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INFORMATION & TECHNOLOGY MANAGEMENT | REVIEW ARTICLE

Education 4.0 Maturity Models for Society 5.0: Systematic literature review

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Abstract: Society 5.0 is a transformative vision for the future driven by integrating digital technologies and human-centered approaches, fusing with cyber-physical spaces to create a smart society that addresses megatrends through innovative and collaborative solutions by stakeholders. This article analyzes Maturity Models (MMs) in Higher Education to identify the components of Education 4.0 that aim to achieve Society 5.0, seeking the dimensions and levels associated with the quintuple helix and the mission of the HEIs. We conducted a systematic literature review (SLR) guided by research questions to highlight studies that address Maturity Models worldwide, identify components of Education 4.0 in the MM, research methods and instruments used, internal and external stakeholders, and some characteristics of the university missions. The study method employed was a Systematic Review analyzing 26 articles from 2018 to 2023 found in WoS and Scopus databases using inclusion and exclusion criteria under a Prisma workflow. The findings were that the HEIs must: a) analyze dimensions of various Education 4.0 components in a balanced way, b) incorporate comparative designs and mixed methods of the MM models, c) provide technology transfer services, training, and data centers, d) provide fully open environments to educate all citizens inclusively, and e) use sustainable MMs for a significant difference in impact. This review offers educational leaders and policymakers the methodologies for measuring the Education 4.0 path to Society 5.0.

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1. Introduction

Undoubtedly, innovative educational ecosystems are adopting Education 4.0's ethical, moral, resilient, sustainable, and wellness components in new operational modes of digital transformation (DT). Society 5.0 is a super-intelligent society that promotes the convergence of cyberspace and physical space (Fukuyama, 2018) and focuses on human-oriented solutions and social innovation (Morawska-Jancelewicz, 2021), where the expectations are to develop an environment where humans and robots with artificial intelligence (AI) coexist and work to improve the quality of human life (Cabinet Office, Japan, 2022). In this sense, Shahidan et al. (2021) revealed in a study of art that engineering-related fields like artificial intelligence (AI) and the Internet of Things (IoT) dominate the intellectual structure of Society 5.0, which has a robust connection in the temporal co-map to the Sustainable Development Goals (SDGs), where Industry 4.0 technologies aim to improve human well-being (Martínez-Pérez & Rodríguez-Abitia, 2021). Morawska-Jancelewicz (2022) pointed out that global challenges and rapid technological progress are increasingly complex, leading to higher expectations of universities roles in modern ecosystems. Therefore, Higher Education Institutions (HEIs) must converge physical and digital learning spaces, design pedagogical strategies that prepare students to participate in this era of digital transformation and sustainable development, and link it with industry, government, and civil society sectors.

HEIs are assuming new roles in modern ecosystems, adapting educational systems and integrating Education 4.0 advanced technologies with the principles and values of Society 5.0, opening to the knowledge generated by research and innovation, and preparing students to participate in this digital transformation and sustainable development era. Incorporating changes to organizational structures with technologies involves responsible innovation and transformative research to implement and modularize regulatory and organizational frameworks (Nagy et al., 2020). From the perspective of the universities' missions, authors such as Carayannis et al. (2023) have integrated the Triple Helix Model (Etzkowitz & Leydesdorff, 1997) and the Quadruple Helix (Carayannis et al., 2019) within the framework of the Quintuple Helix: academia, industry, government, civil society, and the environment to achieve a model of collaboration and synergy. Carayannis and Campbell (2022) introduced the "Emerging Unified Theory of Helical Architectures (EUTOHA)" as a means to provide clarity, coherence, and consistency in leveraging helical architectures; the objective of their framework was to facilitate solution designs that contribute to the digital transformation of modern knowledge economies and societies. HEIs must establish conditions to implement new social innovation, entrepreneurship, and lifelong learning paradigms to achieve a genuine digital transformation.

Maturity Models (MMs) are a valuable tool for HEIs to facilitate digital transformation and measurement strategies in Education 4.0 to align with the values of Society 5.0. MMs systematically evaluate organizational processes (Proença, 2016). There are several MMs mechanisms, for example, descriptive, prescriptive, or comparative (De Bruin et al., 2005); each has its purpose, components, indicators, levels, and dimensions Carvalho et al. (2019) and, in the case of HEIs, aim at ensuring the quality of pedagogical and technological components and guaranteeing business continuity and facilitate knowledge management (Tocto-Cano et al., 2020). Additionally, a holistic vision of the organization's digital transformation and sustainability models will comprehensively address critical aspects of teaching activities, cyber-physical infrastructure, digital governance, and other educational processes.

Understanding the evolutionary Education 4.0 process to prepare individuals to participate in the future educational models of Society 5.0 highlights the need for interdisciplinary collaboration and spaces for innovation and ethical responsibility. Education 4.0 responds to Industry 4.0, where humans and technology join for new possibilities (Hussin, 2018). Asad and Malik (2023) emphasize the significance of collaborative learning practices in Higher Education 4.0 and underscore the potential for its improvement through physical instructions integrated with cyber-based learning; this approach coincides with the Society 5.0 paradigm. HEIs face challenges when using cloud technologies due to security threats, access to control, and data security. A survey conducted by Jenay (2022) discovered that a significant portion of students visit campuses for hardware access (21%) and free Wi-Fi (14%).

Additionally, the survey revealed that students strongly prefer hybrid or entirely online teaching modalities. These findings hold value as educational institutions rethink the purposes of their physical spaces and pedagogical methods. In a separate study, Zhanna and Nataliia (2020) employed the modeling method to create a cognitive and metacognitive model of the educational process. Their research specifically concentrated on pedagogical approaches that develop competencies necessary for Industry 4.0, focusing on enhancing interpersonal skills. Additionally, other studies, such as the one conducted by Law et al. (2018), examined the cultivation of digital skills, while Ramírez-Montoya et al. (2022) explored the development of complex thinking skills. These studies collectively address the demands and challenges presented by HEIs and provide valuable insights into the necessary skills for success in Education 4.0 and Society 5.0.

1.1. Related work on maturity models in HEIs in education 4.0

UNESCO promotes access to good quality education as a human right, and within this approach, learning is at two levels: (a) the learner and (b) the learning system (Colclough et al., 2005). Therefore, a supportive structure is needed to implement policies, set standards, allocate resources, and measure learning outcomes to achieve the best possible impact on learning for all. Alenezi (2021) discusses technological corporations' digital maturity models led by digital transformation in HEIs; he presents education-specific transformation frameworks. Tocco-Cano et al. (2020) present a novel approach that detects gaps in the existing HEI maturity models, as they do not entirely address the dimensions. Studies related to MMs for Education 4.0 performed by Rodríguez-Abitia and Bribiesca-Correa (2021) argued that the digital maturity of HEIs can be assessed by observing its information technology infrastructure and digital tools used in classrooms, labs, and administration; they assessed how the institutes have applied digital tools in teaching and learning. Fatimah et al. (2020) contributed to the evolution of organizations using Artificial Intelligence (AI) to explain the concepts, approaches, and elements of maturity models.

