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Components of education 4.0 in open innovation competence frameworks: Systematic review

Nurken Akimov[a], Nurlan Kurmanov[b,*], Assel Uskelenova[c], Nazgul Aidargaliyeva[d], Dinara Mukhiyayeva[b], Saule Rakhimova[a], Bagdat Raimbekov[e], Zhuldyz Utegenova[f]

[a] Astana International University, Astana 010000, Kazakhstan
[b] L.N. Gumilyov Eurasian National University, Astana 010008, Kazakhstan
[c] Al-Farabi Kazakh National University, Almaty 050040, Kazakhstan
[d] Alikhan Bokeikhan University, Semey 070000, Kazakhstan
[e] Karaganda Buketov University, Karaganda 100028, Kazakhstan
[f] Kokshetau Shoqan Ualikhanov University, Kokshetau 020000, Kazakhstan

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ABSTRACT

Development of competencies for Open Innovation (OI) plays a very important role since new skills and abilities are required at all levels: to design and adapt products and processes, to develop new business models and to modify the organization of work and processes. This paper analyzes Education 4.0 features, main components, and characteristics; adaptation of teaching and learning practices to changed requirements of Industry 4.0 for the successful implementation of the Open Innovation model. This paper systematically reviews a total of 48 WoS and Scopus studies, ultimately allowing us to determine components of Education 4.0 used in the framework of the OI model in recent years. Four research questions have been directed to data analysis. The results showed that (a) there is little literature research on issues related to important aspects in the dynamics of open innovation (partnerships, critical thinking, self-assessment, leadership, friendships, and risk-taking); (b) the main literature focuses on a comprehensive study of knowledge and skill parameters, application of appropriate strategies for their development, there are gaps in character development and meta-learning; (c) there is a noticeable lack of research on the competence framework of OI aimed at schoolchildren and the use of learning and teaching strategies to strengthen open educational innovations in schools; and d) there is a lack of research on development of OI competencies using cloud resources. This paper is intended for researchers, education and open innovation experts interested in the possibilities of educational technologies for the further dynamic development of the OI model.

Introduction

Effective innovation process solutions can be obtained through an open platform that includes a system of direct relations connecting youth, education, science, industry, and business. The "open innovation" model is one of the tools for organizing such interaction. In this case, the company relies not only on its own internal developments, but also actively attracts outside competencies and innovations. The concept of open innovation is based on the following notion: "If we make the best use of internal and external ideas, we will win." (Chesbrough, 2003).

OI model associates innovative development with training of personnel who meet modern business needs in the global market. We are not talking just new knowledge, but also development of project competencies and shaping readiness for professional activity under uncertainty. The main educational technologies associated with development of Education 4.0 and OI include development of a technological platform, cooperation of innovation system elements, open educational resources, and introduction of modern learning and teaching strategies. Development of the technology platform contributes to the spread of mobile learning. Based on development of special software, forms of distance learning are being introduced into the traditional educational process, and as a result of their interaction with traditional forms of education, mixed and flexible learning develops. Availability of technologies for students increases the role of self-education and

* Corresponding author.
E-mail address: Kurmanov_NA@enu.kz (N. Kurmanov).

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educational self-organization in online communities, promotes introduction of informal education elements into traditional educational process.

The need and ability to master new knowledge is the key competence of modern experts who will be working within the new industrial technologies. Education 4.0 infrastructure is developing independently of educational institutions, although requires active teacher participation in development of interdisciplinary educational content, development of an information and educational environment to achieve educational goals that meet the Industry 4.0 challenges.

A successful implementation of an Open Innovation model requires a clear understanding of Education 4.0 features, main components, and characteristics. It also requires adaptation of teaching practices to the changed requirements.

This paper focuses on determining components of Education 4.0 used in the framework of the OI model over the past five years and finding the learning and teaching strategy most appropriate for the development of future skills and abilities. Other previous studies have made a certain contribution to understanding the features and components of Education 4.0 in the structure of OI competencies. For instance, González-Pérez and Ramírez-Montoya (2022) focused on analyzing Education 4.0 components taken into account within the skills system of the 21st century, on identifying modern teaching and learning methods, and on identifying key stakeholders in the educational process. Ramírez-Montoya et al. (2022) analyzed integrated thinking as a new field of research within Education 4.0 and OI. This paper contributes to the study of five Education 4.0 components within OI competencies. To that end, firstly, components of Education 4.0 have been given a detailed description. Secondly, the method of systematic literature review have been proposed for analysis, which consists of five protocol stages and includes four research questions. This discussion is followed by results and data analysis, and ends with conclusions and practical recommendations.

Accordingly, Education 4.0 starts a very important, complex and open conversation about the key issue of modern society, that is how to modify education system to make it effective and responding to the demands of the rapid development of Industry 4.0 technologies and changes in thinking under the OI model's influence. Research focuses on the need for such a change at five following levels of thinking: (1) competencies, (2) learning and teaching strategies, (3) information and communication technologies, (4) infrastructure, and (5) stakeholders. It consequently offers a much-needed structure into which fundamental reforms in natural sciences, technology, engineering and mathematics (STEM) fit perfectly.

The paper is intended for researchers, education and open innovation experts interested in possibilities of educational technologies for further dynamic development of the OI model.

Materials and methods

Education 4.0 components

The paper discusses five main components of Education 4.0, which our research uses for a systematic literary review:

1. Competencies. Formation and development of desired transversal and disciplinary competencies among students and professionals.
2. Learning and teaching strategies. Learning and teaching strategies (technologies) proposed within the four-dimensional learning model by Center for Curriculum Redesign: knowledge, skills, character, meta-learning.
3. Information and communication technologies. Tools and platforms of information and communication technologies in educational process.
4. Infrastructure. Access to innovative educational infrastructure (platforms, software).
5. Stakeholders. Stimulating active cooperation between key stakeholders within the framework of triple helix models.

Competencies

Miranda et al. (2021) propose dividing competencies into two groups and their development in higher education system as part of Education 4.0:

1. Transverse competencies: Critical thinking, cooperation, collaboration, communication, creativity.
2. Disciplinary competencies: Training and development of functional, technical knowledge and skills of successful work; development of research and design skills through creation and implementation of new technologies; use of the latest technologies and best practices in technological solutions.

Podmetina et al. (2018) have compiled an open innovation expert's profile that includes knowledge about the ecosystem, outgoing, incoming, external and internal cooperation processes. In addition, an open innovation expert needs a number of intrapersonal competencies, such as leadership and entrepreneurial skills, creativity, and risk-taking.

McPhillips et al. (2022) have compiled a competence profile of open innovation in the context of a cluster ecosystem, including creativity, entrepreneurship, communication and networking, open-minded thinking, risk-taking, and self-efficacy in digital skills.

In our study, we used a four-dimensional learning model by Center for Curriculum Redesign (CCR) that includes the following:

(1) Knowledge. First and foremost, basic knowledge and skills that help address everyday tasks: reading and writing skills, mathematical and financial literacy, natural science knowledge, information and computer, cultural and civic literacy. This includes traditional subjects, e.g., mathematics; new subjects, e.g., entrepreneurship; interdisciplinarity.
(2) Skills. Creativity and critical thinking, sociability (ability to communicate) and collaborativeness (ability to work in a team).
(3) Character. One of important aspects is the need for personal growth that forms character traits that help overcome environmental changes more effectively: curiosity and perseverance, initiative and self-regulation, flexibility and adaptability, leadership and responsibility, citizenship and cultural awareness.
(4) Meta-learning. The ability to learn or how people comprehend and adapt to learning. It is based on metacognitive activity, the ability to think strategically, planning, monitoring, and evaluating personal progress, as well as the desire to learn. Meta-learning can be viewed from three perspectives. First, students need to be shown how to master more. Secondly, students need to know how to increase the effectiveness of their learning. Thirdly, they need to be shown how to become the best students. The first step to self-acquisition of knowledge is formation of personal cognitive strategy. Next up is understanding key brain mechanisms, that is, basics of neurodidactics.

In this regard, the main task of education is to train competent people able to apply their knowledge and skills in changing conditions, whose main competence would be the ability to engage in constant self-learning throughout their lives.

