunities;
- Determine the extent to which physics students are ready for digital educational experience in terms of digital literacy.

This article aims to answer the question: “Is the readiness of students for digital learning within the framework of the “University 4.0” model a necessary and important condition for the successful implementation of the policy of digital transformation of individual educational programs as part of the comprehensive professional training of a new generation of students?”.

Theoretical Background

Education 4.0 can be seen as a new paradigm that rethinks the concepts of learning, student, teacher, and educational institution in line with the needs of the Industrial Revolution 4.0 [20]. Figure 1 depicts the university format evolution. It shows how the educational paradigm and learning approaches have evolved. University 1.0 is the first generation of universities that focus and thrust on the education and training of their faculty and staff members. University 2.0 refers to universities that are second generation and focus on research and research functions. University 3.0 refers to universities that are third generation and focus on combining education, research, and business. University 4.0 refers to fourth-generation universities that emphasize multiparametric knowledge formation and digital and biotechnological opportunities, and being entrepreneurial, opportunistic, creative, and progressive educational structures capable of solving socio-economic problems in modern society. Education 4.0 places the student at the center of the ecosystem and enables the creation of an individualized educational strategy based on the desired outcome [21]. Students can control their own learning and develop self-learning skills in a technology-based learning environment with various forms of multimedia. Big data, mobile computing, social networks, and the cloud offer the potential to create a learning environment and innovative educational contexts that encourage self-learning regardless of location or time, allowing students to develop their own educational path based on their personal goals [22].

Due to the rapid development of innovative technologies under the influence of the Fourth Industrial Revolution (4IR) [11], the digitalization of the educational process has gained importance in recent decades, resulting in an incremental transition from traditional learning to digital learning [23]. New technologies are now used not only to provide new forms of communication but also to organize and manage educational processes that support a wide range of educational activities. In any innovation process, the use of new technologies and digital tools in teaching becomes a critical component [24].

Education 4.0 focuses on innovative educational content from a didactic point of view. Its goal is to train future professionals who will work in the context of Industry 4.0 [25]. Industry 4.0 has given educational transformations and changes a new impetus. The use of technology as a tool and means of learning in the 4IR era should work in tandem with a powerful educational environment. This will fundamentally alter the educational process of learning and teaching, allowing students to gain knowledge in a more rewarding and comprehensive manner. Recently, experts in the field of education have realized that new technology has a big impact on the way students learn. Furthermore, they agree that the 4IR educational process will be shaped by innovation and that students will need to be prepared for it [22]. The primary goal of the national education system is to produce competent, knowledgeable, and qualified students who will contribute to a skilled workforce. The current challenge is to provide Industry 4.0 with professional staff who are knowledgeable in all technical aspects of cyberspace interaction [26] while also recognizing the importance
of developing non-technical skills. Cognitive skills, problem-solving skills, communication skills, interpersonal skills, teamwork skills, and the ability to solve complex problems and manage complex situations in professional contexts are examples of non-technical skills [27]. In terms of student well-being, increasing attention is being paid to how technology can be used to support students’ mental health to the extent that educational processes are concerned. When used correctly, learning analytics, for example, can identify students who are at risk. Furthermore, artificial intelligence-controlled digital assistants that use natural language processing can serve as effective communication channels with students [28].

E-learning is rapidly growing in popularity, significantly expanding the learning space, and allowing students to delve deeper into university programs. Participants in the educational process can now exchange information over long distances thanks to computer technology. Because students can study at their own pace and in their own space with this method of learning, it has a lot more advantages than the traditional way of learning. Interactivity is a major advantage of e-learning, as it facilitates the creation of an ideal learning environment for each individual [29,30]. Based on requests, computer software and virtual experimental environments can provide new learning and teaching opportunities for teachers and students. Not only can virtual reality (VR) and augmented reality (AR) technologies transform abstract material into interactive knowledge, but they can also present abstract knowledge as visible, audible, and perceivable dynamic content [31]. Modern scientific research highlights the fact that technology not only facilitates learning but also develops students’ social skills such as creativity, collaboration, communication, and problem-solving skills [32].