This article analyzes which components of Education 4.0 have been considered in HEI Maturity Models for Society 5.0. The maturity models for education must include dimensions and levels measuring not only teaching and learning practices or organizational processes but also citizen participation, social innovation, sustainability, knowledge openness, and other wellness scenarios already identified as targets in Society 5.0. The essential objective of this study was to conduct a systematic literature review on the dimensions of Maturity Models (MMs) to identify the components of Education 4.0 that aim to achieve Society 5.0's goals. The specific objectives of the study were: (a) Identify the components of Education 4.0 in MMs and the research methods, instruments, and key stakeholders and determine whether there are schemes to assess sustainability, (b) analyze the dimensions, stages, and levels of measurement utilized in MMs for HEIs, and (c) identify MMs related to the framework of the Quintuple Helix and the connections with the mission of the HEIs.

Based on the research objectives, the research questions were: (1) RQ1: How many studies over time regard Maturity Models (MMs), and which components of Education 4.0 are the focus? (2) RQ2: What research methods, instruments, and mechanisms have been used in Maturity Models (MMs)? (3) RQ3: What dimensions and levels of measurement are utilized in Maturity Models (MMs)? (4)

RQ4: According to the studies, which stakeholders of Education 4.0 have Maturity Models (MMs) that include the quintuple helix sectors? (5) RQ5: Which studies are related to the HEIs' mission and their impact on quintuple helix sectors?

The sections of this paper are as follows: The immediate section presents the materials and methods relating to MMs and Society 5.0 literature, the missions of the HEIs, the framework of the quintuple helix, and the components of Education 4.0. The Methodology section explains the review process and the research questions. The subsequent section covers the literature review findings, and the final section discusses the conclusion.

2. Materials and methods

2.1. Education 4.0 Maturity Models for Society 5.0

To foster collaboration and knowledge sharing, one must develop comprehensive capability models and disciplinary applications that promote the integration of physical and cyber spaces in an intelligent society. Society 5.0 aims to prioritize innovation for humans by leveraging the potential of technology and Industry 4.0 to enhance the quality of life, social responsibility, and sustainability (Martínez-Pérez & Rodríguez-Abitia, 2021). These aspects address emerging challenges effectively. Maturity Models (MMs) have gained wide acceptance in management science as they provide a systematic approach to gathering information and enabling continuous improvement (Lahrmann et al., 2011). To meet the demands of Society 5.0 and Education 4.0, HEIs require indicators for informed decisions and periodically review and update their educational programs, operational processes, frameworks for cyber and physical infrastructure, and the impacts on the social environments.

2.2. Research methods and mechanisms to conduct maturity models

The need for such models led to the development of MMs, which can be classified based on typologies established by De Bruin and colleagues (De Bruin et al., 2005) (Table 1).

The validity of digital maturity models lies in their scientific nature, which requires demonstrating their accuracy and reliability through methods and techniques of the scientific method. Furthermore, the research and evaluation process employ methods to establish relationships, strategies, and techniques that seek to approach "reality" within the study design (Ramírez-Montoya & Lugo-Ocando, 2020). These research methods fall into empirical, conceptual, or mixed categories. Neuman (2014) defines empirical research as collecting objective and verifiable data through observation or experimentation. As Creswell and Creswell (2017) described, conceptual research involves exploring and clarifying existing ideas, theories, and concepts in academic literature. Plano-Clark and Ivankova (2016, p. 57) define mixed methods as integrating quantitative and qualitative research approaches to address a research problem effectively. It is important to note that mixed methods do not simply combine quantitative and qualitative methods but integrate methodologies to provide comprehensive insights and answers to specific research questions.

Table 1. Maturity model mechanisms

MM Mechanisms	Description
a) Descriptive	Assists in the assessment of given situations
b) Prescriptive	Supports the definition and implementation of a development plan
c) Comparative	Allows for comparisons of industries or regions and facilitates benchmarking

2.3. Dimensions and levels of measurement utilized in maturity models

The maturity level has fundamental components of dimensions and stages, according to Paulk et al. (1993), who developed a maturity model called the Capability Maturity Model (CMM). The CMM consists of five levels for increasing levels of process maturity. The dimensions represent an organization's key functional areas or critical aspects that are assessed and improved as it progresses through the model. For example, in a business context, Fraser et al. (2002, pp. 244–245) described the five dimensions and stages of a maturity model as a “staged” representation with levels 1–5: Repeatable, Defined, Managed, and Optimizing. Within each level are several key process areas, and each key process area further breaks down into five sections called “common features.” These common features include commitment to perform, ability to perform, activities performed, measurement & analysis, and verifying implementation. In an educational context, Carvalho et al. (2019) highlighted the main dimensions for MMs in Higher Education to evaluate: ICT, management, process management, course curricula, course/HEI accreditation, e/m-learning, online courses, and pedagogical strategies. They pointed out the need to develop comparative MMs to include other elements emerging due to new challenges, requiring profound changes in their internal and external processes.

2.4. Missions of higher education and the quintuple helix

One way HEIs can increase their positive impact on society is to foster initiatives supported by technologies that bring more significant benefits to citizens in their environments and their four main missions: teaching, research, knowledge transfer (third mission), and community engagement (fourth mission). Cavallini et al. (2016) defines these missions as relations with non-academic decision-makers and business and society policymakers. Riviezzo et al. (2020) defined the fourth mission. For example, the Quadruple/Quintuple Helix Innovation Model (Q2HM) by Goddard et al. (2016) ensures that the HEIs are drivers of knowledge that play a crucial role in orchestrating innovation and pursuing change. Authors Carayannis and Morawska-Jancelewicz (2022) looked for highlights that address the gap of relatively few studies on institutional changes and incentive structures influencing the ability of universities to engage in (digital) social innovation within digital and green transitions. They proposed the elements for universities' digital transformation and mission levels (Table 2).

2.5. Stakeholders in education 4.0

On the other hand, to classify the main stakeholders and HEIs in Education 4.0, we used the classification proposed by González-Pérez and Ramírez-Montoya (2022), which were a) students, b) teachers, and c) managers. Similarly, external stakeholders from the perspective of the Quintuple Helix are Government, Industry, Civil Society, and Environment (Carayannis et al., 2019, 2023). This approach allows for adding new stakeholders.

2.6. Core components of Education 4.0 and stakeholders in a MM in HEIs

To identify core components of Education 4.0 and digital aspects of HEI MMs for Society 5.0, we identified some authors who addressed the components of Education 4.0 or approached assessing areas of HEIs. In addition, we propose other categories that may be useful for reviewing MMs in the context of the 5.0 society. Rodríguez-Abitia and Bribiesca-Correa (2021) proposed the following dimensions of the digital maturity model: a) the ability to provide appropriate IT infrastructure, b) the ability to apply technology to the teaching and learning process, and c) the ability to provide collaboration and organizational platforms to integrate processes and people. Table 3 presents the categorization for this study.

