ARCHITECTING THE NEW-GENERATION UNIVERSITY: INTEGRATING INDUSTRY 4.0, SOCIETY 5.0, AND DIGITAL TRANSFORMATION

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Abstract

This paper explores the organizational and functional architecture of the new-generation university, focusing on the integration of Industry 4.0, Society 5.0, and digital transformation. On the other side, Bologna Process also provides benchmarks for universities to follow, and are closely related to these three concepts. European Higher Education Area reforms as known Bologna Process, and European Research Area reforms are supporting European science and technology ecosystem. And as a full member candidate, Türkiye is supposed to carry all these reform agendas. As higher education faces the demands of rapid technological advancements and evolving societal needs, universities must adopt flexible, decentralized governance models, advanced digital infrastructures, and innovative curriculum designs.

This study highlights the importance of artificial intelligence (AI)-driven learning platforms, smart classrooms, and interdisciplinary research hubs in fostering innovation and enhancing student outcomes. Additionally, challenges such as technological, financial, cultural, and institutional barriers are examined, with recommendations for overcoming these obstacles through collaborative leadership and public-private partnerships. Drawing from current literature, this paper presents a proposed model for new-generation universities that emphasizes learner-centered education&training, digital readiness, recognition of prior learning, core competences&qualifications framework, and lifelong learning. This model aims to position universities at the forefront of global educational innovation while addressing critical societal challenges in the digital age.

Keywords: New-Generating University, Industry 4.0, Society 5.0, Digital Transformation

YENİ NESİL ÜNİVERSİTE MİMARİSİ: ENDÜSTRİ 4.0, TOPLUM 5.0 VE DİJİTAL DÖNÜŞÜMÜN ENTEGRE EDİLMESİ

Özet

Bu bildiri, Endüstri 4.0, Toplum 5.0 ve dijital dönüşümün entegrasyonuna odaklanarak yeni nesil üniversitenin örgütsel ve işlevsel mimarisine yönelik bir model geliştirmektedir.. Öte yandan, Bologna Süreci de üniversitelerin uyması gereken kıstaslar sağlamakta ve ve bu üç kavramla yakından ilişki içindedir. Bologna Süreci olarak da etiketlenen Avrupa Yükseköğretim Alanı reformları ve Avrupa Araştırma Alanı reformları Avrupa bilim ve teknoloji ekosistemini desteklemektedir. Tam üye adayı olarak Türkiye'nin de tüm bu reform gündemlerini takip ederek uygulaması beklenmektedir. Yüksek öğrenim, hızlı teknolojik ilerlemelerin ve gelişen toplumsal ihtiyaçların talepleriyle karşı karşıya kaldıkça; üniversiteler esnek, merkezi olmayan yönetim modelleri, gelişmiş dijital altyapılar ve yenilikçi müfredat tasarımları benimsemelidir.

Bu çalışma, yenilikçiliği teşvik etmede ve öğrenci sonuçlarını iyileştirmede yapay zeka (YZ) odaklı öğrenme platformlarının, akıllı sınıfların ve disiplinler arası araştırma merkezlerinin önemini vurgulamaktadır. Ek olarak, teknolojik, finansal, kültürel ve kurumsal engeller gibi zorluklar incelenmekte ve bu engellerin işbirlikçi liderlik ve kamu-özel sektör ortaklıkları yoluyla üstesinden gelinmesine yönelik öneriler sunulmaktadır. Güncel literatürden yararlanarak, bu bildiri öğrenci merkezli eğitim ve öğretim, dijital hazırbulunuşluk, önceki öğrenmenin tanınması, çekirdek yetkinlikler & yeterlilikler çerçevesi ve yaşam boyu öğrenmeyi vurgulayan yeni nesil üniversiteler için önerilen bir model sunmaktadır. Bu model, dijital çağda toplumsal süreçlerde çeşitli meydan okumaları ele alırken, üniversiteleri küresel eğitim inovasyonunun ön saflarına yerleştirmeyi amaçlamaktadır.

Anahtar Sözcükler: Yeni Nesil Üniversite, Endüstri 4.0, Toplum 5.0, Dijital Dönüşüm

Introduction: Challenges in University-Society Interaction and Problem Statement

The rapid technological advancements of the 21st century, particularly those encapsulated within the framework of Industry 4.0 and Society 5.0, are reshaping the higher education landscape. Universities, as key institutions responsible for cultivating future generations, are now tasked with evolving from traditional structures into new-generation institutions capable of harnessing integrated digitalization, smart systems, and innovative educational practices.

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The emergence of a new-generation university calls for an overhaul of its organizational and functional architecture to align with these global transformations.

The concept of a new-generation university has gained increasing traction in academic and administrative circles over the past decade. Globalization, technological advancements, and changing societal needs have compelled universities to rethink traditional models of education delivery and institutional governance. Central to this reformation are three critical pillars: quality assurance, accreditation, and digital transformation (Lemaitre & Karakhanyan, 2018).

Industry 4.0 represents the fourth industrial revolution, characterized by automation, machine learning, and the fusion of physical and digital systems (Lasi et al., 2014). Within the educational sphere, this revolution demands a paradigm shift toward more adaptive, technologically-driven institutions. Society 5.0, on the other hand, is Japan's vision of a super-smart society, integrating cutting-edge technologies like artificial intelligence (AI) and the Internet of Things (IoT) with human-centered innovation (Fukuyama, 2018; Ferreira & Serpa, 2018). For universities, adopting Society 5.0 means balancing technological innovation with societal well-being.