Learning and teaching strategies

Today's world is changing rapidly, all aspects of life get digitalized. The key competence required now to adapt to the new world is digital skills and abilities. Questions related to them are questions of the multitude of interactions possible between people and data. Understanding the existing methods of teaching and teaching digital skills, digital transformation, knowledge of the stages of its formation will allow building an effective educational strategy.

Table 1
Teaching and Learning Strategies and Technologies.

Strategies	Technologies	Description
Knowledge application strategy	Project technology Case technologyModule technology	These strategy and technologies aim at increasing the interest of students in applying knowledge in specific situations
Skills development strategy	Critical thinking development TechnologyGroup technologiesPedagogy of cooperation	Group training and pedagogy of cooperation are effective tools in achieving a high level of knowledge and developing basic qualities for personal and professional development. These are also effective in developing creativity, critical thinking, and sociability
Strategy for successfully coping environmental change	Technology of problem-based learningGaming technologies	This strategy aims at formation of character traits that help overcome environmental changes more effectively: curiosity and perseverance, initiative and self-regulation, flexibility and adaptability, leadership and responsibility, citizenship and cultural awareness
Strategy for the development of metacognitive activity	Technology of creative workshopsMeta-learningTechnology of developmental education	These strategies include understanding, creativity, professional self-perception, the ability to think strategically, reflective observation, decision-making, power to communicate, social commitment, ability to offer improvements, etc.
Strategy for the development of digital competencies	E-learningMobile educationOpen educational resources	Digital competencies include a communication component as a set of user skills for using services and cultural offerings supported by computers and distributed online, and an information component that focuses on key aspects of a knowledge-based society: ability to optimally find, receive, select, process, transmit, create, and use digital information

In the course of the research, we analyzed the best practices of introducing methods of teaching and learning digital competencies in educational processes. Our study uses learning and teaching strategies (technologies) proposed within four-dimensional learning model by Center for Curriculum Redesign (CCR) adapted for formation and development of competencies for OI (Table 1).

Information and communication technologies

The use of information and communication technologies in educational process (introduction of new information technologies) is an attempt to offer one of the ways to intensify educational process, optimize it, raise interest of students in studying the subject, implement ideas of developmental education, increase the pace of lesson, increase the amount of independent work. It promotes development of logical thinking, culture of intellectual work, formation of independent work skills, and also significantly affects motivational sphere of the educational process.

Our study analyzes the tools and platforms of information and communication technologies in educational process divided into two groups:

(1) Synchronous learning, when interaction between teacher and student, as well as students among each other (group training) occurs “here and now” as in live. For example, a webinar in M-Teams, ZOOM, and Webex with answers to questions from listeners live, a synchronous training.

(2) Asynchronous learning, when such interaction is separated in time. For example, viewing a recording of the same webinar with the option of sending questions to the teacher and getting answers after some time, an asynchronous format.

Infrastructure

Training personnel for OI, as far as material and technical equipment goes, requires the following: Educational and laboratory buildings and structures and other specialized premises in operable and good working condition; access to modern equipment and software necessary for the educational process; accessibility of the environment for teaching children with special needs.

Online learning mechanisms offer flexible educational paradigms at any time and in any place, thus allowing universities to overcome infrastructural constraints by using their educational resources on a wide audience using technological channels. Students can use technological learning tools in various ways.

The tool used to develop personality-oriented Education 4.0 technology is, among other things, public web services built on the basis of social software and cloud technologies. Web services, along with the internal resources of an educational organization, are an effective mechanism for the development of an electronic information and educational environment. Web resources are becoming one of the important tools of students’ learning activities; their use contributes to formation of key competencies in accordance with new generation of educational standards. Students actively use web services to address educational tasks and for self-education, thus forming a mobile, person-oriented educational environment.

Education market is influenced by such open learning resources as MOOCs (massive open online courses). Innovative and interactive teaching methods have led to demand for MOOCs and the MOOC market is estimated to have grown fivefold from 2015 to 2020. Universities use MOOCs to develop personalized educational trajectories in the development of their programs, while simultaneously developing industry connections for learning in practice and to reduce costs. Being initially an additional learning resource for expanding the understanding of the subject of individual disciplines, MOOCs are now turning into independent learning platforms with clearly defined program paths. The range of features and experiences that were once free of charge has shrunk dramatically in recent years, which raises the question of how “open” MOOCs really are. From the point of course providers’ view, simultaneous availability to thousands of students is no longer an advantage. There has been a definitive shift in focusing on “professional” students who take these courses to achieve career-related results, and on amateurs attending the courses out of pure curiosity. MOOCs cannot compete with universities, but can be used as a branding and student marketing tool. Universities can offer MOOCs to provide potential students with their educational experience and promote their best courses and the best teachers, thus attracting students to their full-time courses.

Improvement of staff training opportunities has led to increased company investment in e-learning. Companies realize the benefits of online training for professional development and, consequently, spend more and more on their employees’ e-learning. For instance, SAP has developed the openSAP MOOC platform for training its employees and SAP technology experts.

In our research, we investigate application of Education 4.0 generation of infrastructure software:

- Social software,
- Cloud resources,
- MOOCs, and
- Professional software.

Stakeholders

Students, teachers and professionals are the main stakeholders in Education 4.0, each of whom has different perspectives for competency development.

The teacher's role changes from the lecturer role to that of a facilitator, a coach, and a mentor. Classrooms designed to have a teacher at the front may now require technical support for an environment in which students work independently on their personal devices and interact with each other in collaborative projects. Classrooms become places where knowledge and ideas are generated as a result of collaboration and debate with the teacher acting as an intermediary.

Digital technologies allow teachers to create more interactive, engaging and flexible learning materials in various digital and multimedia formats and make them available to students online. These changes provide educators with a more diverse set of pedagogical approaches to support learning, which means they can be more inclusive in their teaching methods.

The possibilities of some popular web services in organization of educational process are discussed in the works by Soegoto et al. (2020); Sagayaraj and Santhoshkumar (2020). Using web resources allows creation of a virtual platform for storing and modernizing educational content, organizing cooperation with students, developing a personally oriented electronic educational environment for each student, creates conditions for self-education.

The need and ability to master new knowledge is the key competence for modern experts who are to work with new industrial technologies. The Education 4.0 infrastructure is developing independently from educational institutions, although requires active participation of teachers in development of interdisciplinary educational content, development of an information and educational environment to achieve educational goals that meet the challenges of Industry 4.0.

Systematic research review

A systematic review of studies on a specific scientific topic in economics is an independent scientific study itself. Its mandatory components are generalization and critical analysis. A systematic review uses precise systematic methods to compare and summarize results of studies devoted to a clearly formulated question (a specific topic). This distinguishes a systematic review from a literature review, an unsystematic, quite widely represented and even prevailing at present in the scientific literature.

Among many other reasons for turning specifically to systematic review as a type of research, one can note the need to find an answer to the question in the case when individual studies cannot provide one. Systematic review in economics is used, for instance, to identify associations between any phenomena, events, as well as to assess the effectiveness of interventions in economic process.

The methodology of a systematic review dictates the need to comply with the principles of transparency and completeness of the search undertaken and presentation of its results. A description of the review creation is recommended to be as complete as to allow another researcher, using the described algorithm, to obtain similar results. A systematic review's key questions are as follows: "Why was it done?", "What was done by the researchers?", and "What results were obtained?".

Research questions

To analyze the components of Education 4.0 in the competence structure of open innovation, four research questions were set, as shown in Table 2.

Search process

A systematic review of research results was conducted according to the PRISMA 2020 criteria.

In 2020, requirements for systematic review and presenting its results were updated. A detailed description of an updated systematic review methodology is presented in the PRISMA 2020 protocol (PRISMA stands for The Preferred Reporting Items for Systematic reviews and Meta-Analyses). This manual defines an algorithm for creating a systematic review in accordance with a checklist of 27 control points with their detailed descriptions and examples of their accounting/compliance both when creating a review and its qualitative assessment. For convenience, creators of the updated version of PRISMA 2020 offer convenient online forms (https://www.prisma-statement.org/PRISMAStatement/Checklist), which can be filled in when creating a systematic review and meta-analysis, checking completeness and accuracy of the latter and ensuring uniformity of the format for presenting the results.

Table 2
Research Topics and Questions (RQ) (Self-Developed).