2.7. Systematic literature review

To carry out the study, we used a systematic literature review (SLR) as a strategy to identify studies about MMs in HEIs with the following objectives: a) analyze the dimensions, stages, and levels of measurement of MM used in HEIs, b) identify the Education 4.0 components, research methods, instruments, and key stakeholders, and c) identify the Quintuple Helix sectors involved in the objectives of creating MMs in HEIs. SLRs identify, evaluate, and interpret the

Table 2. HEIs missions based on Carayannis and Morawska-Jancelewicz (2022)

Mission	Methodologies and digital tools	Relation to Q2HM
Teaching	Digital Social Innovation Pedagogy Digital literacy Educating about Social Innovation (and Sustainable Development Goals (SDG) New education tools: 3D platforms, virtual simulators Open educational resources like Massive Open Online Courses (MOOC)	Delivering knowledge and skills related to sustainable priorities and digital challenges and creating power capital
Research	Research on Digital Social Innovation Pedagogy Research creating social innovation. Research using Artificial Intelligence tools	Establishing new channels for transdisciplinary research on Digital Social Innovation Digital Social Innovation is included in regional strategies. More inclusive and sustainable innovation ecosystem
Third mission (Knowledge transfer)	Public/community/stakeholder engagement in green and digital activities through citizen science Community service Service learning Community-based participatory research (CBPR) Action-research, citizen science, science shops (as methodology) Living labs (as methodology) Promoting Digital Social Innovation pedagogy through outreach & science communication Social entrepreneurship programs	Mutual learning and the new channels of knowledge flow to and from the university, allowing for new Digital Social Innovation. Digital Social Innovation as part of a regional innovation system New investments in physical, digital, and green regional infrastructures of Digital Social Innovation Regional leadership in Digital Social Innovation
Fourth mission (Community engagement)	Universities as open systems in their environments delivering (digital) social innovation, Co-design, co-creation, and co-delivery for sustainability, DSI as a tool for implementing SDGs	Open system of education, research, and innovation focused on the environment and sustainability using new digital tools. Continuing exchanges between the university and stakeholders. Building regional capacity and resilience through DSI

data available within a period in each field of research. This review process followed, in general terms, the guidelines established by Brereton et al. (2007), which focused on conducting SLRs in software engineering (Kitchenham, 2004) and based in other contributions (Chambers et al., 2009; Higgins & Green, 2006). To address the research questions, we employed the systematic literature review method based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines by Page et al. (2021). The five phases were: 1) identifying the research questions; 2) the search process; 3) inclusion and exclusion criteria; 4) the data selection and extraction process; and 5) data synthesis. The five phases of the review are shown in Figure 1.

2.7.1. Phase 1. Identifying the research questions

During phase 1, five questions defined the dimensions related to the research and the possible review answers. The questions aimed to cover the research's objective and identify relevant dimensions based on authors that could answer the questions (Table 4).

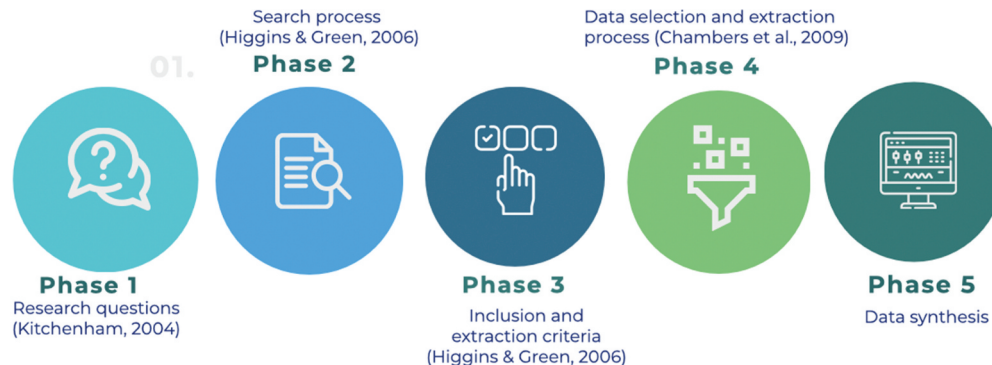
Table 3. Categories of components of Education 4.0 for Society 5.0

Categories	Description	
Competencies Miranda et al. (2021)	Transversal competencies	i) Critical Thinking, (ii) Cooperation, (iii) Collaboration, (iv) Communication, (v) Creativity
	Disciplinary competencies	(i) Training and developing functional, technical, and technological knowledge and successful workplace performance skills. (ii) The capacity to research, design, create, and implement new technologies. (iii) The use of emerging technologies and best practices to propose technology-based solutions
Learning methods Miranda et al. (2021)	Learning delivery modalities	(i) Face-to-Face learning, (ii) Online distance learning, (iii) Hybrid or blended learning, (iv) Mobile learning
	Learning strategies	(i) Pedagogical approaches such as active learning, collaborative learning, challenge-based learning, problem-based learning, learning-by-doing, gamification-based learning
Infrastructure level (Own proposal for Society 5.0)	Cyber Space	Technological enablers 4.0: open technologies, digital pedagogies, adaptive technologies, smart technologies, technological innovation models, disruptive technologies González-Pérez et al. (2022)
	Physical Space	Buildings and Infrastructure: library, immersive rooms, lecture halls, residence halls, research facilities, staff offices, classrooms, technological labs, internet access, robots, Gesell rooms, telecommunication infrastructure, production multimedia labs, security, and comfortable spaces (own proposal)
Organization dimensions	Collaboration and organizational platforms Rodríguez-Abitia and Bribiesca-Correa (2021) Rodríguez-Abitia and Bribiesca-Correa (2021)	Leadership and culture, Market digitalization, Logistics, Dynamic and digital capability, financial viability Rodríguez-Abitia and Bribiesca-Correa, (2021)
	Liaison (own proposal for Society 5.0)	Liaisons with other sectors, institutional agreements, lifelong learning, I+D projects (own proposal)
	Research and Innovation (own proposal for Society 5.0)	Knowledge transfer, Living Lab for citizens, Innovation, Entrepreneurship, Open education, dissemination, diffusion, data governance, science governance (own proposal)

2.7.2. Phase 2. Search process

The search process in the SCOPUS and WoS databases began with defining the keywords to use in their search engines with the “AND” operator and the inclusion and exclusion criteria. The search was performed on 1 March 2023. Table 5 shows the search strings for both databases.

Figure 1. Systematic literature review process (own elaboration, based on Brereton et al., 2007; Chambers et al., 2009; Higgins & Green, 2006; Kitchenham, 2004).



2.7.3. Phase 3. Inclusion and exclusion criteria

Table 6 shows the search protocol with the inclusion and exclusion criteria for selecting and evaluating relevant studies:

2.7.4. Phase 4. Data selection and extraction process

In phase 4, the articles were searched, then data extraction was performed. Subsequently, the information was entered into an Excel database. The search yielded 69 studies: 24 in Scopus and 45 in WoS. The information extracted from each article included the author(s), keywords, title, type of access, year of publication, publication name, number of citations, DOI number, affiliations, language, country, and abstract. Based on this data, 14 duplicate articles were identified and moved to another database sheet. Next, 3 studies without access to the document were excluded; 9 studies referred to as Review Systematic Literature, 7 studies did not present a Maturity Model, and nine presented a maturity model but in different sectors than education. After applying the exclusion criteria, only 26 studies remained as review candidates. Figure 2 shows the delimitation based on the PRISMA method.

