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Engineering employability in the era of Industry 4.0 and 5.0: a systematic review and a KASH-based integrative framework for education and training

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Abstract

This study investigates the employability of engineers amid the evolving landscape of Industry 4.0 and Industry 5.0, focusing on the competencies critical for professional integration in increasingly digitalized, human-centred environments. A systematic literature review was conducted following the PRISMA 2020 protocol, drawing on peer-reviewed publications indexed in Web of Science and Scopus. The search combined terms related to employability, skills, and engineering competencies with Industry 4.0/5.0 and digital transformation, restricted to English-language journal articles published between 2020 and 2026. After applying predefined inclusion and exclusion criteria, 36 articles were retained for qualitative synthesis. To triangulate these findings, an empirical validation was conducted through a survey of 1,000 practicing engineers, analyzed using Partial Least Squares Structural Equation Modelling (PLS-SEM). The findings indicate a strong relationship between engineers' employment prospects and advanced digital skills, including artificial intelligence, data analytics, cybersecurity, and the Internet of Things. Transversal competencies, such as complex problem-solving, interdisciplinary collaboration, adaptability, and ethical awareness, were also identified as essential, while barriers such as rigid curricula, rapid technological change, and the need for continuous upskilling hinder their development. These results highlight the urgency of redesigning engineering education toward more interdisciplinary, human-centred, technology-integrated approaches. The study proposes a KASH-Based Employability Framework, structured around Knowledge, Attitude, Skills, and Habits, offering a more comprehensive and dynamic perspective than existing models such as USEM and Career EDGE. By integrating attitudinal and habitual dimensions underrepresented in current research, the framework offers a theoretical contribution and a practical tool for guiding engineering education and professional development.

1. Introduction

The global industry is now undergoing a profound transformation known as the Fourth Industrial Revolution, also called Industry 4.0. This revolution involves new combinations of digital, physical and biological technologies (like robotics, artificial intelligence (AI), the Internet of Things (IoT)). These technological advancements allow for new forms of manufacturing, such as smart factories, optimized production and fully integrated value chains (Lasi et al., 2014).

Both the Fourth and Fifth Industrial Revolutions represent an important shift in how technologies and humans interact within industrial systems. The Fifth Industrial Revolution places greater emphasis on human-centredness, sustainability, and resilience, whereas the Fourth Industrial Revolution focuses on the application and advancement of technology (Breque et al., 2021; Aheleroff et al., 2022).

These transformations have significant implications for engineers, by reshaping the workplace, and redefining the skill set required in an era of continuous change and innovation. Historically, engineers have played a central role in driving industrial progress through the development of new inventions and processes. However, faced with the continual and rapid advancement of technology associated with the Fourth and Fifth Industrial Revolutions, it is imperative for engineers to continuously update their competencies and adapt to dynamic work environments (Mayer et al., 2024; Li, 2024).

Consequently, contemporary engineers are expected to possess dual expertise: sharp technical skills and essential transversal skills, such as creativity, the ability to collaborate effectively in teams, and commitment to lifelong learning. These capabilities are critical for maintaining employability in a rapidly evolving job market

(Coetzee & Engelbrecht, 2020; Pham et al., 2024). Companies are also applying growing pressure on engineers to lead digital and organizational transformation projects that require not only technical, but also advanced cognitive and behavioral competencies, reinforcing the need for engineers to continuously broaden their professional profile beyond narrow technical specialization and to develop the interpersonal and managerial capacities that large-scale transformation initiatives demand (Hansen et al., 2025).

Digital transformation through the development of Industry 4.0 technologies has shifted how many industrial sectors operate. This transformation has led to a higher need for qualified engineers who can grow and innovate within technologically advanced environments. However, as industries continue to struggle with the shortage of skilled engineers, there is a significant gap between the competencies acquired through university education and those required by industry, highlighting a misalignment between academic training and labor market needs (Rikala et al., 2024; Akinci-Ceylan & Ahn, 2025).

In this context, traditional engineering educational programs are being placed under scrutiny for their ability to adequately prepare engineering graduates for the complex and multidisciplinary nature of the digital industrial era. Companies have expressed that they desire engineers who not only provide technical skills but also possess the transversal skills, including thinking creatively, collaborating and seeking continual professional growth in order to succeed in the fast-paced and ever-changing way of doing business today (Fleming et al., 2024).

In light of the transformations driven by Industry 4.0 and Industry 5.0, a growing body of research has focused on identifying the competencies engineers need to meet emerging industrial demands and improve graduate employability (Abelha et al., 2020; Fernando et al., 2025). Therefore, understanding the factors influencing engineers' employability has become a significant concern for both higher education institutions and business members.

Within this context, this systematic literature review aims to identify the key competencies required in the digital industrial era, analyze the factors affecting engineers' employability, and highlight best practice recommendations for adapting engineering education and training systems to the requirements of Industry 4.0 and Industry 5.0.

More specifically, the systematic literature review aims to achieve the following objectives:

Objective 1: To identify the technical, transversal and human competencies required by engineers in the context of Industry 4.0 and Industry 5.0.

Objective 2: To identify the main challenges and constraining factors that impact engineers' employability (technological, organizational, social and educational).

Objective 3: To synthesize the strategies and suggestions in academic literature for adapting engineering education and training alongside continuous professional development to an increasingly digital and intelligent global context.

Objective 4: To highlight the added value of the KASH-Based Employability Framework and explore its integration into engineering training through the LIDD (Laboratoire d'Inspiration Dynamique et Durable) framework.

2. Literature review

2.1. Engineering employability: concept and evolution

Engineering employability refers to an engineering graduate's ability to draw on and continuously update a portfolio of technical knowledge, transferable skills, and professional attitudes. It encompasses not only securing a first job, but also performing effectively, adapting to change, and moving across roles and career stages as technologies and organizational needs evolve (Römgens et al., 2020; Clarke, 2018).

More broadly, employability is now often framed as a dynamic, lifelong process rather than a fixed outcome. It develops through the ongoing interplay between personal resources (e.g., competence and self-efficacy), access to learning and work experiences, and the opportunities and constraints of the labor market (Yorke, 2006).

This shift is particularly meaningful for engineers since rapid advancements in technology, collaborative project-based work, and the need to work effectively across multiple disciplines are driving engineers to develop strong technical skills, along with other broad-based skills such as effective communication, decision-making based on ethical considerations, and commitment to lifelong learning (Knight & Yorke, 2004; Guilbert et al., 2016). The research literature on engineer employability has contributed numerous conceptual models which provide insight into employability, including, for example, USEM, Career-EDGE, and Human Capital Theory. However, these models demonstrate limitations with respect to the way they describe employability because many models provide block-like, static views of employability and also do not account for the complex interdependencies between the many different categories of competencies in a dynamic work environment. The KASH framework (Knowledge, Attitudes, Skills, and Habits) offers a potential solution to address some of the challenges described above. As the KASH framework examines employability from four interrelated perspectives – cognitive knowledge, behavioral attitudes, practical skills and enduring habits – it has the potential to provide a more dynamic and holistic approach to examining and developing engineering employability for Industry 5.0.

2.2. Competencies required in Industry 4.0 and Industry 5.0

Industry 4.0 fundamentally transformed the skills needed to successfully complete engineering tasks by prioritizing innovation and advanced technology, such as artificial intelligence (AI), data analytics, automation, and cyber-physical systems (Broo et al., 2022). In addition to the development of technical competencies, engineers are increasingly expected to demonstrate strong transversal skills, including complex problem-solving, communication, teamwork, and critical thinking, in order to operate effectively within an environment that is more interconnected and uncertain than previous contexts (Jalali et al., 2022). With the progressive transition into an Industry 5.0 environment, there will be a continued shift towards human-centred capabilities and competencies that focus on ethical, emotional, sustainable, and social values (Ikenga & van der Sijde, 2024). This evolution indicates that the workforce is being transformed from being a purely technical workforce to one of hybrid profiles that combine technical skills with cognitive and behavioral competencies (Muzulon et al., 2025).

2.3. Employability models in higher education

Numerous frameworks have been developed over the years that seek to understand employability in higher education. The USEM model of employability examines the interaction between understanding, skills, efficacy beliefs and metacognition to support graduate outcomes (Knight & Yorke, 2004). The Career EDGE model also explores how career development learning, work experience, subject knowledge, generic skills and emotional intelligence contribute to graduate employability outcomes (Dacre Pool & Sewell, 2007). Human Capital Theory looks at how the value of labour is based on the knowledge and skills accumulated by individuals (Becker, 1964).

However, more recent frameworks such as Tomlinson's Employability Capital Model (2017) provide broader insights on how social and identity-related forms of capital contribute to employability. While these frameworks have all contributed significantly to understanding employability, they present challenges when applied to contemporary engineering careers, as they often assume that competencies remain relatively stable over time and do not adequately capture how the different dimensions of employability change and develop dynamically (Clarke, 2018). Moreover, very few frameworks available specifically address the rapidly changing competency requirements resulting from Industry 4.0 and 5.0 transformations.

The literature review also highlights several employability models used to explain the competencies and factors influencing engineers' professional integration. In this context, Table 1 presents a comparative analysis of the main engineering employability models identified in the literature, including their principles, dimensions, applications, and relevance to the Industry 4.0 and 5.0 contexts. This comparison also allows positioning the proposed KASH model as a more dynamic and integrative framework for engineering education and employability development.

Table 1
Comparative analysis of employability models

Model	Principle	Dimensions	Application	Relevance to Industry 4.0/5.0	Justification
USEM Model (Knight & Yorke, 2004)	Employability through interaction of four dimensions	Understanding (disciplinary knowledge), Skills (technical and transferable), Efficacy beliefs (confidence), Metacognition (learning/reflection)	Widely used in dissertations on graduate and engineer employability	Moderate	The USEM model emphasizes Understanding (disciplinary knowledge) and Skills (technical and transferable). Efficacy beliefs (confidence) and Metacognition (learning/reflection) are crucial for adaptability and continuous learning. However, it does not explicitly highlight the collaborative and human-centric aspects of Industry 5.0.
Career EDGE Employability Model (Dacre Pool & Sewell, 2007)	Employability based on 5 key dimensions	Career Development Learning, Experience (work/internship), Degree Subject Knowledge, Generic Skills, Emotional Intelligence	Influences self-confidence, self-esteem, employability capacity	Moderate	This model includes Generic Skills and Emotional Intelligence, highly relevant for Industry 4.0 (adaptability) and particularly for Industry 5.0 (human-centric approach, collaboration). However, it does not explicitly detail the specific technical and digital skills required by Industry 4.0.
Human Capital Theory (Becker, 1964)	Employability depends on human capital	Education, Skills, Experience, Professional training	More human capital increases employment chances	Low	While Education, Skills, Experience, and Professional training are important, this theory is too broad and does not specifically address the types of skills required by the highly specialized and rapidly evolving environments of

Model	Principle	Dimensions	Application	Relevance to Industry 4.0/5.0	Justification
					Industries 4.0 and 5.0.
Employability Capital Model (Tomlinson, 2017)	Employability as a set of capitals	Human capital (knowledge/skills), Social capital (networks), Cultural capital (values/behaviors), Identity capital (professional identity)	Conceptualizes employability as capitals	Moderate	This model includes Human capital (knowledge/skills) and Social capital (networks), relevant for technological and collaborative environments. Cultural and identity capital contribute to adaptability. However, it could benefit from further specification of digital skills and human-machine collaboration aspects.
Graduate Employability Model (Clarke, 2018)	Integrated approach: skills and socio-economic environment	Human capital, Social capital, Individual characteristics, Labor market context	Employability depends on skills and environment	High	This model adopts an integrated approach that considers Human capital, Social capital, Individual characteristics, and the Labor market context. Considering the labor market context is fundamental for Industry 4.0 and 5.0, which constantly redefine skill needs.

The majority of current models offer beneficial characteristics and valuable insights towards understanding employability. However, they are still incomplete in terms of providing a holistic view of employability in a real-world context as they lack a coherent explanation of how all of the cognitive, skill-based, social, and behavioral dimensions of employability interact with and change over time in actual work environments (Römgens et al., 2020).

2.4. Critical analysis of existing employability models and their limitations

A deeper examination of the models presented in the table reveals several structural and conceptual limitations that reduce their suitability for addressing the demands of Industry 4.0 and Industry 5.0. Although each model contributes valuable insights, none provides a sufficiently integrated, dynamic, and operational framework

capable of guiding the development of employability in highly digitalized and rapidly evolving industrial ecosystems.