This paper explores how these emerging paradigms necessitate a rethinking of the organizational and functional architecture of universities. Through a comprehensive review of the latest literature and the works of key scholars, this study seeks to propose a model for the new-generation university that integrates the tenets of Industry 4.0, Society 5.0, and advanced digitalization.

The functional architecture of a new-generation university refers to the structures and processes that support the delivery of education, research, and community engagement. In the context of Industry 4.0 and Society 5.0, universities must adopt functional architectures that are flexible, technology-driven, and student-centered. This requires the integration of digital tools and platforms into all aspects of university operations, from teaching and learning to research and administration.

The traditional university structure, with its rigid hierarchy, fixed curriculums, and analog administrative systems, is ill-equipped to meet the challenges posed by the digital revolution. As the fourth industrial revolution reshapes industries, economies, and societies, higher education must likewise adapt to ensure that it continues to serve its critical role in preparing students for an increasingly complex and interconnected world.

Key challenges facing universities today include:

- Outdated governance models that hinder rapid adaptation to technological changes (Peters, 2017).
- Inflexible curriculums that fail to prepare students for careers in evolving industries driven by automation and data analytics (Toprak, et al., 2021b).
- Insufficient digital infrastructure and the slow integration of advanced technologies like AI, IoT, and big data analytics into educational delivery (Baygin et al., 2016).

Moreover, as universities expand their digital presence, they must address the growing demand for inclusive, accessible, and flexible education models. This entails designing curricula and learning environments that cater to diverse student populations, including remote learners and lifelong professionals.

1. Literature Review

1.1. Industry 4.0 and Higher Education

Industry 4.0 is characterized by the integration of cyber-physical systems, big data, automation, artificial intelligence (AI), and Internet of Things (IoT) into industrial processes. In the context of higher education, Industry 4.0 has revolutionized how universities operate,

requiring the incorporation of digital technologies into teaching, research, and administration. Universities must prepare students for a world dominated by automation, robotics, and data-driven decision-making, making digital literacy and interdisciplinary skills essential components of modern curriculums. Industry 4.0 challenges universities to integrate digital tools and methodologies into both their organizational structures and pedagogical practices. Technologies such as big data, robotics, artificial intelligence, and cloud computing are central to Industry 4.0, pushing universities toward the development of smart campuses (Zhou et al., 2015).

Through digitalization, universities are adopting AI-powered learning platforms, cloud-based infrastructure, and smart campuses. These tools enable personalized learning experiences, streamline administrative processes, and facilitate international collaboration. The integration of Industry 4.0 technologies into higher education fosters a more responsive, adaptive, and innovative learning environment, ensuring that universities remain competitive and aligned with the demands of future industries.

Scholars have explored the implications of Industry 4.0 on higher education, particularly regarding the need for universities to shift from traditional knowledge transmission to a more dynamic, skills-based curriculum (Roblek et al., 2016). Industry 4.0 emphasizes practical, hands-on learning and the cultivation of critical digital skills, including coding, data analysis, and machine learning (Lasi et al., 2014).

1.2. Society 5.0: A Human-Centered Approach

While Industry 4.0 focuses on technological advancements, Society 5.0 emphasizes a human-centered approach to digital transformation. Society 5.0, introduced by Japan, envisions a future where digital technologies are used not just to enhance productivity but to improve the quality of life for all people (Fukuyama, 2018; Ferreira & Serpa, 2018). In the higher education context, Society 5.0 emphasizes the role of universities in addressing societal challenges such as sustainability, health, and social equity through technological innovations.

The incorporation of Society 5.0 principles into higher education requires universities to focus on inclusive education, ensuring that digitalization benefits all students, including those from disadvantaged backgrounds. It also encourages the development of ethical AI and technologies that respect privacy and promote social well-being, aligning with the human-centered values of Society 5.0. Society 5.0 must focus on inclusive education, ensuring that technological advances contribute to societal well-being. Toprak et al. (2021a & 2021b) notes that universities must play a key role in bridging the gap between technological advancements and societal needs. He emphasizes that the integration of human-centric AI and digital platforms in education must prioritize ethical considerations, including the digital divide and data privacy (Aydin, 2024; Marina and Turb, 2023; Toprak,et al., 2021a & 2021b; O'Brien, 2020).

1.3. The Bologna Process: Ensuring Quality and International Standards

The Bologna Process provides a framework for ensuring quality and comparability in higher education across Europe. Established to create a European Higher Education Area (EHEA), the Bologna Process emphasizes standardization of degrees, the establishment of quality assurance mechanisms, and the promotion of mobility for students and academics (Wächter, 2004).

In light of Industry 4.0, Society 5.0, and digitalization, the Bologna Process serves as a foundation for ensuring that universities maintain high-quality educational standards while embracing new technological advancements. The emphasis on learning outcomes, skills-based education, and lifelong learning in the Bologna Process aligns closely with the demands of Industry 4.0, where continuous upskilling and adaptability are crucial.

Digitalization enhances the goals of the Bologna Process by facilitating virtual mobility, online degrees, and digital credentialing systems such as micro-credentials, which allow students to acquire specific skills recognized across the EHEA. Additionally, quality assurance systems, a cornerstone of the Bologna Process, must now incorporate digital metrics to assess the effectiveness of AI-driven platforms and online learning tools, ensuring that technological adoption maintains educational rigor.

