DEVELOPMENTS IN THE INDUSTRY 4.0 ERA AND ITS REFLECTIONS ON THE FIELD OF EDUCATION

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ABSTRACT

The ongoing transformations brought about by globalization have led to a shift from an industrial society to an information society, and the developments referred to as the Industry 4.0 process have triggered significant changes in working life and in nearly all aspects of human life. In this most recent stage of societal evolution throughout history - the information society - major transformations have occurred in terms of production management and in crucial areas of life such as health, education, and the environment. This study analyzes the concept of Education 4.0, which reflects the impact of Industry 4.0 on the field of education, and examines potential changes that may arise in current educational systems. Today, technology continues to evolve rapidly, and it is of great importance to train a workforce capable of adapting to the technological demands of modern working life. By taking into account the fundamental elements of the Education 4.0 stage, this study aims to analyze how an education system compatible with technological advancements and free from technological anxieties can be shaped. In the century we live in, technological unemployment concern is an important social policy problem. Compliance with the education 4.0 process is of great importance in preventing technological unemployment concerns. The Education 4.0 process attaches great importance to the adaptation of the education system to technological developments. The new student-centered education system aims to prevent technological unemployment. In our study, the education 4.0 process is discussed in all its aspects. In addition, all studies carried out so far on the subject were examined and a general evaluation was made.

Key words: Industry 4.0, Education 4.0, Technological Unemployment, Technology Education, Information Society

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1.INTRODUCTION

In today's world, significant transformations are occurring in all aspects of social life as a result of globalization. The continuous advancements in technology and the challenges of adapting to these technologies are becoming increasingly evident in every sphere of society. When we examine the historical transformation of social structures, we see that the invention of the steam engine marked the First Industrial Revolution, the discovery of electricity triggered the Second Industrial Revolution, and developments in management and information technologies laid the foundation for the Third Industrial Revolution. The advances in digitalization and computer technology have paved the way for the emergence of the Fourth Industrial Revolution (Öztemel 2018: 26).

Various studies have been conducted on the impact of the Industry 4.0 process on social life. Liao and colleagues have analyzed several such studies. As digital production (including production methods, technology, and data exchange), the integration of communication networks (the Internet of Things), smart manufacturing, and cyber-physical systems emerge, we witness significant transformations in the quality of products and services offered to society (Liao et al., 2017: 3609).

With the Industry 4.0 production process, the size of produced goods and services has been reduced, while their capabilities have increased. Communication is now established with customers when necessary, providing post-sale support. Meanwhile, the social composition of occupations in the production process has shifted. Jobs have begun to fragment. Core professions have been subdivided into intermediate professions, which in turn have split into sub-professions. As a result, the pace of human labor has begun to align with that of machines, making human work capacity increasingly dependent on machinery. Furthermore, developments in artificial intelligence suggest that those who fail to adapt to technological changes may face technological unemployment—revealing a rising level of technological anxiety. To prevent technological unemployment and mitigate the negative effects of Industry 4.0 while highlighting its positive aspects, it is essential to initiate new transformations in the field of education. The reflection of the Industry 4.0 process in education is referred to as Education 4.0 (Puncreobutr 2016: 92; Öztemel 2018: 25).

2.TRANSITION TO THE INDUSTRY 4.0 PROCESS

With the transition to an information society and the increasing dominance of computer technologies in social life, it has been observed that employees operate in line with the pace of machines and are now able to generate alternative solutions to problems that could not be resolved under normal working conditions, thanks to advancements in computer technology. In

fact, it has even been witnessed that computers can develop their own languages to communicate with one another. As a result of the developments brought about by Industry 4.0, competencies such as technology production, research and development, marketing, entrepreneurship, computational thinking, coding, and alternative problem-solving have come to the forefront (Bayburt, Eğin 2021: 137).

