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Management

DEVELOPING I4.0 LEADERSHIP SKILLS IN ENGINEERING AND MANAGEMENT STUDENTS: A REVIEW OF HIGHER EDUCATION INSTITUTION PRACTICES

Mohini Pooja Huggahalli	Research Scholar, GITAM School of Business, Hyderabad, GITAM (Deemed to be University), Rudraram, Sangareddy District, Telangana. ORCID: orcid.org/0009-0004-0037-8537
Dr. Divya Kirti Gupta	Associate Professor, and HoD-HRM, GITAM School of Business, Hyderabad, GITAM (Deemed to be University), Rudraram, Sangareddy District, Telangana.

ABSTRACT

Higher education institutions (HEIs) must equip engineering and management students with the requisite leadership abilities for this new era as Industry 4.0 (I4.0) changes how organizations function. The evaluation aims to recognize and evaluate the existing HEI practices for developing I4.0 in engineering and management students. According to the findings, HEIs are introducing I4.0-related subjects into their curricula, employing cutting-edge teaching techniques, including project- and problem-based learning, giving leadership development courses, and offering hands-on learning experiences and virtual simulations. The prominence of leadership qualities by HEIs needs to be more consistent, and there is a need for further studies on how beneficial these practices are. The evaluation emphasizes the necessity of interdisciplinary cooperation between higher education institutions and business partners to guarantee that students have the abilities and information required to be successful in I4.0 leadership roles. It also points out several difficulties and restrictions with the current HEI practices for developing I4.0 leadership abilities, including the requirement for standardized procedures, a lack of faculty experience, and insufficient funding. The study offers a thorough review of HEI practices from the body of literature that supports the development of I4.0 in engineering and management students' leadership abilities. The findings can assist in addressing the skills gap in the quickly developing field of I4.0 and guide the creation of future HEI practices that can better prepare students for leadership jobs within the environment of I4.0.

1. INTRODUCTION

The fourth industrial revolution is known as Industry 4.0 (I4.0). It is defined by the incorporation of innovative technologies such as artificial intelligence, robotics, and the Internet of Things into the manufacturing and production process (Bauernhansl *et al.* (2014) & Xu *et al.* (2021)). Different countries have attempted to adopt I4.0 into their manufacturing processes since Germany introduced its applicability in 2011 in the manufacturing industry (Kagermann *et al.,* 2013).

I4.0 is a manufacturing trend incorporating AI, IoT, automation, and robotics that can transform the global economy by offering new competitive opportunities, innovation, and long-term prosperity while improving productivity, efficiency, and creativity (Kagermann *et al.*, 2013). Changes in employment structure, requirements, and educational methods have resulted from I4.0. Leaders, particularly those in positions of leadership, require strategic thinking, inventiveness, agility, emotional intelligence, and technological proficiency to navigate and manage these changes (Kagermann *et al.*, 2013), (Kamaruzaman *et al.*, 2019) & (Saniuk *et al.*, 2021)

1.1. Background and Context

Including I4.0 in manufacturing and production processes can enhance productivity, lower the associated costs, and improve product quality (Lee *et al.*, 2015). The manufacturing industry is undergoing a significant transformation with the advent of I4.0 (Bauernhansl *et al.,* 2014).

The need for I4.0 arises from manufacturing industries' challenges, such as increasing productivity, reducing costs, and improving quality. I4.0 will address these challenges by creating more efficient and flexible manufacturing processes.

Alternatively, for the successful implementation of I4.0, it is essential to have skilled workers who can operate and maintain the advanced technologies used in I4.0 (Mavrikios *et al.*, 2019). However, the success of I4.0 requires highlyskilled professionals, including engineers and managers, possess the necessary skills to design, operate, and manage future intelligent factories to manage and optimize these advanced technologies (Jagannathan *et al.*, 2019).