Themes	Research Questions (RQ)	Possible Answers Based on Literature
Characteristics of the published articles of the OI competence structures	RQ1. How many studies Scopus and WoS have accumulated over the past five years and what direction do they take? RQ2. How are research keywords related?	Article IDs and direct links.Number of Scopus and WoS articles from 2018 to 2023?
Characteristics of Education 4.0 components in the OI competence structure	RQ3. What are the core competencies of Education 4.0 that the main stakeholders should have?	Knowledge, skills, character, and meta-learning (Fadel and Groff, 2019) - Students, - Teachers, - - Professionals (self-developed)
	RQ4. What strategies and what information and communication technologies or infrastructure are used to develop Education 4.0 competencies?	Knowledge application strategySkills development strategyStrategy for successfully coping with environmental changeStrategy for the development of metacognitive activityStrategy for the development of digital competencies (self-developed) - Synchronous learning, - Asynchronous learning (Ramírez-Montoya et al., 2022). - Social software, - Cloud resources, - MOOS, - - Professional software (self-developed)

Table 3
Search Strings Used in Databases.

Web of Science (WoS)	Scopus
(TS = ("Open Innovation" AND (competence) AND (Frameworks)))	(TITLE-ABS-KEY ("Open Innovation" AND Competence) AND (Frameworks))

Web of Science and Scopus served as a publication search bases. Here and throughout the text of the paper, generalized name "databases" will be used.

The following keywords were used to search for information in databases: Open innovation, Competence, Frameworks. Table 3 shows the search strings in the databases.

Inclusion and exclusion criteria

Competencies, skills and abilities for open innovation have been analyzed in the context of the broader field of "open innovation." It is these keywords that form the competence model in open innovation. To increase efficiency of keyword search, we used AND operators (the totality of all keywords).

Inclusion criteria stipulated that the title, abstract, or keywords of scientific publications shall contain the words "competence" and "open innovation." These words were used only as the main search terms without determining whether the OI model was intentionally and/or directly considered as a problem in the articles. Conditions for excluding articles for analysis were the time period of our study, which is five years starting from 2018.

Data selection and extraction process

Fig. 1 shows a step-by-step algorithm for finding studies corresponding to the topic of the review.

Databases would be searched for papers, then data would be extracted. Later on, the data would be entered into the Excel database. As a result of the search, 59 studies were found: 14 in WoS and 45 in Scopus. Data extracted from each paper included the author(s), publication title, abstract, keywords, database, publication year, journal title, and DOI number.

Based on these data, seven duplicate articles have been identified. These were excluded from the Excel database to avoid duplication. As a result, we took 52 articles. After selection according by the inclusion criterion (the title, abstract, or keywords of scientific publications need to contain the words "competence" and "open innovation"), 48 articles were selected for systematic review. Figure 1 shows the differentiation based on the PRISMA method.

Results

RQ1. *How many studies Scopus and WoS have accumulated over the past five years and what direction do they take?*

We have analyzed journals and their publication years (see Figure 2, Appendix Tables A1, A2).

The analyzed papers were published between 2018 and 2023. Of these, the major portion was published in 2021 and 2022, 12 publications each, followed by eight papers in 2018 and 2020. Then, seven articles in 2019 and one article in 2023 whose topic matches ours.

Most of articles on research topic were published in the following journals: Sustainability (5), Journal of Open Innovation: Technology, Market, and Complexity (3), Technological Forecasting and Social Change (3). Only one publication was identified in a different journal.

All the analyzed papers analyze OI competencies. In this vein, Zhang et al. (2023) explores the role of organizational learning and knowledge management capabilities in mediating between sustainable competitive advantage and open innovation. McPhillips et al. (2022) researches individual competencies that promote knowledge exchange in OI projects. David et al. (2022) focuses on the role of social capital and network competence in high-tech SMEs' OI. Liao and Tsai (2019) reveal the constraining role of technological competencies of innovative openness of enterprises. Podmetina et al. (2018) develops a competence model for open innovation.

Bagno and Freitas (2022); McPhillips et al., 2021; Dvoryatkina et al. (2021); Kovaliuk and Kobets (2021); Papageorgiou et al. (2021); Chung et al. (2021); Charosky Larrieu-Let, Bragós Bardia (2021); Iglesias-Sánchez, et al., 2021; Fernandez-Diaz et al. (2020); Costa (2020); Cortés et al. (2022); Gutiérrez et al., 2018 explore formation and development of students' competence for open innovation.

Kaisle and Grill, 2022; Luhgiatno and Dwiatmadja (2020); Roša and Lace (2018) discuss creation of open innovative competency models reflecting relationships between relevant forms, typesm and technologies of training.

To create additional value in an open innovation context, entities need to expand their organizational boundaries. This requires an increase in the level of knowledge and ensuring its exchange with a wide range of interested parties (Hernández-Dionis et al., 2022; Kurniawati et al., 2022; Filiou, 2021; Zobel and Hagedoorn, 2020; Pohlisch, 2020; Behnam and Cagliano, 2019; Beuter Júnior et al., 2019; Myhren et al., 2018; Osarenkhoe and Fjellström, 2018).

Digital transformation of the modern world is a key driver of the development of open innovations for collection and transfer of knowledge both inside and outside the company. This is noted in the works by Liu et al. (2022); Nasullaev et al. (2020); Behnam et al. (2018); Thanasopon et al. (2018).

Mikelsone et al. (2022); Cirule et al. (2022); Keinz and Marhold (2021); Yang and Fang (2018) explore competencies required for company development through promotion of open innovative technologies.

A cross-border mechanism for the search and integration of knowledge, building the company's capacity for open innovation is in the focus of Meyer et al. (2021); Gao et al. (2021).

Cabigiosu (2022); Abdulmuhsin and Tarhini (2022); Olubajo et al. (2022), Beretta et al. (2021); Prendes-Espinosa et al. (2021); Ahn et al. (2020); Vidmar (2019); Meissner and Shmatko (2019); Pranciulytė-Bagdžiūnienė and Petraitė (2019) focus on issues of promoting development of individual competencies to increase innovative efficiency of companies and development of opportunities for open innovation in creation of new organizational processes.

RQ2. *How are research keywords related?*

Figure 3 shows keywords the study analyzes papers for.

The most common keywords found in the articles were Open Innovation, Performance, Management, and Knowledge followed by the words Innovation Management and Impact.

Open Innovation cluster unites groups of competencies related to development of creative thinking, collaboration, cooperation, and formation of an innovation ecosystem. Among other things, Open Innovation cluster includes issues of coordinating efforts of various participants in innovation process through open laboratories, organizing hackathons and business incubators.

One of the studies identified structure of open innovation competencies for a promising workforce, including creativity, entrepreneurship, and cooperation competence groups (McPhillips and Licznerska, 2021). Another study developed a competence model for open innovation consisting of three groups: professional, interpersonal, and intrapersonal competencies (Podmetina et al., 2018). The authors develop a general model of OI competencies applicable in different