Contextually, the educational model University 4.0 encourages lifelong learning, which involves the acquisition of new knowledge and professional competencies throughout life [33]. Education 4.0 offers a wide range of opportunities to contribute to educational practice, from competency development methodologies (critical, systemic, scientific, and innovative thinking) to the design and implementation of infrastructures that accompany learning [34]. The rapidly growing use of digital technologies in teaching and learning is accompanied by structured competency requirements for both teachers and students. In order to use the potential of digital technologies in teaching and learning processes and be able to plan and implement high-quality digital learning, teachers and students need certain technological competencies [35]. Despite belonging to the generation of the so-called “digital natives”, participants in the educational process need prior training and education in the productive use of digital technologies [36]. Hence, it is obvious that the modern academic world needs two things: specialists trained according to the new educational model, and additional efforts to increase the readiness of teachers and students for a full transition to it [33]. To provide skills for 4IR, educators need to work closely with employers to understand what skills are in demand and how they are used in the workplace (WEF, 2022). Students must be well prepared to have a high intention to participate in the educational process of an innovative format. Preparatory work includes technical readiness, self-efficacy of online communication, independent learning, student supervision, and motivation [37].

As the rapid development of IR4.0 requires new talents, experiences, and skills for current and future generations, higher education must change accordingly to meet future job demands [38]. Education systems must adapt to give students the skills they need to build a more just and productive society. Education 4.0 aims to equip students with cognitive, social, interpersonal, and technical skills to meet the needs of the Fourth Industrial Revolution [39].
build a more just and productive society. Education 4.0 aims to equip students with cognitive, social, interpersonal, and technical skills to meet the needs of the Fourth Industrial Revolution [39].

The digital transformation towards Education 4.0 must be carried out holistically. It is necessary to develop a program for the use of digital educational technologies in educational processes taking into account the characteristics of students. Organizational educational processes and practices must be carried out in accordance with the new social and working relations. Efforts need to be focused on developing the digital skills of teachers, and equipping students with the technical, cognitive, social, and emotional skills needed to learn and work in the 21st century. The introduction of innovative pedagogical techniques should focus on the transfer and acquisition of knowledge on demand to solve a problem or complete a task [39].

2. Materials and Methods

2.1. Research Design

This survey was conducted to study the extent to which physics students were ready to embrace digital learning approaches in terms of innovation. It took place during the online forum University 4.0: Prospects for Modernising Approaches to Teaching Physics, which was attended by 84 students from 3 universities of Kazakhstan (Table 1). The survey structure is shown in Figure 2.

In December 2021, two experts used the Google Forms service to conduct the survey and evaluate the results. The psychometric Likert scale was used in the survey. The survey items were straightforward statements that respondents were asked to rate on a five-point Likert scale: 1—strongly disagree; 2—disagree; 3—neutral; 4—agree; 5—strongly agree, using emoticons in WhatsApp (Figure 3).

Figure 1. University format evolution. Developed by the author using work of Strielkowski and Wang [40].
Table 1. Survey participants.

<table>
<thead>
<tr>
<th>Number of Students</th>
<th>Degree</th>
<th>Major</th>
<th>University/Faculty</th>
<th>Higher Educational Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>Master’s Program</td>
<td>Physics, 7M05302</td>
<td>Faculty of Physics, Mathematics, and Information Technology</td>
<td>Atyrau University named after Khalel Dosmukhamedov</td>
</tr>
<tr>
<td>27</td>
<td>Bachelor’s Program</td>
<td>Physics, 5B011000</td>
<td>Faculty of Physics and Technology</td>
<td>L.N. Gumilyov Eurasian National University</td>
</tr>
<tr>
<td>32</td>
<td>Master’s Program</td>
<td>Technical Physics, 7M05304</td>
<td>Faculty of Physics and Technology</td>
<td>Al-Farabi Kazakh National University</td>
</tr>
<tr>
<td>Total: 84</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. The Structure of the Survey of Physics Students’ Innovative Readiness for Digital Learning within the University 4.0 Model. Developed by the author.