2.7.5. Phase 5. Data synthesis

In phase 5, we synthesized the data of the 26 studies included in this review to respond to the research questions RQ1, RQ2, RQ3, RQ4, and RQ5 described in Table 4. To achieve this, we sought to identify the HEI MMs through the abstract information, keywords, and titles and categorize each article properly, which allowed us to link the dimensions and the possible answers according to the criteria of each.

3. Results

The SLR database is available here: <https://doi.org/10.5281/zenodo.8026284>. This section presents the results related to the research questions. The tools used for the graphs were Excel and Tableau. Table 7 shows the selected studies, with Id Study for identification purposes in the sections responding to each research question and the discussion section.

The results for each of the research questions follow.

3.1. RQ1. How many studies through time regard maturity models (MMs), and which components of education 4.0 are the focus?

Figure 3 shows HEI MM studies between 2018 and 2023. Note that before 2021, these models primarily measured competency levels.

From 2021, the HEI MMs primarily measured infrastructure levels, and organizational dimensions, and less the learning processes and competencies. The Figure 3 shows 5 studies related to competencies, 5 related to infrastructure levels, 3 on learning methods, and 11 on organizational dimensions.

Table 4. Dimensions, research questions, and possible answers

Dimension	Research Questions (RQ)	Type of answer sought
Number of published studies on MM in Higher Education Institutions	RQ1: How many studies over time regard Maturity Models (MMs), and which components of Education 4.0 are the focus?	<p>Id of articles and named model.</p> <p>No. of articles from 2018 to 2023, organized for core components of Education 4.0</p> <p>Core components of education:</p> <ol style="list-style-type: none"> <i>Infrastructure level</i> Miranda et al. (2021), Rodríguez-Abitia and Bribiesca-Correa (2021) <i>Learning methods</i> Miranda et al. (2021) <i>Competencies</i> Miranda et al. (2021) <i>Organization dimensions</i> Rodríguez-Abitia and Bribiesca-Correa (2021)
Methods, instruments, and mechanisms	RQ2: What research methods, instruments, and mechanisms have been used to conduct MMs?	<p>Research design (Ramírez-Montoya & Lugo-Ocando, 2020)</p> <ol style="list-style-type: none"> <i>Conceptual</i> Creswell and Creswell (2017) <i>Empirical</i> Neuman (2014) <i>Mixed</i> Plano-Clark and Ivankova (2016) <p>Mechanisms of MMs De Bruin et al. (2005)</p> <ol style="list-style-type: none"> <i>Descriptive</i> <i>Prescriptive</i> <i>Comparative</i>
Dimensions and levels	RQ3: What dimensions and levels of measurements are utilized in MMs?	<p>Dimensions</p> <p>Functional areas and key aspects.</p> <p>Levels Fraser et al. (2002):</p> <ol style="list-style-type: none"> <i>Initial</i> <i>Repeatable</i> <i>Defined</i> <i>Managed</i> <i>Optimizing</i>

(Continued)

Table 4. (Continued)

Dimension	Research Questions (RQ)	Type of answer sought
Stakeholders of Education 4.0	RQ4: According to the studies, which stakeholders of Education 4.0 have Maturity Models (MMs), including the quintuple helix sectors?	Stakeholders in Education 4.0: González-Pérez and Ramírez-Montoya (2022): a. <i>Students</i> b. <i>Professors</i> c. <i>Managers</i> Quintuple helix Goddard et al. (2016): a. <i>Academia</i> b. <i>Governments</i> c. <i>Industry</i> d. <i>Civil Society</i> e. <i>Environment</i>
The mission of the HEIs and their impact on quintuple helix	RQ5: Which studies are related to the mission of the HEIs and their impact on the quintuple helix?	HEIs Missions Carayannis and Morawska-Jancelewicz (2022): a. <i>Teaching</i> b. <i>Research</i> c. <i>Knowledge Transfer</i> d. <i>Community Engagement</i> Quintuple helix Goddard et al. (2016): a. <i>Academia</i> b. <i>Governments</i> c. <i>Industry</i> d. <i>Civil Society</i> e. <i>Environment</i>

Table 5. Search string

Scopus	Wos
(TITLE-ABS-KEY ("maturity model") AND TITLE-ABS-KEY ("higher education")) AND (LIMIT-TO (PUBYEAR, 2023) OR LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018)) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO (LANGUAGE, "English"))	"maturity model" (All Fields) and "higher education" (All Fields) and 2023 or 2022 or 2021 or 2020 or 2019 or 2018 (Publication Years) and Article or Review Article (Document Types) and Article or Review Article (Document Types) and English (Languages)

Table 6. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
<ul style="list-style-type: none"> • Search resources: Scopus database and Web of Science database. • Period: 2018–2023 • Type of document: Articles • Language: English 	<ul style="list-style-type: none"> • Duplicate. • The articles refer to Systematic Literature Review. • The articles without access to documents • The articles do not present MM. • The articles present a MM aimed at a sector other than education.

3.2. RQ2: what research methods, instruments, and mechanisms have been used in maturity models (MMs)?

Table 8 presents studies using conceptual, empirical, or mixed methods and the mechanisms. Among the most prominent instruments for validating MMs in HEIs. A few instruments are case studies, Delphi approaches, benchmarking, interviews, surveys, and others, some accompanied by literature reviews.

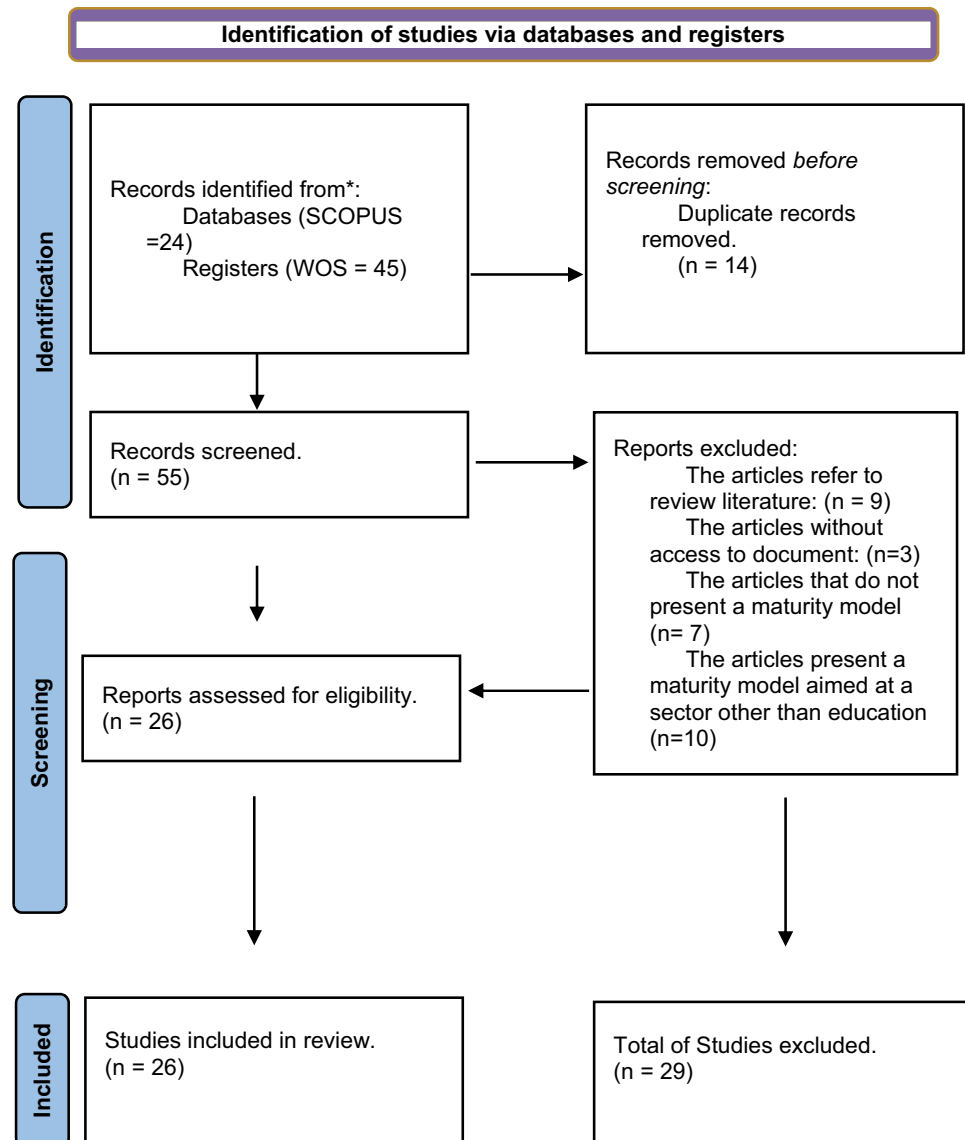
Table 8 provides an overview of the research methods used for each study from a scientific point of view, as well as the mechanisms used from the approach and scope of each model. Only studies S7 and S2 had a comparative mechanism, and 15 studies with a descriptive mechanism (S4, S22, S19, S3, S14, S10, S16, S25, S17, S23, S20, S18, S1, S21 and S12), and 9 with a prescriptive mechanism (S15, S13, S9, S26, S6, S24, S8, S5 and S11). Thus, only 23 % of the studies used the conceptual method, 38.5 % the empirical method, and 38.5 % mixed methods.