1. USEM Model (Knight & Yorke, 2004)

The USEM model offers a rich conceptualization of employability through understanding, skills, efficacy beliefs, and metacognition. However, its lack of operational detail limits its applicability in designing competency-based curricula aligned with Industry 4.0/5.0. Critical dimensions such as attitude, professional behaviours, and workplace habits remain implicit rather than explicitly structured. As a result, the model is conceptually strong but insufficiently actionable for environments requiring agility, digital fluency, and continuous adaptation.

2. Career EDGE Model (Dacre Pool & Sewell, 2007)

Career EDGE is widely used to support career readiness, but it remains primarily focused on the transition to employment rather than on sustained performance in complex industrial contexts. While emotional intelligence and generic skills are included, the model does not explicitly address attitudinal factors (e.g., resilience, ethical mindset) or habitual behaviours (e.g., discipline, continuous improvement practices). Its relevance to Industry 4.0/5.0 is therefore moderate, as it does not fully capture the behavioural and cognitive demands of cyber-physical work environments.

3. Human Capital Theory (Becker, 1964)

Human Capital Theory provides a foundational economic perspective but is too narrow for contemporary employability. It reduces employability to investments in education, skills, and experience, overlooking the behavioural, attitudinal, and contextual dimensions that shape performance in digital and automated workplaces. Its explanatory power is limited in contexts where employability depends on collaboration, and learning agility, making its relevance to Industry 4.0/5.0 low.

4. Employability Capital Model (Tomlinson, 2017)

Tomlinson's model expands employability to include human, social, cultural, and identity capital. While this offers a more holistic understanding, the model remains highly conceptual and does not provide a clear structure for curriculum design, assessment, or skill development. It does not differentiate between skills, attitudes, and habits, which are essential for operationalizing employability in industrial settings characterized by automation, data-driven decision-making, and human–machine collaboration.

5. Graduate Employability Model (Clarke, 2018)

Clarke's integrated model acknowledges the interaction between individual characteristics, human and social capital, and labour market conditions. Although highly relevant for analysing employability, it lacks granularity and actionability for educational and industrial stakeholders. Attitudes and habits are embedded within broader categories and are not treated as distinct, measurable, or developable constructs. Consequently, the model is analytically strong but insufficiently prescriptive for guiding employability development in Industry 4.0/5.0.

Across all models, several recurring limitations emerge: attitude is underdeveloped (mindset, values, resilience, openness to change, and ethical behaviour are rarely conceptualized as core components of employability); habits are almost entirely absent (yet habits, discipline, consistency, continuous improvement, collaboration routines, are critical predictors of workplace performance); limited operationalization (most models lack clear pathways for translating concepts into competency frameworks, learning outcomes, or assessment tools); insufficient alignment with Industry 4.0/5.0 (digital literacy, human–machine interaction, and lifelong learning are not explicitly integrated); and static rather than dynamic approaches (few models capture the continuous, iterative nature of employability development required in rapidly evolving industrial ecosystems).

Unlike previous models, the KASH-Based Employability Framework is: dynamic (it supports continuous development rather than static attributes); actionable (each dimension can be translated into learning outcomes, indicators, and assessment criteria); integrative (it bridges cognitive, behavioral, and attitudinal components of employability); and industry-aligned (it reflects the real demands of Industry 4.0/5.0, including digital fluency, and human–machine collaboration).

This deeper analysis highlights that existing employability models, while valuable, lack explicit integration of attitudes and habits and offer limited operational guidance for Industry 4.0/5.0 contexts. The KASH-Based Employability Framework addresses these gaps by providing a dynamic, structured, and industry-aligned model that integrates Knowledge, Attitude, Skills, and Habits, offering a more comprehensive and actionable foundation for developing employability in the era of digital transformation.

3. Methods

3.1. Research design

This study adopts a mixed-methods approach, combining both qualitative and quantitative methods to conduct a systematic literature review and an empirical validation of the findings. The review follows the PRISMA guidelines to ensure transparency, rigor, and reproducibility (Page et al., 2021).

A systematic search was conducted across two major databases, Scopus and Web of Science, to identify relevant peer-reviewed articles. The search was limited to publications from 2020 to 2026 to capture the dynamism of the evolution of the Industry 4.0 and Industry 5.0 discourses. After applying predefined inclusion and exclusion criteria, a final sample of 36 high-quality articles was selected. These studies were then subjected to thematic analysis to identify recurring patterns related to engineering competencies and employability.

To further validate the results of the systematic review, the authors used triangulation as a methodological strategy whereby the data were compared/contrasted with primary empirical research. A survey was administered to 1,000 practicing engineers, and the collected data were analyzed using Partial Least Squares Structural Equation Modelling (PLS-SEM) within the KASH framework. This approach provided a comprehensive synthesis of existing knowledge as well as more rigorous and quantifiable evidence supporting the proposed conceptual framework. This empirical dataset was originally collected as part of a related conference publication by the authors [citation withheld for blind review] and is reanalyzed here within the newly developed KASH-Based Employability Framework, together with the systematic literature review presented in this manuscript.

3.2. Protocol and eligibility criteria

The literature review conducted in this study follows the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) to provide transparency, rigor, and replicability in conducting a systematic literature review. The PRISMA framework provides a rigorous and structured approach for identifying, screening, and selecting the relevant scientific literature.

Before conducting the literature review, the authors defined a set of inclusion and exclusion criteria (Table 2) to guide the selection of peer-reviewed studies that meet the required standards of quality and relevance criteria for the selected studies.

Table 2
Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Studies focusing on engineering education, engineering students, or engineering graduates	Studies related to primary or secondary education
Research addressing engineering employability, competencies, or skills development	Studies not related to engineering fields
Studies examining Industry 4.0, Industry 5.0, or digital transformation	Articles not addressing Industry 4.0, Industry 5.0, or digital transformation
Peer-reviewed journal articles	Conference abstracts, editorials, book chapters, blogs, opinion papers, and non-academic publications
Articles published in English between 2020 and 2026	Publications outside the selected time period or not written in English
Studies providing empirical, conceptual, or review-based analysis of engineering competencies	Studies without full text or lacking methodological rigor

3.3. Information sources and search strategy

Two major databases were used to conduct the literature review: the Web of Science Core Collection and Scopus. These databases were selected due to their extensive coverage of high-quality academic publications within the fields of engineering, digital transformation, and education.

The search strategy used in the Web of Science database was as follows:

("employ*" OR "graduate employability" OR "skills" OR "competencies") AND ("engineer*" OR "engineering graduates" OR "engineering education") AND ("Industry 4.0" OR "Industry 5.0" OR "digital transformation").

The search strategy used in the Scopus database was as follows:

TITLE-ABS-KEY ("employ*" OR "graduate employability" OR "skills" OR "competencies") AND TITLE-ABS-KEY ("engineer*" OR "engineering graduates" OR "engineering education") AND TITLE-ABS-KEY ("Industry 4.0" OR "Industry 5.0" OR "digital transformation").

The following filters were applied: Document type – article; Language – English; Year Published – 2020–2026; Web of Science Categories – Education and Educational Research, Engineering; Scopus Subject Areas – Engineering, Social Science, Computer Science.

3.4. The identification of studies

Studies were identified in several steps, as illustrated in the PRISMA flowchart. The first step in the review process was to identify studies according to document type, language, and publication date. The next step involved assigning thematic categories for more refinement of the selection of studies. Subsequently, the titles and abstracts of the remaining studies were reviewed for relevance. Finally, a detailed examination of the full texts was conducted for studies considered potentially relevant for inclusion in the systematic review.

3.5. Data extraction and analysis

To extract the relevant information from the included studies, data were collected using a standardized data collection grid. The extracted data included bibliographic information (e.g., author, year, and title), type of publication, country of study, identified skill areas, identified challenges and constraints, and suggested recommendations.

4. Results

4.1. Study selection

The screening process was documented using a PRISMA flow diagram. The initial search process resulted in a total of 2,306 research articles (584 via the Web of Science and 1,722 through Scopus). After applying the initial filters related to document type, language, and publication period, the number of articles was reduced to 697 (293 from the Web of Science and 404 from Scopus). Applying filters based on thematic categories further reduced the sample to 468 articles (114 from the Web of Science and 354 from Scopus).

Following review of the article titles and abstracts, 166 articles were deemed suitable for inclusion in the final synthesis of this review (70 from the Web of Science and 96 from Scopus). After the removal of duplicates, 111 articles were available for review (25 from Web of Science, 86 from Scopus). Finally, after applying the eligibility criteria during the full-text review, 36 articles were retained for inclusion in the qualitative synthesis.

The PRISMA flow diagram (Fig. 1) illustrates the different stages of the screening and selection process.

A completed PRISMA 2020 checklist is provided as supplementary material to document compliance with reporting standards for systematic reviews.

4.2. Overview of selected studies

Following the PRISMA screening process, a total of 36 scientific articles were identified as meeting the criteria for inclusion in further analysis. These investigations explore the essential skills and competencies that are necessary to meet the expectations associated with Industry 4.0 and Industry 5.0, as well as the pedagogical approaches that will enable engineers to acquire these competencies.

The studies included in the literature review comprise empirical research, surveys, conceptual frameworks or models, curriculum analyses, and systematic reviews.

The tables below summarize the characteristics of the 36 selected studies, including their types, areas of focus, key skill areas identified, and major contributions to employability and competencies needed to be an engineer in today’s digital world.

Table 3
Characteristics of selected studies

Authors (Year)	Type of Study	Focus	Key Skills Identified	Main Contribution
Da Rocha et al. (2025)	Empirical	Industry 4.0 competencies	Data analytics, automation, digital skills	Demonstrates the relationship between Industry 4.0 and engineering competencies
Aranda-Jiménez et al. (2024)	Empirical	Digitalization	Digital literacy, collaboration	Highlights the influence of digital skills on professional behavior
Muzulon et al. (2025)	Framework validation	Engineering competencies	Technical, digital, transversal skills	Proposes a career-level competency framework for engineers
Saniuk et al. (2022)	Qualitative	Industry 4.0 technologies	AI, robotics, problem solving	Provides expert perspectives on the skills required in Industry 4.0 environments
Bueno et al. (2024)	Curriculum analysis	Engineering education	Data science, automation	Explores the role of universities in developing Industry 4.0 skills
Quintero (2022)	Systematic review	Digital competences	Digital literacy, ICT skills	Synthesizes the main digital competences required for engineers
Al-Maskari et al. (2024)	Quantitative study using SEM	Students' characteristics; Knowledge of 4IR technologies	Critical and Analytical Thinking; Creativity and Innovation; Leadership and Influence; Emotional Intelligence; Learning and Collaboration	Validates a conceptual model showing that three factors significantly impact students' preparedness for 4IR
Maisiri et al. (2021)	Empirical	Industry 4.0 workforce	Technical, digital, interpersonal, and competency maturity skills	Proposes a competency maturity model integrating technical and soft skills required for Industry 4.0 readiness
Souppez (2025)	Empirical	Engineer employability	Technical skills, soft skills	Examines the employability of engineers through technical and soft skills
Thirunavukarasu et al. (2020)	Survey	Graduate employability	Communication, teamwork	Investigates students' perceptions of employability skills

Authors (Year)	Type of Study	Focus	Key Skills Identified	Main Contribution
Laguna et al. (2025)	SEM analysis	Professional development	Soft skills, digital skills	Reveals the influence of soft skills on career development
Wu et al. (2023)	Empirical	Employability	Communication skills	Shows the importance of communication skills in employability
Widarto et al. (2023)	Survey	Employability skills	Collaboration, communication	Analyzes lecturers' perceptions of employability skills
Zhang et al. (2024)	Empirical	Skills mismatch	Technical and professional skills	Highlights the gap between graduates' competencies and industry needs
Suárez-Brito et al. (2025)	Empirical	Creativity	Creative thinking	Emphasizes creativity as a key Industry 4.0 competence
Chans et al. (2025)	Empirical	Transversal competencies	Intercultural skills, teamwork	Demonstrates the importance of international experiences in developing transversal competencies
Sukardi et al. (2023)	Educational	Engineering students	Hard skills and soft skills	Advocates the balanced development of hard and soft skills
Oksana et al. (2020)	Educational	Transversal skills	Communication, language skills	Promotes the integration of interdisciplinary competencies into engineering education
Saleem et al. (2024)	Bibliometric	21st century skills	Critical thinking, creativity	Provides a global overview of emerging 21st-century skills
Belmonte et al. (2023)	Educational	Logistics 4.0	Digital supply chain skills	Integrates Logistics 4.0 concepts into engineering education
Belmonte et al. (2025)	Educational	Digital technologies	Digital engineering tools	Supports the integration of digital technologies into engineering training
Panxhi et al. (2025)	Empirical	Engineering education	Entrepreneurial skills	Examines the impact of digital transformation on