The core components of the Fourth Industrial Revolution can be classified as follows (Öztemel 2018: 26):

- **Autonomous Robots**: With Industry 4.0, robots used in production management are capable of making independent decisions and resolving issues during the manufacturing process.
- **Smart Information Networks**: Computers communicate both with each other and with humans via software, managing data exchanges and overseeing digital communications.
- **System Integration**: In production management, all systems are capable of making independent decisions but must operate in coordination with one another.
- **Cyber-Physical Systems**: These systems ensure communication and a holistic approach to manufacturing processes in production management.
- **Cybersecurity Systems**: Cybersecurity plays a key role in ensuring that all organizational and operational activities are carried out safely, protecting against cyberattacks.
- **Internet of Things (IoT)**: Communication between objects across society—primarily in production management—is made possible through IoT protocols.
- **Big Data Analytics**: The volume of data produced in digital environments grows each year. Through comprehensive and detailed analysis of big data, businesses can access the necessary information to support effective decision-making. Providing the right information at the right time and place is critical in this process.
- **Cloud Computing**: Cloud technology offers cost-effective solutions for both data storage and software use.
- **Simulation and Augmented Reality**: Industry 4.0 enables the integration of real-world and simulated environments. In the case of a system malfunction, virtual models can be used to repair the actual system.
- **Additive Manufacturing and 3D Printing**: In production management, entering model specifications into a computer and using 3D printers enables the creation of products with desired characteristics.
- **Preventive Maintenance**: In the Industry 4.0 process, workers operate on a continuous production line under a completely transformed occupational structure. Since machines must run continuously, preventive maintenance is essential to avoid costly breakdowns and reduce production disruptions.

The Industry 4.0 process introduces not only innovations brought about by digitalization in production management but also the emergence of smart products. Each manufactured product gains a unique identity. Robots operate within cyber-physical systems by receiving instructions from digitally integrated parts, interacting with humans, and taking their place in the production process (Özsoylu 2017: 52–53).

3-REFLECTION OF THE INDUSTRY 4.0 PROCESS ON EDUCATION 4.0

Throughout history, industrial revolutions have reshaped societies and paved the way for the transformation of individuals who make up those societies. After every industrial revolution, ensuring that individuals adapt to technological innovations and alleviating technological anxiety has always relied on education. In parallel with the developments that emerged from each industrial revolution, the field of education has evolved through phases known as Education 1.0, Education 2.0, Education 3.0, and Education 4.0. Studies by Wyman, Sadiku, Omotoso, Puncreobutr, and Lopez have discussed the reflections of industrial revolutions on the field of education (Oktay, Yüzer 2013: 357).

Education 4.0 is the approach that has emerged as part of the Industry 4.0 process, emphasizing digitalization, flexibility, and personalized learning in education. It presents a dynamic model that redefines the value and use of knowledge through digital integration in the education process (Halili 2019: 63). Advances in technology naturally require adaptation and the transformation of education systems. Education 4.0 adopts a student-centered learning model, allowing learners to manage their own learning processes, choose learning paths that align with their interests, and efficiently use their personal talents. Since technology is constantly evolving, this model also aims for continuous change and development in education (Adeniyi et al., 2024: 1676; Dağaşan 2025: 39).

The transformation in education over time can be outlined as follows (Öztemel 2018: 26–27; Dağaşan 2025: 39; Bayburt, Eğin 2021: 145; Asıl et al., 2024: 23):

Education 1.0

Before the industrial revolution, during the era of agricultural production, educational activities were carried out primarily to meet basic survival needs. With the industrial revolution in the 18th century, educators became the central figures in education. They identified and disseminated the essential knowledge learners needed. During this time, learners typically followed the educators and attempted to apply the teaching methods used. Efforts were made to develop new teaching methods (Ramirez, Montoya et al., 2021: 90; Öztemel 2018: 26).

Education 2.0

Education 2.0 emerged in the early 20th century. Its primary goal was to train individuals for active roles in industry (Zengin 2022: 330). Educational institutions were designed similarly to industrial production systems, operating on input-output-feedback principles. Standardization in educational institutions and exam systems was emphasized (Birekul, 2020, p.5). For the first time, technology and the internet were introduced to both educators and learners, raising the importance of educating individuals who could adapt to technological advancements (Ramirez, Montoya et al., 2021: 91).

Education 3.0

Towards the end of the 20th century, the rise of computerization and automation, as part of the Third Industrial Revolution, led to the emergence of Education 3.0. Technological developments began to significantly influence social life, making adaptation to technology crucial for both educators and learners. In this phase, learners were no longer passive recipients of knowledge—they also became contributors. Educators and learners began to act collaboratively. The learning process in Education 3.0 is supported by virtual tools, practical environments, and multimedia platforms (Qureshi et al., 2021: 31).