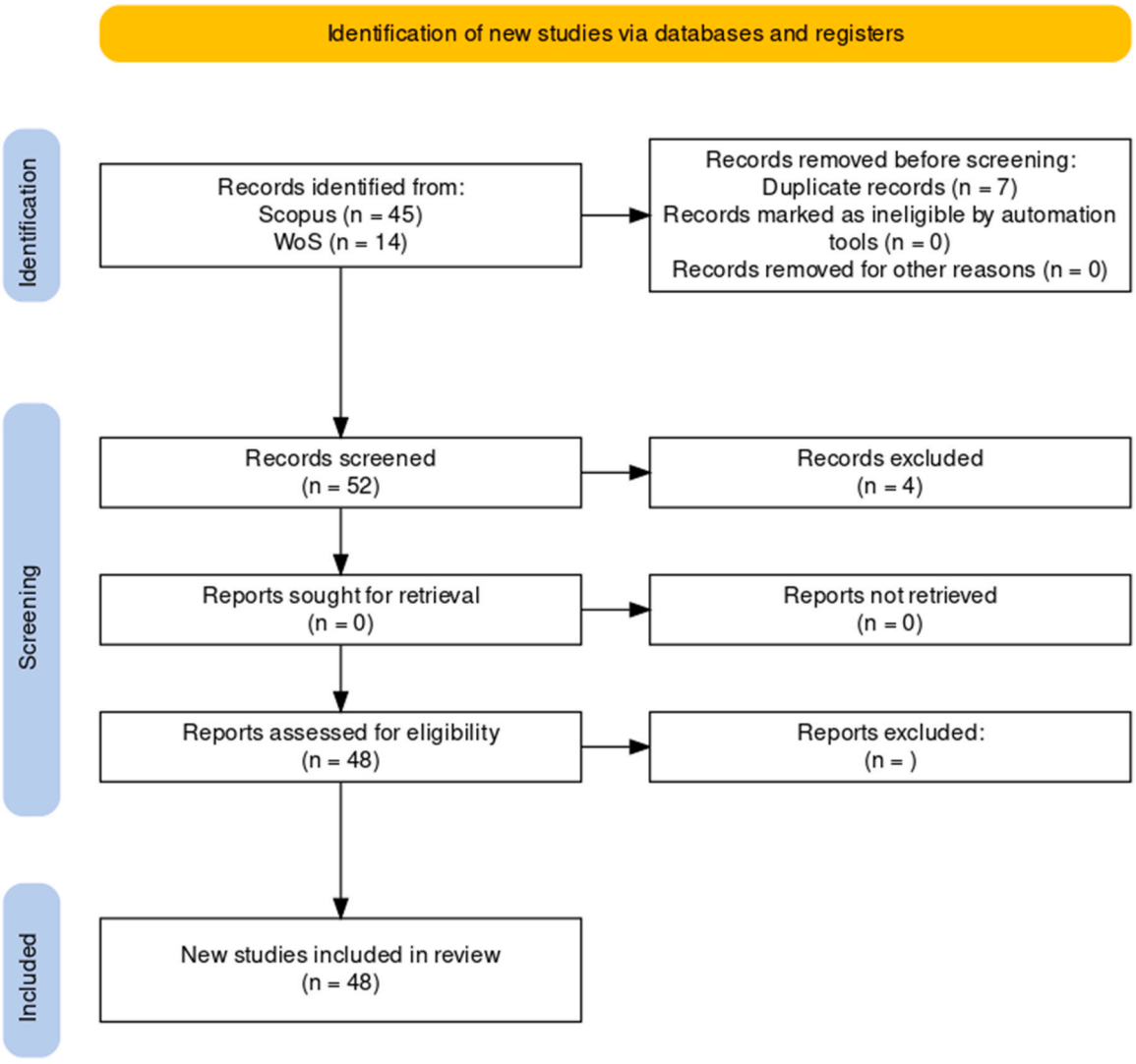

Fig. 1. Selection Process (PRISMA Based on Page et al., 2021).

industries. Podmetina et al., 2018 base clusters of competencies on empirical analysis addressing various OI issues and subsequently develop recommendations for competence management in the context of OI.

Mikelsone et al. (2022) highlight which competencies require stimulation for successful application of networked idea management systems. The authors note that organizations need to stimulate both common organizational competencies and technology management

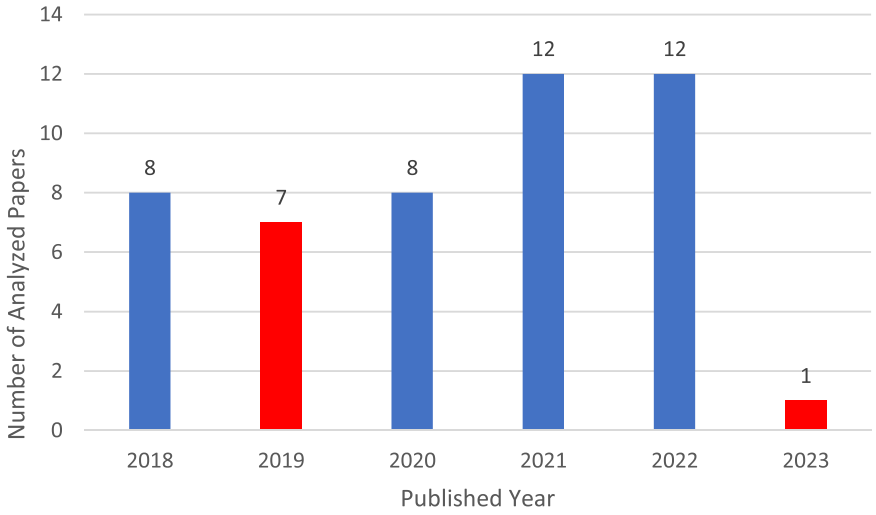

Fig. 2. Analyzed Papers by Year.

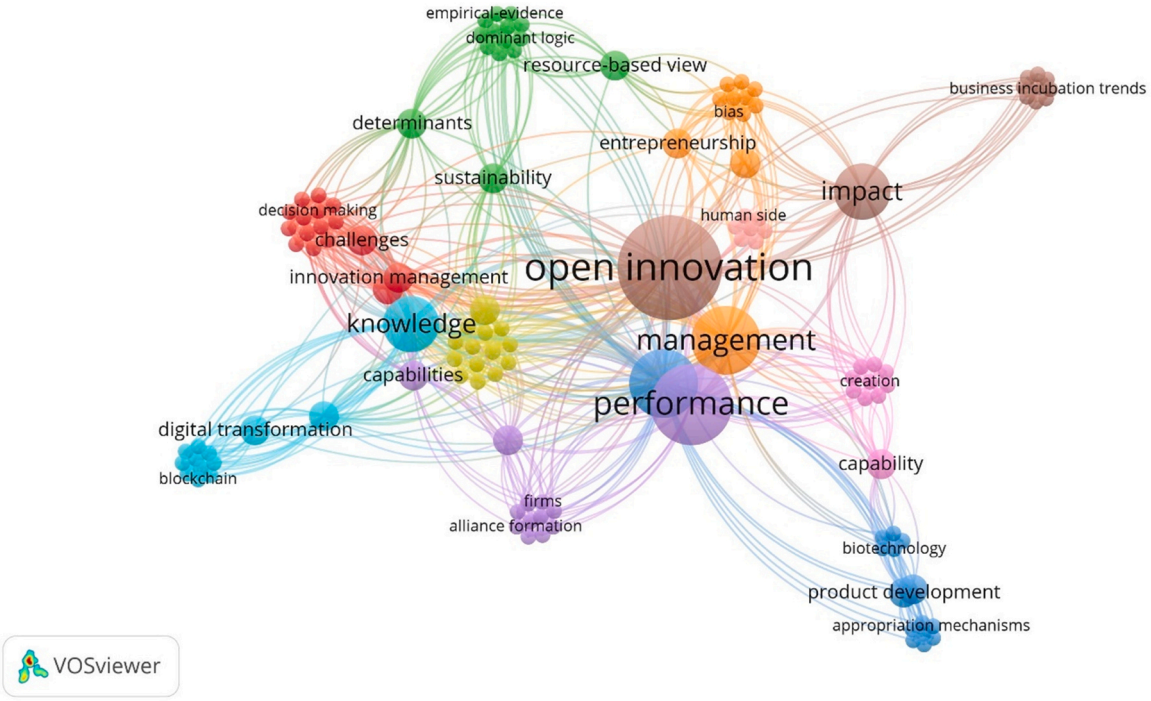

Fig. 3. Research keywords and their relations

competencies. They count analytical, communicative, social, and monitoring competencies as general organizational ones. From the point of technology management, the structure of OI competencies has to include process competencies, project competencies, system competencies, and operational system competencies. Abdulmuhsin and Tarhini (2022) take an interesting approach of concluding that for the successful implementation of the OI model, managers of family enterprises need to encourage wise, intelligent, well-informed, and strong leaders who promote change.

Pranciulytė-Bagdžiūnienė and Petraitė (2019) highlight organizational skills in OI, such as openness of organizational culture, organizational learning and trust, and knowledge management system. The authors believe them to be strong organizational tools that help increase the OI efficiency. They also distinguish individual competencies (employee creativity, partnership) and managerial competencies (flexibility, ability to work with various professional communities, strategic thinking) in the structure of OI competencies.

We conducted a content analysis of keywords to identify competencies most related to OI (see Table 4).