Figure 3. Consent gradation. Developed by the author.

2.2. Ethical Issues

Before the survey, the participants learned about the goals and objectives of the study and gave written permission to take part in the survey.

2.3. Limitation

This study is limited to assessing the degree of innovative readiness for the transition to a new model of education University 4.0 of only Kazakhstan’s students. This article focuses on the fact that the transition to the educational model University 4.0 must be a phased and planned process that needs an individual approach and must take into account the interests, capabilities, and level of readiness of each participant of the educational process. The educational University 4.0 model puts the student at the center of the ecosystem...
and provides an opportunity to structure an individual educational strategy, taking into account the final result. A small number of study participants are associated with the need for a narrow-profile audit of the resource, technological, and innovative potential of physics students from Kazakhstan. Since this study was aimed at demonstrating a methodology for assessing the degree of innovative readiness of students studying in similar conditions, there was no need for a larger sample. The results of this study demonstrate the degree of readiness of physics students to study in a new innovative format, which is especially important in the process of developing a policy for the digital transformation of individual educational programs as part of the comprehensive professional training of a new generation of students. The orientation of the sample to only one professional career is associated with the need for a detailed study of the innovative readiness of students with the same competence requirements for future work and similar requests for the organization of the educational process. In this regard, students from three universities were selected for this study, which are characterized by similar organizational and resource capabilities and conditions, in addition to one educational profile: physics. Since the assessment of students’ innovative readiness was carried out within the framework of one educational area, it was important to assess the average level of readiness among students of both bachelor’s and master’s programs.

3. Results

Tables 2–5 present the results of a survey of physics students indicating that students were innovatively prepared to participate in digital education to the extent of the University 4.0 model in four dimensions: (1) personal creativity and attitude toward innovative educational activities; (2) motivation for digital educational activities and understanding the benefits of digital learning; (3) ownership of digital learning tools or equipment and access to technological infrastructure educational opportunities; and (4) digital literacy.

Table 2. Determination of the mean level of physics students’ readiness for digital educational experience in terms of personal creativity and attitude to innovative educational activities.

<table>
<thead>
<tr>
<th>No.</th>
<th>Statement</th>
<th>Mean Score (M)</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>In the learning process, I strive to discover, create, and master some new things</td>
<td>4.08</td>
<td>High</td>
</tr>
<tr>
<td>2</td>
<td>I am always looking for new ways to improve my professional and personal competencies</td>
<td>4.04</td>
<td>High</td>
</tr>
<tr>
<td>3</td>
<td>I like the process of acquiring new knowledge and skills</td>
<td>4.09</td>
<td>High</td>
</tr>
<tr>
<td>4</td>
<td>I like to stay current, so I support the latest technology at all times</td>
<td>4.11</td>
<td>High</td>
</tr>
<tr>
<td>5</td>
<td>I strive to be an innovator in group interactions, bringing intellectual novelty</td>
<td>3.92</td>
<td>High</td>
</tr>
<tr>
<td>6</td>
<td>I know how to convert innovative ideas into practical results</td>
<td>3.87</td>
<td>High</td>
</tr>
<tr>
<td>7</td>
<td>Learning new technologies allows me to put many of my skills into practice</td>
<td>3.92</td>
<td>High</td>
</tr>
<tr>
<td>8</td>
<td>I understand how the technology to implement innovations works</td>
<td>3.40</td>
<td>Moderate</td>
</tr>
<tr>
<td>9</td>
<td>I like to be a participant in innovative group experiments</td>
<td>3.67</td>
<td>Moderate</td>
</tr>
<tr>
<td>10</td>
<td>Innovative design in the process of educational activity is, in my opinion, the best educational methodology</td>
<td>3.71</td>
<td>High</td>
</tr>
<tr>
<td>11</td>
<td>I am open to changes both in my personal and professional lives</td>
<td>4.02</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>3.89</td>
<td>High</td>
</tr>
</tbody>
</table>

Developed by the author.