Educational institutions began functioning like open systems engaging with society, aiming to produce graduates with qualifications. This approach largely continued into the early 21st century (Konca 2020: 5; Embi 2018: 7).

Education 4.0

With the influence of Industry 4.0, the concept of Education 4.0 has come to the forefront, where innovation becomes a fundamental component of the education system. In the age of globalization and the information society, innovation is considered essential for achieving success in global competition.

The transition to the Industry 4.0 era and the information society has necessitated constant adaptation to technological developments. Continuous changes in technology require educational tools to be frequently updated, and demand a continuous, adaptive learning process. The core philosophy of Education 4.0 is lifelong learning. Thus, Education 4.0 is not merely an education model; it is a way of life that emphasizes analytical thinking, innovation, efficiency, knowledge sharing, and career development (Öztemel 2018: 27).

Education 4.0 appears in all areas of social life as a lifestyle that fosters a workforce adapted to technology and free from technological anxiety. It aims to instill critical thinking habits, promote exploration, encourage the generation of alternative solutions, and enhance quick thinking and decision-making in the face of problems.

In this process, a constructivist approach to learning is emphasized, incorporating the following instructional dimensions: 3R (Recalling, Relating, Refining) — for regulating understanding, 3I (Inquiring, Interacting, Interpreting) — for promoting research, 3P (Participating, Processing, Presenting) — for reaching conclusions (Gomaratat 2015: 5; Öztemel 2018: 27; Kocaman, Karaoğlu et al., 2020: 149).

4.TRANSFORMATION IN THE ROLES OF EDUCATORS AND LEARNERS IN THE EDUCATION

In today's world, where technology is constantly evolving, the need to adapt to technological changes brings continuity to the field of education as well. The roles of educators and learners are continuously transforming in line with these developments. According to Ertmer and Newby (Ertmer, Newby 2013: 65), the learning process has been significantly affected by the widespread use of the internet and Web 2.0 tools, the emergence of a new learner profile, and

the implementation of new educational methods. Today's learners, who think and learn differently, are often referred to as digital natives, the net generation, or millennials. Both educators and learners use technology as a means of communication, which necessitates technological expertise. The mindset and information processing approaches of generations who grew up with technology and those who encountered it later in life differ significantly (Kocaman, Karaoğlu et al., 2020: 150). These differing views also influence their understanding of learning. Digital learners believe that knowing how to do a task is more important than just knowing about the task. This perspective enables a more detailed and original understanding of tasks (Ertmer, Newby, 2013: 66).

In a society that has transitioned into the Industry 4.0 phase, learners have different learning needs compared to the past; they are more technologically inclined, tend to question learning processes, and analyze subjects in detail. Learners in the Education 4.0 era feel a greater sense of responsibility for their own learning. Independent learning is emphasized at this stage. While learners undergo significant transformations in the Education 4.0 process, educators are also expected to experience major shifts in their duties and responsibilities. Educators must embrace innovation in their educational strategies and pedagogical thinking, adopting more student-centered practices. At this point, the educator is no longer a person who knows and transmits all knowledge, but instead takes on the role of a guide or consultant for the learner (Robertson 2020: 260).

The Education 4.0 phase has also redefined the responsibilities of educators in an increasingly globalized world. This shift constitutes a major transformation in the roles within education. Educators must be prepared for their new role as advisors in the information society shaped by globalization. In today's world, information is highly diverse, and information pollution has become a significant issue. To combat misinformation, it is crucial that learners gain access to accurate knowledge. Therefore, learners must assume greater responsibility in this regard (Balay 2004: 61).

5.DIGITAL TRANSFORMATION IN EDUCATION AND EDUCATION 4.0

In the Education 4.0 process, it has become increasingly important for learners to utilize their skills. New approaches in education are necessary to foster visual learning, analytical techniques, and the development of alternative problem-solving abilities. To enhance quality in educational institutions, educator candidates must be integrated with technology. An innovation-focused approach will be adopted in this transformation process, and the learning process will evolve into a lifelong journey beginning in childhood (Öztemel 2018: 27).