3.3. RQ3: What dimensions, stages, and levels of measurement are in maturity models, and what is their connection with HEI missions and components of education 4.0?

Table 9 presents the list for each study with their id, model name, dimensions, and level used in HEI MMs. The table also shows how many studies correspond to the component's Education 4.0 and how many are related to the HEI missions.

The studies were grouped according to the components of Education 4.0 and the HEIs missions. The categorizations of the components of Education 4.0 in the first group were the studies related to Competencies S26, S20, S14, S19, and S23. Within the missions of the HEIs, studies S26 and S20 were classified as Community Engagement Mission, study S14 as Knowledge Transfer Mission, and studies S19 and S23 as Teaching Mission. In this group were no studies related to the mission of the research university. In the second group were the studies related to Infrastructure Levels (S7, S12, S17, S18, and S15) related to Knowledge

Figure 2. Selection process
 (PRISMA, based on Page et al., 2021).



Transfer and Research missions. In the third group were the studies related to Learning Methods categorizing the Components of Education 4.0 (S8, S9, S24, S22, and S1), and all were related to the Teaching Mission. In the fourth group were the studies of Organizational Dimensions; most related to the Knowledge Transfer Mission (S13, S5, S4, S11, S21, and S10) and Research Mission (S3, S25, S2, and S16) and only one study related to the Community Engagement Mission (S6). In summary, there were only three studies to measure aspects of the mission for community engagement (S6, S20, and S26), and more studies measured the organization's internal aspects.

3.4. RQ4: according to the studies, which stakeholders of education 4.0 have Maturity Models (MMs) that include the quintuple helix sectors?

Figure 4 presents the main stakeholders for whom the MMs were developed. These can be managers, teachers, and students.

Table 7. Id study, name model, authors, year, and total citations (TC)

ID Study	Name model and authors	TC (up to 1 March 2023)
S1	Project Based Learning Capability Maturity Model (PBLCMM) Al Mughrabi and Jaeger (2018)	8
S2	KPC-Knowledge Management (KM) Alghail et al. (2022)	6
S3	Cybersecurity Maturity Assessment Framework Aliyu et al. (2020)	20
S4	Digital Marketing Capability Maturity Model (CMM) Al-Thagafi et al. (2020)	0
S5	Adaptive Capability Maturity Model Aradea et al. (2020)	4
S6	The Readiness Assessment Approach Bertassini et al. (2022)	0
S7	HE-BIA Maturity Model v.2.0 Cardoso and Su (2022)	3
S8	Capability Maturity Model to Active Learning (CMMAL) Garbin et al. (2022)	3
S9	EMM Goeman et al. (2021)	1
S10	Wendler's model Gunsberg et al. (2018)	17
S11	Maturity for Service-Oriented Architecture (IAMSOA) Hamzah and Shaubari (2022)	0
S12	Knowledge Exchange Dynamics (KED) Harin et al. (2023)	0
S13	3D - SuMa HEI Model Herzner and Hommerová (2022)	0
S14	Ethical Risk Maturity Model Lincke and Khan (2020)	0
S15	Virtual Index of Maturity (VIM) Mach-Król and Gładysz (2022)	0
S16	Financial Management Maturity Model Malherbe and Schutte (2021)	1
S17	UX Maturity McDonald and Burkhardt (2021)	1
S18	IT Governance Capabilities Merchan-Rodríguez and Zambrano-Vera (2023)	0
S19	Human Factor MM Wdważny et al. (2019)	12
S20	Maturity Model to support the employment of graduates Pažur Aničić and Divjak (2020)	7
S21	Maturity Model for Information Systems in HEIS Pereira et al. (2021)	1
S22	Online Course Quality Maturity Model Pereira et al. (2020)	0

(Continued)

Table 7. (Continued)

ID Study	Name model and authors	TC (up to 1 March 2023)
S23	Intercultural Maturity Model Pryshliak et al. (2020)	1
S24	Maturity Model (EMMv2.3) Santally et al. (2020)	4
S25	HE-BIA Maturity Model Su and Cardoso (2021)	1
S26	EDAMMv2 Wiele et al. (2018)	0

Figure 3. Studies over time regarding maturity models (MMs) and their relationship with the core components of Education 4.0.