The assessment results of the extent to which physics students are ready for digital educational experience in terms of personal creativity and attitude to innovative educational activities showed that the mean score was high (Table 2, Figure 4). Respondents agreed that in the learning process, they strived to discover, create, and master some new things (M = 4.08); they were always looking for new ways to improve their professional and personal competencies (M = 4.04); and they liked the process of acquiring new knowledge and skills (M = 4.09). Moreover, they strived to be innovators in group interactions, bringing intellectual novelty (M = 3.92), and knew how to convert innovative ideas into practical results (M = 3.87). Innovative design in the process of educational activity was, in their
opinion, the best educational methodology (M = 3.71). The respondents demonstrated a moderate level of understanding of innovation technology (3.40). The students confirmed that they were open to changes both in their personal and professional lives (M = 4.02) and enjoyed participating in innovative group experiments (M = 3.67). According to the assessment results, it can be concluded that students were open enough to change, and their level of personal creativity was sufficient to participate in innovative educational processes.

Table 3. Determination of the mean level of physics students’ readiness for digital educational experience in terms of motivation for digital educational activities and understanding the benefits that digital learning can bring.

<table>
<thead>
<tr>
<th>No.</th>
<th>Statement</th>
<th>Mean Score (M)</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>I am open to acquiring an innovative educational experience in the virtual educational space using the latest digital technologies</td>
<td>4.21</td>
<td>High</td>
</tr>
<tr>
<td>13</td>
<td>I am interested in studying and testing the possibilities of digital tools that contribute to finding innovative solutions to educational problems</td>
<td>4.10</td>
<td>High</td>
</tr>
<tr>
<td>14</td>
<td>I am inspired by the incorporation of digital technologies into educational practices and see the benefits of online education in terms of developing my professional competencies</td>
<td>4.08</td>
<td>High</td>
</tr>
<tr>
<td>15</td>
<td>I am motivated to learn, and I am willing to devote sufficient time and effort to online education</td>
<td>3.92</td>
<td>High</td>
</tr>
<tr>
<td>16</td>
<td>Participating in systematic online learning gives me a sense of personal congruence</td>
<td>3.78</td>
<td>High</td>
</tr>
<tr>
<td>17</td>
<td>Interacting with peers and teachers in a digital environment within educational contexts comes naturally and comfortably to me</td>
<td>3.85</td>
<td>High</td>
</tr>
<tr>
<td>18</td>
<td>The opportunity to study to the extent that my personal educational needs and organizational preferences allow inspires me</td>
<td>3.79</td>
<td>High</td>
</tr>
<tr>
<td>19</td>
<td>Digital learning enables me to stay current and gain relevant knowledge and skills, which are in high demand in the context of Industry 4.0</td>
<td>4.07</td>
<td>High</td>
</tr>
<tr>
<td>20</td>
<td>I can diversify my educational activities by using digital learning</td>
<td>3.68</td>
<td>Moderate</td>
</tr>
<tr>
<td>21</td>
<td>I can spend less time doing unproductive activities thanks to digital learning</td>
<td>3.70</td>
<td>High</td>
</tr>
<tr>
<td>22</td>
<td>I save money on printed educational materials and transportation costs through digital learning</td>
<td>3.63</td>
<td>Moderate</td>
</tr>
<tr>
<td>23</td>
<td>Digital learning fosters creativity, written communication, and analytical thinking</td>
<td>3.56</td>
<td>Moderate</td>
</tr>
<tr>
<td>24</td>
<td>Digital learning allows me to create my personal schedule and learning trajectory</td>
<td>4.21</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

Total 4.10 High

Developed by the author.

Table 4. Determination of the mean level of physics students’ readiness for digital educational experience in terms of ownership of digital learning tools or equipment and access to technological infrastructure educational opportunities.