Engineering and management students are thus essential for I4.0, possessing the necessary skills to lead (Kagermann *et al.*, 2013), manage complex technological systems, work in interdisciplinary teams, and communicate effectively with stakeholders.

They must also be able to collaborate in multidisciplinary teams and effectively communicate with stakeholders at all levels of the organization. They play a vital role in the I4.0-driven manufacturing industry, as they are the future leaders responsible for shaping the industry's future. A mismatch between the educational system and the labor market and the system's insufficiency to address future issues are significant concerns from the industry's perspective (Chen *et al.*, 2021).

When helping to build smart cities, universities face difficulties. Universities play a significant role in advancing smart city initiatives but face four major obstacles. These difficulties include cultivating an innovative culture, adopting new teaching and learning approaches, collaborating with stakeholders, and developing new skills and abilities. Therefore, HEIs that can tackle these issues are well-positioned to set the pace for creating "smart cities" (Antilla & Jussila, 2018; Sekulic *et al.*, 2022).

Leadership skills, problem-solving, social, project management skills, and teamwork are crucial in I4.0 for driving innovation and managing change in organizations (Guzman *et al.*, 2019; Al Amri *et al.*, 2021; Sekulic *et al.*, 2022). Influential leaders are essential for successfully implementing and managing I4.0 technology and processes.

To address the challenges of I4.0, industrial leaders must have a combination of technological and interpersonal abilities (Guzman *et al.*, 2019 & Helming *et al.*, 2019). So, it is inevitable to train engineering andManagement students for leadership roles in the context of I4.0. This necessitates identifying effective practices HEIs can use to build I4.0 leadership qualities in their students.

Yang *et al.* (2022) and Sekulic *et al.* (2022) emphasize the significance of learning new skills to fulfil the demands of I4.0, such as digital, data analytics, communication, problem-solving, teamwork, and flexibility. These skills should be introduced into industrial engineering and management education programs to equip students for the industry's changing expectations (Rodríguez-Abitia *et al.*, 2021). Engineering and management education must include information about processing efficiency indicators and methodologies for real-time quality management. Future engineers must also be familiar with new intercommunication technologies and data collection approaches. Furthermore, they must be ready to fulfil expanding client needs and solve diverse difficulties within businesses. (Thoben *et al.*,2017).

As a result, higher education institutions (HEIs) must prepare engineering and management students for I4.0 by providing them with the requisite leadership abilities (Hasan *et al.*, 2021). Integrating I4.0 (I4.0) into engineering and management curricula is essential as it helps to bridge the skills gap and ensure that organizations have the leadership roles they need to succeed in I4.0.

1.2. Purpose
This systematic literature review (SLR) tries to study the role of HEIs in fostering leadership skills of I4.0 (I4.0) in engineering and management students. The study aims to identify the consolidated set of leadership skills of I4.0 and the essential HEI practices that are most effective in preparing engineering and management students for leadership roles in this new I4.0 era.

1.3. Scope
This SLR focuses on the current practices of HEIs and their role in fostering leadership skills of I4.0 in engineering and management students. The review included peer-reviewed journal articles published between 2011 and 2023. The research only includes studies that specifically address the evolution of I4.0, the prominence of engineering and management students in I4.0, leadership skills needed for I4.0, and the role of HEIs with their practices in developing leadership skills related to I4.0. The search used various citation and indexing databases such as Scopus, Web of Science, IEEE Xplore, and Google Scholar. The review analysed the identified studies using search strings in the current HEI practices for fostering leadership skills of I4.0 among engineering and management students.

1.4. Research Gap
The practices of HEIs in fostering leadership skills among engineering and management students for I4.0 have been extensively studied in the literature. However, there needed to be more synthesis and clarity on the most effective practices.

Although there is a growing interest in the importance of leadership skills of I4.0 in engineering and management students, there is a gap in the literature that explains the role of HEIs in fostering such skills. While there are studies on I4.0 skills, only a few focus on the specific leadership skills required for I4.0. Furthermore, a dearth of comprehensive and collected lists of HEI practices are utilized to enhance I4.0 leadership skills in engineering and business students.

