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# Factors affecting students' preparedness for the fourth industrial revolution in higher education institutions

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## Abstract

**Purpose** – Knowing the students' readiness for the fourth industrial revolution (4IR) is essential to producing competent, knowledgeable and skilled graduates who can contribute to the skilled workforce in the country. This will assist the Higher Education Institutions (HEIs) to ensure that their graduates own skill sets needed to work in the 4IR era. However, studies on students' readiness and preparedness for the 4IR in developing countries such as the Sultanate of Oman are still lacking. Therefore, this study investigates students' readiness level and preparedness for the 4IR. The findings of this study will benefit the HEIs policymakers, administration, faculties, departments, industries and society at large since they will be informed of the student's readiness and preparedness toward industry 4.0.

**Design/methodology/approach** – The authors adopted the measures from the same context as previous studies in this study. The questionnaire was divided into three sections; the first part described the purpose and introduction of the search with the surety to keep the data confidential. The second part consisted of demographical information like gender, education. The last parts consisted of four subsections, question items in these parts are based on the related previous study. Characteristics consisted of 14 items, knowledge consisted of 18 items related to 4IR technologies, Organizational Dimension comprised of four items related to academic programs, curriculum and training. Preparedness contained two items. The participants have rated all the items in 5-Likert scale.

**Findings** – Results from structural equation modeling showed that students' characteristics, knowledge of 4IR technologies and organizational dimensions significantly impact their preparedness for the 4IR. The study also found that organizational dimensions have the highest impact on students' preparedness. Furthermore, the organizational dimension significantly influences students' knowledge of 4IR technology. Moreover, students' characteristics related to 4IR are significantly affected by their knowledge of 4IR technology and organizational dimension. The findings suggest that HEIs are responsible for increasing the adoption of 4IR, and therefore organizational dimensions such as the academic programs, training, technological infrastructure and others are all critical for preparing students for a better future and should be given a priority.

**Research limitations/implications** – This study has used academic programs and training to measure the organizational dimension. However, other important factors should be considered, such as technological infrastructure and leadership and governance of HEIs. Second, the current research depends on quantitative data, so future research should implement a mixed methodology (questionnaires, depth interviews, document analysis and focus group) to understand the factors affecting students' readiness for 4IR clearly. Finally, although the 4IR has numerous benefits, it also has challenges in its implementation, so future studies should focus on challenges encountered by different stakeholders in implementing 4IR-related technologies.



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**Practical implications** – The curriculum must include mandatory courses related to IT infrastructure design, user experience programming, electronic measurement and control principles, and programming for data science. HEIs should also foster interdisciplinary knowledge by integrating IT, Engineering, Business and Sciences. Furthermore, the HEIs should develop their infrastructure to have smart campuses, labs, classrooms and libraries to make HEIs a space where knowledge can be generated and innovative solutions can be proposed. This entails HEIs offering necessary hardware, software and technical support because if the HEIs improve their technological resources, students will be capable of using 4IR-related technologies effectively.
**Originality/value** – The advancement of technology has resulted in the emergence of the Fourth Industrial Revolution (4IR), such as artificial intelligence, blockchain, robotics, cloud computing, data science, virtual reality and 3D printing. It is essential to investigate students' readiness for 4IR. However, there is no study as per researchers' knowledge talked about students readiness in HEIs in the Arab world. This study could be a basis for more research on students' perception of the 4IR covering students from various backgrounds and levels.

**Keywords** Framework, Fourth industrial revolution, Readiness, Higher education institutions

**Paper type** Research paper

## 1. Introduction

The advancement of technology has resulted in the emergence of the Fourth Industrial Revolution (4IR), such as artificial intelligence, blockchain, robotics, cloud computing, data science, virtual reality and 3D printing. According to the World Economic Forum, these technologies will lead to radical changes in people's social and economic life and will result in the disappearance of some jobs and the emergence of others. Therefore, people's skills need to be upgraded to be able to work and maintain job security in the 4IR era. Here comes the role of Higher Education Institutions (HEIs) in developing the skills of the future generation. Gleason (2018) and Penprase (2018) urged HEIs to respond to the rapid advancement of technological innovation by upgrading their programs and offering new ones to fulfill the demand for skilled graduates who can cope with the 4IR era. Universities are expected to produce dynamic graduates with high-order thinking skills, problem-solving and critical thinking skills (Gleason, 2018; Penprase, 2018). Lamprini and Bröchler (2018) pointed out that creativity, innovation and learning-for-life are necessary for 4IR to create highly skilled learners and workers. AbuMezied (2016) asserted that for HEIs to deliver future generations with the right set of skills and knowledge, it is essential to reflect on how they would be affected by the 4IR and how the delivery of Education will be transformed. It is no longer an option to keep doing things the old way; innovation and accepting change are now prerequisites for survival. The 4IR has altered, and will continue, how HEIs operate; it has affected teaching, research, and services/resources with virtual classrooms and laboratories, virtual libraries, and even virtual teachers (Xing and Marwala, 2017; Butler-Adam, 2018; Mian *et al.*, 2020).

Historically, the 4IR began in the 1780s when machines were manufactured and replaced human and animal labor. Then the second industrial revolution started from the 1920s to the 1970s and was characterized by combustion engines and electrical energy (Puriwat and Tripopsakul, 2020; Ramirez-Mendoza *et al.*, 2018; Gordon, 2016). The third industrial revolution arose with the emergence of computing and the Internet, which transformed all aspects of life: education, health care, transportation, agriculture, energy and commerce (Gleason, 2018; Caudill, 2020). Klaus Schwab launched the term 4IR in 2016 during the World Economic Forum, characterized by the automation of knowledge and the emergence of cyber-physical systems (CPSs), blockchain, artificial intelligence, robotics, 3D printing, the internet of Things (IoT), big data, sensors; virtual reality and augmented reality (Schwab, 2016; Baldassarre *et al.*, 2017).