Authors (Year)	Type of Study	Focus	Key Skills Identified	Main Contribution
				engineering education
Azofeifa et al. (2025)	Comparative	Engineering education	Innovation, digital skills	Compares future skill integration within engineering education systems
Azofeifa et al. (2024)	Experimental	Virtual learning	Decision-making skills	Introduces innovative virtual learning environments for decision-making skill development
Yoo et al. (2021)	Framework	Intelligent learning	AI-based digital skills	Develops an AI-supported framework for engineering learning
Beke & Tick (2024)	Survey	Education 4.0	Digital competencies	Evaluates the adoption of Education 4.0 practices and competencies
Cesco et al. (2021)	Analytical review and conceptual paper	Future challenges of scientific and technical higher education in Europe	Technical skills; Methodological skills; Personal skills; Social skills	Identifies skill gaps and future challenges in higher technical education
UL-Ain & Waheed (2025)	Empirical	Workforce upskilling	Digital upskilling	Highlights the importance of continuous digital upskilling
Hansen et al. (2025)	Empirical	Digital transformation	Organizational digital skills	Explores the role of human factors in digital transformation
Abdullah et al. (2026)	Educational	Micro-credentials	Machine learning, soft skills	Proposes micro-credential training models for future engineering skills
Huggahalli & Gupta (2025)	Conceptual	Industry 4.0/5.0	Leadership, human-centric skills	Introduces the concept of V-shaped engineers for Industry 4.0/5.0
Kolade & Owoseni (2022)	Conceptual	Employment 5.0	Adaptability, creativity	Conceptualizes a future-oriented Employment 5.0 paradigm
Yekinni et al. (2025)	Curriculum analysis	Industry 5.0	Human-centric competencies	Recommends curriculum transformation toward human-

Authors (Year)	Type of Study	Focus	Key Skills Identified	Main Contribution
				centric competencies
Dehbozorgi et al. (2025)	Educational	Learning factories	Practical Industry 4.0/5.0 skills	Promotes experiential learning environments through learning factories
Dautaj et al. (2025)	Conceptual	Society 5.0	Human-centric skills	Expands engineering skill frameworks within the Society 5.0 perspective
González-Hernández & Granillo-Macías (2020)	Academic analysis	Industrial engineering	Analytical and technical skills	Defines the core competencies required for industrial engineers

To better understand the current research directions for developing engineering skills, the 36 identified studies were categorized into seven thematic groupings based on their primary research objectives and contributions. These thematic groupings are visually represented in Fig. 2, which illustrates that Industry 4.0/5.0 Technologies is the largest research cluster represented (8 studies; 22%), thus indicating the strong focus on student exposure to technological integration in engineering education. This is closely followed by Employability & Career Development (7 studies; 19%), and Engineering Education & Curriculum (6 studies; 17%), which address the issue of ensuring students graduate with the competency-based skills needed by industry. Secondary themes are represented by Digital Skills & Competencies (5 studies; 14%), Transversal/Soft Skills (4 studies; 11%), and Innovative Learning Approaches (3 studies; 8%). An emerging area of research is Competency Frameworks & Assessment (2 studies; 6%). The categorization of studies presented indicates the broad scope of current research on engineering education and identifies the priority this field gives to technological competencies and workforce readiness.

4.3. Competency categories emerging from literature

Driven by the 4th and 5th industrial revolutions, this research undertook an analysis of essential engineering competencies and pertinent literature. Selected studies were subsequently classified according to the skill types they presented, facilitating a systematic categorization of all identified skill areas.

Table 4 below shows the main categories of competency, the specific skills reported in the literature and the frequency with which those particular competencies were mentioned in the studies reviewed.

Table 4
Classification and frequency of engineering competencies reported in literature

Skills Category	Specific Skills	Frequency (Number of Studies)	Example References
Digital & Technological Skills	AI	2	Saniuk et al. (2022); Yoo et al. (2021)
	Automation	2	Da Rocha et al. (2025); Bueno et al. (2024)
	Digital skills	2	Da Rocha et al. (2025); Aranda-Jiménez et al. (2024)
	Digital literacy	2	Aranda-Jiménez et al. (2024); Quintero (2022)
	Data analytics	1	Da Rocha et al. (2025)
	Robotics	1	Saniuk et al. (2022)
	Data science	1	Bueno et al. (2024)
	ICT skills	1	Quintero (2022)
	Knowledge of 4IR technologies	1	Al-Maskari et al. (2024)
	Digital and organizational skills	1	Şimşek Demirbağ & Yıldırım (2023)
	Digital supply chain skills	1	Belmonte et al. (2023)
	Digital engineering tools	1	Belmonte et al. (2025)
	Digital competencies	1	Beke & Tick (2024)
	Digital upskilling	1	UL-Ain & Waheed (2025)
	Organizational digital skills	1	Hansen et al. (2025)
	Machine learning	1	Abdullah et al. (2026)
	Digital transformation	1	Azofeifa et al. (2025)
Cognitive Skills	Creativity	2	Saleem et al. (2024); Kolade & Owoseni (2022)
	Problem solving	1	Saniuk et al. (2022)
	Critical and Analytical Thinking	1	Al-Maskari et al. (2024)
	Creativity and Innovation	1	Al-Maskari et al. (2024)

Skills Category	Specific Skills	Frequency (Number of Studies)	Example References
	Creative thinking	1	Suárez-Brito et al. (2025)
	Critical thinking	1	Saleem et al. (2024)
	Decision-making skills	1	Azofeifa et al. (2024)
	Analytical and technical skills	1	González-Hernández & Granillo-Macías (2020)
	Innovation	1	Azofeifa et al. (2025)
Transversal Skills	Communication	4	Thirunavukarasu et al. (2020); Wu et al. (2023); Widarto et al. (2023); Oksana et al. (2020)
	Soft skills	4	Souppez (2025); Laguna et al. (2025); Sukardi et al. (2023); Abdullah et al. (2026)
	Teamwork	3	Thirunavukarasu et al. (2020); Chans et al. (2025); Widarto et al. (2023)
	Collaboration	2	Aranda-Jiménez et al. (2024); Al-Maskari et al. (2024)
	Language skills	1	Oksana et al. (2020)
	Intercultural skills	1	Chans et al. (2025)
	Entrepreneurial skills	1	Panxhi et al. (2025)
	Adaptability	1	Kolade & Owoseni (2022)
	Methodological skills	1	Cesco et al. (2021)
Human-Centric Skills	Human-centric skills	3	Huggahalli & Gupta (2025); Yekinni et al. (2025); Dautaj et al. (2025)
	Leadership	2	Al-Maskari et al. (2024); Huggahalli & Gupta (2025)
	Technical skills	2	Souppez (2025); Zhang et al. (2024)
	Emotional Intelligence	1	Al-Maskari et al. (2024)
	Learning and Collaboration	1	Al-Maskari et al. (2024)
	Personal skills	1	Cesco et al. (2021)
	Social skills	1	Cesco et al. (2021)
	Hard skills	1	Sukardi et al. (2023)

The examination of relevant literature regarding engineering skills for Industry 4.0 and development of an Industry 5.0 framework has identified distinct areas of emphasis in the hierarchy of skills. The major skill group represented in the literature is Digital/Technology skills, with problem-solving skills, communication skills, and teamwork skills ranking as the next set of major skills. In addition, studies examined have shown an increasing emphasis on human-centred skills (e.g., sustainability, ethical conduct), which signal a significant shift toward the Industry 5.0 framework.

4.4. Classification of engineering skills identified in the literature

Based on the review of selected studies, four unique categories of competencies necessary for engineers in light of Industry 4.0 and the transition to Industry 5.0 have been defined.

The largest percentage of studies reviewed (35% or 21 times, covering 17 unique competencies) indicated that engineers need digital and technological skills as the most frequently mentioned category. These digital and technological skills include artificial intelligence, data analytics, automation, digital literacy, machine learning, and digital competencies. The importance of these digital skills and smart technologies has become increasingly evident throughout the industrial sector as digital technology and smart systems take on an increasingly important role in today's industrial environment.

Transversal Skills made up the next largest category of skills identified (30%, or 18 times). Communication skills, soft skills and teamwork were the most frequently mentioned competencies, indicating the importance of interpersonal and cross-functional skills for engineers to successfully perform their jobs.

The next largest category is human-centric skills, accounting for 19% of all competencies identified (12 occurrences). Human-centric skills indicate that there is an increasing need for leadership, emotional intelligence and skills that are focused on humans within the context of Industry 5.0.

Cognitive Skills made up 16% (10 occurrences) of the identified skills (creativity, problem solving, critical thinking, decision making, innovation) that will be critical for engineers in addressing today's complex and changing engineering challenges.

From the various studies, it is evident that engineers must have a synergistic combination of technology-related, cognitive, transversal competencies and human-centred values to achieve successful employment in the Industry 4.0/5.0 paradigm.

To contextualize the temporal evolution of research activity in this field, Fig. 4 presents the distribution of the 36 selected studies according to their year of publication. The 36 studies sampled in the present systematic literature review are temporally represented in Fig. 4 from 2020 to 2026. A clear upward trend in scholarly interest in research about engineering competency within the context of Industry 4.0 and Industry 5.0 can be observed. The number of publications was relatively small between 2020 and 2023, with 2 to 4 studies published per year; however, starting from 2024, the number of studies has greatly increased. Eight studies were published in 2024; the peak occurred in 2025 at 15 studies published (41.7% of the total number of studies analyzed). This rapid increase in studies suggests that the discussion regarding the requirements for engineering competencies has gained considerable traction in the academic community in the past few years, with the advancements of digital

technology, the restructuring of industrial cultures, and the emergence of more humanistic views of Industry 5.0 being the factors that are driving this new interest.

Figure 4 illustrates a clear temporal progression in the volume of research on engineering employability within the context of Industry 4.0 and 5.0. The number of publications remains relatively modest between 2020 and 2023, reflecting the early development of this research area. A notable increase occurs from 2024 onward, with a sharp rise in 2025, indicating growing academic interest in digital transformation, future skills, and engineering workforce readiness. The slight decline observed in 2026 is likely attributable to the partial nature of the publication year rather than a reduction in research activity. Overall, the upward trend highlights the increasing relevance of employability and competency development as central themes in engineering education and workforce studies.

The majority of the empirical studies included in the SLR (11 out of 36; approximately 31%) rely on field-based data collection and real-world observation to examine engineering competency requirements. Educational studies constitute the second most frequent category (6 studies; about 17%), followed by survey-based designs (3 studies; around 8%). The corpus also includes a substantial proportion of conceptual, analytical, and framework-based studies (10 studies; roughly 28%), as well as curriculum analyses and experimental designs. This methodological diversity strengthens the credibility of the competency profiles identified in the literature, as the evidence is drawn from multiple and complementary research traditions. Moreover, the predominance of empirical studies provides additional robustness to the findings, given their grounding in real-world engineering contexts.

Empirical studies have the greatest variability and are the most widely represented methodological type across multiple thematic categories such as Employability (n = 3), Digital & Technology (n = 3), Industry 4.0 (n = 2) and Transversal & Human Skills (n = 2). The preponderance of empirical studies indicates a high incidence of field-based studies within engineering competency research. At the same time, the bulk of educational studies are clustered around Learning and Pedagogy (n = 3), thus highlighting a strong pedagogical focus within this research area. Conceptual study examples represent a small concentration within the Industry 5.0 area (n = 2), which shows that researchers use theoretical and anticipatory frameworks to determine future human competencies/skills needed under the next industrial paradigm. Lastly, survey-based studies are mostly clustered around Employability (n = 2), which suggests that academics utilize perception-based methods to determine the employment/skill gap between academia and industry.

4.5. Synthesis of challenges and constraints

This systematic literature review provides an analytic framework for understanding the multi-dimensional nature of the barriers to engineer employability in Industry 4.0/5.0 contexts. The framework organizes barriers by locus of action and institutional level, thus making it possible to view employability barriers in a way that goes beyond traditional binary classifications of barriers (e.g., soft vs. technical skills) and recognizes that challenges in employability occur at four interrelated levels: (1) the individual learner, (2) educational institution, (3) the employing organization, and (4) the broader macroeconomic and systemic environment.