In general, content analysis of keywords has revealed the most significant competencies for OI: collaboration (13 references), digital skills (12 references), cooperation (7 references), Innovation behavior (7 references), knowledge creation and transfer (6 references), communication (5 references), creativity, entrepreneurial, technology competence 4 references in 48 analyzed papers. One can notice that despite the greater coverage of publications, there is little research into issues related to important aspects in the dynamics of open innovation: partnerships, critical thinking, self-assessment, leadership, friendships, and risk-taking.

RQ3. *What are the core competencies of Education 4.0 that the main stakeholders should have?*

RQ4. *What strategies and what information and communication technologies or infrastructure are used to develop Education 4.0 competencies?*

The González-Pérez and Ramírez-Montoya (2022) paper analyzes Education 4.0 components in the 21st century skills system and

Table 4
Keywords Defining the Structure of OI Competencies.

Competency	Number of References	Paper ID
Collaboration	13	A8, A17, A18, A21, A23, A26, A27, A29, A30, A35, A41, A44, A47
Digital skills	12	A1, A9, A12, A19, A22, A28, A31, A32, A33, A37, A46, A48
Cooperation	7	A2, A10, A12, A15, A44, A45, A47
Innovation behavior	7	A7, A24, A36, A39, A40, A42, A43
Knowledge creation and transfer	6	A5, A6, A13, A16, A21, A24
Communication	5	A1, A3, A7, A17, A24
Creativity	4	A1, A2, A8, A17, A45
Entrepreneurial	4	A1, A2, A17, A38
Technology competence	4	A4, A11, A14, A18
Partnerships	3	A20, A23, A26
Critical thinking	2	A1, A17
Self-assessment	2	A1, A34
Leadership	1	A25
Friendships	1	A25
Risk-taking	1	A1

identifies key stakeholders in this process, as well as teaching and learning methods. The authors determine teaching and learning strategies contained in the structure of Education 4.0 components and target stakeholders. Their study reveals the lack of competence frameworks for teachers and school students. González-Pérez and Ramírez-Montoya (2022) note that most modern research focuses on the development of students' competencies through aspects of character, meta-learning and application of active learning strategies.

Ramírez-Montoya et al. (2022) analyze components of Education 4.0 and the structure of OI competencies. They mainly focus on studying complex thinking as a macrocompetence with sub-competencies of critical, systemic, scientific, and innovative thinking in educational environment. Results of their research has shown the following: (a) there are common characteristics of studies linking complex thinking, critical thinking, and creative thinking; b) most studies apply qualitative method; (c) critical thinking competence is the most studied one; (d) teaching methods and techniques are the predominant components of Education 4.0; and (e) three key education issues are identified, namely, project feasibility, research opportunities, and required skills.

Miranda et al. (2021) describe and display components of Education 4.0 in accordance with the periods of four industrial revolutions. The authors describe in detail the four main components of Education 4.0, which, they believe, will be used as a guideline for new educational innovation projects: (1) competencies, (2) teaching methods, (3) information and communication technologies, and (4) infrastructure. Researchers conducted three case studies applied to engineering education. Results of the study illustrate how the proposed components of Education 4.0 should be considered when developing educational programs.

Digitalization is altering values and fields of activity of existing industries (McPhillips and Licznerska, 2021; Fernandez-Diaz et al., 2020; Prendes-Espinosa et al., 2021; Pohlisch, 2020). Technological advances brought about by Industry 4.0 are developing at an incredibly rapid pace, change our ways, how we work and function in society. Artificial intelligence, robotics, Big Data and the Internet of Things together affect the labor market and economy as a whole. Future employees have to be well trained not only in the new technologies themselves, but, no less importantly, in the values associated with the use of these technologies, and need qualities such as creativity, flexibility, and adaptability. Taking full advantage of the opportunities offered by advanced technologies requires a similar revolution in education for the successful training of experts with new necessary competencies. These factors are reflected in studies exploring the role of education in the dynamics of OI and Industry 4.0. McPhillips et al. (2022); Kovaliuk and Kobets (2021) note that digital evolution gave rise to a new educational model Education 4.0, which was developed in response to Industry 4.0.

Figure 4 shows the four-dimensional learning model by Center for Curriculum Redesign (Skills, Knowledge, Character, and Meta-Learning). The most commonly used ones are Skills (36 studies, Paper IDs: A1, A2, A4, A7, A8, A9, A10, A12, A14, A17, A18, A19, A20, A21, A22, A23, A24, A25, A26, A27, A28, A29, A30, A31, A32, A33, A35, A37, A38, A39, A41, A44, A45, A46, A47, A48) and Knowledge (12 studies, Paper IDs: A3, A5, A6, A10, A11, A13, A15, A16, A24, A28, A37, A45). Used least of all are Character (6 studies, Paper IDs: A25, A36, A40, A41, A42, A43) and Meta-Learning (5 studies, Paper IDs: A17, A27, A34, A38, A43). It is noteworthy that the main stakeholders identified within OI competencies are professionals, not students, teachers, or training partners.

Table 5 shows strategies for teaching and learning OI competencies within Education 4.0, as well as infrastructure used for their development. Most of the studies are focused on Skills Development Strategy (23, Paper IDs: A1, A2, A4, A7, A8, A10, A12, A17, A20, A21, A22, A23, A24, A26, A27, A29, A30, A35, A38, A39, A41, A44, A45, A47). Concurrently, the following infrastructure is used: Social Software (14) and Professional Software (9). This is followed by a Strategy for the Development of Digital Competencies (12, Paper IDs: A9, A11, A14, A18, A19, A22, A28, A31, A32, A33, A46, A48) using Social Software (6) and Professional Software (4) and MOOS (2). A small number of studies are focused on a Strategy for Successfully Coping with Environmental Change (5, Paper IDs: A25, A36, A40, A42, A43) and a Strategy for the Development of Metacognitive Activity (1, Paper ID: A34). It is interesting to note the lack of research on development of OI competencies using cloud resources.

Figure 5 shows Strategies for Teaching and Learning OI Competencies within Education 4.0, and information and communication technologies used for their development. Both synchronous learning (27 papers) and asynchronous learning (22 papers) are the most commonly used ones. It is worth noting that synchronous learning is mainly used for implementing the Strategy for Successfully Coping with Environmental Change and the Strategy for the Development of Metacognitive Activity, and asynchronous learning is used for implementing the Strategy for the Development of Digital Competencies. Also, the analysis revealed that synchronous learning is the most suitable for the development of OI skills, and both methods are great for implementing the Knowledge Application Strategy.

In the analyzed papers, the Strategy for the Development of Digital Competencies contributes to understanding individual competencies aimed at the future needs of OI companies required in the context of digital transformation.

It is interesting to note the lack of research on the main Education 4.0 components within OI competencies in school education and at the vocational training level.

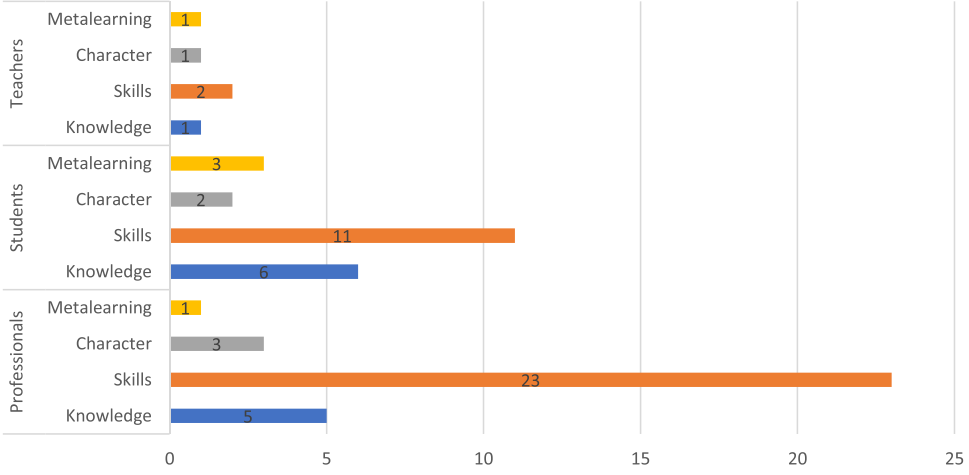

Fig. 4. Stakeholders and Education 4.0 Competencies.

Table 5
Strategies for Teaching and Learning OI Competencies within Education 4.0 and Infrastructure.