Therefore, the countries are urged to prepare their nations to live and work in the 4IR era. HEIs are considered the key player in such a shift since they are responsible for the educational process and preparing their graduates to deal with 4IR technologies and requirements. Gordon (2016) requests the education sector to respond to the rapid advancement of technological innovation, which could be done by upgrading their programs and offering new ones to fulfill the demand for skilled graduates who can fit into this revolution (Jurčić *et al.*, 2018). Graduates should be well-informed, flexible and able to unlearn and relearn, prepared to face the automation challenge, and take advantage of opportunities associated with it. HEIs are expected to produce dynamic graduates with high-order thinking skills, problem-solving and critical thinking skills (McLeod *et al.*, 2017; Penprase, 2018).

Knowing the student's readiness for the 4IR is essential to producing competent, knowledgeable and skilled graduates who can contribute to the skilled workforce in the country. This will assist the HEIs in ensuring that their graduates possess the skill sets needed to work in the 4IR era, given that HEIs are deemed to be training facilitators for other industries (Ujakpa *et al.*, 2020). However, studies on students' readiness and preparedness for the 4IR in developing countries such as the Sultanate of Oman are still lacking. It is needless to stress the potential of 4IR technologies and their application to raise the country's local income and improve the population's quality of life. Thus, if the students are prepared for the 4IR, they will contribute more to the development of their country. Therefore, this study investigates students' readiness level and preparedness for the 4IR. The findings of this study will benefit the HEIs policymakers, administration, faculties, departments, industries and society at large since they will be informed of the student's readiness and preparedness toward industry 4.0. Hence, they will take the required measures and steps to prepare graduates to work in the 4IR era by reviewing policies for integrating technology in teaching, learning and other services, improving the infrastructure to make them compatible for smart-university services and systems, smart university environment, and data-based solutions policies related to HEIs. Also, being prepared for the 4IR era could be obtained by providing essential financial support for HEIs, guiding the program review process and initiating training programs for students and lecturers. In addition, it is imperative to conduct such a study to determine the students' perception so that a suitable approach to teaching and learning can be proposed to ensure students are ready to work in the rapid development of the 4IR era. Therefore, the gap between what students learn in their academic programs and industries will be minimized, which will increase their employability opportunities. Besides, this study could be a basis for more research on students' perception of the 4IR involving students from various backgrounds and years of study. The following section presents the literature review and framework development. The findings are then presented and discussed, followed by the conclusion and recommendations.

## 2. Literature review and framework development

As a psychological concept, readiness has been defined as the level of preparation for a given task sufficient to result in meaningful learning (Hayes and Stratton, 2013). It is also described as "the cognitive precursor to the behaviors of either resistance to, or support for, a change effort" (Armenakis *et al.*, 1993, p. 682). Hence, if the HEIs aim to foster students understanding of 4IR and its applications, they must assess their readiness level since it will enable the HEIs to initiate and develop educational programs and training courses (Tinmaz and Jin, 2019). A few studies have examined students' readiness and preparedness for the 4IR in HEIs in different countries such as South Africa, Malaysia, Thailand, South Korea, Brazil and Italy.

For example, Ujakpa *et al.* (2020) investigated the awareness and preparedness of 24 students in three universities in Namibia using a quantitative approach, and the study found that students were aware of 4IR. Nevertheless, the study suggested that further education on its applications is needed to prepare students further to work within the 4IR era. The study also found that although not much direct education on 4IR was given to students, most of them have used 4IR applications and are competent in using them. The study recommended that HEIs and other concerned government bodies need to implement approaches and strategies to create further awareness of 4IR and its applications. In South Africa, Kayembe and Nel (2019) reported that the education sector faces many challenges in adapting to the 4IR, including pedagogical adaptation, teacher development, insufficient funding and infrastructure, and skills to prepare graduates for technological development advancement.

Ahmad *et al.* (2019) investigated the 200 undergraduate students' readiness for 4IR at University Tun Hussein Onn (UTHM) in Malaysia. The findings revealed that most students were ready to apply technical skills required in the 4IR era and ready to learn new knowledge and adapt to the changes caused by the advancement of 4IR. The students expressed that they own skills needed for the 4IR era, such as communication skills and leadership skills, yet they need to develop skills related to solving problems without getting help from others, especially problems related to technology. Similarly, in 2019 in Malaysia, a study was conducted by INTI International University and Colleges and International Data Corporation (IDC) on graduate readiness for the 4IR workplace. It has involved 560 respondents comprising students, graduates and parents. The study revealed that these respondents lack clarity on 4IR. The study also showed that students felt unprepared to join the 4IR workforce since more than half of the students and graduates could not articulate what 4IR involves. The study concludes that universities and colleges in Malaysia may not be doing enough to prepare them for the 4IR era. Another study was conducted in Malaysia by Ismail *et al.* (2020), who examined the readiness of 136 Vocational Education Bachelor students at one of Malaysian Technical University. They found that students' knowledge of 4IR was weak, although their interests and readiness were high. The study recommended that the university should conduct more seminars, training programs and forums to raise students' awareness of 4IR.

