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Education 4.0: The Concept, Skills, and Research

Elena Tikhonova[1,2], **Lilia Raitskaya**[3]

[1] National Research University Higher School of Economics, Moscow, Russian Federation

[2] Peoples' Friendship University of Russia (RUDN University), Moscow, Russian Federation

[3] Moscow State Institute of International Relations (MGIMO University), Moscow, Russian Federation

ABSTRACT

Introduction. With Industry 4.0 and Work 4.0 entering the world, modern education is undergoing transformations in terms of educational practices, skillsets and competencies, teaching and learning methodologies (including flipped classroom, blended learning, self-regulated learning, project-based learning, inquiry-based learning, student-centred pedagogy), digital tools used at all educational levels, as well as barriers and challenges. This string of changes is covered by the new buzzword "Education 4.0". It is not so far finally defined. There are various explanations of the concept. Most align with the Fourth Industrial Revolution and Industry 4.0. The JLE editorial aims to overview the emerging research field of Education 4.0 aligned with Industry 4.0, outlining the potential lines of research for JLE authors.

Industry 4.0. The transformation of production at large is beginning on the basis of a set of innovative technologies and completely brand-new processes. Their combination constitutes the underpinning of Industry 4.0.

Skillsets in Education 4.0. There are numerous views of the skills needed for graduates ready for Industry 4.0. One of the most replicated lists embraces the 10 skills offered by the World Economic Forum in 2016 with later updates. Most researchers outline numerous technical, communication, digital, and cognitive skills as a skillset of Industry 4.0.

Teaching and Learning in Education 4.0. The traditional pedagogy or face-to-face learning, still dominant worldwide, is going to combine with innovative approaches, including, e-learning, and blended learning as a mixture of e-learning ang face-to-face learning. In addition, all student-centered technologies add to the future pedagogical landscape: self-regulated learning, project-based learning, flipped classroom, etc.

Research on Education 4.0. The authors searched the Scopus for the documents related to "Education 4.0" to find that the total of 483 results unevenly distributed from 2010 to 2023, with a high of 137 in 2022. The analysis of the publications on Education 4.0 proves that the research field is developing fast, though publications authored by researchers from the developing countries prevail in the search results. At the same time, most of the selected publications came out in the Scopus-indexed low-quartile or discontinued journals. A disproportionately low number of articles published by the authors from the OECD countries depletes the quality of the research field.

Conclusion. The editorial overview of the concept of Education 4.0 may serve as a topical guidance for researchers at large and potential JLE authors focused on educational research. Further studies in the field may cover skillsets and competencies for Industry 4.0; teaching and learning approaches in Education 4.0; new educational frameworks and environments.

KEYWORDS

Industry 4.0, Fourth Industrial Revolution, Education 4.0, skills, competencies, blended learning, e-learning, face-to-face learning.

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Correspondence:
Elena Tikhonova,
etihonova@hse.ru

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INTRODUCTION

Innovation has been transforming the ways the economy functions throughout the mankind history. In the past, there were periods of great innovations that are marked as industrial revolutions: (1) The Industrial Revolution began when the steam engine was invented by

Thomas Newcomen in 1712, and consequently introduced in various industrial sectors (starting with a steam powered mass-producing print technology). From 1781 on, it brought about Industry 1.0. (Yıldız, 2019). The transition from hand production to machines and "from farming and feudal society to the new manufacturing process" (Xu et al., 2018) marked that period; (2) Industry 2.0. was based on electrical power and assembly lines built at factories and followed the Technological Revolution and the spread of railways and telegraph networks. The invention of the internal combustion engine ushered in a new era of rapid industrialization (Xu *e*t al., 2018). The beginning of the Second Industrial Revolution dates back to the 1860s-1870s. It lasted into the early 20th century till World War I; (3) The second half of the 20th century witnessed flourishing brand-new technologies related to the Internet and accompanying innovations called the Digital Revolution. They transformed the ways of production and were labelled as "Industry 3.0". The greatest achievements of the period were computers and robots; (4) The term "Industry 4.0" has been popularized by the World Economic Forum to describe the trends towards to technologies and processes, including cyber-physical systems, Internet of things, cloud computing, artificial intelligence, computer generated product design, three-dimensional (3D) printing. Industry 4.0 encapsulates a set of technological changes in industry at large. The concept is generally defined via an enumeration of the technologies (Fuchs, 2018). The Third and the Fourth Revolutions have merged while "the lines between physical, digital, and biological spheres" (Xu et al., 2018) are beginning to blur initiated by the amalgamation of Internet, information, and communication technologies (ICTs) and physical machinery (Kumar et al., 2019). Industry 4.0 is often described as the Industrial Internet, or Internet 4.0 (Echeberria, 2020).

