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Industrial Engineering Students' Readiness Towards Industrial Revolution 4.0 at Technical and Vocational University: Literature Review

*Nur Batrisya Binti Anwar, Asnula Dahar Minghat**

Universiti Teknologi Malaysia, Malaysia

Correspondence: E-mail: asnul@utm.my

ABSTRACT

The purpose of this study is to review current reports on the relationship between student performance and student readiness toward Industrial Revolution 4.0 in the Industrial Engineering program at the technical university while discussing the current student performance towards Industrial Revolution 4.0 as well as examining the level of readiness for Industrial Engineering students to adapt to the challenges of this industrial revolution. This study explains several sections, including the definition of Industrial Revolution 4.0 and Education 4.0 with its impacts on higher education. We also explain factors influencing student performance and their technical skills. This study will give additional references for researchers, academicians, educators, as well as practitioners and stakeholders.

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1. INTRODUCTION

This paper focuses on the literature review of the research study topic, which revolves around the Industrial Revolution 4.0 (IR4.0). The primary emphasis is on its implementation in higher education, specifically within the context of a technical university. Moreover, the paper delves into the implications that arise from integrating IR4.0 in the field of education and engineering courses, as well as the readiness of students in the context of IR4.0. The paper aims to identify the skills of engineering students and the main objective of the research is to examine students' level of readiness in anticipation of IR4.0. More specifically, the study will analyze how students' performance in engineering courses aligns with their readiness at technical universities.

2. METHODS

This paper reviews data from articles published in international journals. We collected articles, concluded, and summarized data.

3. RESULTS AND DISCUSSION

3.1. Industrial Revolution 4.0 (IR4.0)

In 2011, the German government launched a nationwide strategic effort known as IR4.0 to accelerate the development of digital manufacturing through the increased digitalization and connectivity of goods, marketing strategies, and supply networks (Uei and Shing, 2021). In the private sector, IR4.0 will lead to the full implementation of automated and digitalized procedures, as well as the increased use of electronics and IT. It's a sector where devices, software, and hardware all work together in coordination to create a seamless system (Tortorella *et al*., 2019). The Fourth Industrial Revolution and the creation of the Industry 4.0 concept and its area of research have arisen as a result of the expansion of markets, the globalization of economies, and the introduction of competitive forces.

The four phases of industrialization are illustrated in **Figure 1**. Commencing with the onset of the 18th century, the initial industrial revolution took place. The advent of the first mechanized innovation in 1784 marked the inception of this epoch (Nor Asmawati *et al*., 2020). Furthermore, a significant portion of the 20th century witnessed a profound transformation driven by the electrification and digitalization revolution that commenced in the 1870s, marking the onset of the subsequent phase of the industrial revolution. During that period, the advent of large-scale production based on the specialization of tasks became prominent. Furthermore, the incorporation of computer technologies in the automation of manufacturing processes was commonly believed to have commenced at the onset of the third industrial revolution in 1970 (Nor Asmawati *et al*., 2020). Therefore, Industry 4.0 surpasses Industry 3.0, which is characterized by technological and industrial cooperation (Lase, 2019). The term "Industry 4.0" pertains to an economic domain that utilizes both mechanization and cyber technologies. It's a movement towards more widespread use of automated data sharing in industrial settings. During this period, the industry expanded its reach into the digital sphere through the interconnection of people, machines, and data (Lase, 2019). To further propel the industry's shift towards IR4.0, nine fundamental technologies are encompassed Nor Asmawati *et al*. (2020) as shown in **Figure 2**.

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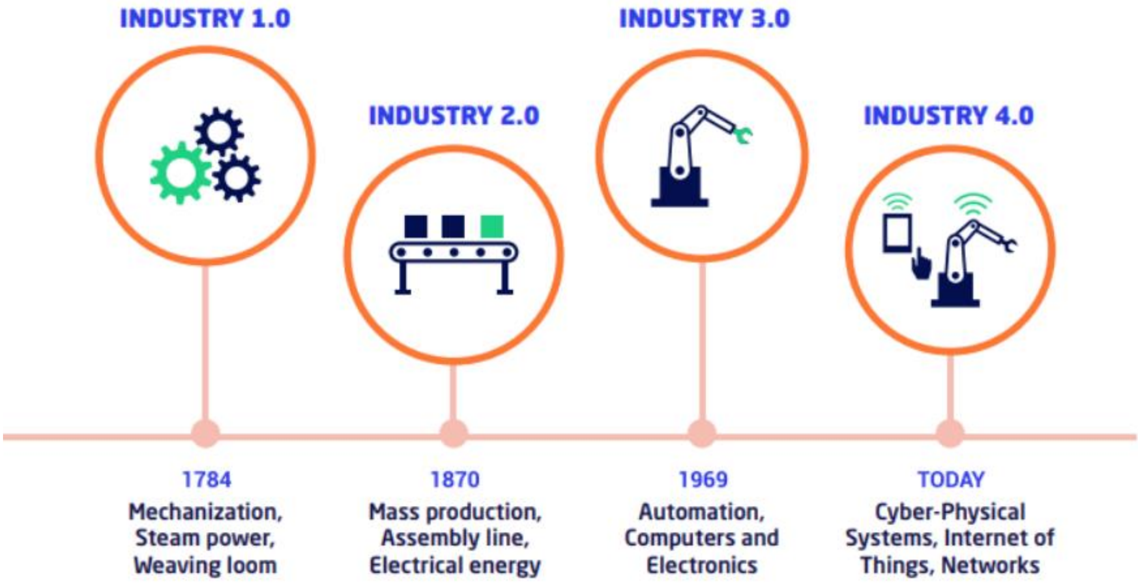

Figure 1. Phase of industrial revolution (Sima *et al*., 2020).