Thus, SLR aims to address this research gap by making the literature on essential HEI practices for preparing engineering and management students for leadership roles in I4.0. The following questions are framed to identify the research gap from the existing literature, guide the study, and combine results.

1.5. Research Questions
The following research questions are included in this section to assist in understanding the current level of knowledge in the study and the HEI practices intended for engineering and management students.
I.   What are the leadership skills needed for I4.0 that must be developed in engineering and management students?
ii. What is the role of HEIs in fostering leadership skills needed for I4.0 in engineering and management students?
iii. What are the significant gaps in the literature on HEI practices that foster leadership skills needed for I4.0 in engineering and management students?

The following study objectives are set to guide the selection of studies, data extraction, and result synthesis based on the research questions. They can help to ensure that the review is thorough.

1.6. Research Objectives
The research objectives listed below serve as a road map for conducting a comprehensive literature review with precise and measurable goals obtained from the research questions stated above:
i. To identify the leadership skills needed for I4.0 in engineering and management students
ii. To study the HEI practices that foster leadership skills in engineering and management students for I4.0.

1.7. Methodology Overview
Research questions (section 1.5) and objectives (section 1.6) enabled the researchers to conduct an exhaustive literature study. The SLR methodology involves a systematic and comprehensive literature search, data extraction, analysis, and synthesis to identify relevant studies on Higher Education Institution (HEI) practices for fostering leadership skills of I4.0 in engineering and management students.The review utilized a thorough electronic database search from Scopus, web of Science, Springer, IEEE Xplore, and Google Scholar using a combination of keywords mentioned in sub-section 2.2. The search is limited to articles published in academic journals between 2011 and 2023. The inclusion and exclusion criteria are based on the research questions and objectives.

2. Methodology
The methodology portion of a research article describes the research design, data gathering, and analysis methodologies utilized to answer the research questions. This section outlines the methods used to conduct an SLR on the evolution of I4.0 and the requirement for engineering and management students to build leadership abilities for I4.0.

2.1. Research Design
The research design for this SLR is systematic and complete. The goal is to locate and critically assess published studies on the role of HEIs and their practices in building I4.0 leadership abilities in engineering and management students.

The research questions framed to search primarily focus on identifying the effective practices of HEIs for developing I4.0 leadership skills in engineering and management students, the critical competencies required for I4.0 leaders, and the challenges and opportunities for developing I4.0 leadership skills in engineering and management students.

2.2. Search Strategy
This SLR's search method is intended to identify all relevant works from major electronic databases such as Scopus, Web of Science, IEEE Xplore, Springer, and Google Books. The key phrases used in the search are "I4.0," "leadership skills," "engineering students," "management students," "engineering education," "management education," "leadership development," and "Higher Education," "Higher Education Institution practices." The search is restricted to English-language papers published between 2011 and 2023. Section 2.3 describesThe SLR inclusion and exclusion criteria determine which studies should be included or excluded from the review.

2.3. Inclusion and Exclusion Criteria

For article selection, the following inclusion criteria were employed to identify the features that research must include in the review.

i. Studies that focused on the evolution of I4.0 and its importance
ii. Studies that focused on engineering and management education in HEIs
iii. Studies that focused on leadership skills development in the context of I4.0
iv. Studies that focused on HEI practices for fostering leadership skills of I4.0 in engineering and management students
v. Studies that provided empirical evidence on effective practices for developing leadership skills of I4.0
vi. The articles were published in English from 2011 to 2023.

The following exclusion criteria were used to specify the characteristics that studies must not have to be included in the review.

i. Studies that are not related to I4.0 evolution.
ii. Studies that are not focused on engineering or management students.
iii. Studies unrelated to engineering and management education in HEIs.
iv. Studies that are not related to HEI practices or leadership skills.
v. Studies that are not published before 2011.