Puriwat and Tripopsakul (2020) investigated the readiness levels of 132 graduate students in Thailand in adopting and leaping to 4IR. They found that students lacked the digital and information skills needed for the 4IR era, and they called for reforming Thailand's Education to prepare students for 4IR by taking actions such as including programs that aim to develop students' awareness of 4IR and its implementation in real life. Tinmaz and Jin (2019) surveyed 129 undergraduate students at a private university in South Korea to measure the extent of their knowledge of the concept of 4IR. They reported that the participants mainly stated that they had heard about the term but were unsure about its real-life applications. The participant expressed that although 4IR is a commonly spoken term that most students are aware of, they lacked a deeper understanding of its concept, and involvement with any related activity was not evident in this study. They assumed this could be due to a lack of adequate training and specialized programs addressing 4IR and its implication in the HEIs of South Korea.

Dos Santos *et al.* (2018) demonstrate the successful model of integrating 4IR skills in Brazil, involving chemical engineering students in implementing 4IR-related programming skills in their classes. Students were given problems that could be solved by integrating their chemical engineering knowledge with programming skills. Students developed computational tools to solve the problems, which became practical training for them to reinforce 4IR readiness. Motyl *et al.* (2017) have also assessed the 4IR readiness of 463 undergraduate students in three Italian universities. Based on the survey results, there was a need for an adequate education model to provide more structured knowledge to the students.

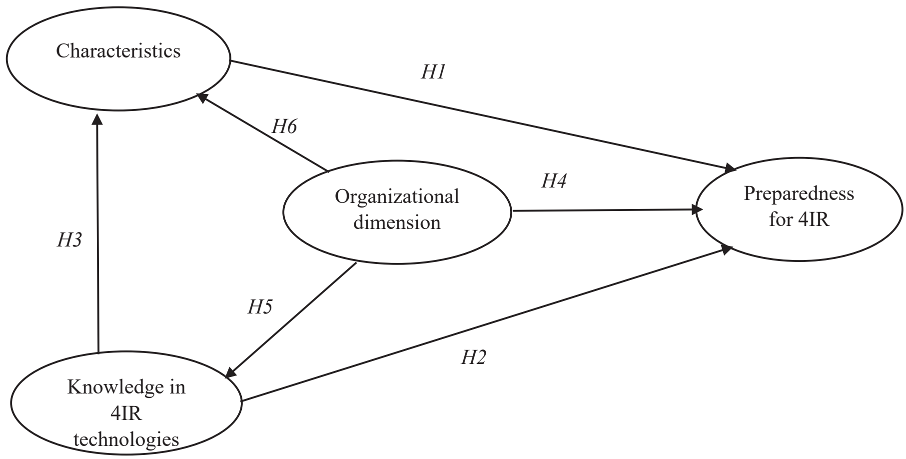
From the studies mentioned above, which have been conducted in different parts of the world, it seems that the participants in these studies were aware of 4IR. Yet, they lacked knowledge of its applications in real-life contexts. In addition, the previous studies concluded that students were interested in learning about the 4IR applications; however, their institutions did not provide them with opportunities to develop their understanding of how 4IR can be implemented. Therefore, most studies asserted that students felt unprepared to join the 4IR workforce, which necessitates the HEIs exert more effort to prepare their students for the 4IR era. The previous studies also showed that many factors contribute to students' preparedness, including their characteristics, organization dimension and knowledge of different IR4 technologies, as will be explained in the coming section. It is worth exploring the impact of these factors in different contexts and environments in the Middle East, in the Sultanate of Oman, other than in South Africa, Malaysia, Thailand, South Korea, Brazil and Italy.



*2.1 Factors that impact students' readiness for 4IR*

This study expects three factors are likely to influence students' preparedness for the 4IR: students' characteristics, their knowledge of 4IR technology and organizational dimensions (Figure 1).

*2.1.1 Students' characteristics.* Considering the rapid changes in the labor market and the inconsistency of job roles in different organizations, it is becoming more difficult for universities to continually identify and meet the technical skills required by employers (Bennett, 2019; Pham and Jackson, 2020). This has led the HEIs to focus on enhancing their students' soft skills and personal competencies, which are considered to have a long-lasting effect on graduates' employability, and they are more valued by the employer (Suleman, 2018; Tsiligiris and Bowyer, 2021). Empirical research univocally highlighted the critical role of students' personal competencies and characteristics in their preparedness for the 4IR era. For instance, Eleyyan (2021) investigated 77 pre-service Science teachers' perceptions about the implications of 4IR in the educational system in Oman. The findings revealed that for students to be prepared for 4IR, they need to have technical skills, critical thinking, coordination, verbal communication and time management skills. Similarly, Rampasso *et al.* (2020) stated that students need several characteristics to be prepared for the 4IR era, including decision-making, communication, leadership and digital literacy. Halim *et al.* (2019) stated that students in Malaysia need communication, creativity, collaboration and critical thinking to be prepared for the 4IR era. In addition, Puriwat and Tripopsakul (2020) surveyed the characteristics of students (digital literacy, innovation, adaptability, collaboration, self-direction, communication) and their impact on the readiness levels of 132 graduate students in Thailand. The results revealed that graduate students lacked digital and information skills and learning and innovation skills. They also found that the participants' communication




**Source(s):** Author suggestion

**Figure 1.**
A proposed framework to measure students' preparedness for 4IR

skills were fair compared with other skills, such as collaboration skills and flexibility. They concluded that students' preparedness for the 4IR era was weak based on their characteristics. Assante *et al.* (2019) stated that 4IR requires students to have various skills and abilities, including analytical thinking, decision-making, organizational capabilities, emotional intelligence, technical expertise and complex problem-solving skills. Sahu *et al.* (2021) asserted that students in India must have problem-solving, communication, interpersonal, lifelong learning and technical skills to be prepared for the 4IR era. Therefore, the empirical discussion furthers the following hypothesis (H1):

*H1.* Students' characteristics significantly affect their preparedness for the 4IR era.