Dimensions	Knowledge	Skills	Character	Metalearning
A Strategy for Successfully Coping with Environmental Change			5	
Social Software			5	
Knowledge Application Strategy	6			
MOOS	1			
Professional Software	1			
Social Software	4			
Skills Development Strategy		23		
Professional Software		9		
Social Software		14		
Strategy for the Development of Digital Competencies	1	12		
MOOS		2		
Professional Software	1	4		
Social Software		6		
Strategy for the Development of Metacognitive Activity				1
Social Software				1
Total	7	35	5	1

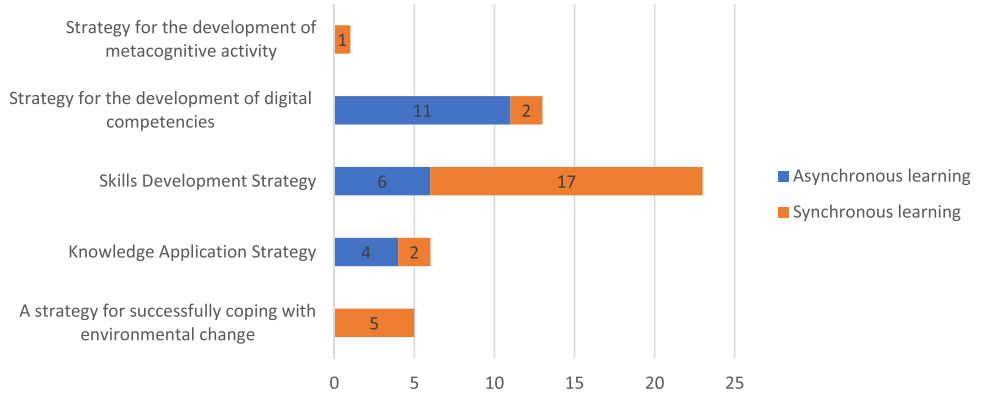

Fig. 5. Strategies for Teaching and Learning OI Competencies within Education 4.0 and Information and Communication Technologies.

Discussion

This paper provides a systematic review of 48 WoS and Scopus studies, which allowed us to determine Education 4.0 components that have been used in the OI model in recent years. In general, the studied papers present successful OI competency development cases at the student, teaching, and professional levels. Papers apply various learning and teaching strategies using both synchronous and asynchronous tools and platforms of information and communication technologies in educational process. Directions of development of student, teacher, and professional competencies are explored using the Education 4.0 generation infrastructure software: social software, MOOS, and professional software.

Industry 4.0 is transforming the world of labor in a sustainable way. Increasing network connections, flexibility, and complexity of innovation processes impose new requirements on qualifications of both companies and their employees. Moreover, Industry 4.0 is also changing the structures and forms of organization in enterprises and workplace designs. A successful qualification for Industry 4.0 cannot be obtained solely through “traditional” training and advanced training formats, such as full-time training in the classical Bachelor’s and Master’s degree system. To successfully address the problem of providing a developing economy with highly qualified specialists, a modern educational institution must activate all its activity areas: science, education, especially management system. This implies timely and complete provision of educational institutions with all necessary resources that would meet the realities of modern society. The issue of adapting education to market requirements can be addressed from the point of view of introducing open innovations into all components of Education 4.0.

Research analysis has revealed gaps in formulation of new competencies for OI, in application of learning and teaching strategies, in using information and communication technologies and infrastructure in competency development.

We have identified the most significant competencies for OI: collaboration, digital skills, cooperation, innovation behavior, knowledge creation and transfer, communication, creativity, entrepreneurial, and technology competence. In this regard, our results correlate with McPhillips et al. (2022); Podmetina et al. (2018). One could also notice the fact that despite the greater publication coverage, there is little research on issues related to important aspects in open innovation dynamics: partnerships, critical thinking, self-assessment, leadership, friendships, and risk-taking. Although creation of open innovation partnerships plays an important role in improving innovation and quality. (Du et al., 2014). Ramírez-Montoya, 2022; Gajdzik and Wolniak (2022) believe critical thinking to be responsible for independent obtaining of new knowledge, its systematic organization and a conscious process of choosing between available alternatives, which directly reflects the set of key competencies an “innovative person” should possess. Self-esteem, as an important personality feature, affects the decision-making process in innovation (Millers and Gaile-Sarkane, 2021; Meijer, 2019), on relationships with others, on mental health. Meanwhile, leadership has a significant positive indirect impact on stimulating open innovation through establishment of friendly workplace relationships (Abdulmuhsin and Tarhini, 2022).

In open innovation model, we need to resort to introducing technical innovations and bold, non-trivial actions, and this increases the risk (Lendowski et al., 2022). Therefore, we need not to avoid, but to be able to accept risk, assess its degree and manage it.

A systematic review has revealed a minimal number of papers focusing on character development and meta-learning. According to researchers (Joshi et al., 2022), meta-awareness and growth mindset support well-being since all aspects of meta-learning directly affect a person's well-being and self-perception. By setting personal goals, believing in oneself and trying to live a thoughtful life, a person can better understand and formulate their sense of purpose and direction. The qualities in the modern world's demand are as follows: awareness, curiosity, determination, resilience, ethicality, and leadership (Kunat et al., 2019; Li et al., 2022). We believe that for starters, we need to highlight formation of character traits that can potentially be associated with higher educational results in literacy as there is a positive correlation between mindfulness, intrinsic motivation, interest, perseverance and success in both reading and writing.

We would like to note that the main stakeholders identified within OI competencies are professionals, not students, teachers, or training partners. We find interesting the lack of research on main Education 4.0 components within OI competencies in school education and at the vocational training level. Among key players on the path of knowledge development in Industry 4.0, we can single out providers of educational services operating within the group or in the market. Although classical educational institutions, schools, and universities need to master Industry 4.0 qualifications as well. School and college education gives a decisive impetus to development of competencies in Industry 4.0. This calls for the existing curricula to be adapted to Industry 4.0 standard requirements and (or) curriculum adjustments. In this context, data analysis and evaluation, work with digital networks, development of innovative business models or system engineering appear important for both Education 4.0 and OI model. In the sense of interdisciplinary thinking and action, the main goal is to transfer crucial competencies and knowledge for Industry 4.0 beyond disciplinary boundaries as well, e.g., by providing engineers of tomorrow with additional skills in school and college.

It is interesting to note the lack of research on OI competency development using cloud resources. Their use opens up many opportunities in teacher's professional activity, expands student's tools. Students master new applications intuitively. Certainly, using mobile devices for learning purposes has a special appeal for students (Alam, 2022). With their help, students can be interested in an unusual material presentation, joint work could be organized, access to educational materials and remote work with them could be provided.

Conclusion

Digitalization is changing values and fields of activity in existing industries. Technological advances caused by Industry 4.0 are developing at an incredibly fast pace, changing the way we live, work and function in society. Artificial intelligence, robotics, Big Data and the Internet of Things have a combined impact on the labor market and the economy as a whole. Future employees must be proficient not only in new technologies themselves, but, equally importantly, in values associated with the use of these technologies. Qualities such as creativity, flexibility, and adaptability are a must as well. Taking full advantage of opportunities offered by advanced technologies requires a similar revolution in education for the successful training of specialists with new necessary competencies.

This research focuses on analysis of Education 4.0 components over the past five years, which are applied within OI model. A systematic paper review shows that (a) literature mainly emphasizes on the study of competencies important for OI, such as collaboration, digital skills, cooperation, innovation behavior, knowledge creation and transfer, communication, creativity, entrepreneurial, and technology competence. However, there is little research on issues related to important aspects in the dynamics of open innovation: partnerships, critical thinking, self-assessment, leadership, friendships, and risk-taking; (b) main literature is focused on a comprehensive study of knowledge and skill parameters, on application of appropriate strategies for their development. There are gaps in research on character development and meta-learning; (c) there is a noticeable lack of research on OI competence framework aimed at schoolchildren and application of learning and teaching strategies to strengthen open educational innovations in schools; d) there is a lack of research on development of OI competencies using cloud resources.

Education systems around the world are increasingly recognizing the need to teach their students a new set of competencies that go beyond traditional disciplines. To be successful in their studies, life, and work, students must master 21st century skills, such as creativity and critical thinking; socio-emotional learning characteristics, such as curiosity and resilience; and meta-learning abilities often described as ability to learn.