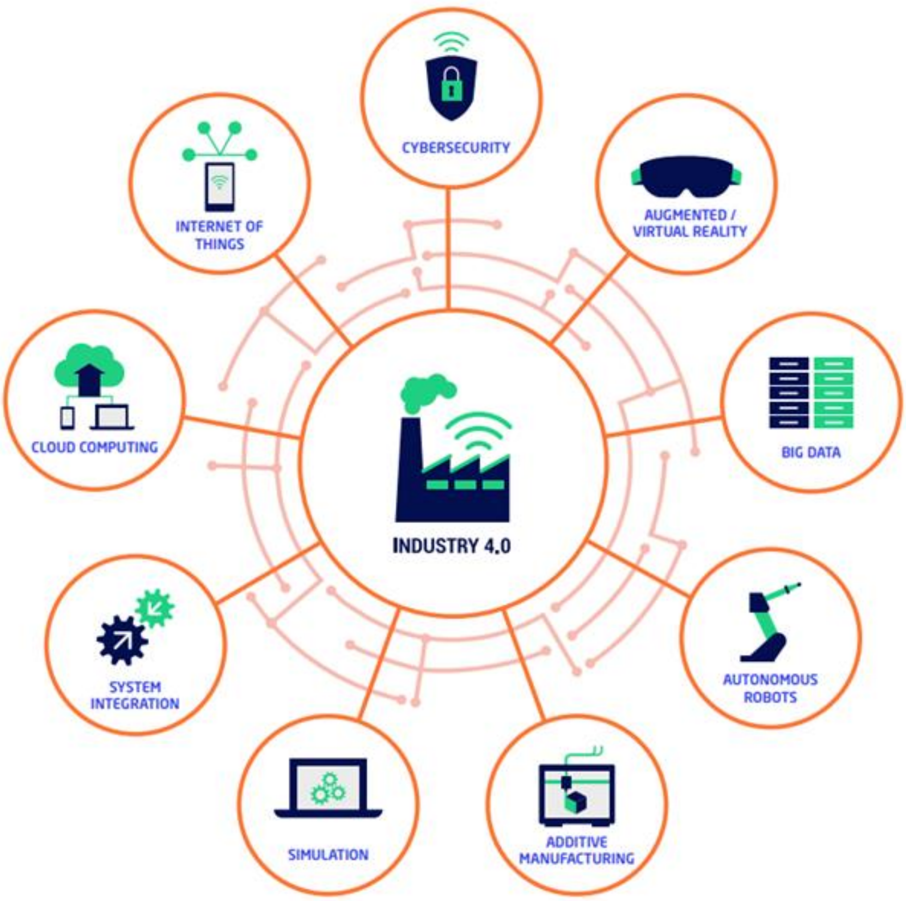

Figure 2. The nine technological foundations of the IR4.0 (Noor *et al*., 2021).

To a significant extent, all products on the market can be traced back to the manufacturing process, and the vast majority of produced goods are created in factory settings. Its roots may be traced back to ancient times when people recognized the value of adapting nature's bounty for human benefit. A key contributor to the economies of the countries and regions

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in which it is situated, manufacturing is a global economic force (Gereffi, 2019). Currently, the manufacturing sector is undergoing a shift from the era of Industry 3.0 to the era of IR4.0. Consequently, only a limited number of enterprises have capitalized on the full range of opportunities presented by the concepts and resources encompassing IR4.0 (Rahamaddulla *et al*., 2021). Manufacturers in developing markets might have a lower propensity to adopt IR4.0 owing to factors such as reduced technological sophistication, restricted investment funds, and inadequate manpower (Tortorella *et al*., 2019).

Despite a robust manufacturing economy in ASEAN, Malaysian manufacturers are novices who possess an inadequate comprehension of the principles and methodologies associated with IR4.0 (Ling *et al*., 2020). Manufacturers in Malaysia remain novices when it comes to the principles and practices of IR4.0, considering the country's status as an industrial powerhouse in the ASEAN manufacturing sector (Ahmad *et al*., 2019). Additionally, this issue is understandable given the market's requirement for educated, qualified personnel. Despite this, some university graduates are unaware of market needs. Frequently, direct instruction loses its relevance when students fail to make an emotional or practical link between classroom theory and the field of labor (Ramli *et al*., 2022). Integrating IR4.0 into the course is essential for universities to fulfill their role in educating graduates about Industry 4.0 and meeting the demands of the modern economy (Rawi *et al*., 2022).

3.2. Education 4.0

The emergence of "Education 4.0" is a direct result of the requirements of IR4.0 in which both individuals and machines work together to discover answers to pressing concerns and explore new avenues of innovation that can be used to better the lives of contemporary people (Lase, 2019). The education sector is responsible for providing the candidates and will need to adapt the methods of student training to produce a workforce of individuals capable of fulfilling the future requirements of the industry (Maria *et al*., 2018). The goal of the new educational model known as "Education 4.0" is to raise students' levels of skill in digital technologies. Moreover, it grants students greater autonomy in their learning process, empowering them to determine their objectives and progress at their preferred speed.

There are primary objectives of IR4.0 in the realm of education which are ensuring that each student has the opportunity to acquire a fundamental digital education, and equipping educators with proficient skills in leveraging digital tools for teaching and facilitating student learning (Uei and Shing, 2021). Malaysia has to get its workforce in line so that it can deal with what is predicted to happen in the field of education in the IR4.0 era (Maria *et al*., 2018). Success in implementing Industry 4.0 at both the local and national levels will depend to a large extent on the accessibility of necessary skills and competencies within the working population (Maisiri *et al*., 2019). The primary characteristics of Education 4.0 as described by Miranda *et al*. (2021) are summarised in a single illustration as shown in **Figure 3**. The main goal of this diagram is to provide a visual representation of the many facets that comprise the Education 4.0 framework. It provides a visual representation of these features to aid researchers, educators, and stakeholders in quickly grasping the fundamentals of this game-changing approach to education.

Education, as evidenced by expanding knowledge, must adapt to the changing needs of students if it is to guarantee them a bright future. To make the transition from education to work as seamless as possible, Education 4.0 employs cutting-edge technological technologies to simulate real-world settings. In Education 4.0, the focus is on the students, not the educators, and educators are required to tailor their lessons to the needs of the students. The ability to learn on one's own is a crucial pedagogical skill that every student should have. It is

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also expected that students' requirements would be met through a procedure that allows for some degree of customization. Furthermore, it is important to emphasize the development of soft skills, such as problem-solving and critical thinking, during the educational system (Maria *et al*., 2018).

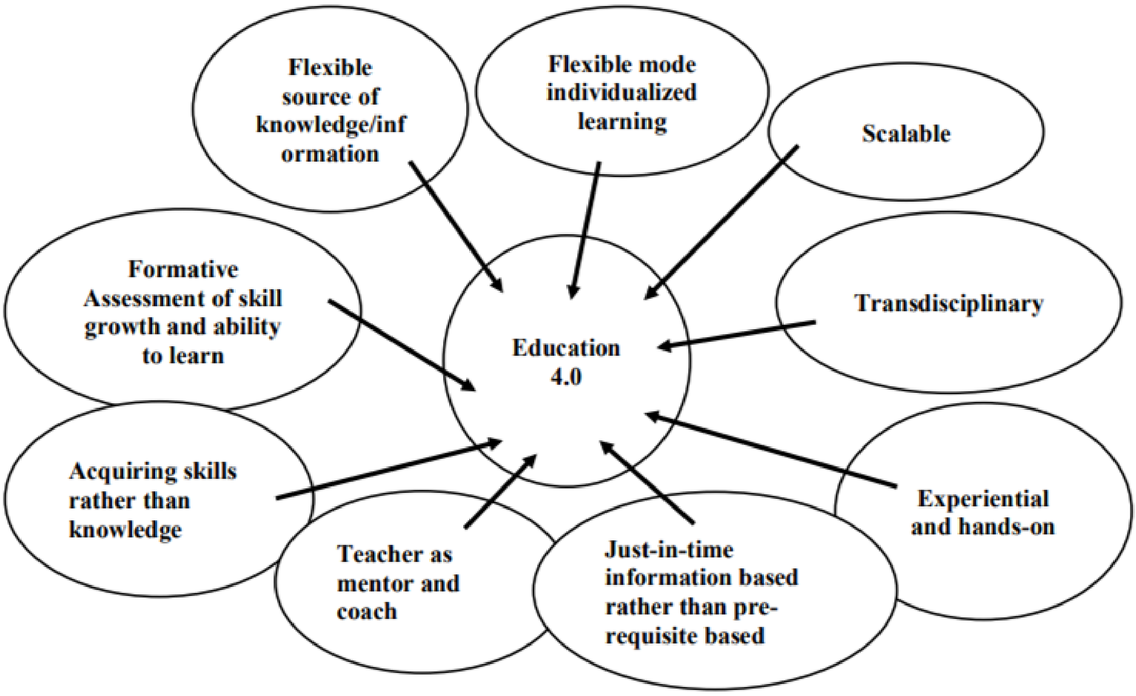

Figure 3. Characteristics of education 4.0 (Miranda *et al*., 2020).