1.4. Integrated Digitalization and Smart Universities

Digital transformation is more than the adoption of new technologies; it represents a fundamental change in how universities operate. Digital transformation is understood as a cyclical process involving four stages: digitization, digitalization, digital transformation, and digital readiness. These stages reflect a progressive shift in how universities manage information, learning environments, and institutional workflows. Toprak et al. (2019) highlights the importance of digital transformation in enhancing the efficiency of universities, particularly in relation to administrative operations and learning management systems (LMS). The integration of artificial intelligence (AI) and big data into the academic environment allows for the optimization of learning outcomes, personalized education, and enhanced decision-making in governance structures (Gros et al., 2012).

The use of digital platforms in higher education has been transformative, enabling new learning methods such as online courses, MOOCs (Massive Open Online Courses), and hybrid learning models. These tools not only improve access to education but also support the scalability of teaching and research programs. Digital transformation fosters a more integrated educational experience, streamlining communication and data management across departments.

Integrated digitalization refers to the seamless incorporation of digital technologies across all university functions, from teaching and research to administration and community engagement. Smart universities leverage AI, IoT, and big data analytics to create personalized learning experiences, streamline administrative processes, and foster collaboration between faculty, students, and external partners (Polin et al., 2023). Smart classrooms, which are equipped with advanced digital tools such as interactive whiteboards, AI-driven learning platforms, and IoT devices, are another important feature of the new-generation university. These classrooms provide a more engaging and interactive learning experience, allowing students to collaborate with their peers and instructors in real-time, regardless of their physical location (Zhou et al., 2015). Smart classrooms foster a student-centered learning environment, where education is personalized and tailored to the needs of each individual student.

Toprak's work on smart universities highlights the importance of developing a digital strategy that not only modernizes the physical infrastructure of universities but also enhances learning outcomes and operational efficiency (Toprak, et al., 2019, 2021b). Toprak et al. argues that the transformation of universities into digital ecosystems is critical for maintaining relevance in an increasingly competitive global education market.

Toprak's research on the intersection of digitalization and higher education provides essential insights into how universities can successfully transition into new-generation institutions. His works explore the role of digital governance in fostering innovation, the importance of integrating Industry 4.0 technologies into curricula, and the need for a student-centered learning environment (Toprak et al., 2018).

1.5 Interrelation of Industry 4.0, Society 5.0, Digitalization, and the Bologna Process in Higher Education

The convergence of Industry 4.0, Society 5.0, digitalization, and the Bologna Process marks a pivotal transformation in higher education. Each of these dimensions plays a critical role in

shaping universities into modern institutions that are responsive to the technological and societal demands of the 21st century.

Together, Industry 4.0, Society 5.0, digitalization, and the Bologna Process form a cohesive framework that drives the modernization of higher education. Industry 4.0 provides the technological backbone, enabling automation, AI, and big data to enhance learning and research environments. Society 5.0 ensures that these technologies serve humanity, fostering inclusivity, ethical innovation, and societal well-being. The Bologna Process sets the standards for quality and comparability, guiding universities in their adoption of digital technologies while ensuring that education remains student-centered and internationally competitive.

Ultimately, the synergy of these dimensions empowers universities to become new-generation institutions that are equipped to meet the challenges of the future, ensuring that both technology and human values remain at the heart of education.

2. Hot Topics in the New Generation University Understanding

The following dimensions should be taken into account fundamentally in the organizational and functional restructuring of the new generation university: quality assurance, accreditation, lifelong learning and recognition of prior learning, research and innovation, inclusivity and accessibility, curriculum and pedagogical innovation, internationalization and global collaboration (Toprak et al., 2016a & 2016b), and finally governance and organizational structure.

2.1. Quality Assurance and Accreditation in the New-Generation University

Quality assurance (QA) in higher education ensures that academic institutions meet defined standards of education, research, and administrative performance. It encompasses systematic processes for evaluating and improving the quality of teaching, learning, and administrative functions (Harvey, 2014). In the context of new-generation universities, QA mechanisms must align with international frameworks such as the European Standards and Guidelines for Quality Assurance (ESG) and other global benchmarks (Ryan, 2015).

Quality assurance systems ensure that institutions can provide evidence of continuous improvement. A critical part of QA involves the development of internal and external evaluation processes. Internal mechanisms, such as faculty assessments, student feedback, and course evaluations, must be supplemented by external audits to ensure transparency and accountability (Kleijnen, 2014). These systems are essential for maintaining accreditation and ensuring that graduates are prepared to meet the challenges of a competitive global workforce.

Quality assurance (QA) remains a cornerstone of institutional credibility and educational excellence. As Toprak et al. (2021a & 2021b) discusses, quality assurance frameworks must evolve in tandem with technological advancements and new educational paradigms. QA ensures that institutions can meet the demands of accreditation bodies, employers, and students alike, fostering a culture of continuous improvement within universities (Toprak et al., 2019).

In the context of the new-generation university, QA must incorporate both traditional metrics, such as teaching quality and research outputs, and newer indicators like digital literacy, innovation capacity, and global engagement (Ryan, 2015). Digital technologies support QA by automating data collection and analysis processes.

Accreditation serves as a formal recognition that an institution meets specific standards of academic quality. In an era where higher education is becoming increasingly globalized, accreditation plays a critical role in ensuring that degrees are recognized and respected internationally (Adiatma, Mahriadi & Suteki, 2022). Various accreditation bodies, such as the Higher Education Accreditation Commission (HEAC) or regional agencies, evaluate

institutions based on predetermined standards that often include curriculum quality, faculty qualifications, research outputs, and student support services.