As practical recommendations for educational institutions go, we offer the following:

1. Form learning competencies in a digital format. Digital learning formats and methods provide companies and employees with important access to knowledge on opportunities and challenges of Industry 4.0. They can or should be selectively combined with classical forms of learning, e.g., in a sense of blended learning. It is important to develop demand-oriented, self-oriented informal and formal courses. Innovative teaching and learning solutions offer new opportunities for purposeful, individual development of competencies and support of employees with the help of assistance systems. Proposals for initial and continuing education must be flexibly adapted to different stages of life and training of employees.
2. Develop framework conditions for achieving the desired qualifications. A sound analysis of educational achievements and levels of competence of schools, universities, and other educational institutions is the basis for a more detailed determination of decisive competencies in OI model, as well as for the development of successful learning and teaching strategies. It is extremely important to involve all relevant actors at all levels: national, regional, and corporate – all in a timely manner. Institutionalization of the system of continuing education creates conditions for individualized, open, and continuous learning. Orientation of training and professional development system is of great importance here.
3. Adapt the education system to future requirements. Preparing students for participation in the Industry 4.0 project requires schools and universities to teach working with software products and digitalization. Within the framework of the dual education system, training in vocational schools and enterprises must be synchronized with technological changes. Prerequisites for this are targeted training and advanced training of teachers, as well as adaptation of training courses. In general, initial and continuing professional training for Industry 4.0 must focus on the company level.

The value of the research consists in identification of trends in OI competencies for students, teachers, professionals, and decision makers interested in development of open educational innovations. Results confirm the need for further study of competencies in the context of dynamic process of the OI concept development and open educational innovations. Further research may focus on the following aspects:

(a) A detailed and complete study of such important competencies as partnerships, critical thinking, self-assessment, leadership, friendships, and risk-taking in the dynamics of open innovation,
(b) Implementation of a meta-learning approach and open innovation experts' character development,
(c) Formation and development of the OI competence framework in schools and vocational educational institutions, and/or
(d) d) Research of the use of educational cloud resources in OI competency development.

Institutional review board statement

Not applicable.

Informed consent statement

Informed consent was obtained from all subjects involved in the study.

Author contribution

Conceptualization, N.K.; Methodology, N.K., A.N. and A.U.; Formal analysis B.R.; Investigation N.A.; Resources Zh.U.; Data curation S.K.; Writing – original draft N.K.; writing – review and editing, N.K., A.U., N.A., B.R., D.M., Zh.U., and A.N.; funding acquisition A.N., S.K., and D.M. All authors have read and agreed to the published version of the manuscript.

Appendix

Funding

Not applicable.

Data Availability

The data presented in this study are available on request from the corresponding author.

Declaration of Competing Interest

This is no conflict of interest in this study.

Table A1. –
Journals of Analyzed Papers.

Identificator	APA
A1	McPhillips, M., Nikitina, T., Tegtmeier, S., & Wójcik, M. (2022). What Skills for Multi-Partner Open Innovation Projects? Open Innovation Competence Profile in a Cluster Ecosystem Context. Sustainability, 14(20), 13330.
A2	McPhillips, M., & Licznerska, M. (2021). Open Innovation Competence for a Future-Proof Workforce: A comparative study from four European universities. Journal of Theoretical and Applied Electronic Commerce Research, 16(6), 2442–2457.
A3	David, K. G., Wu, Y., & Pei, C. (2022). Openness to Innovation as a Driver of Knowledge Integration in High-Tech SMEs: The Roles of Social Capital and Network Competence. International Journal of Knowledge Management (IJKM), 18(1), 1–21.
A4	Liao, Y. C., & Tsai, K. H. (2019). Bridging market demand, proactivity, and technology competence with eco-innovations: The moderating role of innovation openness. Corporate Social Responsibility and Environmental Management, 26(3), 653–663.
A5	Zobel, A. K., & Hagedoorn, J. (2020). Implications of open innovation for organizational boundaries and the governance of contractual relations. Academy of Management Perspectives, 34(3), 400–423.
A6	Filiou, D. (2021). A new perspective on open innovation: established and new technology firms in UK bio-pharmaceuticals. R&D Management, 51(1), 73–86.
A7	Mikelsone, E., Segers, J. P., & Frisfelds, J. (2022). Bridging the gap between web-based idea management and organisational competences by systematic literature review and four case studies. 10.3846/bm.2022.823.
A8	Cirule, I., Uvarova, I., & Caune, G. (2022). European Trends in Business Incubation Through Open Innovation Approach. European Integration Studies, (16), 111–124.
A9	Fernandez-Diaz, E., Rodriguez-Hoyos, C., DOMINGUEZ, J. L. B., & SALVADOR, A. C. (2020). Who takes a MOOC? Profile of students in the framework of a European project. Turkish Online Journal of Distance Education, 21(2), 1–16.
A10	Zhang, X., Chu, Z., Ren, L., & Xing, J. (2023). Open innovation and sustainable competitive advantage: The role of organizational learning. Technological Forecasting and Social Change, 186, 122114.
A11	Hernández-Dionis, P., P é rez-Jorge, D., Curbelo-González, O., & Alegre de la Rosa, O. M. (2022). The coordinator of information and communication technologies: Its implication for open innovation. Journal of Open Innovation: Technology, Market, and Complexity, 8(1), 42.
A12	Meyer, C., Gerlitz, L., & Henesey, L. (2021). Cross-border capacity-building for port ecosystems in small and medium-sized baltic ports. TalTech Journal of European Studies, 11(1), 113–132.
A13	Gao, J., He, H., Teng, D., Wan, X., & Zhao, S. (2021). Cross-border knowledge search and integration mechanism–a case study of Haier open partnership ecosystem (HOPE). Chinese Management Studies, 15(2), 428–455.
A14	Keinz, P., & Marhold, K. (2021). Technological competence leveraging projects via intermediaries: Viable means to outbound open innovation and mediated capability building?. International Journal of Project Management, 39(2), 196–208.
A15	Pohlisch, J. (2020). Internal open innovation—Lessons learned from internal crowdsourcing at SAP. Sustainability, 12(10), 4245.
A16	Costa, J. (2020). Why do publicly funded firms find the university more useful to innovate than others? Can we accomplish the RIS3 target?. Regional Helix Ecosystems and Sustainable Growth: The Interaction of Innovation, Entrepreneurship and Technology Transfer, 45–66.
A17	Daniel Cortes, Jose Ramirez, Arturo Molina. Open Innovation Laboratory: Education 4.0 Environments to improve competencies in scholars. In 18th LACCEI International Multi-Conference for Engineering, Education, and Technology: "Engineering, Integration, and Alliances for a Sustainable Development" "Hemispheric Cooperation for Competitiveness and Prosperity on a Knowledge-Based Economy", July 27–31, 2020
A18	Yang, H. W., & Fang, S. C. (2018). Open innovation: Powered by people, enabled by IT. In 22nd Pacific Asia Conference on Information Systems-Opportunities and Challenges for the Digitized Society: Are We Ready?, PACIS 2018. Association for Information Systems.
A19	Behnam, S., Cagliano, R., & Grijalvo, M. (2018). How should firms reconcile their open innovation capabilities for incorporating external actors in innovations aimed at sustainable development?. Journal of Cleaner Production, 170, 950–965.
A20	Cabigiosu, A. (2022). Sustainable development and incumbents' open innovation strategies for a greener competence-destroying technology: The case of electric vehicles. Business Strategy and the Environment, 31(5), 2315–2336.
A21	Behnam, S., & Cagliano, R. (2019). Are innovation resources and capabilities enough to make businesses sustainable? An empirical study of leading sustainable innovative firms. International Journal of Technology Management, 79(1), 1–20.
A22	Liu, L., Long, J., Fan, Q., Wan, W., & Liu, R. (2022). Examining the functionality of digital platform capability in driving B2B firm performance: evidence from emerging market. Journal of Business & Industrial Marketing, (ahead-of-print).
A23	Beretta, M., Frederiksen, L., Wallin, M., & Kulikovskaja, V. (2021). Why and how firms implement internal crowdsourcing platforms. IEEE Transactions on Engineering Management.
A24	Kurniawati, A., Sunaryo, I., Wiratmadja, I. I., & Irianto, D. (2022). Sustainability-Oriented Open Innovation: A Small and Medium-Sized Enterprises Perspective. Journal of Open Innovation: Technology, Market, and Complexity, 8(2), 69.
A25	Abdulmuhsin, A. A., & Tarhini, A. (2022). Impact of wise leadership, workplace friendships on open innovation in family firms: a developing country perspective. Journal of Family Business Management, 12(1), 1–23.
A26	Olubajo, L., Dimitri, P., Johnston, A., & Owens, M. (2022). Managing interorganisational collaborations to develop medical technologies: the contribution of interpersonal relationships. Journal of Medical Engineering & Technology, 46(6), 482–496.
A27	Bagno, R. B., & Freitas, J. S. (2022). Setting the three-stage R&D shared portfolio methodology: an innovative approach to industry–university collaboration. Revista de Gestão, (ahead-of-print).
A28	Dvoryatkina, S. N., Zhuk, L. V., Smirnov, E. I., Khizhnyak, A. V., & Shcherbatykh, S. V. (2021). Open Innovation Model of Student's Research Activities. Journal of Teacher Education for Sustainability, 23(2), 77–90.