Numerous studies have shown that, in practice, curriculum implementation degrades, becomes disjointed, and no longer aims to help students comprehend research in the context of every day and life-long learning competencies, but rather focuses solely on the objective accomplishment of academic ideals (Lase, 2019). To be successful in the era of IR4.0, students need to be equipped with the appropriate knowledge and abilities. Inadequate training programs and a shortage of professionals in universities, industry, and training institutions across most IR4.0 technologies contribute to Malaysia's talent gap, which is a major problem (Ling *et al*., 2020).

3.3. Industrial Revolution 4.0 in Higher Education Institutions

As a result of IR4.0, many areas of mankind have changed (Lase, 2019). In every way, the education sector is affected along with the rest of the economy. To meet the demands of IR4.0, this new paradigm reconceives traditional notions of education, including the roles of students, educators, and institutions (Uei and Shing, 2021). In the IR4.0, HEI represents an accessible, logical, and innovative gateway to a new philosophy that has the potential to raise people's level of living. Counterfeiting sparked IR4.0 and subsequently disrupted the conventional office setting. The literature reveals that MoHE is attentive to IR4.0, as seen by their initiative to restructure the country's higher education system and by their production of the Malaysia Education Blueprint 2015-2025, which incorporates the 10-shift program (Maria *et al*., 2018). To make the transition from education to employment as smooth as possible, Education 4.0 employs cutting-edge rapid technology resources to simulate real-world settings. Thus, Education 4.0 is a more pragmatic and realistic learning technique, with the potential to yield exceptional results for student learning.

DOI:
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According to the researcher, implementing IR4.0 into the curriculum is essential for universities to fulfill their roles in educating students about IR4.0 and meeting the demands of the modern economy (Rawi *et al*., 2022). Educational institutions must make significant changes to train graduates who can successfully navigate the workforce (Tilak and Singh, 2018). In a survey by Rawi *et al*. (2022) the data presented in **Figure 4** above shows only 15.8% of HEI have implemented any components of IR4.0. Those that are still standing have included the IR4.0 components. The IoT was adopted by 88.2% of IR4.0 components, followed by Cloud Computing (76.5%), and Cybersecurity (58.8%). The percentage of HEI that have adopted additional IR4.0 features remains quite low, nevertheless.

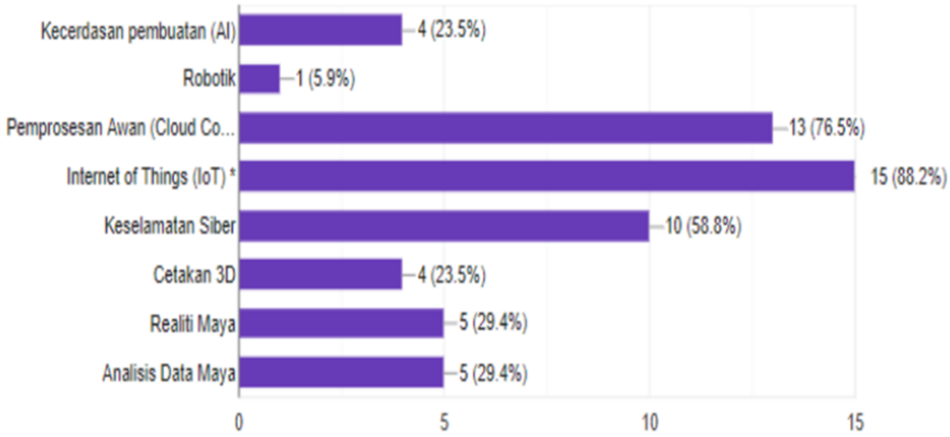

Figure 4. Adaptation IR4.0 elements in HEI Malaysia (Rawi *et al*., 2022).

Besides that, how well-prepared students of TVET at UTHM are in terms of intelligence, abilities, and mindset to meet the difficulties posed by IR4.0 is examined (Ismail *et al*., 2020a). The survey found that generally, student knowledge of IR4.0 was limited. This may be because students are not likely to be accustomed to utilizing IR4.0 technology in class or in their daily lives (Mohamad *et al*., 2022). According to Rawi *et al*. (2022), this particular aspect holds significant value in fostering and directing students toward learning and utilizing IR4.0 technology in their daily lives. Students who possess a strong inclination and readiness to embrace IR4.0 technology can be nurtured more effortlessly compared to those who lack interest.

3.3.1. Industrial revolution 4.0 in technical university

As a result of IR4.0, universities of all stripes are being challenged to provide their students with more than just the theoretical information that has traditionally been their focus. Skills for the IR4.0 necessitate a re-evaluation of the value placed on degrees from technical and vocational schools. MTUN is the nation's premier technical and vocational education and training institution. The Universiti Teknikal Malaysia Melaka (UTeM), Universiti Tun Hussein Onn Malaysia (UTHM), Universiti Malaysia Pahang (UMP), and Universiti Malaysia Perlis (UniMAP) have merged to form MTUN, a network of technical universities in Malaysia. Through synergistic and strategic linkages with industry, it seeks to cultivate extremely capable technical people resources to promote the nation's sustainable growth and competitive advantage (Jam and Puteh, 2022). MTUN has collaborated with several sectors from the very beginning of its research and development.

Skills development is a critical concern for the industry, universities, and governments to address in IR4.0, just as it was in past industrial revolutions. Students will need to acquire new skills and should be well-equipped to do so to succeed in meeting the IR4.0 objective

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p- ISSN 2828-3287 e- ISSN 2828-3295

(Kamaruzaman *et al*., 2019). MTUN must equip students in TVET to make effective use of technology in the classroom. There will be long-term effects of the new method of instruction on both students' hard and soft abilities. To that end, TVET is a two-track vocational education and training system that focuses on both academic and occupational competencies. TVET is a realm of education that generates highly skilled workers. MTUN has taken on the responsibility of providing the TVET workforce in the manufacturing industry by producing qualified individuals. Consequently, MTUN is swiftly embracing Education 4.0 to merge the institution's well-established teaching methods with state-of-the-art scientific breakthroughs stemming from the emergence of IR4.0. This transition necessitates the adaptation of the educational system to adopt Education 4.0. There has been a noticeable transformation in the instructional approach at MTUN, credited to the adoption of teaching practices that align with Education 4.0.

Graduates in Malaysia, according to The National Graduate Employability 2012-2017, nevertheless, continue to be deficient in technical competence and knowledge (Ramli *et al*., 2022). Nonetheless, in today's industrialized world, workers require not just technical competencies like digital, IT, and automation knowledge, but also soft skills like communication, collaboration, and problem-solving (Ismail *et al*., 2020b). As supported by Maisiri *et al*. (2019) to thrive in today's industrial period, engineers require a wide range of abilities, not just technical ones. Institutions of higher learning face a significant problem in developing and implementing curricula that will help engineering students improve their non-technical skills (Azmi *et al*., 2018).