Every period of industrial history requires the corresponding form of education. The first three industrial revolutions led to Education 1.0 (teacher-centered approach), Education 2.0 (peer assessment encouraged, high teacher important), and Education 3.0 (co-constructed, first student-centered) respectively (Miranda et al., 2021). At present, Education 4.0 is coming into existence, with new educational technologies based on a range of tools in various environments. It is to response to all the requirements the economy of Industry 4.0 will impose towards employees of the future.

This editorial review overviews the fledging field of Education 4.0, with the objective of outlining the JLE potential key lines of research for further publications. To this end, the JLE editorial dwells upon the background of Industry 4.0, fuelling transformations in Education 4.0 (Industry 4.0); the key aspects of the pedagogy in the Industry 4.0-driven environments (Education 4.0 in Focus); the challenges Industry 4.0 and Work 4.0 make in respect of graduates' employability (Skillsets in Education 4.0), the major pedagogical approaches applied in Education 4.0 and most efficient ways of teaching and learning in online and mixed environments (Teaching and Learning in Education 4.0), and an overview of the research on Education 4.0 to explore the emerging field (Research on Education 4.0).

Industry 4.0

The concept of Industry 4.0 was originally formed in Germany ahead of other countries. It lay a foundation for the European Union (EU) concept accepted in 2016. The Ministry of Education and Research of Germany highlighted that in Industry 4.0 "equipment, machines and single components continuously exchange information" along the value chain[3].

The European Union outlined the key characteristics of Industry 4.0, reduced to interoperability, virtualization, decentralization, real-time capability, service orientation, modularity[4]. Simply put, the concept of Industry 4.0 is an integration of cyber and physical worlds via introducing new technologies (Sony & Naik, 2020). The gist of transformations in Industry 4.0 embraces the following features:

(1) vertical networking in smart production;

(2) horizontal integration via global value chain networks;

(3) through-engineering across the entire value chain;

(4) acceleration of production through exponential technologies (Echeberria, 2020).

Learners within Education 4.0 must get prepared for Industry 4.0 and Work 4.0. The technologies related to Industry 4.0 shorten the life cycle of most professions. The concept ща Education 4.0 marks "the impacts of the systematic changes brought about by the Fourth Industrial Revolution" in education (Oliveira & Saraiva, 2023). It implies "self-regulated learning, critical thinking, collaborative and teamwork skills supported by digital expertise" (Thite et al., 2021).

Skillsets in Education 4.0

Industry 4.0 requires professional who are ready for change, capable of acquiring new knowledge, and improving their skills. Professional education within the concept must be adapted with new models for teaching and learning with a

[3] Bundesministerium für Bildung & Forschung (2013). *Zukunftsbild „Industrie 4.0"*[Federal Ministry for Education and Research]. Bundesministerium für Bildung und Forschung. S.6. https://www.plattform-i40.de/IP/Redaktion/DE/Downloads/Publikation/zukunftsbild-industrie-4-0.pdf?__blob=publicationFile&v=4

[4] Directorate-General for Internal Policies (2016). *Industry 4.0. Study for the ITRE Committee.* European Parliament. https://www.europarl.europa.eu/RegData/etudes/STUD/2016/570007/IPOL_STU(2016)570007_EN.pdf

focus on interdisciplinary skills (Kipper *et al*., 2021). At present, there is no unanimous skillset covering all potential demands of the future labour market. One of the widely replicated lists is the one offered by the World Economic Forum headlined "The 10 skills you need to thrive in the Fourth Industrial Revolution: Top skills in 2020" (World Economic Forum, 2016 and updates) that include:

(1) complex problem solving;

(2) critical thinking;

(3) creativity;

(4) people management;

(5) coordinating with others;

(6) emotional intelligence;

(7) judgement and decision making;

(8) service orientation;

(9) negotiation;

(10) cognitive flexibility[5].

Many authors highlight other skills, including self-management, flexibility, adaptability, communication skills, initiative, collaborative work, teamwork, interdisciplinary, problem solving, creativity, give and receive feedback, leadership, and other skills (Kipper et al, 2021; Chigbu et al., 2023; Karpenko et al., 2021; Teo et al., 2021).