*2.1.2 Students' knowledge.* Students' knowledge of 4IR-related technologies also critically influences preparedness for the 4IR era. For instance, Tinmaz and Jin (2019) stated that being aware of various 4IR technologies is needed for students to be prepared for the 4IR age. Their study found that IoT was the most unknown technology, whereas 3D printing was the most familiar technology, which signifies a lack of 4IR readiness among undergraduate students in South Korea since IoT is one of the most fundamental technologies for 4IR. However, Ujakpa *et al.* (2020), in their study of three HEIs in Namibia, found that 90% of their respondents had moderate to very high awareness of IoT, cloud computing, AI, machine learning and data security. In addition, they stated that 70% had moderate to very high knowledge of robotics, smart sensors, simulation, human–machine interface and 3D printing. The researchers consider such awareness positive sign for 4IR readiness among students in Namibia. Al Mayahi and Al-Bahr (2020) investigated the effect of a training program on increasing students' awareness of 4IR in high schools in Oman through a semi-experimental approach with a pre-test and post-test model using a questionnaire distributed to 143 students. The result revealed a statistically significant difference in the mean of the results of the two applications in favor of the post-test questionnaire, which means that students became more aware of 4IR and its applications after the awareness program. Furthermore, Mian *et al.* (2020) investigated the perceptions of 124 students, staff and researchers from various departments (IT, Business, Engineering and Healthcare) on the factors that contributed to students' readiness for the 4IR era. The results revealed that students should be familiar with different IR-related technologies such as AI, IT, data analytics and robotics. Hence, the previous studies have conclusively shown the critical role of students' awareness of various 4IR-related technologies on their preparedness level for the 4IR era. Therefore, the second hypothesis is stated as follow:

*H2.* Students' knowledge of 4IR-related technologies significantly affect their preparedness for the 4IR era.

Students' knowledge of 4IR related technologies not only affect their preparedness for the 4IR era but also their interpersonal skills and characteristics. For instance, Oke and Fernandes (2020) investigated the readiness and acceptability of 4IR in the education sector through semi-structured interviews with 33 stakeholders in Africa. The results showed that knowledge of 4IR could facilitate students' learning experience and make them capable of gaining skills needed for the workplace, such as analytical thinking, innovation, complex problem-solving, leadership and social influence, coordination and time management. Likewise, Sahu *et al.* (2021) emphasized that most students were unaware of 4IR concepts, which hindered them from gaining skills required by the job markets, such as problem-solving, interpersonal, lifelong learning and technical skills. They asserted that being abreast with 4IR-related technologies assisted them in gaining expected skills and increasing their employability opportunities. Given the importance of soft skills in the workplace, universities are responsible for developing their students' soft skills and other competencies (Tsiligiris and Bowyer, 2021). A recent bibliometric analysis and systematic literature review (Alhloul and Kiss, 2022) in determining industry 4.0 skills and competencies identified that interpersonal and innovation competencies are the most important skills. They suggested that more attention be paid to the development of analytical skills in education and vocational training. Therefore, all of the studies reviewed in this section support the third hypothesis:

*H3*. Students' knowledge of 4IR-related technologies significantly affect their characteristics.

*2.1.3 Organizational dimension.* Organizational dimension such as curriculum, academic programs, training courses offered by the HEIs and technological infrastructure is another factor that facilitates students' preparedness for the 4IR era. Previous research has shown that taking academic courses or attending training programs related to 4IR positively affects students' readiness for the 4IR age. For example, Ujakpa *et al.* (2020) found that 40% of their participants received education on 4IR, and 70% had worked with its applications, which is deemed a positive indication that students are getting prepared for 4IR. Similarly, they found that less than 50% of the students believe that discussions related to 4IR are taking place in their HEIs in Namibia. Additionally, they found that students were not well-informed of the implications of 4IR in their future careers; therefore, they recommended that more training and seminars should be prompted to raise students' readiness for the 4IR era and its implications for better employability chances.

Similarly, Puriwat and Tripopsakul (2020) investigated the impact of educational background on the readiness levels of 132 graduate students in Thailand. They found that educational background significantly affects students' preparedness for 4IR. To elaborate, they found that graduate students with a Science background reported higher preparedness levels for 4IR than those with Social Sciences and Business backgrounds. This indicates that academic programs impact students' readiness to adopt and leap to the 4IR era. Halim *et al.* (2019) asserted that the curriculum should be innovative and prepare students for the requirement of this digital era. They added that the fixed structure approach of the curriculum, which most HEIs in Malaysia use, is no longer adequate for preparing students for the 4IR age. The HEIs should use a flexible system that considers students' interests and the job market's needs. Hence, students can apply the knowledge they get in their courses to develop skills needed where augmented reality, IoT, artificial intelligence and others are used to address each students' needs and interests. Previously, Assante *et al.* (2019) suggested for the HEIs to prepare their students for 4IR, the academic and training programs should include different activities and materials such as videos, presentations, assignments, case studies, exercises and tasks that assist students in obtaining soft and transversal skills related to 4IR technologies and their applications.

