Digital Twins in MetaUniversity: A New Era of Personalized and Immersive Education*

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Abstract

Digital twins are revolutionizing education and learning in the present time. In this ecosystem, digital twins may act as avatars for students, faculty, or learning environments, enabling adaptive learning, smart tutoring, and immersive virtual environments in a MetaUniversity. The paper presents the specific role of digital twins in MetaUniversities and their potential to increase personalized teaching, engagement, or administrative efficiency. Moreover, this paper describes the concerns with data confidentiality, artificial intelligence-oriented decision-making, scalability, and prospects for employing digital twin technology for higher education. The implementation of the digital twin module of the International Information Technology University (Almaty, Kazakhstan), associated with practical training in a virtual classroom, is presented. The findings suggest that digital twins have the potential to reshape the educational landscape, fostering more accessible, efficient, and student-centered learning ecosystems.

Keywords

digital twins, MetaUniversity, virtual learning environments, personalized learning, smart campus, educational digital transformation

1. Introduction

The rapid development of artificial intelligence (AI), virtual reality (VR), and data-driven technologies has brought about certain changes in education. Among them are digital twins, virtual copies of physical objects that provide real-time monitoring, simulation, and interaction. At the same time, using AI, big data analytics, and immersive technologies, digital twins make learning more personalized, provide real-time feedback, and optimize academic processes. In the context of a meta-university, digital twins offer unprecedented opportunities to increase student engagement, automate administrative business processes, and create adaptive learning environments. Such digital twins can simulate learning, predict performance, and adapt educational content based on individual learning preferences. Moreover, they provide intelligent assistance to teachers, virtual lab simulations, and intelligent campus management, paving the way for a more efficient and scalable education model.

Despite its potential, the implementation of digital twins in higher education faces a number of challenges, including data privacy issues, AI bias, infrastructure requirements, and scalability limitations. Addressing these challenges is essential to ensuring equitable, secure, and efficient digital twin-driven education ecosystems. This article explores the role of digital twins in MetaUniversities, focusing on their applications in personalized learning, immersive education, and institutional optimization. It also discusses the challenges and prospects for implementing digital twins in the higher education context.

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An example of the MetaUniversity of the International Information Technology University (Almaty, Kazakhstan)'s own concept is given, as well as the development of a module on practical training on physics in virtual space.

2. Related Works

The concept of Digital Twins has gained significant traction in various fields, particularly in education, where it is poised to revolutionize personalized and immersive learning experiences. The integration of digital twin technology into educational frameworks, particularly in the context of a Metauniversity, offers a transformative approach to addressing the diverse needs of learners in an increasingly digital world. This literature review synthesizes recent studies that explore the applications, challenges, and implications of digital twins in educational settings.

Digital twins can significantly enhance interactivity in educational settings, particularly in Massive Open Online Courses (MOOCs). The article [1] identifies key challenges in current MOOC models, such as limited interactivity and insufficient cognitive skill stimulation. They propose that digital twins can address these issues by providing personalized learning experiences that adapt to individual learner profiles. This aligns with findings from [2], where it was demonstrated that a digital twin learning system effectively assists students in engineering education, confirming a high intention among students to utilize such systems. The adaptability of digital twins allows for tailored educational experiences, which can lead to improved engagement and learning outcomes.

The application of digital twins extends beyond traditional educational frameworks into innovative pedagogical models. It was discussed the integration of digital twins within a cognitive apprenticeship model, emphasizing their role in facilitating experiential learning in fields such as smart agriculture [3]. This model allows learners to engage with complex systems in a controlled environment, thereby enhancing their understanding and skills. However, it is important to note that the specific application of digital twins in cognitive apprenticeship models may vary, and further research is needed to fully understand their effectiveness in diverse educational contexts.

The potential of digital twins to revolutionize personalized education is further supported by studies that explore their application in various educational contexts. For instance, [4] illustrates how digital twins can be utilized in engineering education to familiarize students with automated production systems before they interact with physical equipment. This preemptive exposure not only enhances learning but also prepares students for real-world applications. Additionally, the work [5] emphasizes the immersive capabilities of digital twins, which allow students to conduct virtual experiments that may be impractical in traditional settings due to safety or resource constraints.

Despite the promising applications of digital twins in education, challenges remain. For example, the integration of digital twins into existing curricula requires careful planning and consideration of technological infrastructure. The article [6] notes that while the use of digital twins is on the rise, there are still significant gaps in understanding their full potential and the risks associated with their implementation. Furthermore, ethical implications must be addressed, as highlighted in [7], who discuss the need for ethical guidelines in the context of personalized learning environments created by digital twins.

The concept of immersive learning through digital twins has gained attention with technological advancements enabling highly interactive educational environments. As virtual replicas of physical entities, digital twins have the potential to revolutionize education by enhancing learning experiences and outcomes.