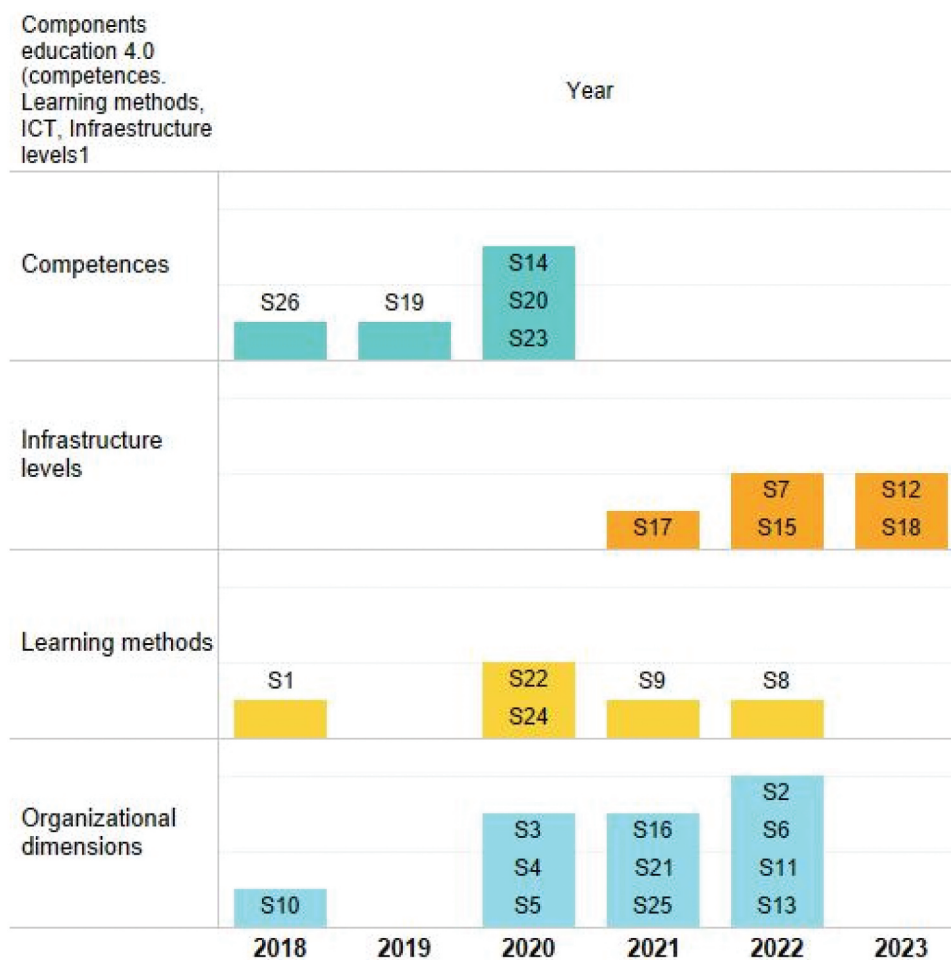


Figure 4 shows studies aligning stakeholders with the HEI missions, finding that most are Research and Knowledge Transfer managers. Of the total studies, 23% focused on Research, 23% on Teaching, 42% on Knowledge transfer, and 11% on Community engagement.

Research Method	Instruments	MM Mechanisms (Table 1)		
		Comparative	Descriptive	Prescriptive
Conceptual	Benchmarking		S4	
	Comparative study that considered three methodologies De Bruin et al. (2005)		S22	
	Design Science Research in Information Systems (DSRIS)			S15
	Literature maturity models and international standard: PN-EN ISO 9004:2000		S19	
	Mapping regulators of security		S3	
	Qualitative analysis and Sandman's outrage factor		S14	
Empirical	Case study approach			S13
	Case study of Griffith University and Survey		S10	
	Delphi approach			S9
	Design science research			S26
	Literature review, a Fuzzy Delphi, a Fuzzy inference system			S6
	Mainly desk studies and analysis of annual reports			S24
	Semi-structured interviews		S16	
	Squares structural equation modeling with a sample of 352 respondents from the project management departments in 10 public universities in Yemen	S2		
	Study Case		S25	
	Web-based survey		S17	

(Continued)

Table 8. (Continued)				
Research Method	Instruments	MM Mechanisms (Table 1)		
		Comparative	Descriptive	Prescriptive
Mixed	Analysis, survey, interview, conversation, methods of observation.		S23	
	Design science paradigm and exploiting four case studies across Europe		S20	
	Empirical with a descriptive and correlational scope		S18	
	Evaluation of two artifacts: the MM and the maturity assessment method, and three case studies with universities and two workshops with practitioners from more than 10 countries	S7		
	Literature review, expert interviews, and two case studies		S1	
	Literature review and survey			S8
	Monitor-analyze-plan-execute-knowledge control loops approach			S5
	Multi-case study approach and literature review to identify the dimensions		S21	
	Systematic literature review validated by experts		S12	
	MM validity: Expert review, Case Study			S11

Table 9. Dimensions and levels used to assess MMs in HEIs				
HEIs missions	ID study	Model name	Dimensions	Levels
E4.0: Competences				
	Community engagement			
		S26	EDAMMv2	Curriculum, Leadership, Quality Measurement, Industry Relations, Employability Services
		S20	Maturity model to support graduates' early careers within higher education institutions (HEIs)	1. Traditional, 2. Exposed, 3. Enacted, 4. Integrated, 5. Optimized
		S14	Ethical risk maturity model	1. Plan, 2. Do, 3. Check, 4. Act
Knowledge transfer		S19	Human Factor MM	Levels not found
		S23	Intercultural Maturity Model	1. Ignoring, 2. Defining, 3. Adapting, 4. Managing, 5. Integrating
				1. Initial, 2. Intermediate, and 3. Mature level
E4.0: Infrastructure levels				
	Knowledge transfer			
		S7	HE-BIA maturity model v.2.0	Levels not found
		S12	Knowledge exchange dynamics (KED)	1. Initial, 2. Managed, 3. Defined, 4. Quantitatively Managed, 5. Optimized
		S17	UX maturity	1. Ad hoc, 2. Establishing, 3. Scaling, 4. Sustaining, 5. Thriving

(Continued)

Table 9. (Continued)				
HEIs missions	ID study	Model name	Dimensions	Levels
E4.0: Infrastructure levels				
Research	S18	IT governance capabilities	1. Structures, 2. Processes, 3. Relational Mechanisms	Levels not found
	S15	Virtual Index of Maturity (VIM)	Virtual Index: Didactic, Research, Administration	0. NonVirtual, 1. Previrtual, 2. Partially virtual, 3. Predominantly virtual
Learning methods				
Teaching	S8	Capability maturity model to active learning (CMMAL)	1) Structure, 2) Teaching, 3) Learning and evaluation process, 4) Organizational strategies, 5) Development of competencies,	1. Initial, 2. Managed, 3. Defined, 4. Quantitatively Managed, 5. Optimized
	S9	EMM	Course design process, student learning, institutional support, sharing and openness, professional development, quality assurance.	Level 1, Level 2, Level 3
	S24	Maturity Model (EMMv2.3)	1. Delivery, 2. Planning, 3. Definition, 4. Management, 5. Optimization	1. Learning, 2. Developing, 3. Support, 4. Evaluation, 5. Organization
	S22	Online Course Quality Maturity Model	1. Identify a new opportunity, 2. Define Scope, 3. Design model, 4. Evaluate design, 5. Reflect evolution	1. Design 2. Evaluation
	S1	Project Based Learning Capability Maturity Model (PBLMM)	Quality of problem, Quality of learning facilitation, quality of assessment	Capability levels: CL0, CL1, CL2, CL3
Organizational dimensions				
Community engagement	S6	The readiness assessment approach	Mindset values, behavior values, capabilities values, competency values,	Levels not found

(Continued)