(*continued on next page*)

Table A1. – (*continued*)

Identificator	APA
A29	Kaisler, Grill (2021). Enabling Transdisciplinary Collaboration: Stakeholder Views on Working With “Children With Mentally Ill Parents” Research Groups. Frontiers in Psychiatry, 12, 760716.
A30	Chung, J., Ko, N., & Yoon, J. (2021). Inventor group identification approach for selecting university-industry collaboration partners. Technological Forecasting and Social Change, 171, 120988.
A31	Prendes-Espinosa, P., Solano-Fernández, I. M., & García-Tudela, P. A. (2021). Emdigital to promote digital entrepreneurship: The relation with open innovation. Journal of Open Innovation: Technology, Market, and Complexity, 7(1), 63.
A32	Kovaliuk, T., & Kobets, N. (2021). The Concept of an Innovative Educational Ecosystem of Ukraine in the Context of the Approach" Education 4.0 for Industry 4.0". In ICTERI (pp. 106–120).
A33	Papageorgiou, G., Mihai-Yiannaki, S., Ioannou, M., Varnava-Marouchou, D., & Marneros, S. (2021, February). Entrepreneurship Education in an Era of Digital Communications. In Universities and Entrepreneurship: Meeting the Educational and Social Challenges. Emerald Publishing Limited.
A34	Charosky Larrieu-Let, Bragós Bardia (2021). Investigating students’ self-perception of innovation competences in challenge-based and product development courses. International journal of engineering education, 37(2), 461–470.
A35	Ahn, J. M., Lee, W., & Mortara, L. (2020). Do government R&D subsidies stimulate collaboration initiatives in private firms?. Technological Forecasting and Social Change, 151, 119840.
A36	Luhgiatno, L., & Dwiatmadja, C. (2020). Developing Optimal Distinctive Open Innovation in Private Universities: Antecedents and Consequences on Innovative Work Behavior and Employee Performance. International Journal of Higher Education, 9(5), 19–27.
A37	Nasullaev, A., Manzini, R., & Kalvet, T. (2020). Technology intelligence practices in SMEs: Evidence from Estonia. Journal of intelligence studies in business, 10(1), 6–22.
A38	Iglesias-Sánchez et al. (2019). Training entrepreneurial competences with open innovation paradigm in higher education. Sustainability, 11(17), 4689.
A39	Vidmar, M. (2019). Agile space living lab–the emergence of a new high-tech innovation paradigm. Space Policy, 49, 101324.
A40	Meissner, D., & Shmatko, N. (2019). Integrating professional and academic knowledge: the link between researchers skills and innovation culture. The Journal of Technology Transfer, 44, 1273–1289.
A41	Beuter Júnior, N., Faccin, K., Volkmer Martins, B., & Balestrin, A. (2019). Knowledge-based dynamic capabilities for sustainable innovation: The case of the green plastic project. Sustainability, 11(8), 2392.
A42	Pranciulytė-Bagdžiūnienė, I., & Petraitė, M. (2019). The interaction of organizational capabilities and individual competences for open innovation in small and medium organizations. Information & Media, 85, 148–175.
A43	Roša, A., & Lace, N. (2018). The open innovation model of coaching interaction in organisations for sustainable performance within the life cycle. Sustainability, 10(10), 3516.
A44	Podmetina, D., Soderquist, K. E., Petraite, M., & Teplov, R. (2018). Developing a competency model for open innovation: From the individual to the organisational level. Management Decision, 56(6), 1306–1335.
A45	Myhren, P., Witell, L., Gustafsson, A., & Gebauer, H. (2018). Incremental and radical open service innovation. Journal of Services Marketing, 32(2), 101–112.
A46	Osarenkhoe, A., & Fjellström, D. (2018). The oxymoron of digitalisation-A study of critical factors. In 32nd International Business Information Management Association Conference, IBIMA 2018, 15–16 November 2018, Seville, Spain (pp. 4428–4430). International Business Information Management Association (IBIMA).
A47	Molina Gutiérrez et al. (2018). Open innovation laboratory for rapid realisation of sensing, smart and sustainable products: motives, concepts and uses in higher education. In Collaborative Networks of Cognitive Systems: 19th IFIP WG 5.5 Working Conference on Virtual Enterprises, PRO-VE 2018, Cardiff, UK, September 17–19, 2018, Proceedings 19 (pp. 156–163). Springer International Publishing.
A48	Thanasopon, B., Papadopoulos, T., & Vidgen, R. (2018). How do firms open up the front-end of service innovation? A case study of IT-based service firms in Thailand. International Journal of Innovation Management, 22(01), 1850010.

Table A2. –
Years and Journals of Analyzed Papers.

Database/journals, conferences	Years						Total
	2018	2019	2020	2021	2022	2023	
Scopus	8	5	6	8	7	1	35
12th International Scientific Conference Business and Management					1		1
18th LACCEI International Multi-Conference for Engineering, Education, and Technology			1				1
22nd Pacific Asia Conference on Information Systems-Opportunities and Challenges for the Digitized Society	1						1
32nd International Business Information Management Association Conference, IBIMA 2018	1						1
Collaborative Networks of Cognitive Systems: 19th IFIP WG 5.5 Working Conference on Virtual Enterprises, PRO-VE 2018	1						1
Frontiers in Psychiatry				1			1
Information & Media		1					1
International journal of engineering education				1			1
International Journal of Higher Education			1				1
International Journal of Innovation Management	1						1
International Journal of Project Management				1			1
Journal of Cleaner Production	1						1
Journal of Family Business Management					1		1
Journal of intelligence studies in business			1				1
Journal of Medical Engineering & Technology					1		1
Journal of Open Innovation: Technology, Market, and Complexity				1	2		3
Journal of Services Marketing	1						1
Journal of Teacher Education for Sustainability				1			1
Main Conference, PhD Symposium, Posters and Demonstrations ICTERI-2021				1			1
Management Decision	1						1
Regional Helix Ecosystems and Sustainable Growth: The Interaction of Innovation, Entrepreneurship and Technology Transfer			1				1
Revista de Gestão					1		1
Space Policy		1					1
Sustainability	1	2	1		1		5

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Table A2. – (*continued*)

Database/journals, conferences	Years						Total
	2018	2019	2020	2021	2022	2023	
Technological Forecasting and Social Change			1	1		1	3
The Journal of Technology Transfer		1					1
Universities and Entrepreneurship: Meeting the Educational and Social Challenges				1			1
WOS		2	2	4	5		13
Academy of Management Perspectives					1		1
Business Strategy and the Environment					1		1
Chinese Management Studies				1			1
Corporate Social Responsibility and Environmental Management		1					1
European Integration Studies					1		1
IEEE Transactions on Engineering Management				1			1
International Journal of Knowledge Management					1		1
International Journal of Technology Management		1					1
Journal of Business & Industrial Marketing					1		1
Journal of Theoretical and Applied Electronic Commerce Research				1			1
R&D Management			1				1
TalTech Journal of European Studies				1			1
Turkish Online Journal of Distance Education			1				1
Grand total	8	7	8	12	12	1	48

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