In the process of accreditation, universities must demonstrate compliance with a series of criteria that reflect both academic rigor and operational efficiency. Accreditation is not only a mark of prestige but also an essential element in securing funding, attracting international students, and forming global partnerships (Stensaker & Harvey, 2011). Furthermore, accreditation processes encourage institutions to engage in continuous self-assessment, leading to long-term improvements in teaching, research, and administrative practices (Singh, 2017).

Toprak et al. (2019) further elaborates on how accreditation systems, aligned with global standards like ISCED (International Standard Classification of Education), are essential for maintaining the international competitiveness of universities. Accreditation ensures that universities meet international benchmarks, thereby enhancing student mobility, research collaboration, and the overall reputation of the institution (Schneider, 2019).

The ISCED framework provides a robust structure for categorizing educational programs and degrees, facilitating comparability across national borders. This is crucial for universities aiming to expand their global footprint (Toprak et al. 2020). Through international accreditation, universities can ensure their programs are recognized and valued globally, making them more attractive to prospective students and faculty.

2.2. Research and Innovation: Driving Academic Excellence

Research and innovation are the lifeblood of any higher education institution. A new-generation university fosters an environment where cutting-edge research can thrive and where the commercialization of research outputs is encouraged (Etzkowitz, 2016). Technology transfer offices play a critical role in connecting university research with industry needs, ensuring that academic innovations contribute to broader societal advancements (Siegel & Wright, 2015).

Collaborations between academia and industry, particularly in fields such as biotechnology, engineering, and information technology, have become central to the mission of many universities (Perkmann et al., 2013). These partnerships not only enhance the university's research profile but also provide students and faculty with valuable real-world experience.

Research is a fundamental component of any university's mission, and new-generation universities must excel in fostering innovative, impactful research. Toprak et al. (2019) discusses the importance of research in driving not only academic reputation but also practical solutions to societal challenges. Universities must create environments where faculty and students can engage in cutting-edge research, supported by technology and global collaboration.

The establishment of a Technology Transfer Office (TTO) is critical in this regard. TTOs facilitate the commercialization of research outputs, ensuring that innovations developed within the university can be transferred to the market (Toprak et al., 2020; Etzkowitz, 2016). This office also fosters partnerships with industry, enabling research to have a tangible impact on the economy and society.

The new-generation university must also foster a research and innovation ecosystem that supports interdisciplinary collaboration and the commercialization of research. This requires the establishment of research hubs and innovation labs, where faculty and students can work together on cutting-edge research projects that address real-world problems. These hubs must be equipped with the latest technologies, including AI, big data analytics, and robotics, to ensure that researchers have the tools they need to succeed (Perkmann et al., 2013).

Toprak et al. (2019) emphasizes the importance of technology transfer in the research and innovation ecosystem of a new-generation university. Universities must establish Technology Transfer Offices (TTOs) to facilitate the commercialization of research outputs, ensuring that innovations developed within the university are transferred to industry and society. This not only enhances the university's impact but also provides valuable real-world experience for students and faculty.

2.3. Curriculum Design and Pedagogical Innovation

One of the most significant challenges facing universities today is the need to redesign curricula to prepare students for the demands of Industry 4.0. Traditional curricula, which focus on theoretical knowledge and discipline-specific skills, are no longer sufficient in a world where automation, AI, and big data are transforming entire industries (Roblek et al., 2016). Instead, universities must adopt curricula that emphasize interdisciplinary learning, critical thinking, and the development of digital competencies.

Toprak et al. (2019, 2021a) argues that the new-generation university must offer skills-based curricula that are aligned with the needs of the modern workforce. This includes courses in data science, programming, and machine learning, as well as opportunities for students to gain hands-on experience through internships, co-op programs, and collaborative projects with industry partners. Furthermore, curricula must be flexible and adaptable, allowing students to tailor their education to their specific career goals and interests.

Curriculum development is central to the mission of a new-generation university. Universities must develop curricula that not only reflect academic rigor but also prepare students for the demands of the modern workforce. Toprak et al. (2019) emphasizes the need for curricula to incorporate interdisciplinary learning, critical thinking, and digital competencies.

One of the key innovations in curriculum design is the integration of practice-based learning and on-the-job training (OJT). Toprak et al. (2019) argues that universities must move beyond traditional theoretical instruction to provide students with practical, hands-on experience in their fields of study. This is particularly important in disciplines like engineering, medicine, and business, where real-world experience is essential for success.

2.4. Lifelong Learning and Inclusivity

Lifelong learning is another critical component of the new-generation university model. In an era of rapid technological change, individuals must continuously update their skills to remain competitive.

Inclusivity and accessibility are critical to creating equitable learning environments. A new-generation university must be committed to providing education to all students, regardless of background, ability, or socioeconomic status. Digital transformation offers numerous opportunities to improve accessibility, such as through online courses, digital learning materials, and assistive technologies (Seale, 2013).

Furthermore, inclusivity extends beyond technology to encompass curriculum design and institutional policies that promote diversity, equity, and inclusion (DEI) (Gurin et al., 2002). Universities must create learning environments that reflect the diverse needs of their student populations and that support all learners in achieving academic success (Yusof et al., 2018).

Toprak et al. (2021a & 2021b) also highlights the importance of inclusivity in lifelong learning. Universities must ensure that their programs are accessible to all, including students from disadvantaged backgrounds or those with disabilities. Digital platforms can play a significant role in this regard, offering flexible learning options that cater to diverse needs.