3.3.2. Industrial revolution 4.0 in industrial engineering

In the mentioned timeframe, a rising discipline known as Industrial Engineering merged the realms of engineering and management. From that point forward, it has aided numerous industries worldwide in establishing a cohesive theoretical basis to enhance their competitive advantage and strive for continuous improvement. The demand for industrial engineers is substantial, with an estimated employment growth of 10% between 2016 and 2026. This rate of expansion surpasses that of all other specialized areas within the field of engineering (Bilge and Severengiz, 2019). Furthermore, concerning overall workforce participation, industrialized economies maintain their distinct position. This is evident in **Figure 5**, which highlights the prevalence of manufacturing and transportation occupations in Eastern European economies. These two sectors are particularly compatible with automation advancements until the year 2030.

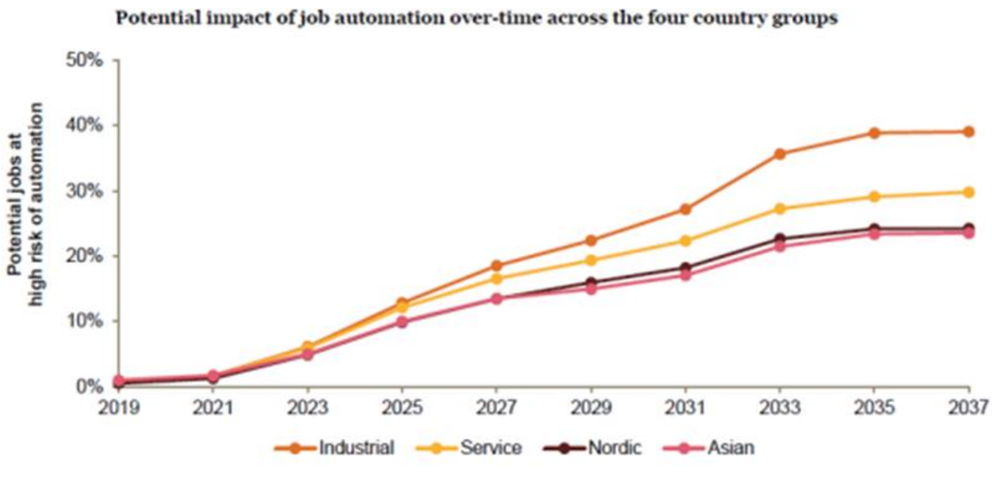

Figure 5. Job automation in the four country groupings.

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The growing strategic importance of adapting to IR4.0 has led to a severe shortage of qualified engineers able to aid in the transition. Consequently, one of the most pressing concerns of colleges and universities is to include discussions about IR4.0 in engineering courses (Salah *et al*., 2020). The correlation between Industrial Engineering and the Industrial Revolution evolved gradually, as depicted in **Figure 6** provided. Starting from the initial IR1.0 system and progressing to the present IR4.0, industrial engineering has played a vital part in ensuring the triumph of the revolution. Consequently, it is the responsibility of the university to furnish its students with a comprehensive set of competencies, encompassing both technical expertise and non-technical abilities, for them to thrive as accomplished engineers.

With time, the realm of IE has evolved in conjunction with various manufacturing-oriented movements. It has become a vibrant and multidisciplinary field, playing a pivotal role in generating fresh concepts, innovative strategies for challenges, and tangible advancements in contemporary society (Mangaroo and Roopa, 2021). In the United States, there is currently an approximate total of 257,899 individuals employed as industrial engineers, with an additional projected increase of about 9.7% (Ong *et al*., 2021).To address concerns spanning various industries, IE engages with both the physical and social sciences (Hopp, 2021). Moreover, proficient industrial engineers are indispensable in diverse domains including logistics, manufacturing, business operations, supply chain management, sales, advisory, technology development, and innovation. Therefore, the demand for these skilled professionals is expected to experience a significant surge in the forthcoming decade (Ong *et al*., 2021).

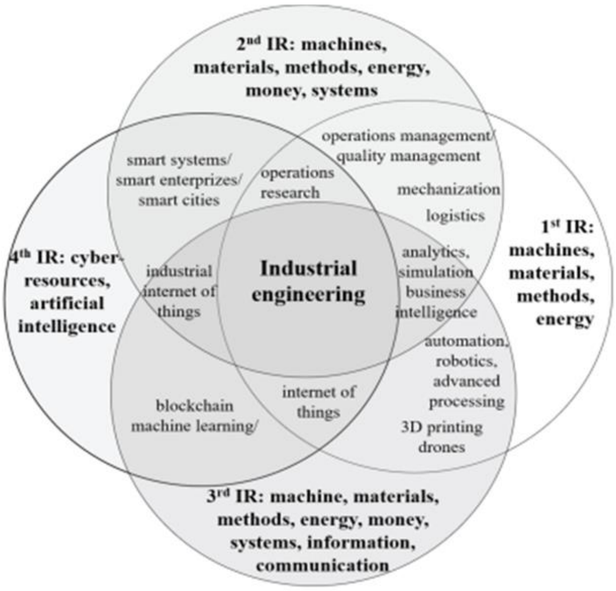

Figure 6. Correlation between industrial engineering with industrial revolution (Maisiri, *et al*., 2021).

Improvements in industrial and systems engineering may be seen in the present day, between the third and fourth waves of industrialization (Mangaroo and Roopa, 2021). All branches of engineering, and IE in particular, have developed in parallel with the growth of the industrial revolutions from their first to their fourth phases (Maisiri *et al*., 2021) as shown in **Figure 6** above. The advent of IR4.0 requires outstanding efficiency, which in turn calls for a wide range of skills and proficiencies. These include not only essential technical knowledge but also crucial collaborative qualities such as creativity, tolerance, and adaptability. Moreover, a thorough understanding of cutting-edge technologies is imperative. It is worth

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p- ISSN 2828-3287 e- ISSN 2828-3295

noting that the emergence of subfields like economics, industrial equipment, efficiency, human factors, connectivity methodologies, and decision theory can be attributed to the development of industrial engineering and operations research during the second and third industrial revolutions (Mangaroo and Roopa, 2021).

As a result of technological advancements in IR4.0, businesses may improve their internal communication and coordination, as well as their interactions with external parties like suppliers and consumers (Sembiring and Tambunan, 2021). Building upon this foundation of decentralized control and intelligent connection, IR4.0 serves as a starting point for intelligent automation. Consequently, IE students and graduates must familiarize themselves with the ongoing digital transformation within their field (Salah *et al*., 2020). Failure to adapt their education to reflect the capabilities demanded by IR4.0 may lead to a decline in the significance of industrial engineers (Salah *et al*., 2020).

3.4. Factors Influencing Student Performance

Student performance encompasses various components, including their cumulative grade point average (CGPA), knowledge acquisition, fulfillment with their education, and skill level. Academic standing, synonymous with student performance, serves as a characterization of a student's achievements. Typically, academic standing is represented by grades considered in CGPA calculations, which factor in grades from previous semesters. Students receive rankings based on their CGPA, ranging from First Class, Second Class (Upper Division and Lower Division), and Third Class, to Pass grades (Wang *et al*., 2023). By considering these factors, educational institutions and other entities can comprehensively assess student performance. This evaluation offers insights into a student's academic progress, satisfaction levels, and capacity for acquiring new skills. Comparing expected final grades with actual results (Adekitan and Salau, 2019), analyzing final semester grades, examining individual course grades (Tomasevic *et al*., 2020), and assessing performance in interviews and exams for potential job opportunities are all potential methods for evaluating academic performance. Student attrition and underachievement in Higher Education Institutions (HEIs) have been associated with various variables, both internal and external to the institution itself (Maphosa *et al*., 2023).