The Education 4.0 process will bring about profound changes and transformations:

1. Educational and learning activities will be conducted at different times, using various tools and in diverse locations. Therefore, the understanding of lifelong, anytime, and anywhere education will dominate. Learners will receive conceptual knowledge outside of formal institutions while engaging in face-to-face activities for practical knowledge (Öztemel 2018: 27).

2. With Education 4.0, the evolving demands of the industry require learners to be better prepared for the workforce. It is essential that learners are guided through an educational process aligned with their individual abilities in order to integrate them successfully into working life. Learner-centered education is crucial for equipping them with competencies and adaptability (Bayburt, Eğin 2021: 146).

3. Learners in Education 4.0 will be able to design their learning processes using their own personal devices. They will complete their education through flexibly structured programs based on personal preferences (Saxena , Bhat 2017: 20).

4. Since learners will be expected to work independently in Education 4.0, they will gravitate toward project-based learning. Time management will emerge as a critical skill that learners must acquire to prepare for the future in organizational and managerial contexts (Gelen, Demircioğlu 2020: 497).

5. As learners become more independent in the learning process, educators will assume a central supporting role. With their experience, educators will act as advisors to learners. In addition to subject-matter expertise, educators will also need to develop counseling skills (Gelen 2019: 435).

6. Due to technological advancements, numerical operations are now performed via computers. Aoun emphasized that individuals in the Industry 4.0 era need data literacy, human literacy, and technological literacy. Today's Society 5.0 focuses on data-driven insights, where software tools analyze data to generate interpretations. In this context, social needs are identified through data analysis. Learners in Education 4.0 are expected to deconstruct data and establish relationships between different data sets. Developing interdisciplinary data analysis skills is of increasing importance. It is essential to integrate knowledge from seemingly unrelated areas to form meaningful wholes (Gelen, Demircioğlu 2020: 497).

7. The examination system for learners will be entirely transformed in Education 4.0. Instead of traditional exams, the learning process will be assessed based on acquired knowledge, its application in practice, and the success of learners' projects. The traditional exam-based system will be replaced with performance and situation-based evaluations (Öztemel 2018: 28).

8. Learners will contribute to the development of course content and their feedback will form the basis for the design of learning programs (Gelen, Demircioğlu 2020: 496).

9. As learners become more autonomous, mentoring will become widespread, particularly through virtual mentors (Kocaman, Karaoğlu et al., 2020: 153).

10. Learners will be able to register for all courses and training programs online. Web interfaces and access systems will become essential in ensuring learners master the subject matter (Öztemel 2018: 28).

11. Alongside Industry 4.0, new technological developments are transforming educational processes. These new technologies have become an integral part of educational

programs for both learners and educators. It is anticipated that 13 specific technologies will be actively integrated into curricula (Öztemel 2018: 29; Kocaman, Karaoğlu et al., 2020: 152):

12. Big data analytics

13. Implant technologies

14. Cloud-based data storage

15. Mobile internet usage

16. Internet of Things (IoT)

17. Advanced robotics

18. Automation

19. Genetic science

20. Renewable energy and energy storage

21. Use of autonomous devices

22. 3D printing technology

23. Smart materials

24. Use of unmanned vehicles

25. Blockchain and Bitcoin technology

The current century is characterized by the prominence of operational problems and the removal of geographical constraints. Today, even the most remote libraries are accessible with just a click. The diversity of information is evident across all fields. Cloud systems, artificial intelligence, robotics, and mobile technologies signal an unprecedented transformation in educational institutions (Garrison 2000: 2).

Digital transformation in education will also bring changes to higher education. University programs will prioritize innovation. There will be a shift toward multidisciplinary programs, and adaptation to evolving accreditation processes will be necessary. Static programs will give way to flexible curricula that respond to continuous change. Learners will study in personalized and autonomous learning environments (Asıl et al., 2024:26).

6.LITETARURE REVIEW ON THE EDUCATION 4.0 PROCESS

Studies analyzing the changes brought about by the Education 4.0 process have become increasingly important today. To develop a comprehensive perspective on Education 4.0, it is beneficial to examine various studies available in the literature.