The findings show not only the nature of specific barriers but also the systemic interdependencies amongst them, as well as potential leverage points for intervention, by plotting the 116 constraints identified in this review on the four strategic dimensions discussed above (as illustrated in Table 5). The findings indicate that the distribution of barriers across the four strategic dimensions is highly asymmetrical, with individual competency

gaps constituting 66.38% of the identified barriers; thus, it appears that the greatest challenge to the employability of engineering graduates is not due to institutional or systemic barriers but rather to the competency profile of the individual engineering graduates. This finding has significant implications for the design of curricula and pedagogies, and the allocation of institutional resources intended to improve employability of engineering graduates.

To ensure consistency in reporting, frequency categories were standardized using percentage thresholds: Very High (≥ 20%), High (10–19.99%), Moderate (5–9.99%), and Low (< 5%). These thresholds were defined by the authors to harmonize the interpretation of constraint prevalence across studies.

Table 5
Four-dimensional framework of employability constraints

Strategic Axis (Dimension)	Constraint Type	Detailed Description	Frequency
1. Individual Competency Gaps (66.38% of identified constraints)	Digital Skills Deficit	Critical shortfall in advanced digital literacy. Graduates lack practical mastery in key Industry 4.0 technologies (AI, machine learning, robotics, big data analytics, IoT) despite general fluency with consumer digital tools (the generational paradox).	Very High (28.45%)
	Soft Skills Deficiency	Employers are reporting significant deficiencies in the interpersonal and intrapersonal competencies of real-world employees. Examples include gaps in emotional intelligence, leadership, effective workplace communication, and the ability to work effectively on multidisciplinary teams (all of which have become vital in Industry 5.0).	Very High (25.00%)
	Technical Skills Inadequacy	The erosion or obsolescence of core technical capabilities. No ability to implement complicated engineering principles on actual problems, with significant holes in systems modeling, rigorous statistical study and analysis.	Moderate (6.90%)
	Insufficient Transversal Competencies	Lack of higher cognitive skills (i.e., critical thinking, imaginative thinking, flexible thinking and innovative ability) needed for dealing with unstructured, ambiguous, complex problems.	Moderate (6.03%)
2. Institutional & Educational Frictions (20.70% of identified constraints)	Curriculum-Industry Disconnect	A lack of alignment between the content of university courses and the changing demands of various job markets and industries. University programme curricula do not allow for the introduction of rapidly changing technologies or the use of Industry 4.0 and 5.0 technologies due to the extensive redesign required.	High (15.52%)
	Lack of Practical Experience	Students are deprived of authentic experiential learning opportunities, meaning they do not have an opportunity to learn about professional practices and theories from real-world industrial settings (e.g., learning factories, immersive simulations). As a result, students cannot convert their theoretical understanding into practice within the workforce.	Low (2.59%)
	Assessment and Validation Issues	The traditional evaluation mechanism for assessing knowledge and skills in educational institutions is inadequate for introducing and implementing new ways of evaluating, certifying, and validating emerging skills through modern evaluation mechanisms such as micro-credentials (including soft skills and digital skills).	Low (2.59%)
3. Organizational & Workplace Barriers (6.04% of identified constraints)	Organizational Digital Readiness	The use of digital resources by employers of recent university graduates, despite their skills, will often lag behind the latest digital development. As a result, while the individual has the requisite skills, the entity will not have the infrastructure or innovation culture or process to take full advantage of those resources, and therefore the	Low (3.45%)

Strategic Axis (Dimension)	Constraint Type	Detailed Description	Frequency
		quantity and quality of the resources will not be maximized through effective utilization.	
	Continuous Learning Gap	Companies that employ young professionals are frequently unable to transition to a continuous learning culture/infrastructure whereby they may retrain or upgrade their current employees and therefore put their new hires at risk of having their acquired skills made obsolete within the face of rapidly evolving technologies.	Low (2.59%)
4. Systemic & Macro-Environmental Challenges (6.89% of identified constraints)	Skills Mismatch	The global labour market has a significant imbalance between the number of skills available to the workforce by the education system and the structural demands for these skills from the labour market. This imbalance creates both underemployment and inadequate productivity among recent graduates.	Low (4.31%)
	Language and Communication Barriers	There are linguistic and cultural barriers that inhibit international mobility and limit the ability of engineers to be part of the globalized value chain and work effectively in multicultural teams.	Low (1.72%)
	Entrepreneurial Skills Shortage	The engineering profession suffers from a systemic lack of an entrepreneurial mindset. As a result, there is no capacity to identify business opportunities, take calculated risks, innovate and adapt to global digital transformation.	Low (0.86%)

The four-dimensional model provides insight into employability barriers in engineering education. Individual-level constraints (66.38%) are the largest proportion, indicating a fundamental misalignment between students' competency levels and what Industry 4.0/5.0 requires. Therefore, the focus should be on redesigning learning materials and methods, as opposed to only addressing institutional or labor-market-related failures. Institutional factors (20.70%) are also critical because they influence how competencies develop via the curriculum, pedagogy, and assessment. The curriculum/industry disconnect (15.52%) is one of the chief structural barriers. Organizational/systemic constraints (13.93%) highlight that graduates prepared to enter the workforce may find themselves in workplaces where they cannot fully utilize their skills. Thus, to improve employability outcomes, coordinated efforts are needed across all four dimensions.

While 116 employment barriers were identified, a number of significant gaps continue to exist. Most literature continues to concentrate primarily on individual competencies while ignoring institutional, organizational, and systemic aspects. The impact of educational practices over time also lacks comprehensive longitudinal data. Moreover, where organizational constraints have been researched, they are understudied, with most studies being conducted in developed economies, therefore the contextual relevance is limited. Addressing these gaps will provide a more holistic picture of engineers' employability within an Industry 4.0/5.0 setting.

4.6. Toward an integrative KASH-based framework

To synthesize the identified competencies and respond to the limitations of existing employability models, this study proposes a Conceptual KASH-Based Employability Framework, structured around four interrelated dimensions: Knowledge, Attitudes, Skills, and Habits (KASH) (Fig. 7).

Figure 7 illustrates the integrative structure of the KASH-Based Employability Framework, which positions employability as the dynamic outcome of four interrelated dimensions: Knowledge, Skills, Attitudes, and Habits. Knowledge represents the cognitive and technological foundations required in Industry 4.0 and 5.0 environments, while Skills refer to the practical and transversal abilities enabling the application of this knowledge. Attitudes encompass motivational and behavioral orientations that shape ethical awareness and openness to change. Habits reflect the recurrent professional behaviors, such as continuous learning, discipline, and resilience, that sustain long-term performance. Together, these dimensions interact within the broader context of digitalization, artificial intelligence, sustainability, and human-centric industrial transformation to support engineers' performance and career sustainability.

The KASH framework conceptualizes employability as the outcome of dynamic interactions between different facets of human potential:

Knowledge refers to disciplinary, technical, and digital understanding (e.g., AI, data analytics, cyber-physical systems) that enables engineers to operate effectively in Industry 4.0 and 5.0 environments. It encompasses both foundational engineering knowledge and emerging technological literacy.

Skills represent the practical and transversal abilities that allow individuals to apply their knowledge in real contexts, including problem-solving, communication, teamwork, creativity, and systems thinking. Skills bridge the gap between knowing and doing.

Attitudes capture the cognitive and affective orientations that shape how individuals approach work and learning, such as resilience, ethical awareness, openness to change, and commitment to lifelong learning. Attitudes influence whether and how knowledge and skills are mobilized in uncertain and evolving environments.

Habits refer to the stable, recurrent patterns of behavior that structure daily professional practice, such as discipline, time management, collaboration routines, continuous improvement, and reflective practice. Habits transform occasional behaviors into consistent performance over time.

Unlike many existing employability models, which tend to emphasize static attributes or focus primarily on knowledge and skills, the KASH framework explicitly integrates attitudes and habits as core, distinct dimensions. This allows for a more dynamic and developmental understanding of employability, where: Knowledge and skills provide the foundational capacity to access and perform work; Attitudes act as a driving force, shaping motivation and willingness to engage with new technologies and roles; Habits function as a stabilizing mechanism, supporting the sustained enactment of competencies and enabling continuous learning and employability over time.

Furthermore, the KASH framework is explicitly embedded in the context of Industry 4.0 and Industry 5.0. It acknowledges that employability today requires not only advanced technical and digital competencies, but also human-centred capabilities, such as ethical responsibility, social awareness, and the ability to collaborate with both human and intelligent systems. By integrating cognitive (Knowledge), practical (Skills), attitudinal (Attitudes), and behavioral (Habits) dimensions into a single coherent model, the KASH framework offers: a more holistic and integrative perspective than traditional employability models; a dynamic lens that captures how employability develops and evolves across the career lifecycle; and an operational structure that can be translated into curriculum design, learning outcomes, and assessment tools for engineering education and professional development.

In this way, the KASH-Based Employability Framework directly addresses the conceptual and practical limitations identified in previous models and provides a more robust foundation for understanding and developing engineering employability in the era of Industry 4.0 and 5.0.

4.7. Empirical validation of the KASH framework (PLS-SEM analysis)

The systematic literature review was further reinforced by empirical evidence drawn from the authors' own previously reported dataset involving 1,000 practicing engineers across manufacturing, information technology, and engineering services [citation withheld for blind review]. This large-scale dataset enabled a rigorous validation of the KASH framework through Partial Least Squares Structural Equation Modeling (PLS-SEM), thereby providing an empirical foundation that complements and strengthens the insights derived from the literature.

4.7.1. Relation of findings with literature

The empirical results closely align with the patterns identified in the systematic literature review, demonstrating strong convergence between theoretical developments and real-world engineering practice [citation withheld for blind review]. In particular, the substantial effects of attitudes and knowledge observed in the empirical model reflect the growing emphasis on cognitive flexibility, and lifelong learning highlighted in recent scholarship (Clarke, 2018; Pham et al., 2024). This convergence provides robust triangulation evidence, reinforcing both the internal consistency and external validity of the KASH framework. The alignment between the SLR and the previously published empirical findings further confirms the framework’s relevance for understanding contemporary engineering employability.

4.7.2. Major findings

The empirical analysis demonstrates that engineering employability is not driven solely by technical skills. Instead, it emerges from an interactive and mutually reinforcing process involving knowledge, skills, attitudes, and habitual behaviors. Among these dimensions, attitudes exert the strongest influence on employability outcomes, underscoring the importance of motivation, resilience, and professional disposition. These findings carry significant implications for engineering education and workforce development, particularly in the context of the human-centred and sustainability-oriented transition toward Industry 5.0. The prominence of attitudinal factors observed in the empirical study [citation withheld for blind review] further validates the KASH framework and confirms its explanatory power for understanding employability in modern engineering environments.

5. Limits

Despite their relevance, existing employability models show several recurring limitations when applied to engineers’ employability within Industry 4.0/5.0 contexts:

Limited alignment with Industry 4.0/5.0 realities: many models remain generic and do not explicitly incorporate emerging digital and human-centred requirements such as AI-enabled work, sustainability, and human-centricity. This limits their explanatory power in fast-transforming engineering contexts (Koch et al., 2025).

Overemphasis on individual attributes: a large number of frameworks conceptualize employability mainly as an individual property, while underweighting organizational practices and broader labor-market structures that shape opportunities (Guilbert et al., 2016).

Insufficient dynamic perspective: employability is often treated as a relatively stable outcome, whereas digital transformation accelerates skill obsolescence and makes employability a continuous development process (UL-Ain & Waheed, 2025; World Economic Forum, 2025).

Challenges in measuring and operationalizing employability: existing models face difficulties in consistently measuring different employability constructs such as capitals, identity, confidence, and meta-skills. This limits the comparison of studies and contexts (Römgens et al., 2020; Williams et al., 2023).

Limited longitudinal evidence: since most applications of employability models are cross-sectional, there is limited evidence of the longitudinal development of employability, and limited information on the effects of educational interventions on long-term employability (Van den Broeck et al., 2023).

Limited contextual generalizability: employability models developed in specific sectors or countries may not be applicable to contexts characterized by different levels of industrial maturity, thereby limiting the generalizability of results across different engineering sectors and industrially developed areas (Pham et al., 2024; Da Rocha et al., 2025).