Verma and Yadav (2020) have identified various characteristics that can potentially influence a student's academic success. These attributes can be classified into four main groups, each having its defining characteristics. The first group is referred to as "Background Attributes," which encompasses students' complete demographic information such as age, gender, medium of instruction, category, place of residence, annual income, parental qualifications, parental occupations, and more. Following this, we have the category of "Academic Attributes," which includes data related to high school grades, intermediate grades, JEE Rank, and other relevant academic information. Moving on, the study also examined "Psychological Attributes," which focused on various psychological aspects of students, including motivation, enthusiasm for studying, feelings of loneliness, and dietary habits. Lastly, the "Behavioural Components" category explored student social activities, such as food preferences, internet usage, and interactions with classmates.

According to findings by Alalwan *et al*. (2019), pre-university achievement may serve as a predictor for subsequent academic success. To enhance students' academic outcomes, educators should utilize effective strategies, resources, and tools within the classroom. Furthermore, solid support not only aids students in achieving academic success but also contributes to their overall enjoyment of the school experience. Additionally, students' ages and backgrounds play significant roles in their academic achievements. Paramo *et al*. (2017)

DOI:
p- ISSN 2828-3287 e- ISSN 2828-3295

conducted a study on students' readjustment to college life, considering factors such as gender, upbringing, and level of college preparation. The study revealed that pre-university performance emerged as the sole crucial determinant for university adjustment. Among the numerous factors influencing students' ability to thrive in college, one of the most pivotal factors is their successful adaptation to university life.

According to Islam and Tasnim (2021), most studies in the literature have found that students' academic performance is influenced by various factors, including their gender, high school grade, parents' education level, family income, the language of instruction, residential location, previous semester's performance, attendance, interest in the subject matter, study time, and effort. These characteristics can be classified into individual, household, school, organization, and community types, as discussed by Alzoubi and Ahmed (2022). Personal factors, such as the student's background, thinking, and behavior, fall under the personal factor classification. The second category includes social variables, such as grades and academically linked metrics. The third category encompasses domestic aspects, where family history significantly influences the student's responses, reactions, and overall performance in real-world circumstances. Moreover, factors associated with schools or universities, including academic behavior and a supportive system, can also serve as motivation for students to excel in their coursework.

3.5. Readiness in Industrial Revolution 4.0

The concept of preparedness is an enhanced and extended edition of Zartman's (1989) theory of malfunction. Unlike hypocrisy, this facade utilizes expressions and ideas that are unique to the destination country and highlights one perspective more prominently than the opposing side (Ahmad *et al*., 2019). Because of the constantly shifting features of necessary competencies, it is anticipated that IR4.0 will have a significant impact on the process of employing employees. Competencies such as skill in information technology, knowledge of organizational and procedural aptitude, and the capacity to use state-of-the-art interfaces are all required for those who are active in IR4.0 (Maria *et al*., 2018). Consequently, industrial transformation possesses the capacity to exert a noteworthy impact on education, specifically within educational institutions. This groundbreaking character of IR4.0 has engendered substantial transformations not just at the national level but also within communities and various domains. Notably, an advantageous aspect of IR4.0 is its potential to refine individuals' skills in the realm of critical thinking (Ismail *et al*., 2020).

The notion of "workforce readiness" holds great significance as it highlights the significance of equipping students with the essential abilities and knowledge to succeed in their professional lives. While individuals with exceptional business insight or specialized expertise may perceive this idea as obvious, historically, education has placed more emphasis on academic pursuits rather than fostering practical skills (Adnan *et al*. 2021). The majority of graduates are oblivious to this trend, resulting in occasional failures in transitioning from classroom learning to the workplace (Ahmad *et al*., 2019). It is inadequate to assess the skills and expertise of learners upon completion of a course or program solely to gauge the number of students who have acquired new knowledge (Ahmad *et al*., 2019). Relying solely on this endpoint assessment fails to provide a comprehensive understanding of the learning process and the true impact of the educational experience. To obtain a more accurate measure, it is necessary to consider additional factors and employ a more comprehensive evaluation approach throughout the entire duration of the course or program. By doing so, a deeper insight can be gained into the progress and growth of students, allowing for more informed judgments regarding their acquisition of new knowledge and skills.

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In a study by Ahmad *et al*. (2019) which utilized quantitative research to determine what variables affect UTHM undergraduates' readiness for IR4.0, they discovered no correlation between students' technical and non-technical abilities. On the other hand, Uei and Shing (2021) conducted a separate quantitative investigation, employing descriptive statistics, correlation, and multiple regression to analyze the results. Building upon the previous study, their research concluded that university students in Malaysia are ready for the Education 4.0 paradigm shift. These students demonstrate the ability to learn in various contexts and at their own pace, customize their education to their strengths and weaknesses, and adapt their instructional methods as needed. Moreover, they exhibit rapid assimilation of new information, its application to novel situations, and the utilization of human reasoning to deduce logic and patterns, all of which are essential for their desired career paths. Additionally, they possess a willingness to contribute to course development and have exhibited adaptability to new forms of evaluation.

The research conducted by Adnan *et al*. (2019) utilized descriptive statistics to calculate the average and standard deviation of each variable, as well as reliability testing to measure the inter-variable correlation using an online survey questionnaire. According to the data, undergraduate students not only recognize but also believe they possess the essential abilities required by employers for IR4.0 employment expectations. These findings can be utilized to develop a comprehensive profile of the valuable skill sets possessed by students, thereby enhancing their employability. Furthermore, conducting more extensive qualitative research would yield a deeper understanding of the fundamental skills demanded by employers in the context of current and future industry requirements. Similarly, Adnan *et al*. (2021) employed interviews in their qualitative research to assess the quality of polytechnic manufacturing programs concerning their capacity to prepare students for the challenges posed by IR4.0. The results indicate that Polytechnic Malaysia's manufacturing programs should implement measures to train their students and graduates for IR4.0.

According to a study conducted by Rawi *et al*. (2022), it was observed that students exhibited high levels of enthusiasm, optimistic outlook, and preparedness to confront the challenges associated with IR4.0. The researchers found that students who displayed genuine interest in and readiness to utilize IR4.0 technology were more receptive to guidance and encouragement in their pursuit of this field, in comparison to those who lacked such inclination. The aforementioned studies predominantly relied on quantitative, qualitative, or mixed methods to investigate students' preparedness and the correlation between knowledge and skills concerning IR4.0. Several studies employed descriptive statistics and multiple regression analysis techniques to ascertain the extent of association between knowledge and skills in the context of IR4.0.

3.6. Skills in Industrial Revolution 4.0

The Ministry of Higher Education in Malaysia should incorporate components into their curricula that would enable them to produce versatile graduates who excel in both technical and non-technical domains (Azmi *et al*., 2018). Moreover, technical skill encompasses the skills required for operating tangible machinery. Additionally, engaging in collaborative investigations and knowledge exchange with peers is essential for attaining a heightened level of understanding. To enhance the appeal of education, diverse alternative schemes and instruments can be utilized. Furthermore, effective communication proficiency is necessary for expressing ideas to others (Soni *et al*., 2020). Consequently, employers express significant concern about the inadequate non-technical competencies among recent engineering

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graduates. By participating in industry training programs, undergraduates can greatly enhance their non-technical skills (Azmi *et al*., 2018).