Table 9. (Continued)				
HEIs missions	ID study	Model name	Dimensions	Levels
Organizational dimensions Knowledge transfer	S13	3D - SuMa HEI model	Academic & Education, Governance & Administration, Campus & Operation, Engagement & Partnership	Levels not found
	S5	Adaptive capability maturity model.	Enterprise, Capability, Service	1. Initial, 2. Transition, 3. Defined, 4. Managed, 5. Adapting
	S4	Digital marketing capability maturity model (CMM)	The four business processes of the AIDA marketing communications model Awareness, Interest, Desire, Action	1. Initial, 2. Managed, 3. Defined, 4. Quantitatively Managed, 5. Optimized
	S11	Maturity for Service-Oriented Architecture (IAMSOA)	1) Key Process Area, 2) Key Practice, 3) Quality, 4) Achievement	Level 1, Level 2, Level 3
	S21	Maturity model for information systems in higher education institutions	a) Vertical Dimension: Academic Management, Financial Management, Human Resources Management, Teaching Support, Research Management, Communication, Alumni, International Relations, Project Management, Building Management, Social Services. b) Horizontal dimensions: Data analytics, Reporting tools, Workflow and document management, interoperability, Security, Usability and Ubiquity, Technological Infrastructure, User Support, Persons and Strategy	Levels not found
	S10	Wendler's model (2014)	1. Leadership and management, 2. Innovation, 3. Strategy, 4. Culture, 4. Learning and change, 5. Structure	Levels not found
Organizational dimensions				

(Continued)

Table 9. (Continued)				
HEIs missions	ID study	Model name	Dimensions	Levels
Research	S3	Cybersecurity Maturity Assessment Framework	Without information	1. Incomplete, 2. Initial, 3. Managed, 4. Defined, 5. Quantitatively Managed, 6. Optimizing
	S25	HE-BIA Maturity Mode	Technology and Organization: Data (as a key asset), Data Products, Technical Foundations, Value, Program/Project Management, Business Process/BIA Development, and People	1. Preadoption, 2. Initial, 3. Managed, 4. Systematic, 5. Optimizing
	S2	KPC-knowledge management (KM)	1) Project knowledge acquisition, 2) Project knowledge conversion, 3) Project knowledge application, 4) Project knowledge protection, 5) PMM	1. Initial, 2. Planned, 3. Organizational Standard, 4. Managed, 5. Continuous Improve
	S16	Without name	Inadequate, Basic, adequate, professional, leading edge	Levels not found

Figure 4. Stakeholders in Education 4.0 related to HEI missions.

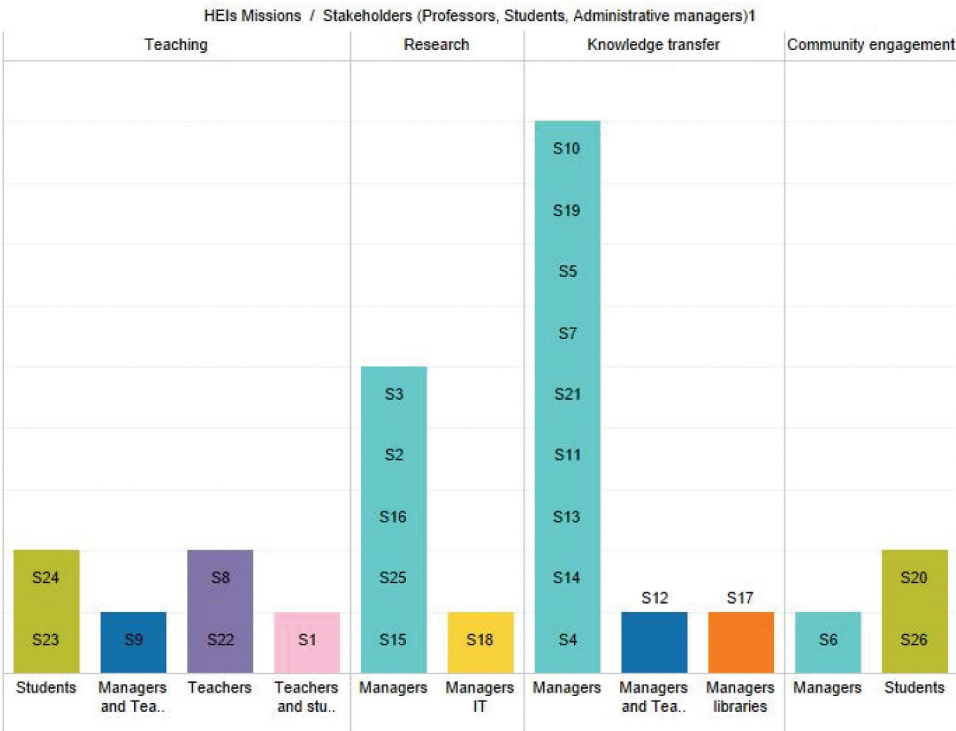


Figure 5. Missions of the HEIs and their impact on the quintuple helix.



3.5. RQ5: which studies are related to the HEIs' mission, and what is their impact on quintuple helix sectors?

Figure 5 presents studies grouped according to the categories of the quintuple helix: academia, industry, government, civil society, and environment, and their intersections with the HEI missions.

Figure 5 shows that 18 studies related to the Academia Helix represent more than 65% of the studies. In comparison, four studies related to the Industry Helix (19%), three studies to the Environment Helix (11%), and only one study for the Civil Society Helix (3%). Notably, no models connected with the Government's Helix.

4. Discussion of findings

With the incursion of Technologies 4.0 in everyday life, HEIs actors must be constantly updated and evaluated as gaps and inequalities in industry, education, government, and society become evident. Figure 3 shows that since 2021, the HEI MMs began to focus mainly on measuring infrastructure levels and organizational dimensions and less on measuring learning processes and competencies. Two studies were found so far in 2023 related to infrastructure, such as Study S18 by Merchan-Rodríguez and Zambrano-Vera (2023), presenting an IT Governance Capabilities model, and Study S12 by Harin et al. (2023) refers to the management of Knowledge Exchange Dynamics (KED), as they try to position the information systems aspects globally. Morawska-Jancelewicz (2022) pointed out that global challenges and rapid technological progress are increasingly complex, leading to growing expectations of universities and their roles in modern ecosystems and incorporating changes to organizational structures, with technologies supporting responsible innovation based on transformative research (Nagy et al., 2020). HEIs must rush to construct a model of Society 5.0, analyzing dimensions that relate to the different components of Education 4.0 in a balanced way, driving change management, and fostering deep responses to society, industry, government, and the environment using systems or technological platforms comprising the core of HEIs business.

The strength of a MM depends on a strategically sound scientific methodology with knowledge and understanding of the elements of the HEI missions. Table 8 presents studies using conceptual, empirical, or mixed methods and the mechanisms utilized. Only two studies (S7 and S2) were found with a comparative mechanism; De Bruin et al. (2005) defined a comparative mechanism as one that compares industries or regions and facilitates benchmarking; the same authors defined a descriptive mechanism as those assisting in the assessment of the given situation, of which 15 studies were found (S4, S22, S19, S3, S14, S10, S16, S25, S17, S23, S20, S18, S1, S21 and S12). Lastly, the studies carried out under the prescriptive mechanism defined the models that support the definition and implementation of a development plan: the nine studies were S13, S9, S26, S6, S24, S8, S5, and S11). From a scientific perspective, only 23 % of the studies used conceptual methods, 38.5 % empirical methods, and 38.5 % mixed methods, which were employed to establish relationships, strategies, and techniques that approach "reality" within the study design (Ramírez-Montoya & Lugo-Ocando, 2020). Therefore, MM models incorporating comparative designs, especially mixed methods, could impact and engage the external stakeholders.