<table>
<thead>
<tr>
<th>No.</th>
<th>Statement</th>
<th>Mean Score (M)</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>I have personal digital devices to access digital learning</td>
<td>3.82</td>
<td>High</td>
</tr>
<tr>
<td>26</td>
<td>I have access to the necessary software installed</td>
<td>3.75</td>
<td>High</td>
</tr>
<tr>
<td>27</td>
<td>My Internet connection allows me to carry out educational activities without difficulty, and the quality of my Internet connection allows me to engage in active learning</td>
<td>3.68</td>
<td>High</td>
</tr>
<tr>
<td>28</td>
<td>The university’s digital infrastructure facilitates the acquisition of practical professional experience and encourages in-depth study of disciplines</td>
<td>3.63</td>
<td>Moderate</td>
</tr>
<tr>
<td>29</td>
<td>The university’s digital infrastructure opens up opportunities for learning using virtual, augmented and mixed reality technologies</td>
<td>3.56</td>
<td>Moderate</td>
</tr>
<tr>
<td>30</td>
<td>Mobile educational applications are widely used in educational practices</td>
<td>3.65</td>
<td>Moderate</td>
</tr>
<tr>
<td>31</td>
<td>Learning management systems help ensure the effectiveness of educational activities and enable me to communicate with peers and teachers</td>
<td>3.69</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

Total 3.68 Moderate

Developed by the author.
Table 5. Determination of the mean level of physics students’ readiness for digital educational experience in terms of digital literacy.

<table>
<thead>
<tr>
<th>No.</th>
<th>Statement</th>
<th>Mean Score (M)</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>I am quite adept at utilizing digital devices, applications, services, and tools to complete assigned learning tasks, regardless of platform or interface</td>
<td>4.10</td>
<td>High</td>
</tr>
<tr>
<td>33</td>
<td>I can find, receive, select, process, transmit, create, and use digital information in the most efficient way possible</td>
<td>3.79</td>
<td>High</td>
</tr>
<tr>
<td>34</td>
<td>I can evaluate information, determine its reliability, and build logical conclusions based on digital information and data that come from a virtual environment</td>
<td>3.71</td>
<td>High</td>
</tr>
<tr>
<td>35</td>
<td>I have sufficient communication and collaboration skills in a digital environment while adhering to the standards and rules of network etiquette</td>
<td>4.08</td>
<td>High</td>
</tr>
<tr>
<td>36</td>
<td>I am quite competent in using mobile educational applications within educational programs</td>
<td>4.12</td>
<td>High</td>
</tr>
<tr>
<td>37</td>
<td>I know how to use technology for digital learning</td>
<td>4.20</td>
<td>High</td>
</tr>
<tr>
<td>38</td>
<td>I know how to access an online library and other educational resources</td>
<td>3.98</td>
<td>High</td>
</tr>
<tr>
<td>39</td>
<td>I know how to use asynchronous digital tools in the learning process</td>
<td>3.86</td>
<td>High</td>
</tr>
<tr>
<td>40</td>
<td>I follow the rules of security in a digital environment</td>
<td>3.78</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>3.96</td>
<td>High</td>
</tr>
</tbody>
</table>

Developed by the author.

Figure 4. Level of physics students’ readiness for digital educational experience in terms of personal creativity and attitude to innovative educational activities. Developed by the author.