Additionally, they asserted that the training program should contain activities centered on the Project-Based Learning (PBL) methodology, which encourages students to analyze authentic problems and identify technical solutions. Likewise, Motyl *et al.* (2017) called for an adequate education model to provide more structured knowledge of 4IR to the students. Dos Santos *et al.* (2018) also stressed the importance of providing sufficient training for students to develop skills required in the 4IR era, such as computational tools to solve problems and initiate solutions using analytical skills.

It is evidenced from the previous literature that having smart infrastructure, not only for learning activities but for all HEIs' activities, including social interaction, resource management and energy-saving, would help HEIs to prepare their students for the IR4 era (Tungpantong *et al.*, 2021; Mian *et al.*, 2020; Dong *et al.*, 2020; Muhamad *et al.*, 2017). In addition, for the students to be prepared for 4IR, the HEIs need to transform their teaching and learning facilities into intelligence (Tungpantong *et al.*, 2021). 4IR and its applications, such as IoT, cloud computing and AI, would help the physical classrooms or laboratories become more interconnected and form intelligent surroundings, contributing to students' preparedness to learn and work in the 4IR era. In addition, the smart environment, which is equipped with software and hardware, encourages students to be more self-independent and co-creator of knowledge (Majeed and Ali, 2018). The literature also describes using IoT applications to facilitate all classroom activities, such as attendance, lecturing, assignment and tutorial, which positively enhances the teaching and learning process (Revathi *et al.*, 2020; Alvarez-Campana *et al.*, 2020). Olaitan *et al.* (2021) concluded that government should focus on infrastructural improvement as well as other factors such as strengthening the resilience of both public and private institutions, investing in relevant 4IR education, and promulgation and enforcement of legal framework to ensure security and privacy of data.

Therefore, the fourth hypothesis is proposed:

*H4.* Organizational dimension significantly affect students' preparedness for the 4IR era.

The previous studies also showed that organizational dimensions such as curriculum, academic programs, training courses offered by the HEIs and technological infrastructure positively affect students' knowledge of 4IR technologies. For instance, Uleanya (2022) investigated the 4IR implementation in the educational sector in Botswana using a scoping review. She found that curriculum, digital infrastructure and training are the main factors affecting students' knowledge of 4IR. She stated that the lack of infrastructure and inadequate academic programs that address 4IR skills hindered students in Botswana from acquiring skills. She also emphasized that schools and universities should ensure adequate training programs for upskilling their students and equipping the necessary 4IR characteristics such as creativity, emotional intelligence, analytical (critical) thinking and decision-making. Saari *et al.* (2021) suggested training should be focused on developing skills related to 4IR, such as proficiency in using high-impact technology, entrepreneurial mindset, digital skills, and a combination of technical and soft skills. The literature has also described the importance of infrastructure to enhance students' knowledge of 4IR by providing them with services that enhance their learning using IoT, artificial intelligence, cloud computing and virtual reality (Tungpantong *et al.*, 2021; Dong *et al.*, 2020; Majeed and Ali, 2018). Eleyyan (2021) emphasized the importance of instructional programs, curricula and learning environments in increasing students' awareness of 4IR-related technologies. In addition, previous studies have highlighted the significance of providing students with facilities that integrate technologies to offer smart services, such as libraries, restaurants and recreation centers, to help increase their awareness of 4IR (Revathi *et al.*, 2020; Alvarez-Campana *et al.*, 2020). Similarly, Rampasso *et al.* (2020) stated that providing the student with academic programs and training courses that address 4IR characteristics would lead to gaining decision-making skills, digital capabilities and verbal communication. Other studies have also pointed out the necessity of having smart infrastructures that help students acquire skills needed in the 4IR era, such as communication, digital skills, collaboration and critical thinking (Puriwat and Tripopsakul, 2020; Halim *et al.*, 2019) to be prepared for the 4IR era. Therefore, the previous discussion of the literature furthers the following hypotheses:

*H5.* Organizational dimension significantly affects students' knowledge of 4IR technologies.

*H6.* Organizational dimension significantly affects students' characteristics.

## 3. Method

### *3.1 Participants*

A total of 878 students (62.5% female and 37.5% male) participated in the online survey. They are studying different majors such as Engineering (220), Business/Economy (192), Computer Science/IT (150), Medicine and Health-related (100), Sciences (24) and Others (191). The random sample method was used for this study due to its suitability. In random sampling, each member of the population has an equal probability of being selected. With randomization, a representative sample from a population provides the ability to generalize to a population (Creswell, 2014). The sample size of this study is considered acceptable, according to Krejcie and Morgan (1970) who noted that as the population increases, the proportion of the population required in the sample size is reduced or even becomes static after reaching a specific limit. They suggested that 384 participants are sufficient if the total population is one million.

This study was initially approved by the university where the authors are affiliated with. Then the survey was distributed to different HEIs in the Sultanate of Oman, and again this study underwent another approval from these HEIs. Students were informed of the purpose of the research and gave their consent to participate before responding to the questionnaire. They were also informed that they could withdraw from the study at any point. Participants were never required to give their names or reveal their identity in order to protect their privacy and confidentiality. All participants were protected physically, psychologically and legally throughout the duration of the research.

The majority of our participants were undergraduates who were less than 24 years old (18.1% foundation, 23.5% in their first year, 18.5 in the second year, 14.4% in the third year, 15.5% in the fourth year, 7.5% in the fifth year and 3.5% master students). The data collection lasted for two months, from October 2021 until December 2021.