It is essential that the effort to lead those changes must be part of the organizational culture and that new dimensions be developed to measure the level of maturity of the core activities of higher education institutions that involve and integrate support and technology areas. Table 9 presents the list for each study with their id, model name, dimensions, and level used in HEI MMs; a relevant example related to competencies is study S26, which used the dimension of employability services related to industry. Another study of infrastructure levels is S15, highlighting measuring the virtual spaces with the Virtual Index: Didactic, Research, and Administration. Regarding learning methods, study S9 highlighted the importance of measuring openness and sharing. In the context of organizational dimensions, study S10, named "Wendler's model," measured aspects that promote a culture of learning and

change in organizations. The studies S7 and S25 presented the HEI-BIMM MM, which has 23 dimensions, including business strategy and technical integration with IT infrastructure, looking to create a holistic assessment to resolve technological and organizational needs. Rodríguez-Abitia and Bribiesca-Correa (2021) proposed dimensions of the digital maturity model: a) the ability to provide appropriate IT infrastructure, b) the ability to apply technology to the teaching and learning process, and c) the ability to provide collaboration and organizational platforms to integrate processes and people. For HEIs to have competitive advantages with other sectors, such as industry and government, they must have technology transfer services, training, and data centers, with the infrastructure and technology to provide quality research-based services.

Detecting the people involved in the MM evaluations provides us with relevant information when assessing the progress of the scope and objective for which the indicators were incorporated. Figure 4 presents the main stakeholders of the MMs, i.e., managers, teachers, and students, finding that the stakeholders for whom the most HEI MMs have been constructed are the Research and Knowledge Transfer managers. Notably, the S1 study measured aspects related to teachers and students and S9 towards managers and teachers, so one can observe how two or more stakeholders can participate in MMs. Among the findings on HEI missions, 23% focused on research, 23% on teaching, 42% on knowledge transfer, and 11% on community engagement. Carayannis and Morawska-Jancelewicz (2022) looked for highlights that address the gap of relatively few studies on institutional change and incentive structures that influence the ability of universities to engage in (digital) social innovation within digital and green transitions. These findings reflect the need for HEIs to provide open environments to educate all citizens inclusively and conduct research focusing on social innovation and sustainability using digital tools.

The maturity models for Society 5.0 require a holistic vision with dimensions that focus on the internal issues of the HEI and look at connecting with external dimensions comprising the other helixes of the context, considering indicators such as data management, security and privacy, and ethical processes in the integration of Technology 4.0. Figure 5 reflects 18 studies related to the Academia Helix (65% of the studies). In comparison, four studies related to the Industry Helix (19%), three studies to the Environment Helix (11%), and only one study for Civil Society (2.6%). Notably, no models were found linked to the Government Helix. Study S16 was the “Financial Management Maturity Model” related to Civil Society, reflecting citizenship activities. Also, only three studies (S6, S13, and S19) addressed the environment or sustainability. University MMs must consider the Quintuple/Quadruple Helix (Carayannis et al., 2019, 2023) and have the methodologies and tools to fulfill their missions toward Society 5.0. Sustainable maturity models that integrate the care and well-being of society and the environment create a significant difference in HEI’s impact on the helix.

5. Implication of the research findings for theory and practice

Successful implementation of Maturity Models through technological platforms for integration and information architectures requires multidisciplinary teams (researchers, educators, engineers, and designers). This highlights the main technological or technical orientation of the analyses, management models, and research methods that can expand and compare studies better to understand HEIs and their integration in Society 5.0 and achieve a significant impact with external actors within the community engagement mission.

There are areas of opportunity to build the core components of Education 5.0 within the conceptualization of the 5.0 Society. Therefore, further research should aim to measure the effectiveness of different maturity models to promote the integration of Education 4.0 components in HEIs for Society 5.0, comparing the different dimensions, stages, and levels of MMs, evaluating their impact on teaching, and learning outcomes, competencies, and other relevant dimensions, and proposing different research methods and instruments for their development and evaluation. Future research could explore MMs that measure dimensions of innovation and

sustainability in HEIs in the quintuple helix, involving the perspectives and priorities of stakeholders from different sectors. For these reasons, we propose challenging research for an integrative maturity model that incorporates the common elements of Education 4.0 and Society 5.0 with a more holistic approach using standard measures that support the design of an integrated route.

6. Limitations and future research

This Systematic Literature Review (SLR) used inclusion and exclusion criteria, with articles in English published in the last five years in Scopus and WoS databases, with keywords related to Maturity Models in Higher Education. This SLR excluded books, book chapters, conference proceedings, notes, reviews, and non-English language publications; thus, the current study is not bias-free. The discussion presents findings from the most representative studies that can help to identify definitions, dimensions, and levels, among others, that can help mold Society 5.0; however, we recommend reading each of the articles presented according to the readers' interest in this research. Future research in Maturity Models could address systematic reviews incorporating keywords such as Education 4.0 and Society 5.0 in Higher Education and additionally delve into the formulation of instruments and empirical models to support the dimensions of a digital maturity model for Society 5.0 and Education 4.0.

7. Conclusions

The pace and velocity of technological innovations and disruptions have created an ever-changing, permanently increasing complexity for society. In this context, HEIs are under tremendous pressure not only to understand the changing context but to adapt and incorporate those forces strategically. In this context, to accomplish their missions, HEIs must have well-structured and scientifically based MMs that are critical to evaluate the status of HEI and support their organizational and cultural changes. This Systematic Review presents significant contributions to understanding the status of the HEI MMs dimensions, levels, stages, and measurements and their actualization of the components of Education 4.0 (competencies, infrastructure, learning methods, and organizational dimensions) for Society 5.0 (human-centered). This review also identified the key stakeholders of the quintuple helix (academia, civil society, environment, and industry) and the mission of the HEIs (teaching, research, knowledge transfer, and community engagement).

A relevant finding was that most of the models are descriptive, i.e., they only looked for a problem but produced no plan to solve it, while the MMs that use prescriptive mechanisms seek to create a development plan in the face of data or information that may present risks to HEIs. Comparative mechanisms measure the impact of other external organizations, which is conducive to innovation and knowledge linkage. Therefore, as mentioned above, MMS must incorporate comparative designs, especially mixed ones, and analyze them more precisely to impact the external stakeholders more significantly.

Furthermore, most of the studies focused on the internal processes aimed at the organizational dimensions, like marketing, library, information technology services, and human resources. For a maturity model to achieve the fourth HEI mission, community engagement, it is necessary to connect with very different aspects than those measured so far to evolve towards the Society 5.0 culture and incorporate and measure the maturity levels of relevant stakeholders, such as civil society, environmental directors, and industry leaders, and identify relevant and standard dimensions and levels. Likewise, Education 4.0 and Society 5.0 emphasize strategically incorporating and combining technologies like artificial intelligence, the Internet of Things, robots, and automation. Both emphasize personalized learning and individualized solutions, encourage stakeholder collaboration, and value creativity and innovation with a lifelong learning approach and a deep interest in sustainability and human-centered approaches.

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