Employable graduates must possess adequate skills, though some studies suggest that there is "a skill gap between university students and fresh graduates in the industry" (Thite et al., 2021). Education 4.0 aims to bridge such gaps by aligning professional education, especially in engineering, with real production. One of the prominent educational technologies of this kind is a Teaching Factory 4.0. Such factories are created to change over to Engineering Education 4.0, for instance, the SEPT Learning Factory, or a state-of-the-art facility simulating the factory of the future for educational and research aims (Elbestawi et al., 2018). Embedding most important graduate skills, including innovation, critical thinking, metacognition, teamwork, collaboration and communication skills, into Education 4.0, especially in online courses, will require great efforts. The academia at large is striving to incorporating and reflecting on the new technologies, concepts, and paradigms, though sometimes too gradually (Catal & Tekinerdogan, 2019). To address this challenge, algorithms, roadmaps, and other blueprints are put forward. For instance, Coşkun et al. (2019) put up a road map which includes three pillars addressing the curriculum development, laboratory concept, and student club activities. More research is necessary to meet the demands of educations institutions across all domains.

Teaching and Learning in Education 4.0

Education has been based on the classroom approach for all its history (Chigbu et al., 2023). It is still a dominant global technology[6]. The modern pedagogical models applied in teaching and learning are shifting to other approaches, including electronic-based (e-learning or internet-based learning), blended learning (a mixture of face-to-face and electronic-based learning; with instructional modalities – classroom, distance, and self-paced learning; instructional designs; and delivery media), self-regulated learning, project-based learning, revised face-to-face learning to provide for a combination of face-to-face, remote, and online interaction (Jones, & Sharma, 2021). Jones, & Sharma (2021) consider revised face-to-face learning as a set of problem-solving, study groups, presentations, formative assessments, and formative peer evaluations. Traditional lectures turn into interactive lectures that no longer look like a teacher's monologue.

These new pedagogies of Education 4.0 are being adapted unevenly on the global scale, with poor countries being far behind the frontrunners. The economies of the former are not ready for Industry 4.0. Their educational systems are less developed and under-equipped to promote novel educational initiatives (Chigbu *et al*., 2023).

Research on Education 4.0

The search query "Education 4.0" in the titles, abstracts or keywords in the Scopus database brought 483 results (as of March 5, 2023), distributed from 2010 to 2023. Though the first publications date to 2010-2013, the concept of Education 4.0 got a boost not earlier than 2019 after it had been adopted by the European Union (2016) and articulated by the World Economic Forum (2019). The trend towards more publications is definite, with a spike of 137 documents in 2023 (see Fig.1).

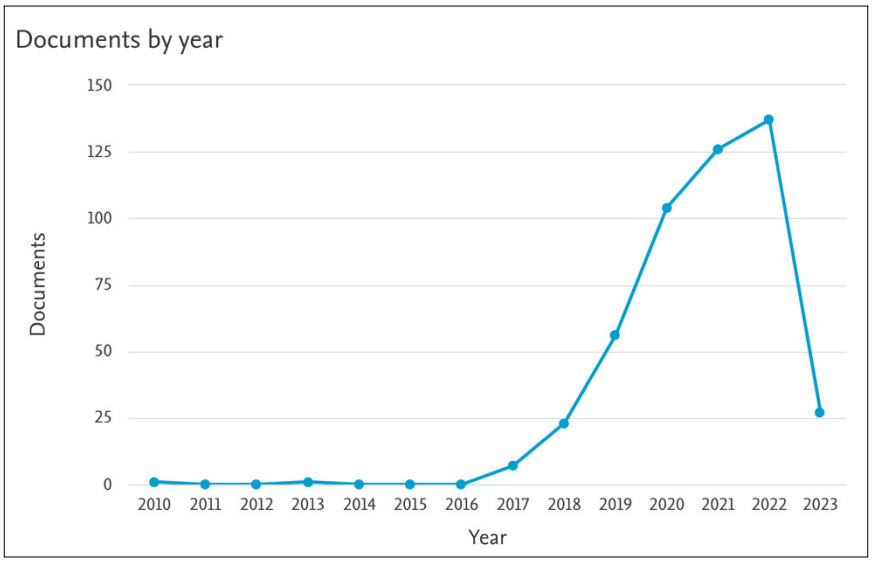
Though, the subject field of Education 4.0 is still getting its shape, there are several reviews on the topic. 16 in the search results, including 8 entirely relevant reviews in English (Ah-

[5] World Economic Forum (2016). The 10 skills you need to thrive in the Fourth Industrial Revolution: Top Skills in 2020. https://www.weforum.org/agenda/2016/01/the-10-skills-you-need-to-thrive-in-the-fourth-industrial-revolution (accessed March 12, 2023).