From the Education 4.0 standpoint, Snape and Turnbull (2011) argued that the skills required by the modern era must be integrated into the current education system. Learners should be able to use their skills independently. If the skills demanded by the era are not integrated into the

education system, negative consequences may arise in terms of economic welfare (Snape, Turnbull 2011: 149).

Yingjie (2013) investigated how the Industry 4.0 process would impact the Chinese education system, examining the effects of Industry 4.0 on the education system and the working life of both educators and learners in the current century (Yingjie 2013: 65-72).

In their 2016 study, Wallner and Wagner observed that the Education 4.0 process creates a complex situation in teaching and research due to intercultural perspectives, multicultural structures, mobile applications, personalized and independent learning plans, diversity of information, and new opportunities for learners (Wallner et al., 2016: 155).

Häkkinen and colleagues emphasized the need for a new pedagogical perspective in educator training. The authors conducted research on solving problems with alternative approaches and strategic viewpoints, as well as on the various ways information and communication technologies can be utilized (Häkkinen et al., 2017: 25-41).

In a seminar exploring the relationships between Industry 4.0 and Education 4.0, Rosik stated that Industry 4.0 would bring about radical changes in education and examined the synergistic interaction between Industry 4.0 and Education 4.0 (Rosik, 2017).

Valtonen and colleagues attempted to measure how prepared prospective educators are with the skills required by today's world. Emphasizing the necessity for current and future learners to possess the skills to utilize technology, they also argued that educators need to be competent in using information and communication technologies (Valtonen et al., 2017: 15-31).

Sahlin et al. (2017) studied the impact of information and communication technologies in primary schools in Sweden, asserting that facilitating learners' use of computer technologies in early education would make teaching and learning more effective (Sahlin et al., 2017: 561-579).

Smyrnova-Trybulska and colleagues researched technology, science, mathematics, and engineering education topics. They argued that the use of robots in educational institutions is a necessity for today's interdisciplinary education (Smyrnova et al., 2017: 296-312).

Hannaway and Steyn (2017) utilized research methods such as visual media, field notes, and semi-structured interviews. They investigated educators' experiences with technological pedagogy and content knowledge to explore how technology can be integrated into the education system (Hannaway, Steyn, 2017: 1745-1759).

Öztemel (2018), in his study, provided a detailed analysis of the Education 4.0 concept, arguing that the education system is transforming into an innovation-focused structure through integration with technological developments. He explained the components of the Education 4.0 system and how systemic transformation can be achieved (Öztemel 2018: 25-30).

In 2019, Halili examined the effects of Industry 4.0 on education and identified four key factors to overcome challenges in the Education 4.0 process. First, learning environments should be redesigned using collaboration charts and smart boards. Second, technology-appropriate educational processes should be implemented. Third, flexible, technology-based new curricula

should be integrated into the traditional education system. Fourth, technological advances must be utilized in education to benefit both educators and learners (Halili, 2019: 63-69).

Sullivan and colleagues (2020) analyzed out-of-school education programs to enhance learners' personal skills in the current century. They argued that the Bridge21 model could improve learners' personal skills from various perspectives (Sullivan et al., 2020: 1-17).

Gelen and Demircioğlu (2020) evaluated the current education system by investigating whether Education 4.0 dimensions vary according to different variables. They found no significant differences in student participation-based curriculum and guidance-focused education dimensions by gender, field, or experience. Similarly, no significant differences were observed in educators' gender or grade levels (Gelen, Demircioğlu 2020:495-512).

Vodenko and Lyausheva (2020) researched the Education 4.0 process and developed a management and organization model within the framework of new educational transformations. They concluded that intellectual capital is a crucial production factor in science and education systems and stated that human intelligence need not dominate in this context (Vodenko et al., 2020:549-564).

Kocaman-Karoğlu and colleagues investigated the effects of digital transformation in education systems. According to the authors, detailed examination of tools and methods in digitalization processes will be extremely important for achieving digital transformation goals in education, especially in developing countries (Kocaman-Karoğlu et al., 2020: 147-158).

In a qualitative study by Bayburt and Eğin (2021), it was noted that technology changes the desired profile of educators and learners. Educators with algorithmic thinking habits, developed coding and problem-solving skills are important in the new education system (Bayburt, Eğin, 2021: 137-154).