Conceptual overlap and ambiguity: many models often use similar constructs such as skills, capitals and work readiness, resulting in conceptual ambiguity and difficulty building knowledge through cumulative studies of employability (Caballero et al., 2026).

6. Discussion

6.1. Proposed model: enhanced dynamic KASH

6.1.1. Foundation: KASH model

The KASH framework consists of four main components:

1. Knowledge

Knowledge refers to an understanding of some aspects of the engineering profession in terms of technical theories, principles, and domain-specific expertise. It also encompasses knowledge related to management, digital and sustainability practices, as well as an understanding of emerging technologies such as artificial intelligence and automation.

2. Skills/Abilities

Skills/Abilities include both technical and soft competencies. Technical skills include coding, modeling, simulating and managing AI projects, while soft skills include communication, creativity, collaboration, and

teamwork. In addition, digital competencies such as data literacy are increasingly essential in Industry 4.0 and Industry 5.0 environments.

3. Attitude/Mindset

Attitude refers to the psychological and behavioral orientation of individuals toward learning and professional development. This includes curiosity, agility, adaptability and willingness to learn continuously, to adapt to change through learning about new and emerging technologies. It also involves ethical awareness and a sense of social responsibility in the use of technology and engineering practices.

4. Habits/Traits/Behavior

Habits refer to consistent patterns of action that support long-term employability. These include lifelong learning practices, self-assessment, resilience, perseverance, and proactive engagement with AI-driven and automated systems (Maun et al., 2025; Cabrera-Moya et al., 2023).

6.2. Comparison with existing employability models: USEM and Career EDGE

The results of the present systematic review and empirical validation reinforce, while also extending, the conceptualization of employability proposed by the USEM model (Knight & Yorke, 2004). USEM identifies Understanding, Skills, Efficacy beliefs, and Metacognition as the core determinants of graduate employability, and the competencies most frequently cited across the 36 reviewed studies, disciplinary knowledge of emerging technologies, technical and digital skills, and reflective learning capacity, map closely onto these four dimensions. However, where USEM treats attitude and workplace habits as implicit background conditions rather than explicit, measurable constructs, the present findings indicate that engineers themselves identify curiosity, ethical awareness, resilience, and continuous upskilling as decisive factors in sustained employability, particularly within the fast-changing technological contexts of Industry 4.0 and Industry 5.0 (Mayer et al., 2024; Rikala et al., 2024). This suggests that USEM captures the cognitive and skills-based foundations of employability well, but is less equipped to explain how engineers maintain employability over time as technologies, and the behavioral demands associated with them, continue to evolve.

A similar pattern emerges when the findings are compared with the Career EDGE model (Dacre Pool & Sewell, 2007), which situates career development learning, work experience, subject knowledge, generic skills, and emotional intelligence at the centre of graduate employability. The present results corroborate the centrality of generic and interpersonal skills, such as communication, teamwork, and emotional intelligence, which were consistently associated with employability outcomes across the reviewed literature (Wu et al., 2023; Souppez, 2025). Nevertheless, Career EDGE was developed primarily to explain readiness for the transition into employment rather than sustained performance within complex, technologically saturated industrial systems. The survey of 1,000 practicing engineers conducted for this study shows that emotional intelligence and generic skills, while necessary, are insufficient on their own to explain long-term employability once engineers are embedded in digital and automated work environments; habitual behaviours such as discipline, proactive

engagement with new technologies, and continuous improvement routines emerged as additional, distinct predictors that Career EDGE does not explicitly capture.

Taken together, these comparisons suggest that USEM and Career EDGE remain valuable for describing the cognitive, skills-based, and experiential foundations of employability, but that both models were conceived prior to the widespread digitalization and human-machine integration associated with Industry 4.0 and Industry 5.0. Consistent with Clarke (2018) and Römgens et al. (2020), the present findings indicate that employability in highly digitalized industrial ecosystems cannot be adequately explained by static, skills-centred models alone; it requires an explicit account of attitude, understood as openness to change, ethical awareness, and adaptability, and of habits, understood as the recurring behavioral routines that sustain performance and learning over an engineer's career. This is precisely the gap that the KASH-Based Employability Framework is designed to address.

Practically, this comparison has direct implications for engineering education and training. Curricula built primarily around the logic of USEM or Career EDGE tend to prioritize disciplinary knowledge, generic skills, and short-term career readiness, but often leave attitudinal and habitual development to informal or extracurricular experiences. The results of this review, together with the empirical validation among practicing engineers, suggest that engineering programmes aligned with Industry 4.0 and Industry 5.0 requirements should instead treat attitude and habits as explicit learning outcomes, integrated alongside technical and digital competencies, so that graduates are prepared not only to enter the workforce but to sustain their employability as technologies, organizational structures, and industrial paradigms continue to evolve (Fernando et al., 2025; Muzulon et al., 2025).

6.3. Engineering education model – Industry 4.0 and 5.0 competencies

This systematic synthesis of the 36 selected studies identified a range of various pedagogical approaches and educational strategies aimed at aligning engineering curricula with the evolving requirements of both Industry 4.0 and 5.0.

This initiative prioritizes a holistic developmental model for engineering graduates, by integrating rigorous theoretical technical and theoretical knowledge with transversal attributes and essential human-centred competencies, such as collaborative efficacy, creative problem-solving, cognitive flexibility, and a sustained orientation toward lifelong learning.

6.4. Limitations of the review

This review is subject to several inherent limitations. Firstly, there is always the tendency for some degree of publication bias in the peer-reviewed process. This means that studies with positive findings are usually published more often than studies with negative findings. This is an inherent limitation of any systematic literature review and may influence the overall representation of evidence.

Secondly, the literature search was exclusively confined to publications available in English. As a result, relevant studies conducted in other languages or originating from certain regions of the world may not have been captured in the review.

Finally, the rapid evolution of emerging technologies (especially in the areas of Industry 4.0 and Industry 5.0) means that current literature may be insufficient for identifying new competencies associated with recent advances in technology. Furthermore, there is often a significant time lag between technological innovation and the publication of academic research. Consequently, synthesizing the evidence available on developing competencies is challenging due to the continuous and rapid transformation occurring across many technological and industrial domains.

7. Conclusion

This study examined the evolution of engineering employability requirements from Industry 4.0 to Industry 5.0 and demonstrated that future engineers must integrate technical, digital, cognitive, and human-centric competencies. By combining findings from the systematic literature review and empirical validation, the proposed KASH-Based Employability Framework provides a multidimensional and industry-aligned model for understanding engineering employability in rapidly evolving technological environments.

A major contribution of this study lies in the integrative structure of the KASH framework, which connects Knowledge, Attitudes, Skills, and Habits into a unified model of employability. Unlike traditional approaches that focus primarily on technical competencies, the framework incorporates behavioral and attitudinal dimensions that are increasingly critical in Industry 4.0 and Industry 5.0 contexts.

From a practical perspective, the framework offers guidance for redesigning engineering education and workforce development strategies. Higher education institutions can use the model to align curricula, learning outcomes, and experiential learning with emerging industrial requirements, while organizations can apply it to competency mapping, continuous learning, and talent development initiatives. The proposed Laboratoire d'Inspiration Dynamique et Durable (LIDD) further provides a potential platform for strengthening collaboration between academia and industry through applied and immersive learning environments.

Future research should investigate the implementation of the KASH framework across different engineering sectors and examine its long-term impact through longitudinal and cohort studies. Additional empirical research is needed to evaluate how the framework influences employability, organizational performance, and innovation capacity within Industry 5.0 ecosystems.

Declarations

Declaration of interest

The authors declare no conflicts of interest.

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Ethical considerations

Ethics Statement

This study involved a survey of 1,000 practicing engineers. The authors' host institution does not have an institutional Research Ethics Committee responsible for reviewing non-interventional survey-based research. Therefore, no formal ethical approval was required or obtained. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Prior to participation, all respondents were informed of the purpose of the study, the voluntary nature of their participation, and their right to withdraw at any time. Informed consent was obtained electronically through a consent statement presented on the first page of the online questionnaire. Participants could proceed with the survey only after agreeing to participate voluntarily. Responses were collected anonymously and treated confidentially for research purposes only.

Artificial Intelligence (AI) Usage Statement

The authors used a generative artificial intelligence (AI) tool (ChatGPT, OpenAI) solely to assist with language editing, grammar correction, and improving the clarity of the manuscript. The authors reviewed, verified, and take full responsibility for all the content of the manuscript. No AI tool was used for data collection, data analysis, interpretation of results, or the generation of scientific conclusions.

References

1. Abdullah, N. F., Heidary, S., Zulkifli, I. H., Abu-Samah, A., Ibrahim, R., Subhi, N., & Zennaro, M. (2026). Micro-credential for Industry 4.0: engineering safety and reliability with integrated machine learning and soft skills. Cogent Education, 13(1), 2598923. https://doi.org/10.1080/2331186X.2025.2598923
2. Abelha, M., Fernandes, S., Mesquita, D., Seabra, F., & Ferreira-Oliveira, A. T. (2020). Graduate employability and competence development in higher education—a systematic literature review using PRISMA. Sustainability, 12(15), 5900. https://doi.org/10.3390/su12155900
3. Aheleroff, S., Huang, H., Xu, X., & Zhong, R. Y. (2022). Toward sustainability and resilience with Industry 4.0 and Industry 5.0. Frontiers in Manufacturing Technology, 2, 951643. https://doi.org/10.3389/fmtec.2022.951643
4. Akinci-Ceylan, S., & Ahn, B. (2025). 'I think it's probably one of the most important skills we could ever know': insights from early-career engineers on the preparedness of undergraduate degrees for the aerospace industry. European Journal of Engineering Education, 50(2), 320–341. https://doi.org/10.1080/03043797.2024.2380888
5. Al-Maskari, A., Al Riyami, T., & Ghnimi, S. (2024). Factors affecting students' preparedness for the fourth industrial revolution in higher education institutions. Journal of Applied Research in Higher Education, 16(1), 246–264. https://doi.org/10.1108/JARHE-05-2022-0169
6. Aranda-Jiménez, J., De-Pablos-Heredero, C., Campos-García, I., San-Martín, J., & Cosculluela-Martínez, C. (2024). Digitalization and Industry 4.0: what skills improve professional behaviours? Journal of Industrial Engineering and Management. https://doi.org/10.3926/jiem.7091
7. Azofeifa, J. D., Rueda-Castro, V., & Caratozzolo, P. (2025). Analyzing the integration of future skills in top universities for engineering education in the age of Industry 4.0. IEEE Access. https://doi.org/10.1109/ACCESS.2025.3590290
8. Azofeifa, J., Rueda-Castro, V., Gonzalez-Gomez, L., Noguez, J., & Caratozzolo, P. (2024). Revolutionizing training in continuing engineering education: an experimental proposal using the multi-sensory virtual decision-making center. IEEE Access. https://doi.org/10.1109/ACCESS.2024.3519015