[6] Marinoni, G., Land, H. Van, & Jensen, T. (2020). *The impact of COVID-19 on higher education around the world: IAU Global Survey Report*. https://www.uniss.it/sites/default/files/news/iau_ covid19_and_he_survey_ report_final_may_2020.pdf.

Figure 1

Research on Education 4.0: Breakdown by Year



Note. Scopus Database as of March 5, 2023. Scopus database. Copyright 2023 by Elsevier.

Table 1

Basic Characteristics of the Search Results on Education 4.0

Characteristics	Number (and/ or Percentage)
Total Search Results	483
Articles	195 (40.4 %)
Review Papers	16 (3.3 %)
Conferences Papers	224 (46.4 %)
Book Chapters	31 (6.4 %)
Journals and Other Sources	205
Authors	318
Most Prolific Author – Ramírez-Montoya, M.S. (Tecnologico de Monterrey, Monterrey, Mexico)	15
One-Authored Documents	57
Top Cited Publication (Benešová & Tupa, 2017)	282
Country with the Highest Results – Malaysia	66
Most Productive Year 2022	137

mad et al., 2022; Butt et al., 2022; Chaka, 2022; Costan et al., 2021; Dao et al., 2023; González-Pérez, & Ramírez-Montoya, 2022; Moraes et al., 2022). Some of the reviews as well as other publications came out in the journals that do not belong to high quartiles or are brought out by the publishers with dubious reputation as a bibliometric review stated (Dao et al., 2023). The bibliometric review on Education 4.0 for 2017-2021 also found that "the research field is very fragmented" (Dao et al., 2023).

The ten most productive countries include Malaysia (n=66), Mexico (n=62), Indonesia (n=60), India (n=44), Germany (n=29), Spain (n=26), Romania (n=21), Brazil (n=19), United States (n=17), and Russian Federation (n=15). As few OECD countries contributed to the research on Education 4.0, the field "cannot develop strongly" (Dao et al., 2023). The contribution on part of many developing countries confirms the fact that their interest in Industry 4.0 and Education 4.0 is outpacing the one of technology-driven countries.

The most frequent keyword "Education 4.0" was included in 367 publications out of the total of 483 (75.98 %). The other most popular keywords were Industry 4.0 (151 publications), student (147), engineering education (145), technology (123), and e-learning (81). Other keywords in our search results covered artificial intelligence, augmented reality, internet of things and others. Almost all most frequent words were in

Figure 2

Word Cloud of the Top 250 Keywords

conformity with the findings in the review mentioned above (Dao et al., 2023).

The thematic spread in the selected publications is rather wide. The most cited articles from the reviewed list cover general features of Education 4.0 (Himmetoglu, Audug, & Bayrak, 2021; Mansor, Abdullah, & Rahman, 20200; requirements for education and qualification in Industry 4.0 (Benešová, & Tupa, 2017); digital transformation towards Education 4.0 (de S Oliveira, & de Souza, 2022; Jain, & Jain, 2022); engineering education (Mogos et al., 2018; Srivani et al., 2022; Polyakova, 2020); and country-related issues of Education 4.0 (Buasuwan, 2018; Anito, & Morales, 2019; Jain, & Jain, 2022). The analysis was subject to the articles only with numerous citations (over 7 as of April 1, 2023).

CONCLUSION

The research on Education 4.0 is on the rise while the Fourth Industrial Revolution is making some evident headway to Industry 4.0. The outline given above may navigate potential researchers through the field. The focus on this prospective field is certain to bring more publications in the near future. It would be reasonable for researchers to analyse national and regional experiences in promoting the concept, compare country-related experiences and the best practices in promoting the appropriate teaching and learning models in the face-to-face, online and mixed environments. Further research may embrace skillsets, both on a national and global scale; competencies of Industry 4.0, specific of various sectors of economy; teaching and learning approaches in Education 4.0; new educational frameworks and environments.

DECLARATION OF COMPETITING INTEREST

None declared.

AUTHORS' CONTRIBUTION

Elena Tikhonova: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing, other contribution.

Lilia Raitskaya: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing, other contribution.

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