The readiness of students for the IR4.0 depends heavily on various independent factors, including their proficiency in both technical and non-technical abilities. On the other hand, the readiness of students for IR4.0 can be considered as the outcome that is influenced by these independent variables (Ahmad *et al*., 2019). Moreover, in the current employment landscape, employers seek individuals who have cultivated "general skills and proficiencies,". These encompass the capacity to engage in critical thinking, effectively convey information, establish robust connections, and contribute as productive team participants (Ahmad *et al*., 2019). The skills have changed according to the changes of the era from IR1.0 to IR4.0 recently. However, certain skills remain unchanged but with a bit of enhancement to complement the needs of today's industry (Azmi *et al*., 2018).

In line with this, Azmi *et al*. (2018) found that engineers in demand today need to be able to communicate well, analyze critically, and solve problems independently. Skills in cooperation, continuing education, ethics, and computer use are all noted by interviewees. Furthermore, there are divergent views on how much of an effect placement has on students' development of non-technical skills throughout industrial training. Only 3 out of 5 businesses thought it was important that the training be directly related to their sector. This disagreement arises because teaching methods and student motivation should both factor towards the growth of students' non-technical abilities.

As can be seen in **Figure 7** of the conceptual framework, the skills necessary for technical knowledge are digital, as stated by Ramli *et al*. (2022) students are unable to learn to use technology effectively without mastering these skills. Furthermore, as noted by Jelonek and Nitkiewicz (2020) non-technical skills are another aspect affecting IR4.0 readiness. Engineers need technical abilities. Besides, as indicated by Ramli *et al*. (2022) today's businesses increasingly value soft skills like communication and cooperation. To effectively communicate with clients and vendors, engineers need to have strong non-technical abilities.

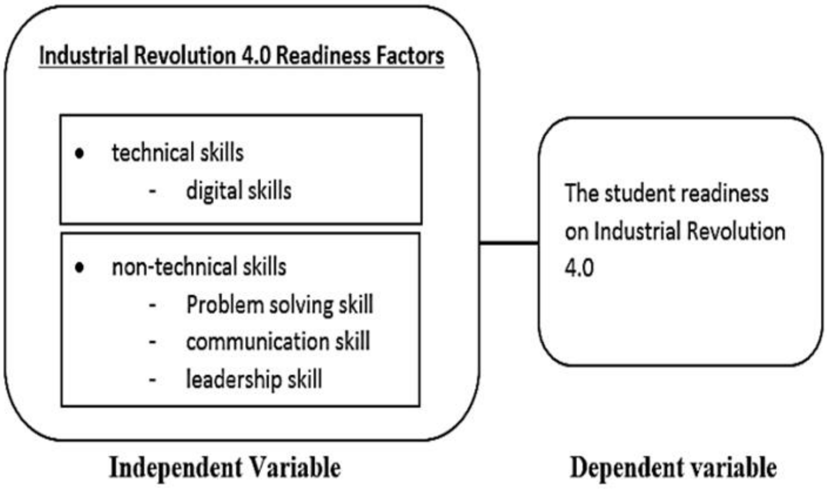

Figure 7. Conceptual framework of IR4.0 readiness (Ramli *et al*., 2022).

The necessary skills during IR4.0 have been broken down into two groups which are technical skills (TS) and non-technical skills (NTS), as summarised by Maisiri *et al*. (2019). In line with their findings, NTS encompasses critical thinking, social and personal abilities, while TS encompasses technology, programming, and digital ability. Moreover, the study emphasizes that engineers need to possess various technical and non-technical skills, including coding, software development, working with the IoT, 3D printing, autonomous robots, digital and cyber security, cloud computing, data analytics, and AI, to thrive in the era of IR4.0.

The inability of today's generation to acquire these skills is a major factor in the generation's poor level of professional preparedness (Ramli *et al*., 2022). Moreover, according to Adnan *et al*. (2021), career readiness refers to a student's ability to successfully make the transition from "campus life" to the working world. Additionally, the "essential human skills" or "soft skills" that Giffi *et al*. (2018) defines as "creativity, complex problem solving, relationship building, communication, emotional intelligence, and critical thinking" are in high demand. However, there are divergent viewpoints on whether soft skills should be added to technical ones to compete in IR4.0 and boost applicants' worth (Adnan *et al*., 2021).

3.6.1. Technical skills in industrial engineering

According to Salah *et al*. (2020), hard skills refer to the essential abilities required for a particular job, such as technical proficiency and industry-specific expertise. However, if training programs for industrial engineers fail to incorporate the capabilities demanded by IR4.0, there is a risk of diminishing demand for their skills. In the context of Industrial Engineering Education, there is a significant emphasis on the development of human-digital skills. Sutopo (2019) highlights that this focus area aims to create value chains for system operations, streamline the incubation process, enhance human resources for technopreneurs, and improve competitiveness. These aspects are crucial for effectively commercializing technology in the Digital Era. To thrive in the future, industrial engineers must possess interdisciplinary thinking abilities, a comprehensive understanding of functional interactions, and a diverse range of information technology skills (Bilge and Severengiz, 2019).

In the realm of industrial engineering, similar to many other disciplines, the emphasis on theoretical lectures often neglects the practical application of concepts through real-life case studies. Consequently, aspiring industrial engineers frequently lack hands-on expertise in implementing the ideas they learn about factory management. To address this gap, some educational institutions have adopted more interactive teaching methods to impart practical knowledge in the field of industrial engineering (Bilge and Severengiz, 2019). Furthermore, industrial engineers play a crucial role in staff training and development, particularly in areas such as process enhancement and workshop facilitation. Proficiency in computer skills is considered a paramount general ability for industrial engineers (Broum *et al*., 2022). In light of management theory, the advent of Industry 4.0 necessitates that industrial engineers possess skills in business model creation and entrepreneurship. Additionally, the feasibility of cradle-to-grave strategies for physical parts is increasing, prompting a shift in focus from marketing products to selling functionality (Bilge and Severengiz, 2019).

According to Broum *et al*. (2022) and Bougaa *et al*. (2015), industrial engineers need to possess a fundamental understanding of virtual and augmented reality, including its implementation and application. However, this does not imply that industrial engineers must be experts in programming, 3D graphics, or image processing. They should instead adapt to the evolving nature of their profession, driven by advancements in technology environments, business models, data management culture, autonomous learning, and other related areas. Industrial engineers should be capable of solving complex engineering problems using digital resources, critically analyzing technology, generating original digital content, and practicing digital responsibility. Furthermore, they should have a comprehensive knowledge of their respective fields, as emphasized by Quintero (2022). An instance of the transferable skills that can be developed through this approach is the multidisciplinary collaboration that combines software engineering and programming, as mentioned by Gladysz (2019).