Khandelwal et al. (2022) emphasized that Education 4.0 is a reflection of the Industry 4.0 process and that educational institutions are undergoing a transformation. They attempted to present how the new system can be implemented in developing countries (Khandelwal, 2022: 364-380).

Gürsev (2022) sought to identify which innovative methods the Education 4.0 concept requires. Using the TOPSIS method, he selected the most effective innovative education institution by considering expert opinions from four different institutions with distinct features (Gürsev, 2022: 162-169).

Mustafa and Emine Asıl (2024) analyzed the essential characteristics educators and learners should possess within the Education 4.0 process. They detailed the skills educators need, emphasizing that the new educational understanding required by Education 4.0 demands educators who are globally aware, student-centered, free from technological anxieties, open to collaboration, proficient in data analysis, and capable of alternative problem-solving (Asıl et al., 2024: 21-39).

Dağaşan (2025) conducted a qualitative study examining the effects of distance education practices on educators within the context of Education 4.0. The study highlighted that

strengthening technological infrastructure, providing feedback and support services can make virtual classroom environments more efficient (Dağaşan, 2025: 38-57).

7. FUTURE EXPECTATIONS IN THE EDUCATION 4.0 PROCESS" A NEW STUDENT-CENTERED EDUCATION SYSTEM"

The Education 4.0 process, which is a human-centered and purpose-driven educational approach, represents a new transformation for educators and learners who adapt to technology. Education 4.0 introduces an educational system that can operate independently beyond the boundaries of educational institutions, emphasizing personalized and project-based learning. The emergence of globalization and the knowledge society, the development of digital technology, fast internet, and high-performance devices have also brought changes in human capital. In the new education system, educators and learners will be familiar with concepts such as artificial intelligence, robots, and the Internet of Things. During the Education 4.0 era, both educators and learners must accept that simply obtaining a diploma will no longer be sufficient for securing employment.

In the Industry 4.0 and Education 4.0 era, individuals must gain expertise and competence in their fields of work and continuously renew themselves in line with changing conditions. It is crucial to be free from technological anxieties and to adapt to technology during this process. Special training for educators aligned with digital transformation is of great importance in the Education 4.0 process. The values and behaviors of educators significantly influence learners, society, and colleagues in the same profession. Being knowledgeable about the new technologies embedded in the Education 4.0 process is also essential. Integrating the existing education system with new technologies is critical for the quality and performance of education. It is of great importance that educators acquire the qualifications required by the new system and transmit these values to learners. Therefore, educators must continuously develop their personal and professional qualifications in accordance with societal developments (Asıl et al., 2024: 33).

Educators should equip learners with multiliteracy skills and teach them transformative competencies. Working conditions are continuously changing in the Industry 4.0 process. Learners need to be prepared for future uncertainties. Educators must provide problem-solving oriented education and ensure technological adaptability. Educational administrators must continuously develop learning environments in their institutions in line with technological innovations and strengthen educational infrastructure. Support programs should be provided considering learners' personal skills and needs. Measures must be taken to protect learners' physical and mental health, combat violence, and provide emotional support (Dağaşan 2025: 52; Asıl et al., 2024: 33).

8.CONCLUSION

The transition to the information society stage and subsequent developments, along with the emergence of the Industry 4.0 process and its reflections in the field of education, have led to a significant transformation in recent years, spanning from primary education to higher education.

Education 4.0 has brought important changes to the fundamental roles of educators: Firstly, pedagogical improvements and innovations have come to the forefront. In the Education 4.0 process, educators no longer serve merely as providers of knowledge; they also transform into facilitators of learners' understanding and interpreters of data produced by learners. Secondly, a new management and organizational structure based on technology and artificial intelligence has emerged in educational institutions, especially in the decision-making processes. Thirdly, educators are expected to have a strong technological infrastructure during the adaptation process. Moreover, both educators and learners will be required to serve as ethical agents who actively participate in education, addressing the ethical dimensions of algorithmic influence.

The Education 4.0 process offers educators opportunities and challenges to move away from old methods and develop professionally. From the perspective of transforming educational institutions, the development of technology-compatible curricula, management changes necessary for the integration of artificial intelligence applications, and the establishment of management and organizational structures that require collaboration among educators, technology experts, and ethics specialists are seen as strategic goals for institutional advancement.