By using those mentioned above clear and transparent inclusion and exclusion criteria along with the key themes (mentioned in sub-section 2.4) and the keywords (mentioned in sub-section 2.2), the SLR can help to ensure that the studies included in the review are relevant to the research questions and research objectives and that the findings of the review are trustworthy and valid.

2.4. Key Themes

The key themes that are important in the development of the above-mentioned inclusion and exclusion criteria for the SLR to ensure that the criteria are relevant to the research questions and research objectives and comprehensive in their coverage of the literature are as follows:

i. Evolution of I4.0
ii. Importance of I4.0
iii. The role of engineers and managers in I4.0
iv. The need for leadership skills in I4.0
v. The HEI practices for fostering leadership skills of I4.0
vi. The role of HEIs in fostering leadership skills of I4.0 in engineering and management students.

Thus, the above-listed key themes play an important role in data extraction in the SLR by helping to identify relevant information from the studies included in the review.

2.5. Data Extraction

After identifying potential studies through a keyword search, the titles and abstracts of those studies are screened using the inclusion and exclusion criteria, which are developed based on the key themes of the research questions. The key themes helped ensure that the criteria are relevant and comprehensive and focus on the critical aspects of the research question. By screening the titles and abstracts of the studies, the reviewers could eliminate those that do not meet the inclusion criteria or that meet the exclusion criteria based on their relevance to the key themes.

This process helped to narrow down the number of potential studies for inclusion in the SLR. The full text of the selected studies is then assessed for eligibility. Data was extracted from the selected studies based on the author and year. Of publication, study design, sample size, higher education practices, leadership skills related to HEI practices, findings, and limitations.

A total of 258 articles were identified through the database search across Scopus and the other three journals from 2011-2023. After a thorough title and abstract screening, 45 articles were selected for full-text review, from which 39 were included in the final analysis.

The 39 articles included in the final analysis were from Scopus (n=18), Web of Science (n=10), IEEE (n=3), and Springer (n=8) journals. The search string used is ((TITLE-ABS-KEY "I4.0" OR "I4.0" OR "Fourth Industrial Revolution" OR "4IR") AND TITLE-ABS-KEY ("leadership" OR "leadership skills") AND (TITLE-ABS-KEY ("I4.0" OR "I4.0" OR "Fourth Industrial Revolution") AND TITLE-ABS-KEY ("leadership" OR "leadership skills") AND TITLE-ABS-KEY ("higher education institution" OR "HEI" OR "Higher Education Practices" OR "Practices") AND TITLE-ABS-KEY ("engineering" OR "management")) AND PUBYEAR > 2010 AND (LIMIT-TO (OA, "all")) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT- TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO (LANGUAGE, "English")).

2.6. Data Collection and Analysis

Thirty-nine articles are included in the review of the data extraction procedure mentioned in the previous section. A narrative synthesis approach is used to analyze the data. This involved a descriptive data analysis to identify key themes from the selected studies. Descriptive analysis is the essential method in SLRs to help identify key data themes and patterns and provide a clear and concise summary of the findings.

The literature was systematically reviewed using the search strategy and inclusion/exclusion criteria described above (Please refer to sub-sections 2.2, 2.3, 2.4). The titles and abstracts of the retrieved articles are screened to identify potentially relevant studies. The full text of the identified studies is reviewed to determine their eligibility for inclusion in the analysis.

2.7. Quality Assessment

The quality of the studies included in the SLR is evaluated according to the methodology mentioned above based on their research design, data collection methods, data analysis, discussion, and conclusions. Quality assessment is subjective, and the study aims to ensure that the studies are of high quality and provide reliable and relevant information to address the research questions.

After conducting the quality assessment of the included studies, it is essential to acknowledge the limitations (mentioned in the next section) in the methodology that may have influenced the review's findings.