The integration of digital twins with immersive technologies like augmented reality and virtual reality can significantly enhance the learning experience. In was discussed how digital twins can serve as platforms for informal learning, allowing users to explore and inquire about their environment in a virtual setting [8]. This immersive exploration is further supported in [9], where it was emphasized the role of multisensory immersive technologies in creating hyper-connected virtual spaces that optimize learning experiences. The ability to simulate real-world scenarios in a

safe and controlled environment is particularly beneficial for disciplines that require hands-on practice, as noted in [10], which advocates for the use of digital twins in conducting experiments that may be impractical in traditional classroom settings.

To enhance interactivity and engagement, digital twins also facilitate collaborative learning experiences. The concept of cognitive digital twins, as discussed in [11], emphasizes the importance of leveraging implicit knowledge from existing systems to foster collaborative learning environments. This is particularly relevant in fields such as smart agriculture, for example how digital twins can support cognitive apprenticeship models [12], allowing learners to engage in collaborative problem-solving and knowledge sharing.

The application of digital twins extends beyond traditional educational settings. For instance, in healthcare [13] the potential of machine learning-enabled digital twins to enhance patient care and medical training. This cross-disciplinary approach underscores the versatility of digital twin technology, which can be adapted to various fields, including engineering, arts, and sciences, as demonstrated in [14] in their integration of digital twins with product lifecycle management and computer-aided design.

The use of digital twins in education is an emerging field that enhances immersive and interactive learning across disciplines. As virtual replicas of physical entities, they improve educational outcomes. Here we explore their applications, benefits, challenges, and use cases.

The integration of digital twins with advanced simulation technologies offers a risk-free environment for practical training. It was emphasized the benefits of using digital twins in critical care education, where standardized clinical scenarios can be simulated to enhance training effectiveness [15]. This aligns with the work [16], where it was shown that digital twins provide engineering students with virtual models that represent real-world systems, thereby facilitating hands-on learning experiences. The ability to simulate real-world scenarios allows students to apply theoretical knowledge in practical contexts, fostering deeper understanding and retention of information.

Digital twins also promote collaborative learning environments. As highlighted in [17], the versatility of digital twins allows for their application across various educational domains, including collaborative projects and interdisciplinary studies. This collaborative potential is further illustrated in [18], where it was shown the use of digital twins in construction management education, where students can engage in team-based projects that replicate real-world challenges. Such collaborative efforts not only enhance learning but also prepare students for the teamwork required in professional settings.

Despite the many benefits, the implementation of digital twins in education is not without challenges. There is a need for standardization and a common model for digital twins [19]. This lack of uniformity may hinder the widespread adoption of digital twin technology in educational contexts. In addition, many institutions are still in the early stages of exploring the full potential of digital twins, indicating the need for further research and development to maximize their effectiveness in education [20].

3. Development of IITU Digital Twin

International Information Technology University (IITU) is a leading university in Kazakhstan and Central Asian countries in training specialists in the field of information technology. The university has significant experience in developing its own projects using immersive technologies [21-25].

One of the promising areas of research at the IITU is the development of the concept of MetaUniversity – an innovative approach to higher education that uses virtual reality to create an immersive educational space.

MetaUniversities provide students with the opportunity to study a wide range of disciplines in an interactive and engaging way, with a number of advantages over traditional learning models:

1. Global accessibility – learning is possible from anywhere in the world, regardless of physical limitations;
2. Interactive format – the educational process includes dynamic, virtual and practice-oriented teaching methods;
3. Personalized approach – adaptation of the educational process to the individual needs and pace of learning of each student, which helps to increase the effectiveness of mastering the material.

This direction is particularly relevant in the context of training future IT professionals, where the development of subject-related communicative language competence also plays a critical role. A recent study by [26] highlights the importance of integrating language and subject learning for IT students, underscoring the value of pedagogical models that combine digital and communicative competencies.

The IITU MetaUniversity's own model was proposed by the Mixed reality laboratory, which is presented in Figure 1.

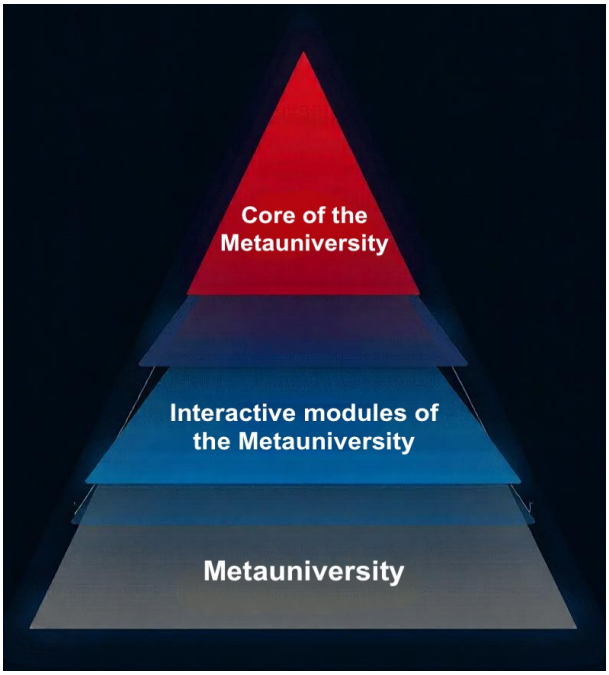

Figure 1: Internal structure of the IITU MetaUniversity

As part of the MetaUniversity concept, the possibility of conducting physics laboratory work in virtual reality has been implemented. This approach allows students to interact with digital models (twins) of physical phenomena, fostering a deeper understanding of the subject and the development of practical skills.