In the coming years, alongside applied studies related to Education 4.0, it is also necessary to focus on long-term research that examines the experiences of educational institutions and their adaptation to changes in parallel with technological advancements.

9.REFERENCES

Adeniyi, I. S., Al Hamad, N. M., Adewusi, O. E., Unachukwu, C. C., Osawaru, B., Chilson, O. U., & David, I. O. (2024). Reviewing online learning effectiveness during the COVID-19 pandemic: A global perspective. *International Journal of Science and Research Archive, 11*(1): 1676–1685.

Asıl, M., & Asıl, E. (2024). Eğitim 4.0 perspektifinde öğretmen becerilerinin incelenmesi. *Recep Tayyip Erdoğan Üniversitesi Eğitim Fakültesi Dergisi, 1*(4): 21–39.

Balay, R. (2004). Küreselleşme, bilgi toplumu ve eğitim. *Ankara Üniversitesi Eğitim Bilimleri Fakültesi Dergisi*, 61–82.

Bayburt, B., & Eğin, F. (2021). Teknoloji ve sanayideki gelişmelerin bir yansıması olarak eğitim 4.0. *JKEM, 16*(2): 137–154.

Birekul, M. (2020). Eğitimde Endüstri 4.0. Available at https://www.mbirekul.com/?p=4576

Accessed 10 January 2020)

Dağaşan, A. (2025). Uzaktan eğitim uygulamalarına yönelik sosyal bilgiler öğretmen adaylarının deneyimleri: Eğitim 4.0 bağlamında bir değerlendirme. *MANAS Sosyal Araştırmalar Dergisi, 14*(1): 38–57.

Embi, M. A. (2018, July 29). Education 4.0 [Workshop presentation]. Workshop of the Educator 4.0, Universiti Malaysia Kelantan, Kota Bharu, Kelantan.

Ertmer, P., & Newby, T. (2013). Behaviorism, cognitivism and constructivism: Connecting yesterday's theories to today's contexts. *Performance Improvement Quarterly*, 65–71.

Garrison, R. (2000). Theoretical challenges for distance education in the 21st century: A shift from structural to transactional issues. *International Review of Research in Open and Distance Learning, 1*(1): 1–17.

Gelen, İ. (2019). Educational behavior expectations of adults according to academicians. *International Review of Social Sciences, 7*(10): 434–445.

Gelen, İ., & Demircioğlu, H. (2020). Endüstri 4.0 ve toplum 5.0 bağlamında: Eğitim 4.0. *ASR Journal, 5*(17), 495–512.

Gomaratat, S. (2015). *Learning productivity: 10 ways of progressive learning encouraging/facilitating the ability of the learner of 21st century*. Bangkok: Education Science.

Gürsev, S. (2022). Eğitim 4.0 kriterleri ve TOPSIS uygulaması ile eğitim kurumu değerlendirmesi. *FBU-DAE Dergisi, 2*(2): 162–169.

Häkkinen, P., Järvelä, S., Mäkitalo-Siegl, K., Ahonen, A., Näykki, P., & Valtonen, T. (2017). Preparing teacher students for twenty-first century learning practices (PREP 21): A framework for enhancing collaborative problem-solving and strategic learning skills. *Teachers and Teaching, 23*(1): 25–41.

Halili, S. H. (2019). Technological advancements in Education 4.0. *The Online Journal of Distance Education and eLearning, 7*(1): 63–69.

Hannaway, D. M., & Steyn, M. G. (2017). Teachers' experiences of technology-based teaching and learning in the foundation phase. *Early Child Development and Care, 187*(11): 1745–1759.

Khandelwal, R., Kolte, A., Pawar, P., & Martini, E. (2022). Breaking out of your comfort zone: An archival research on epistemology in inclusive education pedagogy for Industry 4.0. *International Journal of Educational Management, 36*(4): 364–380.

Kocaman-Karoğlu, A., Bal-Çetinkaya, K., & Çimşir, E. (2020). Toplum 5.0 sürecinde Türkiye'de eğitimde dijital dönüşüm. *Üniversite Araştırmaları Dergisi, 3*(3): 147–158.