Blended learning, which combines traditional face-to-face instruction with online learning, is a key component of the functional architecture of a new-generation university. Blended learning allows for greater flexibility in the delivery of education, enabling students to access

course materials at their own pace and on their own schedule (Garrison & Vaughan, 2012). This is particularly important in the context of Industry 4.0, where students are increasingly seeking flexible learning options that allow them to balance their education with work and other commitments.

2.5. Curriculum and Pedagogical Innovations

The curriculum is at the heart of any educational institution, and new-generation universities must design programs that are flexible, future-oriented, and aligned with the needs of the global workforce. Curricula that emphasize interdisciplinary learning, critical thinking, and the development of digital competencies are essential in today's knowledge economy (Barnett, 2012).

Pedagogical innovations, including flipped classrooms, project-based learning, and competency-based education, offer new ways of engaging students and improving learning outcomes (Garrison & Vaughan, 2012). Additionally, the integration of digital tools, such as learning management systems and AI-driven tutoring systems, can support more effective and personalized learning experiences (Picciano, 2019).

2.6. Internationalization and Global Collaboration

Internationalization is a hallmark of a new-generation university. By forging partnerships with foreign institutions, participating in global research consortia, and promoting student and faculty exchanges, universities can enhance their global presence (Knight, 2015). International collaboration provides access to diverse perspectives and promotes innovation through cross-border knowledge exchange (Marginson, 2017).

Moreover, a commitment to internationalization can improve a university's rankings, attract high-caliber international students, and increase access to research funding from global organizations (Adiatma, Mahriadi & Suteki, 2022; Toprak et al, 2016a & 2016b).

2.7. Governance and Organizational Structure

Effective governance is essential for managing the complexities of a modern university. The adoption of integrated governance models that align with quality assurance and digital transformation strategies can create a more agile, responsive institution (de Boer et al., 2010).

A whole-institution approach ensures that every unit, from academic faculties to administrative departments, operates under a unified vision of excellence (Muftahu, 2023; Toprak&Erdoğan, 2012). The creation of specialized committees—such as digital transformation committees, quality assurance committees, and research development committees—can facilitate cross-functional collaboration and the achievement of institutional goals (Brennan & Shah, 2018).

The organizational architecture of a new-generation university must be designed to foster flexibility, innovation, and responsiveness to the challenges posed by Industry 4.0 and Society 5.0. Traditional hierarchical models, characterized by rigid administrative structures, are increasingly viewed as barriers to adaptation in the digital age (Sursock, 2015). Instead, universities must adopt more decentralized and dynamic governance frameworks, where decision-making is distributed across various levels of the institution, allowing for agility and the rapid implementation of new technologies and processes. The governance of a new-generation university must reflect its commitment to digital transformation and quality assurance. Toprak et al. (2021b) advocates for governance models that emphasize decentralization, collaboration, and accountability, moving away from traditional hierarchical structures that can stifle innovation and responsiveness.

2.7.1. Decentralized Governance

This decentralized structure allows for more efficient decision-making and ensures that key stakeholders, including faculty, students, and administrative staff, are involved in shaping university policies. The decentralization of governance is a key feature of the new-generation university. This model allows for greater autonomy at the faculty, departmental, and even individual level, enabling quicker adaptation to the evolving demands of students, industries, and technology. Decentralized governance models are particularly suited to universities adopting Industry 4.0 principles, as they allow for more flexible, interdisciplinary approaches to education and research (Muftahu, 2023; Toprak&Erdoğan, 2012).

Toprak et al. (2021a & 2021b) argues that decentralized governance is essential for fostering innovation in higher education. By empowering faculty and departments to experiment with new teaching methods, technologies, and curricula, universities can more effectively respond to the rapidly changing educational landscape. Moreover, this model promotes greater collaboration across departments and disciplines, which is crucial for addressing the complex, multifaceted problems of today's society.

2.7.2. Leadership in Digital Transformation

Digital transformation (DT) in universities is not simply about adopting new technologies; it involves the integration of digital tools into every facet of university operations, from teaching and learning to administrative functions and research. The digitization of universities is driven by advances in artificial intelligence (AI), big data, and the increasing use of digital platforms in higher education (Nagy & Burch, 2021).

A new-generation university leverages digital technologies to enhance the learning experience, increase operational efficiency, and expand its global reach. Online learning platforms, digital libraries, and data analytics tools are just some of the technologies reshaping how universities function (Picciano, 2019). The COVID-19 pandemic accelerated this transformation, highlighting the necessity for institutions to adopt flexible, scalable, and resilient digital infrastructures (Bozkurt et al., 2020).

Moreover, digital transformation offers universities the tools needed to personalize education for students. Adaptive learning technologies, for instance, allow for customized learning pathways that meet individual student needs. Such innovations not only improve learning outcomes but also foster student engagement and retention (Gros et al., 2012).

While decentralization is important, effective leadership remains a critical component of the organizational architecture of the new-generation university. Leaders must champion digital transformation, driving the adoption of new technologies and fostering a culture of innovation throughout the institution. This requires a leadership team that is not only well-versed in the technical aspects of digitalization but also committed to promoting inclusivity, accessibility, and ethical considerations in the use of technology (Olatunbosun-Bartholomew, 2024).

Toprak et al. (2019) emphasize the role of visionary leadership in the digital transformation of universities. He argues that leaders must act as digital champions, advocating for the integration of AI, big data, and IoT into both academic and administrative functions. Furthermore, they must be proactive in addressing the potential challenges of digitalization, such as data privacy, security, and the digital divide.