According to Tan *et al.* (2020), the Industry 4.0 Lab has the potential to serve as a foundation for industrial engineering education in Indonesia. By simulating a real-world production environment, students can gain practical experience with cutting-edge technologies. While initially designed for industrial engineers, other engineering programs can also benefit by incorporating their curricula into the lab. Wollschlaeger *et al.* (2017) emphasize the significance of the IoT in the future economy. Therefore, aspiring industrial engineers should familiarize themselves with this topic. To ensure that graduates are well-prepared for the current and future work environment, curriculum modifications are necessary to integrate IoT-related issues.

3.6.2. Non-technical skills in industrial engineering

According to Quintero (2022), the development of a well-rounded industrial engineer relies heavily on professional interpersonal qualities. These qualities encompass leadership, teamwork, creativity, innovation, communication, and cooperation within interdisciplinary and digital teams. The field of industrial engineering is constantly evolving, requiring a broad range of skills and knowledge from various disciplines (Chikasha *et al*., 2021). In the coming years, educators in colleges and universities will play a crucial role in shaping the industrial engineering profession. Their efforts will contribute to the production of innovative professionals who possess strong technical and creative abilities, as well as sound decision-making skills (Quintero, 2022).

Historically, soft skills such as critical and creative thinking, effective collaboration and teamwork, emotional intelligence, sound judgment and decision-making, service orientation, negotiation, and mental flexibility were considered less significant compared to traditionally recognized hard skills. However, in the age of Industry 4.0, these abilities are no longer considered optional extras or secondary to hard technical talents; rather, they are recognized as indispensable for thriving in the workplace of the future (Adnan *et al*., 2019). Research conducted by Adnan *et al.* (2019) demonstrates that complex problem-solving, critical thinking, ingenuity, team leadership, collaboration, empathy, discernment, making sound choices, customer focus, bargaining, and flexibility are all examples of soft skills that were once deemed unimportant but are now acknowledged as essential for entering the labor market and advancing in one's professional journey. Furthermore, with the advent of IR4.0, these skills will no longer be viewed as optional or secondary to technical expertise. Instead, they will be regarded as necessities for not only surviving but thriving in the workplace of the future.

4. CONCLUSION

This paper presents a comprehensive exploration of the research topic by conducting a thorough examination of relevant literature. The primary objective was to trace the evolution of industrial revolutions, from the first to the present, with a specific focus on the emergence of the fourth industrial revolution. Additionally, a detailed review and analysis of the literature were undertaken to investigate the influence of industrial revolutions on higher education institutions, specifically technical universities. Furthermore, this paper highlights the essential skills required for engineering students, particularly those studying industrial engineering, encompassing both technical and non-technical aspects. By emphasizing the significance of assessing student readiness for the Industrial Revolution, it aims to shed light on the role played by industrial engineering in facilitating this transformative process.

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5. AUTHORS' NOTE

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6. REFERENCES

Adekitan, A. I., and Salau, O. (2019). The impact of engineering students' performance in the first three years on their graduation result using educational data mining. *Heliyon, 5*(2), e01250.

Adnan, A. H. M., Rahmat, A. M., Mohtar, N. M., and Anuar, N. (2021). Industry 4.0 critical skills and career readiness of ASEAN TVET tertiary students in Malaysia, Indonesia and Brunei. *In Journal of Physics: Conference Series, 1793*(1), 012004.

Adnan, N. A., Paimin, A. N., and Hasan, A. A. (2019). Readiness of polytechnic manufacturing program in Malaysia towards future industry. *International Journal of Engineering and Advanced Technology, 9*(2), 1654-1659.

Ahmad, A. R., Segaran, P. A. P., Soon, N. K., Sapry, H. R. M., and Omar, S. S. (2019). Factors influence the students‟ readiness on industrial revolution 4.0. *International Journal of Recent Technology and Engineering (IJRTE), 8*(2), 461-468.

Alalwan, N., Al-Rahmi, W. M., Alfarraj, O., Alzahrani, A., Yahaya, N., and Al-Rahmi, A. M. (2019). Integrated three theories to develop a model of factors affecting students' academic performance in higher education. *IEEE Access, 7*, 98725-98742.

Alzoubi, H. M., and Ahmed, G. (2022). Perceived factors affecting students academic performance. *Academy of Strategic Management Journal, 21*(4), 1-15.

Azmi, A. N., Noordin, M. K., Kamin, Y., Nasir, A. N. M., and Suhairom, N. (2018). Factors in non-technical skills development among engineering students: An employers' perspective. *Turkish Online Journal of Design Art and Communication, 8*, 918-926.

Bilge, P., and Severengiz, M. (2019). Analysis of industrial engineering qualification for the job market. *Procedia Manufacturing, 33*, 725-731.

Bougaa, M., Bornhofen, S., Kadima, H., and Rivière, A. (2015). Virtual reality for manufacturing engineering in the factories of the future. *Applied Mechanics and Materials, 789*, 1275-1282.

Broum, T., Hořejší, P., Malaga, M., and Grzona, P. (2022). Competencies of industrial engineers for implementing augmented reality metadata systems. *Sustainability, 15*(1), 130.

Chikasha, P., Ramdass, K., Ndou, N., Maladzhi, R., and Mokgohloa, K. (2021). Industrial engineers of the future – a concept for a profession that is evolving. *Advances in Science, Technology and Engineering Systems Journal, 6*(4), 72-79.

Gereffi, G. (2019). Global value chains and international development policy: Bringing firms, networks and policy-engaged scholarship back in. *Journal of International Business Policy, 2*, 195-210.

DOI:
p- ISSN 2828-3287 e- ISSN 2828-3295

Giffi, C., Wellener, P., Dollar, B., Ashton Mangolian, H., Monck, L., and Moutray, C. (2018). Deloitte skills gap and future of work in manufacturing study. *Deloitte Insights, 2018*, 1-24.

Gladysz, B. (2019). Industrial engineering education – challenging complexity by simple means. *Management and Production Engineering Review, 10*(3), 90-96.

Hopp, W. J., and Spearman, M. S. (2021). The lenses of lean: Visioning the science and practice of efficiency. *Journal of Operations Management, 67*(5), 610-626.

Islam, A., and Tasnim, S. (2021). An analysis of factors influencing academic performance of undergraduate students: A case study of Rabindra University, Bangladesh (RUB). *Shanlax International Journal of Education, 9*(3), 127-135.

Ismail, A., Wan Hassan, W. A., Ahmad, F., Affan, Z., and Harun, M. I. (2020a). Students' readiness in facing industrial revolution 4.0 among students of technical teacher's education. *International Journal of Scientific and Technology Research, 9*(8), 300-305.

Ismail, N. A., Wahid, N. A., Yusoff, A. S. M., Wahab, N. A., Rahim, B. H. A., Majid, N. A., and Zakaria, R. (2020b). The challenges of industrial revolution (IR) 4.0 towards the teacher's self-efficacy. *Journal of Physics: Conference Series, 529*(4), 042062.

Jam, N. A. M., and Puteh, S. (2022). Exploring the teaching and learning indicators towards education 4.0 in MTUN, Malaysia. *International Journal of Information and Education Technology, 12*(2), 179-184.

Jelonek, D., and Nitkiewicz, T. (2020). Soft skills of engineers in view of industry 4.0 challenges. *Quality Production Improvement-QPI, 2*(1), 107-116.