Konca, F. (2020). *Eğitim 4.0: Eğitimin geleceği tartışmalarının neresindeyiz?* Ankara, Turkey: Pegem Yayınevi.

Liao, Y., Deschamps, F., Loures, E., & Ramos, L. (2017). Past, present and future of Industry 4.0 – A systematic literature review and research agenda proposal. *International Journal of Production Research, 55*(12): 3609–3629.

Oktay, Ö. S., & Yüzer, T. V. (2023). Eğitim 4.0 ve yükseköğretimde yenilikçi pedagoji. In *Proceedings of the 3rd International Conference on Educational Technologies and Online Learning* (pp. 357–363). Balıkesir, Turkey.

Özsoylu, A. F. (2017). Endüstri 4.0. *Çukurova Üniversitesi İİBF Dergisi, 21*(1): 41–64.

Öztemel, E. (2018). Eğitimde yeni yönelimlerin değerlendirilmesi ve Eğitim 4.0. *Üniversite Araştırmaları Dergisi,* 1(1): 25–30.

Puncreobutr, R. (2016). Education 4.0: New challenge of learning. *St. Theresa Journal of Humanities and Social Sciences,* 2(2): 92–96.

Qureshi, M. I., Khan, N., Raza, H., Imran, A., & Ismail, F. (2021). Digital technologies in Education 4.0: Does it enhance the effectiveness of learning? A systematic literature review. *International Journal of Interactive Mobile Technologies (iJIM), 15*(4), 31–47.

Ramírez-Montoya, M. S., Loaiza-Aguirre, M. I., Zúñiga-Ojeda, A., & Portuguez-Castro, M. (2021). Characterization of the teaching profile within the framework of Education 4.0. *Future Internet, 13*, 91. https://doi.org/10.3390/fi13040091

Robertson, S. (2020). Digital pedagogy for the 21st century educator. In *Handbook of Research on Innovative Pedagogies and Best Practices in Teacher Education* (pp. 258–275). Hershey, PA: IGI Global.

Rosík, M. (2017, October 12–13). Education 4.0: Is there a synergy between Industry 4.0 and education? Paper presented at the International Workshop on Knowledge Management (IWKM), Slovakia.

Sahlin, J. S., Tsertsidis, A., & Islam, M. S. (2017). Usages and impacts of the integration of information and communication technologies (ICTs) in elementary classrooms: A case study of Swedish municipality schools. *Interactive Learning Environments, 25*(5): 561–579.

Snape, P., & Fox-Turnbull, W. (2011). Twenty-first century learning and technology education nexus. *Problems of Education in the 21st Century, 34*, 149.

Smyrnova-Trybulska, E., Morze, N., Kommers, P., Zuziak, W., & Gladun, M. (2017). Selected aspects and conditions of the use of robots in STEM education for young learners as viewed by teachers and students. *Interactive Technology and Smart Education, 14*(4): 296–312.

Sullivan, K., Bray, A., & Tangney, B. (2020). Developing twenty-first century skills in out-of-school education: The Bridge21 transition year programme. *Technology, Pedagogy and Education*, 1–17.

Valtonen, T., Sointu, E., Kukkonen, J., Kontkanen, S., Lambert, M. C., & Mäkitalo-Siegl, K. (2017). TPACK updated to measure pre-service teachers' twenty-first century skills. *Australasian Journal of Educational Technology, 33*(3): 15–31.

Vodenko, K. V., & Lyausheva, S. A. (2020). Science and education in the form 4.0: Public policy and organization based on human and artificial intellectual capital. *Journal of Intellectual Capital, 21*(4): 549–564.

Wallner, T., & Wagner, G. (2016, June 12–14). Academic Education 4.0. In *Proceedings of the International Conference on Education and New Developments* (pp. 155–159). Ljubljana, Slovenia.

Yingjie, W. (2013). Comparative and international education in China: Definitions, functions and trends. In *Annual Review of Comparative and International Education 2013: International Perspectives on Education and Society* (Vol. 20, pp. 65–72).

Zengin, T. (2022). Eğitim 4.0: Eğitimin geleceği tartışmalarının neresindeyiz? *Türkiye Eğitim Dergisi, 7*(1): 330–334.