One example is the laboratory work on Ohm's Law, where students assemble an electrical circuit, adjust resistance using a rheostat, and analyze changes in current and voltage (Figure 2). This experiment provides a visual demonstration of the relationship between electrical parameters and helps reinforce theoretical knowledge.

Figure 2: Screenshot of the virtual laboratory work “Study of Ohm's law for a section of a circuit”

Another virtual laboratory experiment is dedicated to determining the moment of inertia of a sphere (Figure 3). In this experiment, users observe the motion of a sphere along an inclined plane, measure its movement parameters, and calculate the moment of inertia based on its radius and mass. This enables students to grasp the fundamental principles of rotational dynamics and their practical applications.

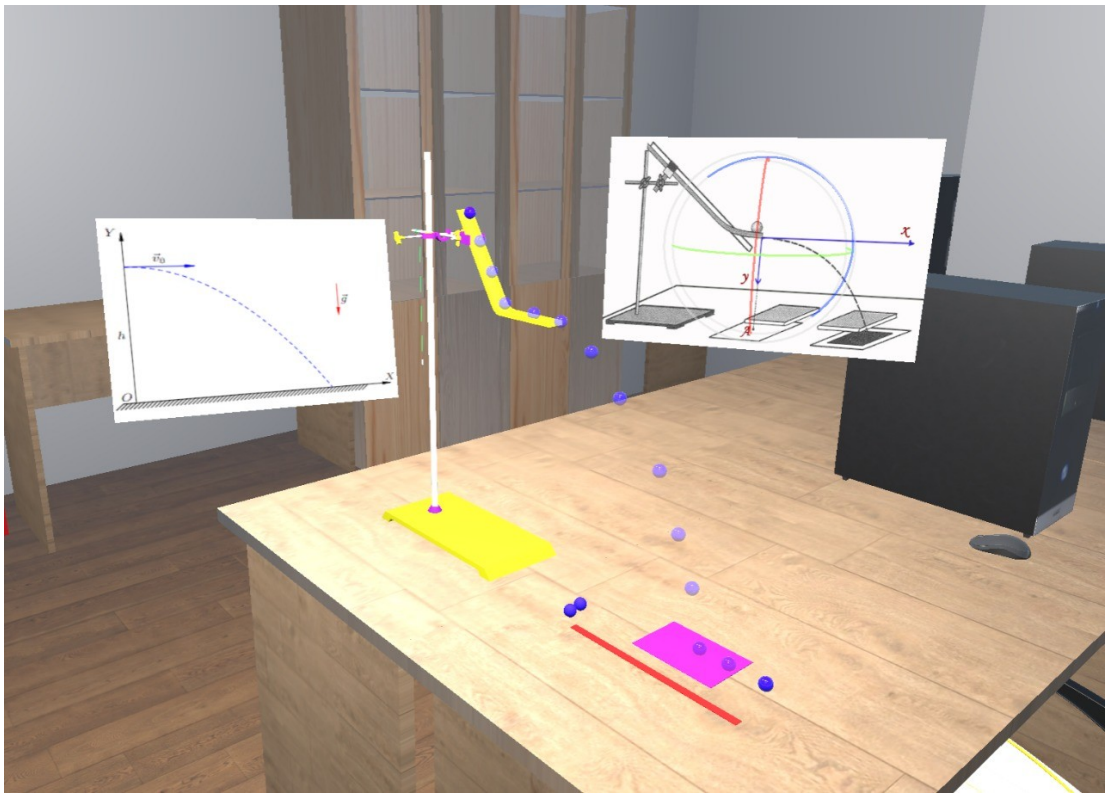

Figure 3: Determining the moment of inertia of a ball

The use of digital twins in the virtual MetaUniversity environment makes learning physics more interactive and accessible, increasing student engagement and enabling them to safely conduct complex experiments. This approach aligns with modern trends in digital education and contributes to the development of competencies necessary for work in high-tech industries.

4. Conclusion

The results of the study confirm that the introduction of digital twins into the educational processes of the meta-university contributes to the personalization of learning, increased student

engagement and optimization of administrative management. The concept of the IITU MetaUniversity is presented, and the module of digital twins of the IITU on practical teaching of physics in a virtual environment is implemented.

Despite the promising nature of the technology, there remain challenges related to data protection, ethical aspects of AI management and ensuring the scalability of digital educational solutions. Further research should be aimed at improving interaction algorithms, integrating digital twins with VR/AR technologies and expanding the possibilities of practical learning.

Thus, digital twins can become a key element of the future of education, creating accessible, innovative and student-oriented learning ecosystems that can adapt to the individual needs of students and the requirements of the labor market.

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Declaration on Generative AI

The author(s) have not employed any Generative AI tools.

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