The assessment results of the extent to which physics students are ready for digital educational experience in terms of their motivation for digital educational activities and understanding the benefits digital learning can bring them showed that the mean score was high (M = 3.85) (Table 3, Figure 5). This indicates that students were highly motivated for digital innovative learning and understood that digital learning could benefit them in educational goals and improving professional and personal competencies. The respondents confirmed that they were open to acquiring an innovative educational experience in the virtual educational space using the latest digital technologies (M = 4.21) and were interested in studying and testing the possibilities of digital tools that contribute to finding innovative solutions to educational problems (M = 4.10). The students were inspired by the incorporation of digital technologies into educational practices and saw the benefits of online education in terms of developing their professional competencies (M = 4.08). Moreover, they were motivated to learn and devoted sufficient time and effort to online education (M = 3.92) and participating in systematic online learning gave them a sense
of personal congruence (M = 3.78). According to the students, digital learning enabled them to stay current and gain relevant knowledge and skills, which are in high demand in the context of Industry 4.0 (M = 4.07). Moreover, interacting with peers and teachers in a digital environment within educational contexts came naturally and comfortably to them (M = 3.85) and the opportunity to study to the extent that their personal educational needs and organizational preferences inspired them (M = 3.79). The respondents demonstrated a moderate level of understanding of the benefits that digital learning can bring in terms of their professional competence development and improvement of educational experience. In their opinion, digital learning fostered creativity, written communication, and analytical thinking in them (M = 3.56). With digital learning, they could diversify their educational activities (M = 3.68), spend less time doing unproductive activities (M = 3.70), save money on printed educational materials and transportation costs (M = 3.63), and create their personal schedule and learning trajectory (M = 3.60).

**Figure 5.** Level of physics students’ readiness for digital educational experience in terms of motivation for digital educational activities and understanding the benefits that digital learning can bring. Developed by the author.

The assessment results of the extent to which physics students are ready for digital educational experience in terms of having digital learning tools or equipment and access to technological infrastructure educational opportunities showed that the technological readiness was moderate (M = 3.68) (Table 4, Figure 6). The respondents confirmed that they had access to personal digital devices for digital learning (M = 3.82) and to the required software (M = 3.75). According to the students, their Internet connections allowed them to carry out educational activities without difficulty, and the quality of their Internet connection allowed them to engage in active learning (M = 3.68). However, the infrastructural technological capabilities of the higher education institutions where the respondents studied were at a moderate level of readiness. According to the students, the university’s digital infrastructure was sufficient for them to acquire practical professional experience and encouraged the in-depth study of disciplines (M = 3.63), and mobile educational applications were partially used in educational practices (M = 3.65). Learning management systems were sufficient to ensure the effectiveness of educational activities and enabled
students to communicate with peers and teachers (M = 3.69). Higher education institutions should prioritize the development of technological infrastructure on educational campuses and devote intellectual and material resources to modernizing and improving intellectual educational systems, according to the assessment results.

**Figure 6.** Level of physics students’ readiness for digital educational experience in terms of ownership of digital learning tools or equipment and access to technological infrastructure educational opportunities. Developed by the author.

The assessment results of the extent to which physics students are ready for digital educational experience in terms of digital literacy showed that the mean score was high (M = 3.96) (Table 5, Figure 7). A high level of digital literacy was confirmed by the respondents in the following areas:

**Figure 7.** Level of physics students’ readiness for digital educational experience in terms of digital literacy. Developed by the author.
- The use of digital devices, applications, services, and tools, regardless of the platform or interface, to solve educational tasks (M = 4.10); the ability to optimally find, receive, select, process, transmit, create, and use digital information (M = 3.79);
- The ability to evaluate information, determine its reliability, and build logical conclusions based on digital information and data that come from a virtual environment (M = 3.71);
- Communication and cooperation skills in a digital environment while adhering to the standards and rules of network etiquette (M = 4.08);
- Knowing how to use mobile educational applications within educational programs (M = 4.12);
- Knowing how to use digital learning technologies (M = 4.20) and access an online library and other educational resources (M = 3.98);
- Knowing how to use asynchronous digital tools in the learning process (M = 3.86), and safety rules compliance in the digital environment (M = 3.78).

4. Discussion

A wide range of research shows that technology should be used to complement teachers, not replace them, and that a clear plan for implementing technology for learning is needed. While technology alone will not lead to an improved quality of education, advances in educational technology can facilitate more inclusive skills-based learning, which can significantly improve educational processes [41].