### *3.2 Measures development*

The authors adopted the measurement items for the survey for this research from previous studies as detailed in Table 1. The questionnaire was divided into three sections; the first describes the purpose and introduction of the search with the surety to keep the data confidential. The second part consisted of demographical information like gender and education. The last parts consisted of four subsections, question items in these parts are based on the previous related studies, as shown in Table 1. Student characteristics construct consisted of 14 items which are adapted from Himmetoglu *et al.* (2020), Clavert (2019), Puriwat and Tripopsakul (2020), Ismail *et al.* (2020) and Rampasso *et al.* (2020). The construct "Awareness of the different IR related technologies" consisted of 18 items which are adapted from Tinmaz and Jin (2019), Mian *et al.* (2020) and Ujakpa *et al.* (2020). The construct "Organizational Dimension" comprised of four items related to academic programs, curriculum and training which are adapted from Olaitan *et al.* (2021), Ujakpa *et al.* (2020) and Puriwat and Tripopsakul (2020). Finally, the construct "Preparedness" contained two items which were adapted from Ahmad *et al.* (2019) and Assante *et al.* (2019). The participants rated all the items in a 5-Likert scale (5 = very high and 1 = is very low). Five lecturers who are experts in educational technology were consulted to validate the items and the survey was modified based on their suggestions.

### *3.3 Analysis*

In this study, we used SPSS v23 to measure the constructs' validity, reliability and exploratory factor analysis (EFA). The sample adequacy and suitability of data were validated using the Kaiser–Meyer–Olkin (KMO) and the Bartlett test. Here the KMO measure is greater than 0.6 (0.957) and the Bartlett test is statistically significant (0.000). Hence, the sample is adequate (Bartlett, 1954). For factor analyses, principal component analysis and Varimax rotation were performed. AMOS 21 software package and SMARTPLS were employed to examine confirmatory factor analysis (CFA) and structural equation modeling (SEM). CFA was used to ensure the validity of the measurement model, SEM was used to estimate the path coefficients (Asparouhov and Muthén, 2010).

| Constructs | | Item | Sources |
|---|---|---|---|
| Students Characteristics | Char1 | Analytical and Critical thinking | Himmetoglu *et al.* (2020), World Economic Forum (2020), Clavert (2019), Puriwat and Tripopsakul (2020), Ismail *et al.* (2020), Rampasso *et al.* (2020) |
| | Char2 | Reasoning, Complex problem-solving and ideation | |
| | Char3 | Creativity and initiative | |
| | Char4 | Innovation and Entrepreneurship | |
| | Char5 | Leadership and social influence | |
| | Char6 | Flexibility and stress tolerance | |
| | Char7 | Social and emotional intelligence | |
| | Char8 | Persuasion and negotiation | |
| | Char9 | Independent and active learning | |
| | Char10 | Collaboration and teamwork | |
| | Char11 | Effective communication | |
| | Char12 | Time management | |
| | Char13 | Effective use of technology | |
| | Char14 | Judgment of situation and decision-making | |
| Awareness of the different IR related technologies | Knw1 | Internet of Things/Cyber-Physical Systems | Mian *et al.* (2020), Ujakpa *et al.* (2020), Tinmaz and Jin (2019) |
| | Knw2 | Data Science (e.g. Data Mining and Big Data Analytics) | |
| | Knw3 | Encryption and Cybersecurity | |
| | Knw4 | Cloud Computing Technology | |
| | Knw5 | Quantum Computing | |
| | Knw6 | Mobile App Development | |
| | Knw7 | Artificial Intelligence (inc. ML and NLP) | |
| | Knw8 | Robots, Non-Humanoid (e.g. Industrial Automation, Drones) | |
| | Knw9 | Sustainable Green Power Technologies | |
| | Knw10 | Additive Manufacturing and Modelling (e.g. 3D and 4D Printing) | |
| | Knw11 | 4G/5G/6G and Advanced Signal Processing Technologies | |
| | Knw12 | New Materials and Additive Technologies (e.g. Nanotubes, Graphene) | |
| | Knw13 | Biotechnology | |
| | Knw14 | Virtual and Augmented Reality | |
| | Knw15 | Distributed Ledger Technology (e.g. blockchain) | |
| | Knw16 | Digital Trade/E-Commerce | |
| | Knw17 | FinTech | |
| | Knw18 | Digital Transformation | |
| Organizational Dimension | OD1 | 4IR is a topic of discussion in my university/college | Olaitan *et al.* (2021), Ujakpa *et al.* (2020), Puriwat and Tripopsakul (2020) |
| | OD2 | Trainings, talks, webinars, symposium/conferences and competitions related to 4IR technologies | |
| | OD3 | Studied some of the 4IR technologies mentioned above | |
| | OD4 | Assignments, or reports, or essays, or projects related to 4IR topics | |
| Preparedness | PRP1 | Overall awareness about 4IR technologies | Ahmad *et al.* (2019), Assante *et al.* (2019) |
| | PRP2 | HEIs has prepared me to work in the 4IR era | |

**Table 1.**
Measurement items

## 4. Factor analysis results

The EFA was first performed to determine whether the items were loaded correctly. The extraction method was principal axis factoring, and the rotation method was varimax. The EFA results showed that some items did not load well on their corresponding construct. For example, characteristics comprised of 14 items, the factor loading was low communalities of less than 0.7 for four items, and therefore, these four items were eliminated (Hair *et al.*, 2017). Some of these items are also cross-loaded on two factors. Similarly, there were 18 items measuring awareness of the different 4IR technologies, and four items were eliminated because they were not sufficiently loaded to their factor, so they were also neglected. Finally, after removing four items, the communality for each item was sufficiently high (all above 0.71) as shown in Table 2, thus indicating the chosen variables were adequately correlated for a factor analysis and factor loads were adequate.