2.8. Limitations

The following limitations of the study are identified to provide a clear understanding of the potential biases or shortcomings of the review.

i. The search is limited to English articles, which may have excluded relevant studies published in other languages.
ii. The study focused on articles published between 2011 and 2023, which may have excluded relevant studies published before 2011.
iii. Articles from four databases, namely Scopus, Web of Science, IEEE, and Springer journals, are only included.
iv. The search is focused only on the role and practices of HEI in inculcating leadership skills of I4.0 in engineering and management students and the types of leadership skills of I4.0. Therefore, other relevant aspects of I4.0 may have been overlooked.

2.9. Overview of the section

The methodology section of SLR outlines the process by which the review is conducted. It includes details on the search strategy, inclusion and exclusion criteria, key themes, quality assessment, data extraction, and data analysis methods. The

methodology section is crucial as it allows readers to assess the validity and reliability of the review's findings.

3. RESULTS

Based on the methodology outlined in the previous section, the results of the SLR present an overview of the key findings, including their implications on the Higher Education Institution practices fostering leadership skills of I4.0 in engineering and management students. The articles considered for the literature review were published between 2011 and 2023, predominantly from engineering, management, and education.

Of the 39 articles included in the final analysis, 21 were empirical studies, 10 were review articles, and 8 were conceptual or theoretical studies. Most empirical studies were cross-sectional surveys (n=12) or case studies (n=7). The following sub-sections focus on the HEI practices helpful in developing leadership skills of I4.0, the leadership skills needed in I4.0, and the evaluation of the identified HEI practices based on the research questions and objectives (Please refer to sub-sections 1.5 and 1.6).

3.1. HEI practices contributing to I4.0 leadership skill development in engineering and management students.

Our review identified the following standard HEI practices fostering leadership skills of I4.0 in engineering and management students:

I. Experiential learning: This practice includes various activities that enable learning through hands-on experiences, such as internships, field trips, and service learning (Hasan *et al*., (2021); Rodríguez-Abitia *et al*., 2021; Sekulic *et al*., 2022).

ii. Internships: It provides students with practical experience in a professional setting (Satpathy *et al*., 2020; Galván *et al*., 2022).

iii. Curriculum design: Engineering and management programs are updating the curricula to include knowledge and skills relevant to I4.0. The use of hands-on activities, case studies, and real-world examples can improve the understanding of I4.0 principles and their applicability in the classroom by students (Rodríguez-Abitia, 2021; Hasan *et al*., 2021; Simeunovic *et al*.,2022; González-Pérez *et al*., 2022).

iv. Project-based learning: Several articles highlighted the importance of project-based learning in developing leadership skills in engineering and management students. Real-world projects that require students to work in groups can help pupils improve communication, problem-solving, and leadership skills (Teng, 2018; Hasan *et al*., (2021); Vieira Nunhes *et al*., 2021).

v. Industry-academia collaboration: Coordination between HEIs and industries can allow students to engage in industry-relevant projects and get practical experience to access real-world challenges and solutions. They also expose students to the skills needed in the I4.0 age and assist them in developing leadership abilities (Teng, 2018; Vieira Nunhes *et al*., 2021).

vi. Simulation-based learning: It requires using simulations to improve problem-solving and decision-making abilities (Teng, 2018; Li *et al*., 2021; Sekulic *et al*., 2022).

vii. Leadership development programs: These are formal programs to help students develop leadership qualities. HEIs should provide leadership development programs focusing on I4.0-related qualities such as critical thinking, problem-solving, and communication (Vieira Nunhes *et al*., 2021; Rodríguez-Abitia *et al*., 2021).

viii.Mentoring programs: Mentoring programs can help students develop their leadership skills by providing direction and assistance. Mentors can share theirExperiences and provides feedback to assist students in developing their leadership skills (Satpathy *et al*., 2020).