The success of digital transformation initiatives in higher education institutions is contingent upon a variety of factors. Access to adequate and competent human resources at universities, the establishment of effective working groups, and corporate internalization of digitalization are all necessary steps in the process of technological transformation of the educational paradigm [42]. Universities must apply synchronous solutions to the innovation-oriented model of an intelligent university, in which innovation and entrepreneurship are the philosophy, goals, and methods of adding value to adapt to Industry 4.0. From a strategic management standpoint, the university should be committed to its mission and strategy in terms of innovative goals; short- and medium-term plans; and specific plans, provisions, and resources for the successful implementation of digital transformation of educational processes. Universities, in particular, should use joint management and a corporate innovation culture to manage all of their changes and progress [43].

To achieve the desired learning outcomes, digital learning necessitates careful thought, planning, and development of technological and human resources [44]. Despite the many benefits of Education 4.0, one of the current system’s main problems is its unwillingness to accept change. Thus, Education 4.0 should align its objectives with those of Industry 4.0, allowing educational institutions and industry to collaborate on achieving high-quality results in the development of students’ professional skills [45]. Without a doubt, the digital transformation of the educational system is unavoidable in higher education, where technology must be used effectively to support collaboration, research, and online learning. Therefore, teachers’ conceptions of how to best teach and learn must shift in favor of rational acceptance and integration of technological solutions into classrooms. Students will be able to engage in active learning that is aligned with Industry 4.0 challenges [46].

There should be an ideal situation in which concepts and technologies are brought together in the study of physics. Ajman University (UAE) investigated the impact of blended learning on the academic performance of dental college students in a physics course. The results of this study show that having the opportunity to study in an interactive, appealing, and motivating way with physical topics improved their academic performance. This means that when the advantages of a web environment are combined with personal interaction in academic courses, education can be more effective [47]. This research looked at how Dutch quantum physics teachers felt about the possibility of using digital tools in their classrooms. The results indicate that an active learning environment encourages students to participate in educational activities and improves their understanding of the
subject and that digital materials and tools used by teachers have the potential to motivate students and help them develop their conceptual understanding [48].

An investigation was conducted into the innovative readiness for digital learning of first- and second-year students at the NOUN Yenagoa Study Centre. The results indicate that individualized innovation and self-efficacy are important factors in a student’s willingness to use e-learning resources and participate actively in a virtual learning environment. Students who are born innovators will readily accept technology and, as a result, will study in a technologically advanced environment [49].

Students respond positively to the integration of Education 4.0 for sustainable technological development in three dimensions, according to a study conducted at the University of Malaysia. These dimensions are their willingness to incorporate the concept of Education 4.0 into educational programs, technological opportunities, and job-related digital skill enhancement. Students confirm their willingness to embrace Education 4.0 for long-term technical development, but only if educational activities are supported by technological equipment and timely feedback from teachers conducive to improved digital skills and expanded employment opportunities [50]. The challenges of the digital transformation of educational structures go beyond the financial investments required to acquire new technologies needed to prepare students for professional activity in the 4IR context. These also include the availability of qualified personnel at all levels of the educational organization who can deal with the operational issues that come with innovative changes [27].

Close attention is being paid to the key opportunities that Education 4.0 brings as technology evolves and academic campuses and educational services become smarter. Teachers and educational institutions should consider how far and in what direction innovative pedagogical methods and approaches to teaching are required. Indeed, technologies such as artificial intelligence and machine learning open up new avenues for implementing innovative educational processes. Nonetheless, it is worthwhile to consider what exactly needs to be accomplished as part of a digital transformation strategy, as technical feasibility does not always imply that the ultimate effects will be entirely beneficial. When implementing digital curriculum design, creating an immersive learning environment, and remote data management, caution must be exercised, and the student must always be at the center of any pedagogical intervention [28]. In addition to determining the readiness of students for the University 4.0 format and the challenges they face, it is also important to obtain student feedback and recommendations on how to improve and increase the effectiveness of the educational process [51].

The widespread digitalization and dynamic development of technologies of the fourth industrial revolution have increased the interest of the scientific community in the aspects of industrial humanization, sustainability, and resilience [52]. Higher education institutions must be aware of the fact that they are an important aspect of society and must make a meaningful contribution to sustainability and sustainable development. Through the education of future generations and the promotion of research and collective knowledge, higher education institutions are leading the transformation of society. In practice, universities can promote a sustainable society through their education, culture, and campus, and provide capable professionals for business, communities, and the economy. Education is critical to encouraging and enhancing society’s ability to participate in and lead SCP and inherently sustainable development [53].