2.7.3. Collaborative Governance Model: Decentralized and Inclusive

In addition to decentralization and strong leadership, collaborative governance models are essential for ensuring that all stakeholders are involved in the decision-making process. This includes not only faculty and administrators but also students, industry partners, and community members. By fostering collaboration between these groups, universities can ensure that their policies and practices are aligned with the needs of their various

constituencies (Kezar & Holcombe, 2017). The governance model shall include the establishment of specialized committees for various functions. Effective governance requires the creation of committees that align with the university's strategic priorities. These bodies play a pivotal role in ensuring that the university's strategic objectives are met and that there is alignment between policy development and implementation. The establishment of an internal control and internal audit office, for instance, ensures that governance practices are transparent and that financial and operational risks are mitigated. This office, along with others, forms the backbone of a university's governance model, ensuring that policies are not only developed but effectively executed.

Collaborative governance models are particularly important in the context of Industry 4.0 and Society 5.0, where the boundaries between education, industry, and society are increasingly blurred. Universities must engage with external partners to ensure that their curricula are aligned with industry needs and that their research efforts are addressing real-world challenges (Polin et al., 2023). Toprak et al. (2021a & 2021b) highlights the importance of industry-university partnerships in fostering innovation and ensuring that students are equipped with the skills necessary for success in the modern workforce.

Effective governance in the new-generation university model is decentralized, empowering departments and individuals to innovate while maintaining a unified strategic vision:

Decentralized Decision-Making: University faculties and departments are given autonomy to adapt to technological changes and design their curricula and research agendas, promoting agility and responsiveness (Toprak et al, 2019). This reduces bureaucratic delays and allows for quicker implementation of innovations.

Stakeholder Collaboration: Governance involves not just faculty and administration, but also students, industry partners, and community leaders. By fostering these collaborations, universities can align their strategies with societal needs and industry demands, supporting Society 5.0's human-centered vision (Fukuyama, 2018; Ferreira & Serpa, 2018).

Public-Private Partnerships (PPPs): Universities partner with private sectors and governments to co-develop research projects and digital infrastructure. This allows universities to overcome financial barriers while staying at the forefront of technological innovation (Toprak et al., 2019).

2.7.4. Conclusion of the Model

This higher education model integrates the core tenets of Industry 4.0, Society 5.0, and Toprak's vision for digital transformation in universities. By focusing on advanced digital infrastructure, flexible student-centered learning, and collaborative, decentralized governance, the model positions universities to meet the complex demands of the digital era while fostering innovation and societal well-being. This holistic approach ensures that universities remain relevant and competitive in a global landscape, ultimately preparing students for the future workforce and contributing positively to society.

2.8. Case Studies: Examples of New-Generation Universities

To further illustrate the organizational and functional architecture of the new-generation university, this section will explore case studies of universities that have successfully adopted the principles of Industry 4.0 and Society 5.0. Examples include institutions such as the Massachusetts Institute of Technology (MIT), which has embraced digital transformation through its MIT OpenCourseWare initiative, and Japan's Keio University, which has integrated Society 5.0 principles into its research and teaching programs.

These case studies will highlight the strategies and best practices employed by these institutions, as well as the challenges they have faced in their journey toward becoming new-generation universities. By examining these examples, this section will provide valuable

insights into how other universities can successfully navigate the digital transformation process.

3. Proposed Model for a New-Generation University

This proposed higher education model is designed to align with the principles of Industry 4.0, Society 5.0, and integrated digitalization. The model emphasizes a decentralized, flexible, and innovation-driven framework that meets the needs of both students and society in the digital age. Creating a flexible, student-centered institution that leverages technology to enhance learning, research, and administration is key in the model. It focuses on three main pillars: Digital Infrastructure, Student-Centered Learning, and Collaborative Governance.

3.1. Digital Infrastructure: Smart, Data-Driven University Ecosystem

The first pillar of the model is the creation of a smart university that integrates cutting-edge digital technologies across all functions. At the core of the new-generation university model is a robust digital infrastructure. Smart university implies the integration of AI-driven learning platforms, smart classrooms, and cloud-based research hubs. These technologies enable personalized learning experiences, streamline administrative processes, and facilitate collaboration across disciplines and geographies.

AI-driven Learning Platforms: Personalized learning paths are created using AI and learning analytics, tailoring education to individual student needs, abilities, and goals. Real-time feedback and predictive analytics help optimize student success.

Smart Classrooms and IoT Integration: Classrooms equipped with interactive technologies and IoT devices allow for a more immersive learning experience. These environments support blended learning, enabling seamless transitions between online and in-person instruction.

Research Hubs and Digital Labs: These spaces use big data analytics, AI, and cloud computing to facilitate cutting-edge interdisciplinary research. They foster collaboration between departments, industries, and global partners, as Toprak et al. (2019) emphasizes the importance of technology transfer and real-world applications of research.

AI and Learning Analytics: AI-driven platforms can analyze student data in real time, providing personalized feedback and recommendations that help students stay on track and improve their learning outcomes (Gros et al., 2012). Instructors can also use these insights to tailor their teaching methods to the needs of individual students, creating a more adaptive learning environment.

Smart Classrooms and IoT: Smart classrooms, equipped with IoT devices, interactive whiteboards, and real-time data collection tools, foster collaboration and active learning. These technologies enable students to engage with course material in more dynamic ways and facilitate remote learning for students who are unable to attend classes in person (Polin et al., 2023).

3.2. Student-Centered Learning: Skills-Based Flexible Curriculum Design

The curriculum in a new-generation university must be interdisciplinary and skills-based, reflecting the needs of Industry 4.0. This means designing programs that emphasize critical thinking, digital literacy, and problem-solving skills, rather than simply transmitting theoretical knowledge. Universities should offer modular, stackable credentials that allow students to customize their learning pathways and acquire specific skills that are in demand in the labor market (Roblek et al., 2016).