ix. Cross-disciplinary education: Collaboration between diverse disciplines, such as engineering and business, should be promoted to foster leadership growth in a multidisciplinary setting. This practice encourages students to learn from other areas to create a broad viewpoint (Yadav *et al*., 2014, cited in Li *et al*., 2020; Hasan *et al*., (2021); Sekulic *et al*., 2022).

x. Industry-specific certifications: Programmes that provide students with industry-specific certifications (Derwik *et al*., 2017; Vieira Nunhes *et al*., 2021).

xi. Entrepreneurship Education: Entrepreneurship education can help students develop leadership qualities by exposing them to the skills required to start and operate a business. Courses in business planning, marketing, and finance management are examples of such education (Maritz *et al*., 2015; Satpathy *et al*., 2020).

These practices are combined into seven vital HEI practices (mentioned in Table 1) that help foster I4.0-related leadership skills in engineering and management students. This consolidation is based on the studies' common research objectives and findings.

Table 1: Consolidated list of vital HEI practices for fostering leadership skills of I4.0 in engineering and management students

Practice Name
Experiential learning -includes practice internships, field trips, and service learning ((2021); , 2021; , 2022)
Curriculum design (Rodríguez-Abitia, 2021; 2021; ,2022; , 2022)
Project-based learning (, 2018; (2021); , 2021)
Industry-academia collaboration (, 2018; , 2020; , 2021 & , 2022)
Simulation-based learning (, 2018; , 2021; , 2022)
Leadership development programs (, 2021; , 2021)
Mentoring programs (, 2020)
Cross-disciplinary education (Yadav et al., 2014, cited in 2020; (2021); , 2022)
Industry-specific certifications (, 2017; , 2021)
Entrepreneurship Education (,2015; , 2020)

Table 1 depicts a consolidated list of the vital HEI practices that help foster necessary I4.0-related leadership skills in engineering and management students. The following section lists the required leadership skills of I4.0.

3.2. Leadership skills of I4.0 needed in engineering and management students

Our review identified leadership skills relevant to I4.0 that should be fostered in engineering and management students. Digital literacy and competence, collaborative problem-solving, change management, strategic thinking, visionary thinking, and promptitude skills are vital for being promising leaders of I4.0 (Helming *et al*., 2019).

Raharja *et al*. (2019) proposed a social learning approach to develop responsive leadership skills among local public leaders, which involves interacting with other leaders and community stakeholders. "Responsive leadership" demands being proactive, collaborative, and adaptable.

This is useful for training their teams and interacting with other leaders and community stakeholders to strengthen these skills to thrive in I4.0.

Amri *et al*. (2021) identified the importance of soft skills, practical experience, and interdisciplinary knowledge in I4.0. They proposed problem-based learning and case studies to provide practical experience, which traditional engineering education lacks. There is an undeniable need for a comprehensive and innovative learning approach to meet the demands of I4.0.

The review identified below listed leadership skills along with those mentioned above. These are important for engineering and management students to thrive in I4.0.

i. Communication: The ability to communicate and collaborate effectively with diverse groups of people helps engineers and managers discuss their ideas and work effectively with others to achieve common goals is essential for effective leadership (Helming *et al.*, 2019; Simeunovic *et al.*, 2022; Galván *et al.*, 2022; Yang *et al.*, 2022).

ii. Problem-solving: Leaders need to be able to identify and solve complex problems to keep up with rapid technological change (Guzman *et al.*, 2019; Li *et al.*, 2020; Satpathy *et al.*, 2020; Hasan *et al.*, (2021); Sekulic *et al.*, 2022).

iii. Agility and adaptability: The I4.0 era is characterized by rapid change and disruption. Leaders in this situation must be quick, adaptive, and able to adjust to changing conditions (Helming *et al.*, 2019; Sekulic *et al.*, 2022; Yang *et al.*, 2022).