9. Becker, G. S. (1964). Human capital: a theoretical and empirical analysis. University of Chicago Press. https://www.nber.org/books-and-chapters/human-capital
10. Beke, É., & Tick, A. (2024). Applicability of Education 4.0 in higher education: engineering students' survey. Journal of Technology and Science Education. https://doi.org/10.3926/jotse.1845
11. Belmonte, L. M., Segura, E., de la Rosa, F. L., Gomez-Sirvent, J. L., Fernandez-Caballero, A., & Morales, R. (2023). Training industrial engineers in Logistics 4.0. Computers & Industrial Engineering, 184, 109550. https://doi.org/10.1016/j.cie.2023.109550
12. Belmonte, L. M., Segura, E., Gómez-Sirvent, J. L., López de la Rosa, F., de las Morenas, J., Fernández-Caballero, A., & Morales, R. (2025). Digital tech integration in industrial engineer training via affordable academic tools. Computers, 14(12), 547. https://doi.org/10.3390/computers14120547
13. Breque, M., De Nul, L., & Petridis, A. (2021). Industry 5.0: towards a sustainable, human-centric and resilient European industry (No. KI-BD-20-021-EN-N). Directorate General for Research and Innovation (DG RTD) of the European Commission. https://doi.org/10.2777/308407
14. Broo, D. G., Kaynak, O., & Sait, S. M. (2022). Rethinking engineering education at the age of Industry 5.0. Journal of Industrial Information Integration, 25, 100311. https://doi.org/10.1016/j.jii.2021.100311
15. Bueno, A., da Rocha Azevedo, M. L., Godinho Filho, M., Ganga, G. M., & Lizarelli, F. L. (2024). Industry 4.0 skills in industrial engineering courses: contributing to the role of universities toward sustainable development. IEEE Transactions on Engineering Management, 71, 8369–8387. https://doi.org/10.1109/TEM.2024.3382951
16. Caballero, C. L., Hansen, L., Walker, A., Rosenberg, C., Orr, P., Claringbold, G., & Forsyth, L. (2026). Untangling graduate employability and work readiness to inform evidence-based practice in higher education. Higher Education Research & Development, 1–18. https://doi.org/10.1080/07294360.2026.2615303
17. Cabrera-Moya, D. R. R., Vasudevan, H., & Prieto-Rodriguez, G. (2023). KASH training models: increasing levels of commitment and organizational effectiveness. Business: Theory and Practice, 24(1), 239–249. https://doi.org/10.3846/btp.2023.17480
18. Cesco, S., Zara, V., De Toni, A. F., Lugli, P., Evans, A., & Orzes, G. (2021). The future challenges of scientific and technical higher education. Tuning Journal for Higher Education, 8(2), 85–117. https://doi.org/10.18543/tjhe-8(2)-2021pp85-117
19. Chans, G., Valle-Arce, A., Salas-Maxemín, S., Caratozzolo, P., & Camacho-Zuñiga, C. (2025). Exploring transversal competencies in engineering students through international experiences. Frontiers in Education. https://doi.org/10.3389/feduc.2024.1457796
20. Clarke, M. (2018). Rethinking graduate employability: the role of capital, individual attributes and context. Studies in Higher Education, 43(11), 1923–1937. https://doi.org/10.1080/03075079.2017.1294152
21. Coetzee, M., & Engelbrecht, L. (2020). How employability attributes mediate the link between knowledge workers' career adaptation concerns and their self-perceived employability. Psychological Reports, 123(4), 1005–1026. https://doi.org/10.1177/0033294119844981
22. Da Rocha, L., Pereira, L., Fernandes, R., Melo, A., Da Silva, D., Rampasso, I., Anholon, R., & Martins, V. (2025). Industrial engineer and Industry 4.0? Empirical evidence from the Brazilian context considering the relation between competences and technologies. Higher Education, Skills and Work-based Learning. https://doi.org/10.1108/HESWBL-11-2023-0305

23. Dacre Pool, L., & Sewell, P. (2007). The key to employability: developing a practical model of graduate employability. Education + Training, 49(4), 277–289. https://doi.org/10.1108/00400910710754435
24. Şimşek Demirbağ, K., & Yıldırım, N. (2023). Getting the measure of the fourth industrial revolution: advantages and challenges of Industry 4.0 in the Turkish white goods industry. Central European Management Journal, 31(1), 82-101. https://doi.org/10.1108/CEMJ-03-2021-0026
25. Dautaj, M., Rossi, M., & Terzi, S. (2025). The importance of skills for Society 5.0. In IFIP International Conference on Advances in Production Management Systems (pp. 93–106). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-032-03550-9_7
26. Dehbozorgi, M. H., Pirola, F., Pozzi, R., Rossi, M., & Terzi, S. (2025). Innovating engineering education: learning factories as an enabler of Industry 4.0 and 5.0 competencies. In Conference on Learning Factories (pp. 249–257). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-98880-6_30
27. Fernando, A. R., Ghazali, N. E. B., Phang, F. A., & Rahman, N. F. A. (2025). Competencies of a holistic engineer: towards the development of a competency model and curriculum framework for future-proof engineers. European Journal of Engineering Education, 50(6), 1305–1345. https://doi.org/10.1080/03043797.2025.2584067
28. Fleming, G. C., Klopfer, M., Katz, A., & Knight, D. (2024). What engineering employers want: an analysis of technical and professional skills in engineering job advertisements. Journal of Engineering Education, 113(2), 251–279. https://doi.org/10.1002/jee.20581
29. González-Hernández, I. J., & Granillo-Macías, R. (2020). Competences of industrial engineers in Industry 4.0. Revista electrónica de investigación educativa, 22. https://doi.org/10.24320/redie.2020.22.e30.2750
30. Guilbert, L., Bernaud, J.-L., Gouvernet, B., & Rossier, J. (2016). Employability: review and research prospects. International Journal for Educational and Vocational Guidance, 16, 69–89. https://doi.org/10.1007/s10775-015-9288-4
31. Hansen, A. K., Christiansen, L., & Lassen, A. H. (2025). Technology isn't enough for Industry 4.0: on SMEs and hindrances to digital transformation. International Journal of Production Research, 63(18), 6585–6605.
32. Huggahalli, R., & Gupta, A. (2025). V-shaped engineers for Industry 4.0/5.0: a conceptual framework. (Reference from systematic review).
33. Ikenga, G. U., & van der Sijde, P. (2024). Twenty-first century competencies; about competencies for Industry 5.0 and the opportunities for emerging economies. Sustainability, 16(16), 7166. https://doi.org/10.3390/su16167166
34. *[Author citation withheld for blind peer review — to be reinstated upon acceptance]*
35. Jalali, Y., Kovacs, H., Isaac, S., & Dehler Zufferey, J. (2022). Bringing visibility to transversal skills in engineering education: towards an organizing framework. In Towards a new future in engineering education, new scenarios that European alliances of tech universities open up (pp. 1252–1259). Universitat Politècnica de Catalunya. https://doi.org/10.5821/conference-9788412322262.1251
36. Knight, P., & Yorke, M. (2004). Learning, curriculum and employability in higher education. Routledge. https://doi.org/10.4324/9780203465271
37. Koch, V., Tomasevic, D., Pacher, C., & Zunk, B. M. (2025). Preparing students for Industry 5.0: evaluating the industrial engineering and management education. Procedia Computer Science, 253, 2219–2228. https://doi.org/10.1016/j.procs.2025.01.282

38. Kolade, O., & Owoseni, A. (2022). Employment 5.0: the work of the future and the future of work. Technology in Society. https://doi.org/10.1016/j.techsoc.2022.102086
39. Laguna, R. F. D., Aguinaga, D. L., Torres, D. E. C., & Cueto, B. A. L. (2025). Soft skills and the use of Industry 4.0 as determinants of professional development in engineering graduates: a SEM approach. Sustainable Futures, 10, 100742. https://doi.org/10.1016/j.sftr.2025.100742
40. Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. Business & Information Systems Engineering, 6(4), 239–242. https://doi.org/10.1007/s12599-014-0334-4
41. Li, L. (2024). Reskilling and upskilling the future-ready workforce for Industry 4.0 and beyond. Information Systems Frontiers, 26(5), 1697–1712. https://doi.org/10.1007/s10796-022-10308-y
42. Maisiri, W., Van Dyk, L., & Coetzee, R. (2021). Development of an Industry 4.0 competency maturity model. SAIEE Africa Research Journal, 112(4), 189–197.
43. Maun, D., Yadav, M., Pandey, A., & Luu, T. M. N. (2025). Developing employability skills: the need to focus on attitudes and habits for lifelong learning. In Career Coaching and Employability Skills Acquisition (pp. 123–148). IGI Global Scientific. https://doi.org/10.4018/979-8-3693-4014-1.ch005
44. Mayer, C.-H., Oosthuizen, R. M., & Vanderheiden, E. (2024). Transformational competences and the Fourth Industrial Revolution. Frontiers in Psychology, 15, 1504360. https://doi.org/10.3389/fpsyg.2024.1504360
45. Muzulon, N. Z., Resende, L. M., Leal, G. C. L., & Pontes, J. (2025). Beyond technical skills: competency framework for engineers in the digital transformation era. Societies, 15(8), 217. https://doi.org/10.3390/soc15080217
46. Oksana, P., Galstyan-Sargsyan, R., López-Jiménez, P. A., & Pérez-Sánchez, M. (2020). Transversal competences in engineering degrees: integrating content and foreign language teaching. Education Sciences, 10(11), 296. https://doi.org/10.3390/educsci10110296
47. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., & Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ, 372. https://doi.org/10.1136/bmj.n71
48. Panxhi, M., Thanasi-Boçe, M., & Hoxha, J. (2025). Digital transformation, entrepreneurial competence, and future job prospects in engineering education. Cogent Education. https://doi.org/10.1080/2331186X.2025.2526429
49. Pham, L. D., Nguyen, N. T., Tang, T. T., & Nguyen, T. H. T. (2024). Employability of engineering technology graduates at a Vietnamese university: an assessment from employers' perspectives. Journal of Contemporary Educational Policies and Practices, 190–202. https://doi.org/10.52296/vje.2024.394
50. Quintero, W. (2022). Digital competences of the industrial engineer in Industry 4.0: a systematic vision. Production. https://doi.org/10.1590/0103-6513.20220028
51. Rikala, P., Braun, G., Järvinen, M., Stahre, J., & Hämäläinen, R. (2024). Understanding and measuring skill gaps in Industry 4.0—a review. Technological Forecasting and Social Change, 201, 123206. https://doi.org/10.1016/j.techfore.2024.123206
52. Römgens, I., Scoupe, R., & Beausaert, S. (2020). Unraveling the concept of employability, bringing together research on employability in higher education and the workplace. Studies in Higher Education, 45(12), 2588–2603. https://doi.org/10.1080/03075079.2019.1623770
53. Saleem, S., Dhuey, E., White, L., & Perlman, M. (2024). Understanding 21st century skills needed in response to Industry 4.0: exploring scholarly insights using bibliometric analysis. Telematics and Informatics Reports,

13, 100124. https://doi.org/10.1016/j.teler.2024.100124

54. Saniuk, S., Grabowska, S., & Grebski, W. (2022). Knowledge and skills development in the context of the fourth industrial revolution technologies: interviews of experts from Pennsylvania state of the USA. Energies, 15(7), 2677. https://doi.org/10.3390/en15072677
55. Souppez, J. B. R. (2025). Engineering employability skills: students, academics, and industry professionals perception. International Journal of Mechanical Engineering Education, 53(1), 125–142. https://doi.org/10.1177/03064190231214178
56. Suárez-Brito, P., Vázquez-Parra, J. C., Alonso-Galicia, P. E., & Cruz-Sandoval, M. A. (2025). Creative thinking as a relevant element for Industry 4.0 professionals: a study in Mexican university students. Journal of Latinos and Education, 24(1), 48–61. https://doi.org/10.1080/15348431.2024.2355146
57. Sukardi, S., Jalinus, N., Islami, S., Sakti, R., Husnuzhan, H., Zaus, A., & Zaus, M. (2023). Soft skills and hard skills needed in Industry 4.0 for electrical engineering students. Journal of Applied Engineering and Technological Science (JAETS). https://doi.org/10.37385/jaets.v5i1.2174
58. Thirunavukarasu, G., Chandrasekaran, S., Betageri, V., & Long, J. (2020). Assessing learners' perceptions of graduate employability. Sustainability. https://doi.org/10.3390/su12020460
59. Tomlinson, M. (2017). Forms of graduate capital and their relationship to graduate employability. Education + Training, 59(4), 338–352. https://doi.org/10.1108/ET-05-2016-0090
60. UL-Ain, N., & Waheed, M. (2025). Digital upskilling and Industry 4.0: examining affordances for sustainable workforce upskilling in SMEs. Communications of the Association for Information Systems, 58(1), 13.
61. Van den Broeck, A., De Cuyper, N., & Akkermans, J. (2023). Toward a contextualized perspective of employability development. European Journal of Work and Organizational Psychology. https://doi.org/10.1080/1359432X.2023.2291763
62. Widarto, W., Nurtanto, M., Johan, A. B., Primartadi, A., & Isnantyo, F. D. (2023). Lecturer perceptions of employability skills: case study in Vocational Education Diploma (VED). Journal of Engineering Education Transformations, 23–31.
63. Williams, S., Dodd, L. J., Steele, C., & Randall, R. (2023). Construction and operationalisation of an Employability Capital Growth Model. Studies in Higher Education. https://doi.org/10.1080/03075079.2023.2219270
64. World Economic Forum. (2025). The future of jobs report 2025. World Economic Forum. https://www.weforum.org/publications/the-future-of-jobs-report-2025/
65. Wu, Y., Xu, L., & Philbin, S. (2023). Evaluating the role of the communication skills of engineering students on employability according to the Outcome-Based Education (OBE) theory. Sustainability. https://doi.org/10.3390/su15129711
66. Yekinni, S. A., Ogbuanya, T. C., & Afyare, A. A. A. (2025). Recurriculation of engineering, technology, and technical education programmes for the adoption of Industry 5.0. Design and Technology Education, 30(3), 194–225. https://doi.org/10.24377/DTEIJ.article2795
67. Yoo, J. J., Günay, E. E., Park, K., Tahamtan, S., & Okudan Kremer, G. E. (2021). An intelligent learning framework for Industry 4.0 through automated planning. Computer Applications in Engineering Education, 29(3), 624–640. https://doi.org/10.1002/cae.22376
68. Yorke, M. (2006). Embedding employability into the curriculum. Higher Education Academy. https://hdl.voced.edu.au/10707/185821