### *4.1 Convergent and divergent validity*

Convergent validity and divergent validity are considered subsets of construct validity. Convergent validity tests the possibly related constructs are indeed related. In contrast, divergent validity confirms that the hypothesized constructs not having a relationship are certainly do not have a relationship (which means they are different). The validity of

| | Item | Factor loading | Composite reliability (CR) | Variance extracted (VE) | Discriminant validity measures | A |
|---|---|---|---|---|---|---|
| Characteristics | ch1 | 0.752 | 0.93 | 0.56 | 0.92 | 0.91 |
| | ch2 | 0.762 | | | | |
| | ch3 | 0.780 | | | | |
| | ch4 | 0.744 | | | | |
| | ch5 | 0.746 | | | | |
| | ch7 | 0.746 | | | | |
| | ch8 | 0.766 | | | | |
| | ch11 | 0.702 | | | | |
| | ch13 | 0.720 | | | | |
| | ch14 | 0.774 | | | | |
| Organizational Dimension | OrgDim1 | 0.745 | 0.86 | 0.60 | 0.78 | 0.78 |
| | OrgDim2 | 0.765 | | | | |
| | OrgDim3 | 0.764 | | | | |
| | OrgDim4 | 0.818 | | | | |
| Knowledge | knw3 | 0.720 | 0.96 | 0.62 | 0.95 | 0.95 |
| | knw5 | 0.745 | | | | |
| | knw7 | 0.795 | | | | |
| | knw8 | 0.781 | | | | |
| | knw9 | 0.793 | | | | |
| | knw10 | 0.802 | | | | |
| | knw11 | 0.784 | | | | |
| | knw12 | 0.830 | | | | |
| | knw13 | 0.819 | | | | |
| | knw14 | 0.807 | | | | |
| | knw15 | 0.801 | | | | |
| | knw16 | 0.707 | | | | |
| | knw17 | 0.793 | | | | |
| | knw18 | 0.801 | | | | |
| Preparedness | Preparedness1 | 0.856 | 0.74 | 0.60 | 0.74 | 0.60 |
| | Preparedness2 | 0.670 | | | | |

**Table 2.**
Reliability and convergent validity testing of the constructs involved in the study

constructs was assessed for convergent validity and discriminant validity. As shown in Table 3, the composite reliability (CR) values of the constructs were above 0.7 for the majority of the constructs and the average variance extracted (AVE) was above 0.5 for all of them (Table 3), which are deemed sufficient and accepted according to Hair *et al.* (2017). The reliability values of Cronbach's alpha coefficient were acceptable in all constructs (0.7). Hence, construct reliability was confirmed.

For the discriminant validity analysis, the square root of AVE was taken to correlate the latent constructs. As shown in Table 4 the square root of the AVE for all constructs is higher than the pairwise correlations. Hence, divergent validity is deemed adequate (Hair *et al.*, 2017).

### *4.2 Structural equation model*

This study aimed to identify the relationships among students' characteristics, knowledge of 4IR-related technologies, organizational dimension and students' perceptions of being prepared for 4IR. To achieve this objective, structural equation modeling (SEM) was employed to test the interrelationships among all the research constructs and compare the modeled relationships with the observed scores. The SEM was conducted to test the model fit. The model fit was found to be acceptable ($\chi^2$ = 2903.495, $p$ < 0.001, NFI = 0.90 and RMSEA = 0.062). The variance explained among the endogenous variables, i.e. the $R^2$-values range from 0.166 to 0.584. The predicted variables influence the dependent variables, and the relationships tested are meaningful and explain sufficient variance in each other.

For analyzing the proposed hypotheses in the developed model, path analysis of SEM was used. The results in Table 4 and Figure 2 show that all the six hypotheses tested in this research are supported. Student's characteristics, student's knowledge of 4IR technology and organizational dimension have significant impact on student' preparedness for the 4IR ($\beta = 0.171, p < 0.001$), ($\beta = 0.328, p < 0.001$), ($\beta = 0.459, p < 0.001$) respectively. This, in turn, supports H1, H2 and H4.

Furthermore, the results also indicate that student's knowledge on 4IR technology and organizational dimension have significant effect on their characteristics ($\beta = 0.332, p < 0.001$), ($\beta$ = 0.4281, $p$ < 0.001) respectively. Hence, H3 and H6 are supported. Moreover,

| | Characteristics | Knowledge | Organizational dimension | Preparedness |
|---|---|---|---|---|
| Characteristics | *(0.750)* | | | |
| Knowledge | 0.446 | *(0.785)* | | |
| Organizational Dimension | 0.416 | 0.407 | *(0.773)* | |
| Preparedness | 0.508 | 0.591 | 0.663 | *(0.768)* |

**Note(s):**** Correlation is significant at the 0.01 level (2-tailed). The square roots of AVE values are in parentheses on the diagonal