iv. Innovation and creativity: Creativity is required to discover novel solutions to issues. To keep up with the quickly changing technological world, leaders must be able to think outside the box and come up with fresh ideas (Kamaruzaman *et al.*, 2019; Satpathy *et al.*, 2020; Murphy and Cuban, 1990 as cited in Hai & Van, 2021; Galván *et al.*, 2022).

v. Critical thinking: The ability to analyze data and make valid decisions (Guzman *et al.*, 2019; Hasan *et al.*, (2021); Li *et al.*, 2020; Satpathy *et al.*, 2020; Sekulic *et al.*, 2022).

vi. Emotional intelligence: Emotional intelligence is the ability to understand and manage one's emotions and those of others. Leaders with high emotional intelligence can better manage teams and navigate complex social situations (Helming *et al.*, 2019).

vii. Collaboration: The ability to work effectively in teams and build partnerships with internal and external stakeholders toward a common goal (Raharja *et al.*, (2019); Satpathy *et al.*, 2020; Sekulic *et al.*, 2022).

viii. Entrepreneurship: The ability to identify and pursue opportunities (Guzman *et al.*, 2019; Bellantuono *et al.*, 2021)

ix.

x. Visionary thinking: The ability to think beyond the current situation and envision a better future (Helming *et al.*, 2019; Murphy and Cuban, 1990 as cited in Hai & Van, 2021; Sekulic *et al.*, 2022).

x. Resilience: Adapting to and overcoming challenges and setbacks (Ramirez-Mendoza, 2018; Galván *et al.*, 2021).

xi. Strategic Thinking: Ability to analyze and plan for the long-term success of an organization (Galván *et al.*, 2021; Bellantuono *et al.*, 2021; Yang *et al.*, 2022).

xii. Change Management: Ability to manage and lead organizational change in response to new technologies or business models (Bellantuono *et al.*, 2021; Yang *et al.*, 2022).

xiii. Data-Driven Decision-Making: Ability to use data and analytics to inform decision-making and problem-solving (Jadhav *et al.*, 2019; Satpathy *et al.*, 2020; Bellantuono *et al.*, 2021)

xiv. Digital Literacy: Familiarity with and ability to use digital tools and technologies (Jadhav *et al.*, 2019; Bellantuono *et al.*, 2021).

The above-mentioned leadership skills are summarized in Table 2, including the name of the leadership skill needed in I4.0 with its brief description. These leadership abilities are categorised based on their relevant leadership categories, similarities, and common qualities that answer the study goals and objectives in subsections 1.5 and 1.6 of the paper.

Table 2: Consolidated List of I4.0 Leadership Skills for Engineering and Management Students

Ÿ Principal Leadership skill	Ÿ Components forming the Principal Leadership Skill	Ÿ Brief description of the leadership skill
Ÿ Strategic Leadership skill	Ÿ Visionary thinking (, 2019; Murphy and Cuban, 1990 as cited in , 2021; , 2022), strategic thinking (,2021; , 2021; , 2022), change management (, 2021; , 2022), and data-driven decision-making (, 2019; , 2020; , 2021)	Ÿ This category comprises big-picture leadership qualities and the capacity to create, implement, and oversee plans for the organization's success.
Ÿ Digital Leadership skill	Ÿ Digital literacy (, 2019; , 2021), innovation Ÿ and creativity (., 2019; , 2020; Murphy and Cuban, 1990 as cited in , 2021; , 2022)	Ÿ Understanding and utilizing technology and digital technologies to boost organizational performance are examples of leadership talents in this category.
Ÿ Interpersonal Leadership skill	Ÿ Emotional intelligence (, 2019), communication(, 2019); ,2022; , 2022; , 2022), and collaboration (, (2019); , 2020; , 2022)	Ÿ This category includes leadership skills such as relationship development and effective teamwork.
Ÿ Adaptive Leadership skill	Ÿ Resilience (Ramirez-Mendoza, 2018; ,2021), agility, and adaptability (, 2019; , 2022; 2022)	Ÿ This category includes adaptability, agility, and flexibility in changing circumstances as examples of leadership characteristics.
Ÿ Entrepreneurial Leadership	Ÿ Critical thinking (, 2019; (2021); 2020; , 2020; , 2022) and entrepreneurship (Guzman Ÿ et al., 2019; Bellantuono et al., 2021)	Ÿ This category includes leadership skills such as taking risks, identifying opportunities, and creating new businesses.