This model redefines the university's role in preparing students for the workforce of the future by adopting a flexible and skills-based curriculum:

Interdisciplinary and Modular Programs: Based on Toprak's insights, curricula are designed to integrate core disciplines with emerging fields such as data science, machine learning, and

robotics. Students are given the flexibility to customize their learning paths, focusing on skills relevant to Industry 4.0.

Lifelong Learning: The new-generation university must also embrace lifelong learning, offering flexible learning opportunities for working professionals and non-traditional students. This includes online courses, micro-credentials, and professional development programs that allow individuals to upskill or reskill throughout their careers (Toprak, 2018). Universities offer online and modular credentials that cater to working professionals and non-traditional students. These courses focus on upskilling and reskilling, enabling learners to stay competitive in a constantly evolving job market (Toprak et al., 2019).

Experiential and Project-Based Learning: The curriculum emphasizes hands-on experience through internships, real-world projects, and collaboration with industries. This focus on practical experience ensures that students are not only knowledgeable but also job-ready upon graduation.

3.3. Research and Innovation Hubs

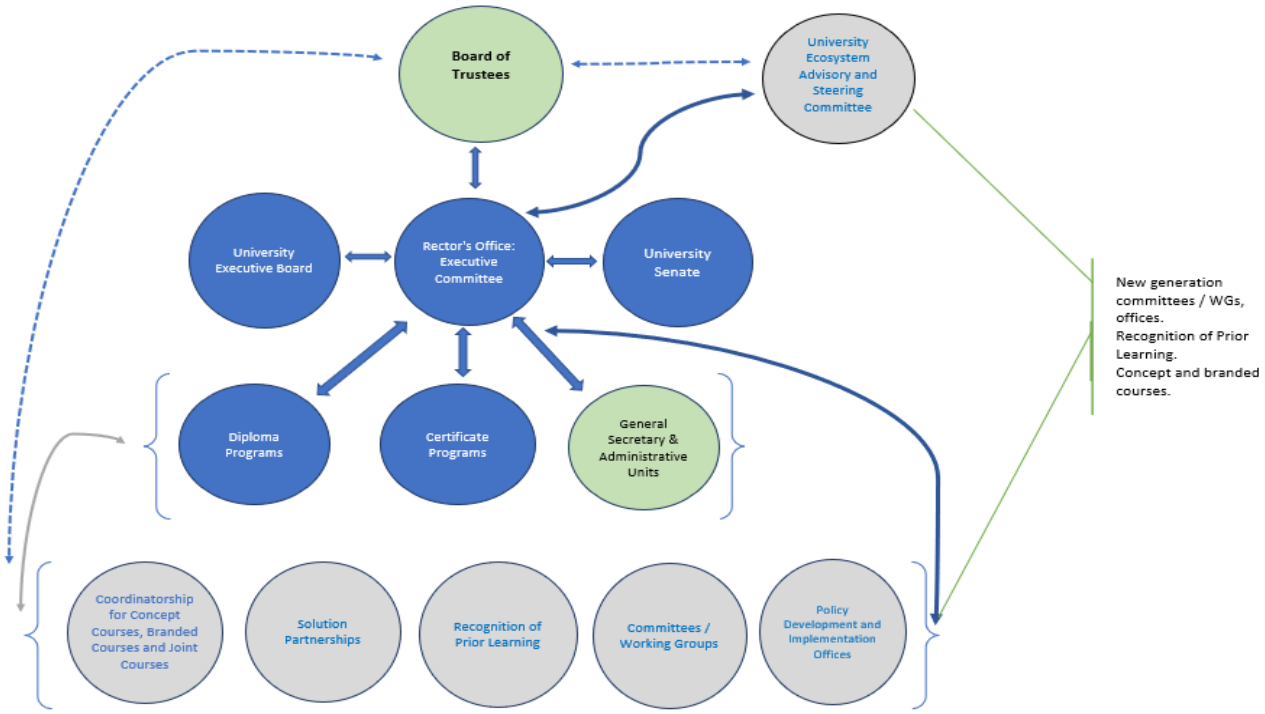
Research is a critical component of the new-generation university model. Universities must establish interdisciplinary research hubs that focus on addressing complex global challenges, such as climate change, healthcare innovation, and sustainable development. These hubs should be equipped with the latest technologies, including AI, big data analytics, and robotics, to ensure that researchers have the tools they need to drive innovation.

Technology Transfer and Commercialization: Universities must also establish Technology Transfer Offices (TTOs) that facilitate the commercialization of research outputs. By forming partnerships with industry and government, universities can ensure that their research has a tangible impact on society and the economy (Perkmann et al., 2013).

3.4. Governance and Leadership

The governance model of the new-generation university must be decentralized, collaborative, and transparent. This allows for more agile decision-making and greater involvement of faculty, students, and external partners in shaping the direction of the institution (Kezar & Holcombe, 2017). Leadership must play a proactive role in driving digital transformation, fostering a culture of innovation, and addressing the challenges of digitalization, such as data privacy and cybersecurity.

Figure 1. New Generation University Model (Foundation University)
(21st century skills, interactive, active participation, corporate governance principles)



Source: Author

4. Challenges and Barriers

While the transition to a new-generation university presents exciting opportunities, it also introduces significant challenges. These obstacles are often technological, financial, cultural, and institutional. Identifying and addressing these challenges is critical for the successful implementation of Industry 4.0, Society 5.0, and integrated digitalization principles in higher education.