69. Zhang, P., Sun, Y., & Zhao, Y. (2024). Investigating the gaps between engineering graduates and quantity surveyors of construction enterprises. Sustainability. https://doi.org/10.3390/su16072984

Figures

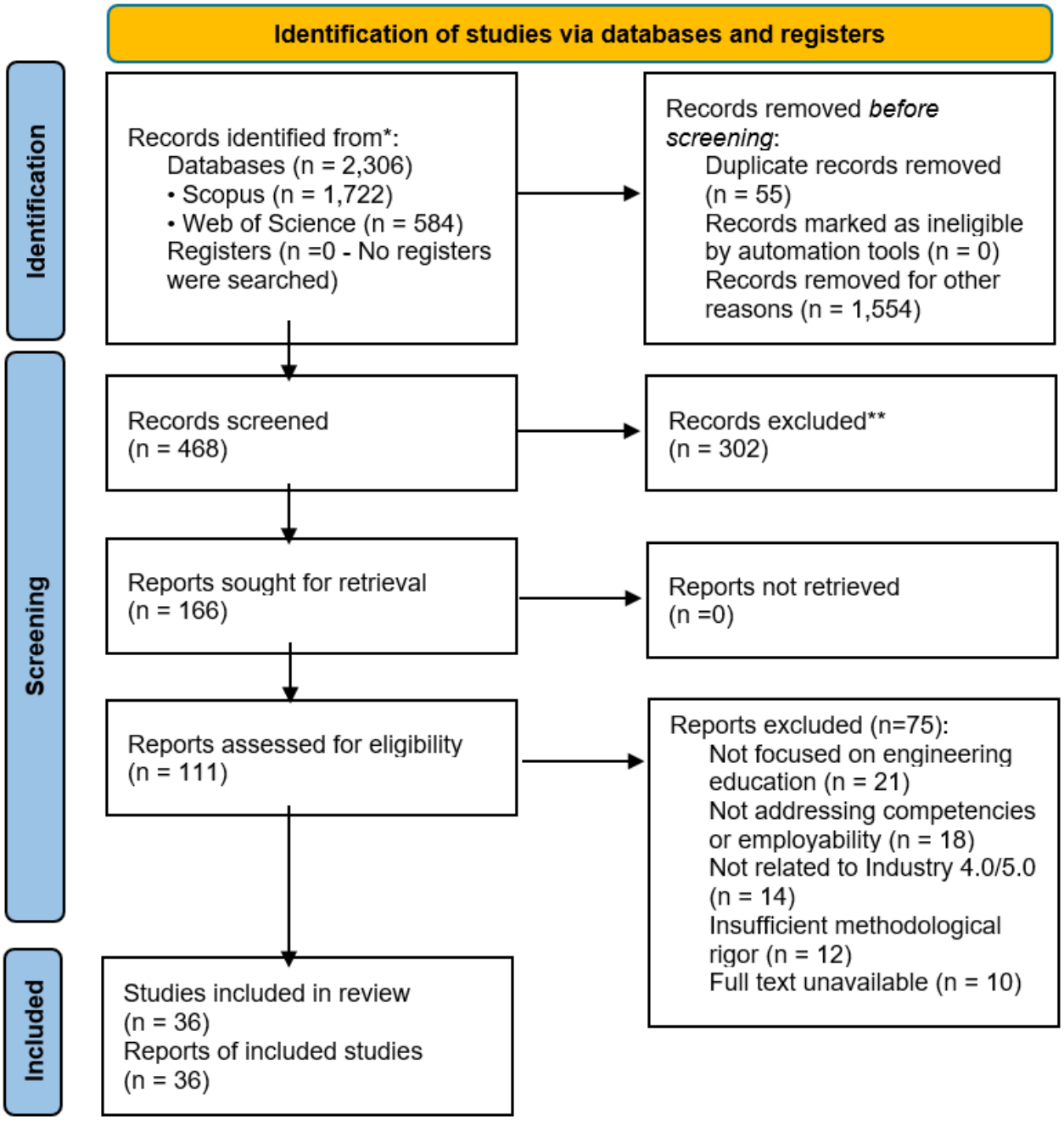


Figure 1

PRISMA 2020 flow diagram of the study selection process

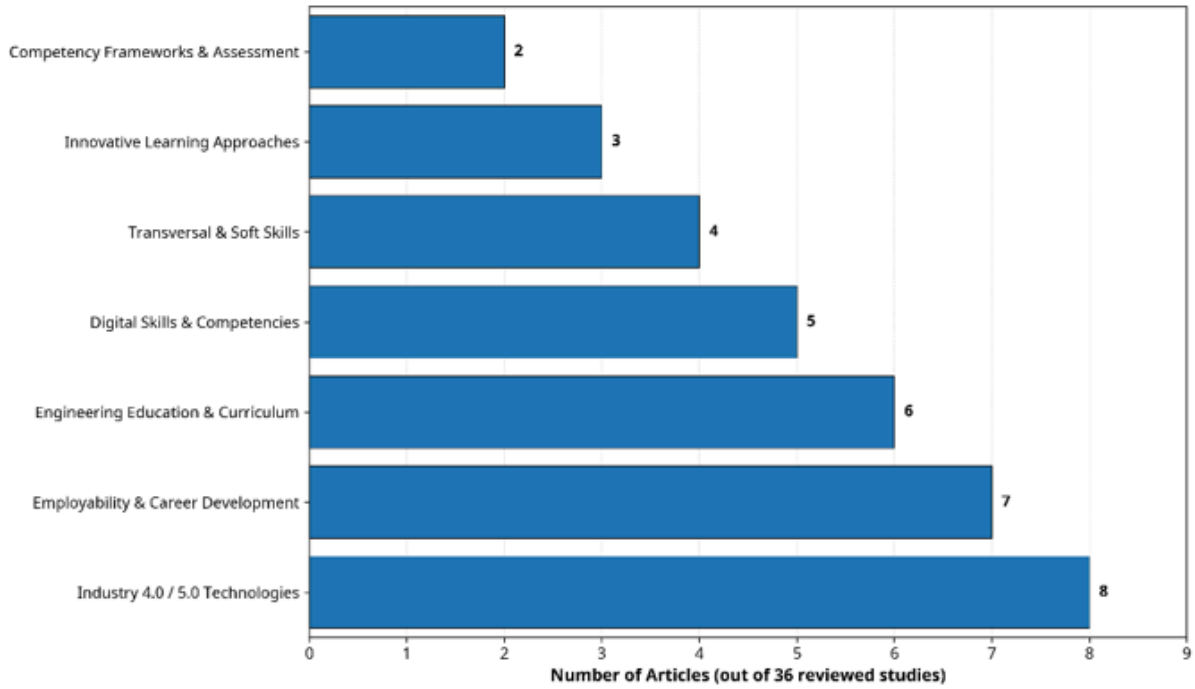


Figure 2

Mapping research themes in engineering competencies development

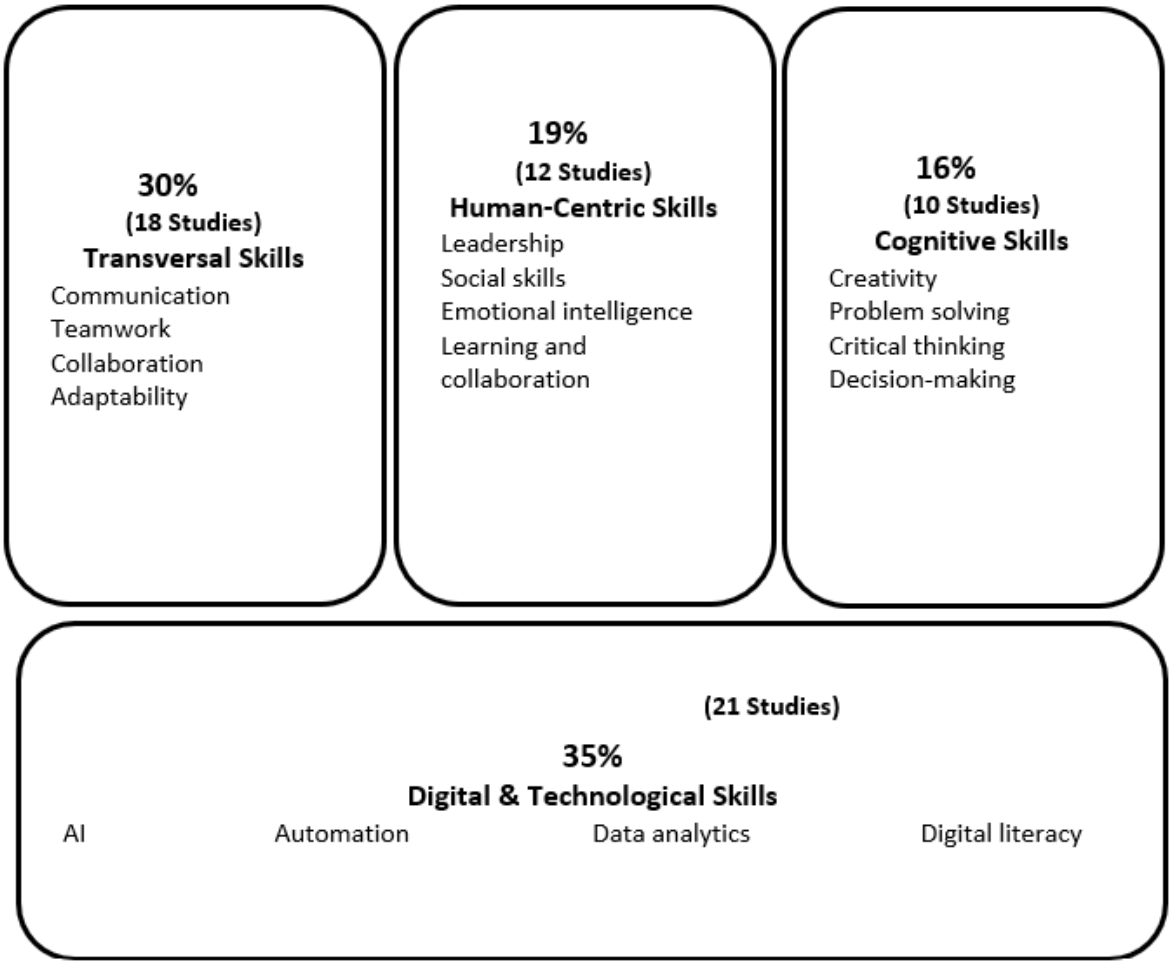


Figure 3