Source: Authors' compilation

Table 2 presents the consolidated list of the leadership skills, based on the category necessary for engineering and management students to excel in I4.0. It is important to note that there may be some overlap between the categories listed in the table and that leadership skills often work together. The subsequent sectionThe study evaluates the practices of HEIs that aim to cultivate the leadership skills identified in Table 2.

3.3. Importance of HEI Practices in Fostering I4.0 Leadership Skills

After synthesizing the literature on HEI practices fostering I4.0-related leadership skills and the leadership skills needed in I4.0, it is essential to evaluate the effectiveness of these practices. This review found that most identified HEI practices have been evaluated in various studies by examining which leadership type of leadership skills they inculcate in the students.

Individuals need knowledge and skills to succeed in the work market, which must be balanced to ensure economic growth (Simeunovic *et al.*, 2022). HEI practices have been found to

foster leadership skills of I4.0 in engineering and management students through their leadership development programs(Vieira Nunhes et al., 2021; Rodríguez-Abitia et al., 2021); mentoring and coaching programs (Satpathy et al., 2020), project-based learning, experiential learning activities such as simulations and case studies (Guzman et al., 2019; Satpathy et al., 2020; Li et al., 2021; Hasan et al., (2021); Sekulic et al., 2022). Thus, it is evident from the study that HEI practices can foster I4.0-related leadership skills through industry-academia collaborations (Teng, 2018; Vieira Nunhes et al., 2021) etc. that include training on emerging technologies.

Thus, the results obtained from the SLR explain that the impact of technology on education is a complex and multifaceted issue. The selected studies suggest that technology positively impacts teaching and learning practices, student engagement and motivation, educational outcomes, and challenges and limitations. Several significant findings of the study will be examined in detail in the next section.

4. DISCUSSION

Given the findings reported in the preceding part, the SLR discussion section reveals an increasing interest in I4.0 and higher education practices, with anemphasis on leadership skills, curriculum creation, readiness, obstacles, and graduates' employability skills. It also proposes that specific I4.0-related leadership abilities can be effectively fostered through practices such as industry-academia collaborations and leadership development programs that involve training on emerging technologies.

These findings have significant implications for higher education institutions attempting to prepare engineering and management students for leadership roles. This review emphasizes the need for additional research to better understand technology's influence on education and discover successful techniques for using technology in teaching and learning practices.

This section examines the current state of I4.0 leadership skill development in higher education, discusses effective practices for developing these skills, and identifies opportunities for future research. These findings suggest that higher education institutions should prioritize the development of I4.0 leadership abilities to equip engineering and management students for success in fast-expanding, technology-driven enterprises. The following section summarises the overall findings of this SLR.

5. CONCLUSION

Based on the study's preceding parts, I4.0 has substantially changed the engineering and management sectors. This has resulted in a desire among students for new skills and abilities to flourish in the fast-changing work market. HEIs employ various practices to help students build I4.0-related leadership skills in response to this demand.

The SLR discovered that HEIs use project-based learning, experiential learning, industry-academia collaborations, cross-disciplinary education, and certifications to create strategic, digital, interpersonal, adaptive, and entrepreneurial leadership abilities. More study is needed, however, to assess theimpact of these practices and to establish best practices for developing I4.0-related leadership skills.

The review's conclusions have significant implications for HEIs attempting to train students for leadership roles in the I4.0 age. Future studies must assess the efficacy of various HEI practices and investigate students' and industry partners' experiences and views. The SLR adds value by underlining the necessity of educating engineering and management students for leadership roles in the digital age.

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