4.1. Technological Barriers

The rapid pace of technological advancement poses a major challenge for universities. Keeping up with the latest innovations, such as AI, IoT, and robotics, requires significant investment in digital infrastructure. Many universities, particularly those in developing countries, lack the financial resources to acquire cutting-edge technologies or to train faculty and staff in their use (Olatunbosun-Bartholomew, 2024). Moreover, integrating these technologies into existing academic structures can be a complex and time-consuming process, particularly when legacy systems and outdated infrastructure are involved.

In addition to infrastructure, the implementation of cybersecurity measures is critical as universities become more reliant on digital systems. Uma-Maheswari et al. (2023) point out that the increasing use of data-driven platforms and cloud computing raises concerns about data privacy, security, and compliance with regulations such as the General Data Protection Regulation (GDPR). Universities must allocate resources to ensure that they can safeguard sensitive information and maintain the trust of students, faculty, and external partners.

4.2. Financial Barriers

The digital transformation of universities requires substantial financial investment. New technologies, including smart classrooms, cloud-based systems, and research hubs, come with high initial setup costs and ongoing maintenance expenses (Polin et al., 2023). In addition, universities must invest in human capital, providing faculty and staff with the training and skills needed to effectively integrate digital tools into their teaching, research, and administrative roles.

Universities often face tight budgets, and securing funding for digital transformation can be difficult, especially in the absence of government support or private sector partnerships. Toprak et al. (2019) emphasizes the importance of exploring public-private partnerships as a means of overcoming financial barriers. Collaborating with industry partners can help universities access the resources they need to modernize their infrastructure and remain competitive in a rapidly evolving educational landscape.

4.3. Cultural Barriers

Cultural resistance to change is another significant barrier to the successful implementation of a new-generation university model. Faculty and administrators who are accustomed to traditional methods of teaching and governance may be reluctant to embrace new technologies or adopt new practices (Baygin et al., 2016). This resistance can slow the pace of digital transformation and hinder the institution's ability to adapt to the demands of Industry 4.0 and Society 5.0.

Addressing cultural resistance requires strong leadership and a clear communication strategy. University leaders must articulate the benefits of digital transformation and create a culture of innovation that encourages experimentation and collaboration. Toprak et al. (2021a & 2021b) stresses the importance of involving all stakeholders in the transformation process, ensuring that faculty, staff, and students have a voice in shaping the future of the institution.

4.4. Institutional Barriers

Institutional inertia, characterized by rigid hierarchies and slow decision-making processes, can also impede the transition to a new-generation university. Traditional governance models are often ill-suited to the fast-paced, technology-driven environment of Industry 4.0. As Toprak et al. (2019) points out, universities must adopt decentralized governance structures that allow for greater flexibility and responsiveness.

In addition, the bureaucratic nature of many universities can hinder the implementation of new initiatives. Streamlining administrative processes and reducing bureaucratic red tape is essential for fostering a culture of innovation and enabling the rapid adoption of new technologies (Muftahu, 2023; Toprak&Erdoğan, 2012).

Conclusion

The transition to a new-generation university, based on the principles of Industry 4.0, Society 5.0, and integrated digitalization, requires a fundamental rethinking of the organizational and functional architecture of higher education institutions. The framework for a new-generation university is built on the pillars of quality assurance, accreditation, and digital transformation. These elements work together to create an innovative, globally competitive institution that is prepared to meet the challenges of the 21st century. By fostering a culture of continuous improvement, embracing digital tools, and engaging in global collaboration, universities can provide high-quality education that is both accessible and relevant to today’s students.

This paper has outlined the key elements of a new-generation university model, including the adoption of advanced digital infrastructure, flexible curriculum design, research and innovation hubs, and decentralized governance structures.

Despite the many opportunities presented by this transformation, universities must also address significant challenges, including technological, financial, cultural, and institutional barriers. By leveraging the latest technologies, fostering collaboration between academia and industry, and embracing a culture of lifelong learning, universities can position themselves as leaders in the digital age.

The new-generation university is an institution that embraces digital transformation, fosters a culture of quality assurance, and adopts innovative governance models to ensure long-term

sustainability and success. As demonstrated by various universities' strategic initiatives, these pillars are essential for any university seeking to remain competitive in the 21st century.

Through the integration of technology, the establishment of transparent governance structures, and a commitment to continuous improvement, universities can create an environment that promotes academic excellence, research innovation, and global engagement.

As Toprak et al. (2021a & 2021b) highlights, universities must not only embrace digitalization but also ensure that it serves the broader goal of enhancing student outcomes and contributing to societal well-being. In doing so, they can fulfill their mission of preparing students for the complex challenges of the 21st century.

The aim of the study is to provide the following contributions to the literature and practice of the new generation university model.

Contributions to the Literature:

- Integration of industry 4.0 and society 5.0 in higher education
- 21st century skills-based and interdisciplinary curriculum development
- Digital transformation in university governance
- Blended learning and smart campuses
- Role of universities in ethical and inclusive technology implementation
- Collaborative public-private partnerships
- Technology transfer and commercialization of research

Contributions to practice:

- Operationalizing digital infrastructure
- Decentralized and collaborative governance models
- Personalized learning environments
- Lifelong learning and flexible education pathways
- Recognition of prior learning
- Inclusive digitalization
- Implementation of interdisciplinary research hubs
- Public-private partnerships for innovation
- Technology-driven ethical education

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