Education 4.0 is what open and inclusive higher education needs to enable different countries to achieve the United Nations Sustainable Development Goals (SDGs). For Education 4.0 to be open and sustainable in the higher education sector, educational technologies must be fully or almost fully integrated, revolutionary, and scalable. Only in this form and format can it be considered sufficiently innovative [34].

Synergy of the concepts of sustainable development and Education 4.0 is an important factor in solving the socio-economic problems of our time [55]. In general, contributing to the sustainable development of Ind4.0, Education 4.0 can greatly support socially responsible aspirations for equality, diversity, inclusion, intellectual capital creation, inter-
generational co-creation of value, and socio-economic protection [56]. Effective education in the 4.0 format is necessary to transfer knowledge, attitudes, and skills that will contribute to the development of organizations and societies capable of solving the world’s problems regarding sustainable development [57].

5. Conclusions

The study of physics students’ innovative readiness for gaining digital educational experience to the extent of the University 4.0 model reveals that students have a high level of creativity and a positive attitude toward innovative educational activities, as evidenced by a high mean score (M = 3.89). Students are adaptable to change and have sufficient personal creativity to participate in innovative educational processes. Respondents showed a high level of motivation for digital innovative learning and a good understanding of the benefits that digital learning can provide in terms of achieving educational goals and improving professional and personal competencies (M = 3.85). According to the survey results, students have a high mean score (M = 3.96) in terms of using digital devices, applications, services, and tools to solve the educational tasks assigned to them, regardless of platform or interface; the ability to find, receive, select, process, transmit, create, and use digital information in the most efficient way possible; and the ability to evaluate information, determine its reliability, and build a digital portfolio. While the students who responded to the survey indicated that they had personal digital learning tools or equipment, they felt that the university’s digital infrastructure needed to be improved further to ensure high-quality and modern digital learning.

The university in question had intellectual, innovative, and infrastructural sufficiency for the implementation of changes, according to the assessment results of students’ innovative readiness for digital transformations of the university format. This, in turn, was due to students’ adequate preparation for interaction in the virtual educational cyberspace. They learned this skill in the wake of the COVID-19 pandemic global crisis, which prompted higher education institutions to switch to distance learning formats. Higher education institutions should focus their efforts and resources on building campus technology infrastructures, and modernizing and improving their intellectual education systems, given the current state of affairs. There is potential here for further research into tools and models of stakeholder interaction to the extent of the concept of partnership between government, business, and education in favor of establishing synergy between Industry 4.0 and Education 4.0 capabilities.

Prospects for further research: Since the educational model University 4.0 involves international cooperation between universities in the framework of training specialists for Industry 4.0, the prospects for further research are to study the innovative readiness of physics students, participants of international projects within the framework of national and international cooperation between universities. The methodology for assessing the degree of innovative readiness demonstrated in this article will be used as an initial guideline for developing common vectors of cooperation and strategic interaction of students within the framework of the new University 4.0 learning model.

Author Contributions: Conceptualization, B.J. and A.M.; Methodology, B.J. and A.M.; Software, B.J. and A.M.; Validation, B.J. and A.M.; Formal analysis, B.J. and A.M.; Investigation, B.J. and A.M.; Resources, B.J. and A.M.; Data curation, B.J. and A.M.; Writing—original draft preparation, B.J. and A.M.; Writing—review and editing, B.J. and A.M.; Visualization, B.J. and A.M.; Supervision, B.J. and A.M.; Project administration, B.J. and A.M.; Funding acquisition, B.J. and A.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The authors declare that the work is written with due consideration of ethical standards. The study was conducted in accordance with the ethical principles approved by the Human Experiments Ethics Committee of Al-Farabi Kazakh National University (Protocol No. 09 of 12 October 2021).
Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data will be available on request from corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

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