Distribution of engineering skill categories identified in the reviewed studies

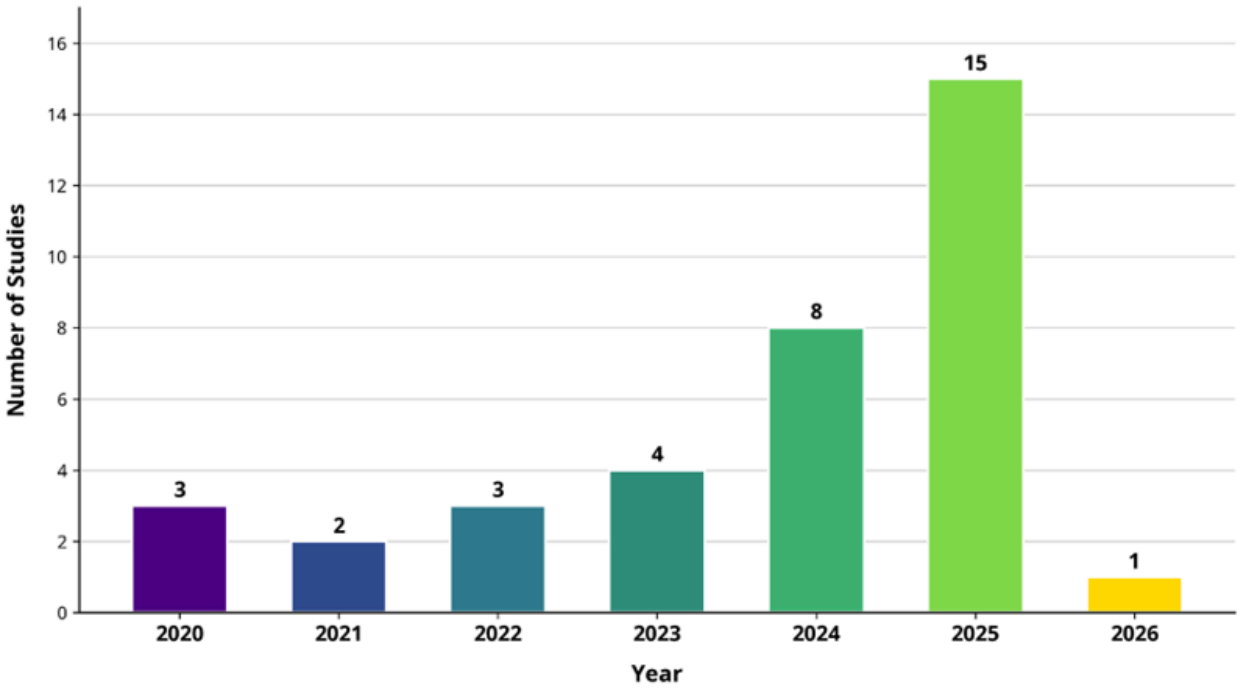


Figure 4

Distribution of selected studies per publication year

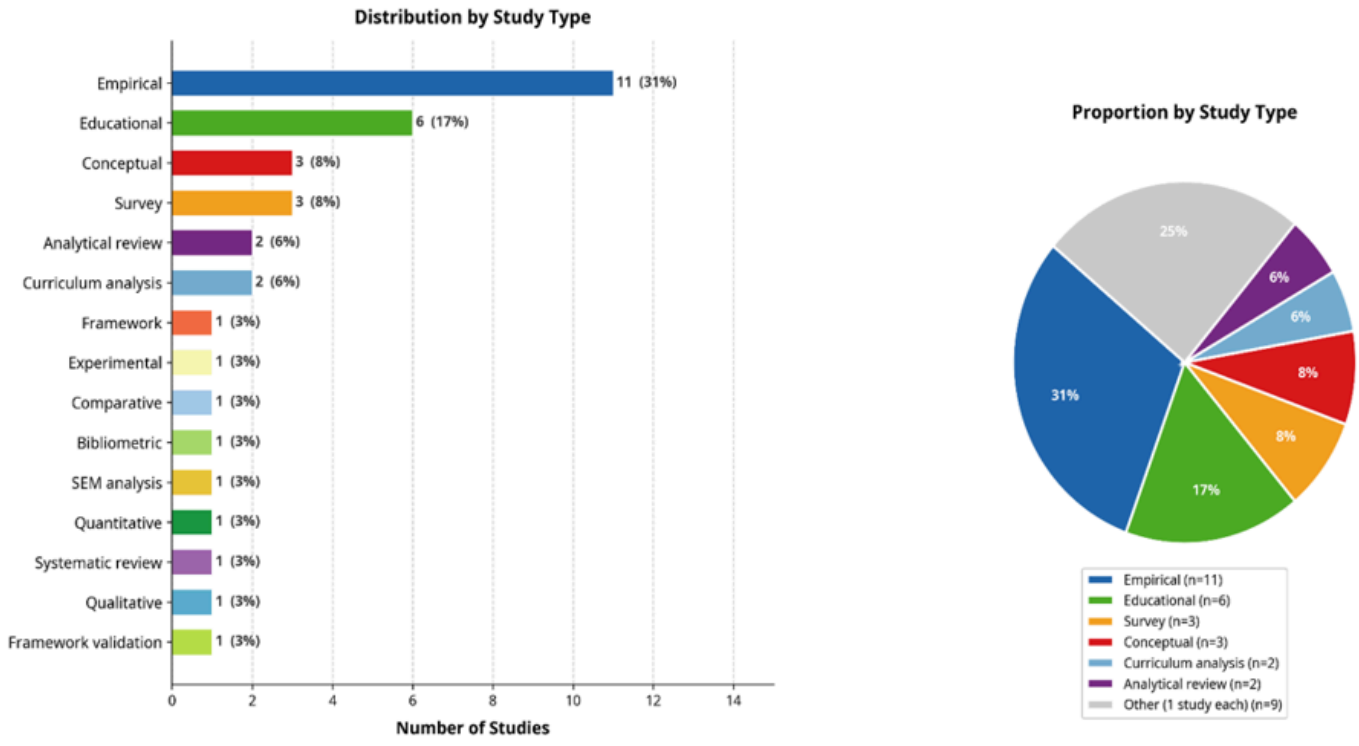


Figure 5

Distribution of selected studies by methodological type (n = 36)

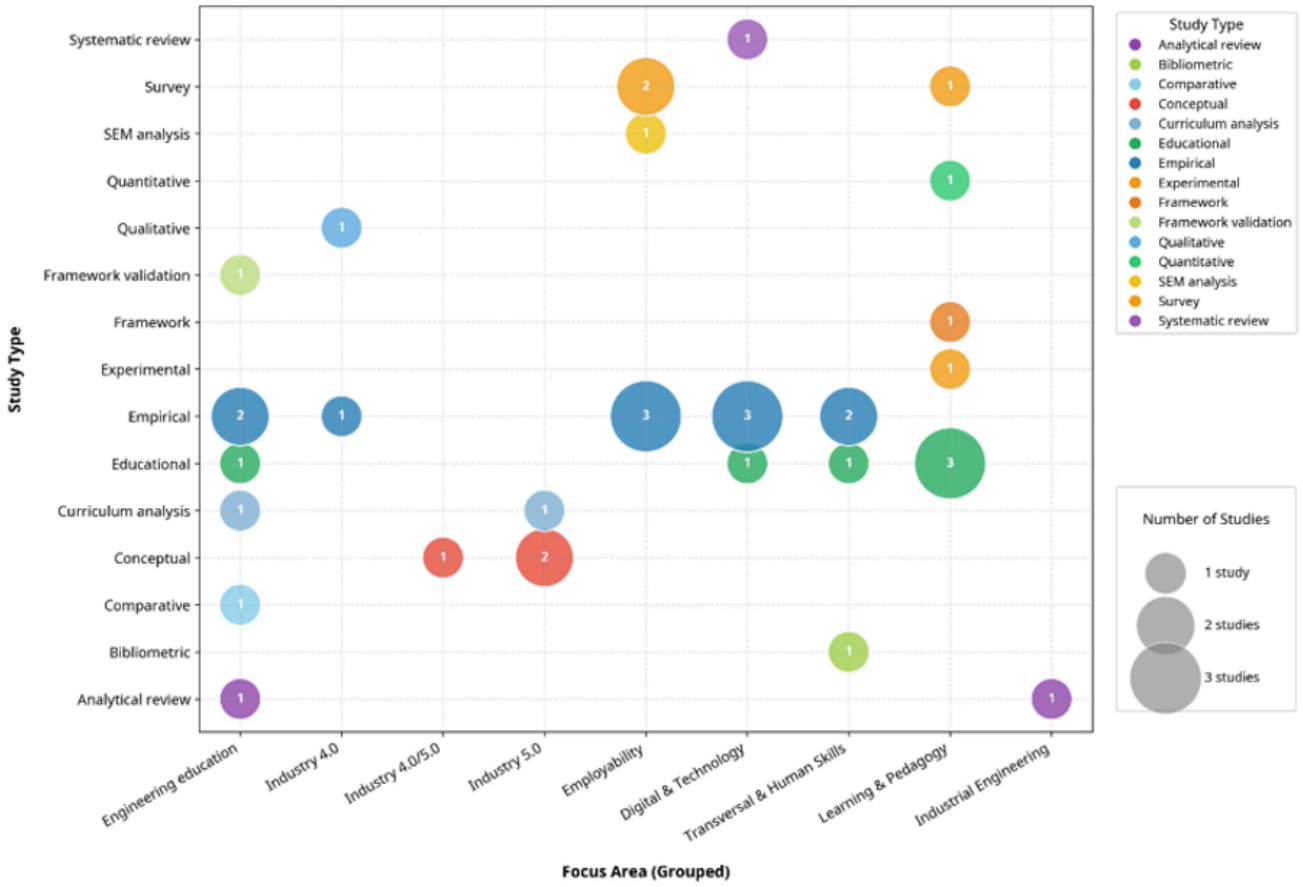


Figure 6

Bubble chart: study type × focus area

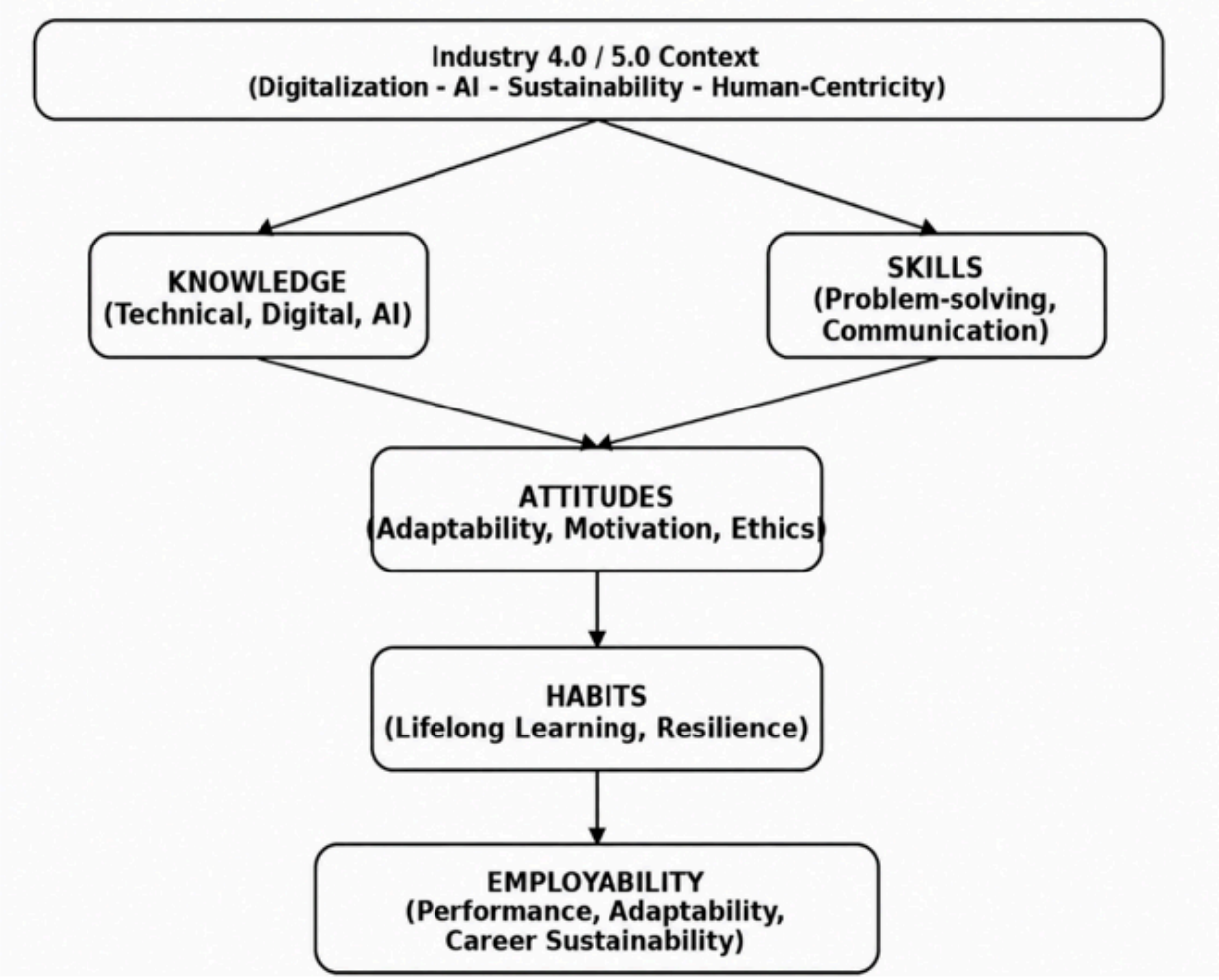


Figure 7

Conceptual KASH-Based Employability Framework