Kamaruzaman, M. F., Hamid, R., Mutalib, A. A., and Rasul, M. S. (2019). Comparison of engineering skills with IR 4.0 skills. *International Journal of Online and Biomedical Engineering (IJOE), 15*(10), 15-28.

Lase, D. (2019). Education and industrial revolution 4.0. *Handayani Journal PGSD FIP Unimed. 10*(1), 48-62.

Ling, Y. M., Abdul Hamid, N. A., and Chuan, L. T. (2020). Is Malaysia ready for industry 4.0? issues and challenges in manufacturing industry. *International Journal of Integrated Engineering, 12*(7), 134-150.

Maisiri, W., Darwish, H., and Dyk, L. v. (2019). An investigation of industry 4.0 skills requirements. *South African Journal of Industrial Engineering, 30*(3), 90-105.

Maisiri, W., van Dyk, L., and Coetzee, R. (2021). Development of an industry 4.0 competency maturity model. *SAIEE Africa Research Journal, 112*(4), 189-197.

Mangaroo-Pillay, M., and Roopa, M. (2021). Beyond the industrial engineering frontier: A few steps in history and a giant leap into the future. *South African Journal of Industrial Engineering, 32*(3), 1-9.

Maphosa, M., Doorsamy, W., and Paul, B. (2023). Student performance patterns in engineering at the University of Johannesburg: An exploratory data analysis. *IEEE Access, 11*, 48977 – 48987.

DOI:
p- ISSN 2828-3287 e- ISSN 2828-3295

Maria, M., Shahbodin, F., and Pee, N. C. (2018). Malaysian higher education system towards industry 4.0 – current trends overview. *In AIP Conference Proceedings, 2016*(1), 1-8.

Miranda, J., Navarrete, C., Noguez, J., Molina-Espinosa, J. M., Ramírez-Montoya, M. S., Navarro-Tuch, S. A., Bustamante-Bello, M. R., Rosas-Fernández, J. B., and Molina, A. (2021). The core components of education 4.0 in higher education: Three case studies in engineering education. *Computers and Electrical Engineering, 93*, 107278.

Mohamad Shuhaimi, M. A., Brahim, J., Mat Yusoff, Z., and Fathi, M. S. (2022). The readiness of public universities in adopting industrial revolution 4.0 (IR 4.0) from a construction management perspective. *ASEAN Engineering Journal, 12*(2), 111-118.

Noor, H. M., Mazlan, S. A., and Amrin, A. (2021). Computerized maintenance management system in IR4. 0 adaptation-a state of implementation review and perspective. *In IOP Conference Series: Materials Science and Engineering, 1051*(1), 012019.

Ong, A. K. S., Prasetyo, Y. T., Young, M. N., Diaz, J. F. T., Chuenyindee, T., Kusonwattana, P., and Redi, A. A. N. P. (2021). Students' preference analysis on online learning attributes in industrial engineering education during the covid-19 pandemic: A conjoint analysis approach for sustainable industrial engineers. *Sustainability, 13*(15), 8339.

Paramo Fernandez, M. F., Araujo, A. M., Tinajero Vacas, C., Almeida, L. S., and Rodriguez Gonzalez, M. S. (2017). Predictors of students' adjustment during transition to university in Spain. *Psicothema, 29*(1), 67-72.

Quintero, W. R. (2022). Digital competences of the industrial engineer in industry 4.0 a systematic vision. *Production, 32*, e20220028.

Rahamaddulla, S. R. B., Leman, Z., Baharudin, B. H. T. B., and Ahmad, S. A. (2021). Conceptualizing smart manufacturing readiness-maturity model for small and medium enterprise (SME) in Malaysia. *Sustainability, 13*(17), 9793.

Ramli, M. F., Majid, M., Badyalina, B., and Shaari, N. F. (2022). Exploring the relationship between engineering students' skills and readiness toward industry revolution 4.0. *International Journal of Education, Psychology, And Counselling (IJEPC), 7*(47), 171-180.

Rawi, R., Mohd Isa, M. R., Ismail, M. N., Sajak, A. A. B., and Sulaiman, M. A. M. (2022). A survey: Readiness of Malaysian higher education institutes towards the adaptations of industry revolution 4.0. *In 2022 1st International Conference on Information System and Information Technology (ICISIT), 2022*, 267-271.

Salah, B., Khan, S., Ramadan, M., and Gjeldum, N. (2020). Integrating the concept of industry 4.0 by teaching methodology in industrial engineering curriculum. *Processes, 8*(9), 1007.

Sembiring, M. T., and Tambunan, R. H. (2021). Analysis of graduation prediction on time based on student academic performance using the naïve bayes algorithm with data mining implementation (Case study: Department of Industrial Engineering USU). *In IOP Conference Series: Materials Science and Engineering, 1122*(1), 012069.

Sima, V., Gheorghe, I. G., Subić, J., and Nancu, D. (2020). Influences of the industry 4.0 revolution on the human capital development and consumer behavior: A systematic review. *Sustainability, 12*(10), 4035.

DOI:
p- ISSN 2828-3287 e- ISSN 2828-3295

Soni, K. M., Hasteer, N., and Bhardwaj, A. (2020). Aspects to foster competences for engineering graduates: Education 4.0 paradigm. *In 2020 9th International Conference System Modeling and Advancement in Research Trends (SMART)*, *2020*, 480-484.

Sutopo, W. (2019). The roles of industrial engineering education for promoting innovations and technology commercialization in the digital era. *IOP Conference Series: Materials Science and Engineering, 495*(1), 012001.

Tan, H.S., Ivander, Oktarina, R., Reynaldo, V., and Sharina, C. (2020). Conceptual development of learning factory for industrial engineering education in Indonesia context as an enabler of students' competencies in industry 4.0 era. *The 3rd International Conference on Eco Engineering Development, 426*(1), 012123.

Tilak, D. G., and Singh, D. (2018). Industry 4.0 – 4th rising industrial revolution in manufacturing industries and its impact on employability and existing education system. *Pramana Research Journal, 8*(11), 161-168.

Tomasevic, N., Gvozdenovic, N., and Vranes, S. (2020). An overview and comparison of supervised data mining techniques for student exam performance prediction. *Computers and Education, 143*, 103676.

Tortorella, G. L., Giglio, R., and Dun, D. H. v. (2019). Industry 4.0 adoption as a moderator of the impact of lean production practices on operational performance improvement. *International Journal of Operations and Production Management, 39*(6/7/8), 860-886.

Uei, P. C., and Shing, J. H. V. (2021). Industrial revolution 4.0: Are students ready for education 4.0?. *Global Business and Management Research: An International Journal, 13*(4), 244-251.

Verma, S., and Yadav, R. K. (2020). Effect of different attributes on the academic performance of engineering students. *In 2020 IEEE International Conference on Advent Trends in Multidisciplinary Research and Innovation (ICATMRI), 2020*, 1-4.

Wang, X., Zhao, Y., Li, C., and Ren, P. (2023). ProbSAP: A comprehensive and high-performance system for student academic performance prediction. *Pattern Recognition, 137*, 109309.

Wollschlaeger, M., Sauter, T., and Jasperneite, J. (2017). The future of industrial communication: Automation networks in the era of the internet of things and industry 4.0. *IEEE Industrial Electronics Magazine, 11*(1), 17-27.

DOI:
p- ISSN 2828-3287 e- ISSN 2828-3295