**Table 3.** Discriminant validity matrix results

| | | Path coefficient | CR | $p$-values | Results |
|---|---|---|---|---|---|
| 1 | Characteristics → Preparedness | 0.171 | 6.463 | 0.000 | Supported |
| 2 | Knowledge → Preparedness | 0.328 | 9.256 | 0.000 | Supported |
| 3 | Knowledge → Characteristics | 0.332 | 8.899 | 0.000 | Supported |
| 4 | Organizational Dimension → Preparedness | 0.459 | 14.835 | 0.000 | Supported |
| 5 | Organizational Dimension → Knowledge | 0.407 | 12.938 | 0.000 | Supported |
| 6 | Organizational Dimension → Characteristics | 0.281 | 8.244 | 0.000 | Supported |

**Table 4.** Results of structural equation modeling

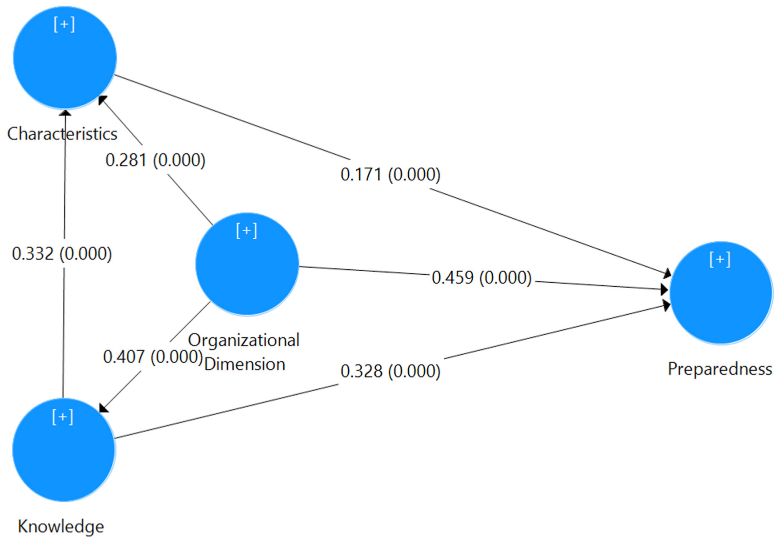



**Figure 2.**
Results of structural equation modeling

organizational dimension significantly impacts students' knowledge of 4IR technology ($\beta = 0.407$, $p < 0.001$), which supports H5.

## 5. Discussion

Investigating the students' readiness for the 4IR is vital to prepare them to contribute to the country's skilled workforce. Based on this idea, the present study explored the factors that impacted students' preparedness for the 4IR era by introducing a conceptual model and testing hypotheses after reviewing available literature related to the issue. SEM of the proposed model showed that the obtained results supported the sixth hypothesis proposed at the beginning of the research. Students' characteristics, students' knowledge of 4IR technology and the organizational dimension significantly impact students' preparedness for the 4IR. Furthermore, the organizational dimension significantly influences their knowledge of 4IR technology. Moreover, students' characteristics related to 4IR are significantly affected by their knowledge of 4IR technology and organizational dimension.

Thus, the policymakers in HEIs need to focus on these factors since they play an essential role in enhancing the students' readiness for 4IR, affecting their future competency and employability. This means that the HEIs should start various initiatives for equipping their students and graduates with the characteristics needed for 4IR and raising their awareness of its technologies to be able to cope with the changes caused by the development of all technologies such as artificial intelligence, blockchain, robotics, cloud computing, data science, virtual reality and 3D printing. According to Ujakpa *et al.* (2020) and Tinmaz and Jin (2019), students should be introduced to practical applications and courses related to 4IR to get hands-on experience and be well-prepared to study and work in the 4IR era. The literature is currently discussing how HEIs should seek to have smart campuses and services (Nenonen *et al.*, 2019; Vasileva *et al.*, 2018; Akhrif *et al.*, 2019), so their students can be prepared to learn and work in 4IR era. This entails the HEIs to develop their infrastructure and have smart campuses, labs, classrooms and libraries to make HEIs a space where knowledge can be generated, and innovative solutions can be proposed. This requires HEIs offering necessary hardware, software and technical support because if the HEIs improve their technological resources, students will be capable of using 4IR-related technologies effectively. Providing smart labs where students can work with 4IR-related technologies and simulate actual production lines is essential for preparing students for the 4IR era (Coşkun *et al.*, 2019; Mian *et al.*, 2020).

The study also indicates that organizational dimensions have more impact on students' preparedness for the 4IR than their characteristics and knowledge of 4IR technology. This suggests that organizational dimensions, such as academic programs and trainings, are critical to preparing students for the 4IR era. This necessitates that HEIs to have a roadmap and strategic goal to prepare their students to work with 4IR-related technologies. The academic programs reflect the development of 4IR-related technologies, which can be done by introducing new programs and enhancing the current ones to suit the requirement of 4IR (Coşkun *et al.*, 2019; Ellahi *et al.*, 2019; Silva *et al.*, 2019; Mian *et al.*, 2020). Their programs should include courses on data science, IoT, cloud computing, virtual reality, artificial intelligence, machine learning and other emerging 4IR-related technologies. In addition, the curriculum must include mandatory courses related to IT infrastructure design, user experience programming, electronic measurement and control principles, and programming for data science. HEIs should also foster interdisciplinary knowledge by integrating IT, Engineering, Business and Sciences (Chemistry, Physics, Mathematics) in their curriculum to build capabilities related to 4IR, which requires skillful people with interdisciplinary knowledge and experience. According to Huba and Kozák (2016), "many current educational programs at all levels provide highly isolated training and offer limited interaction among fields" (p. 104).

The HEIs should also foster the linkage with other HEIs nationally and internationally to share their expertise and establish collaboration in academic programs, research and training related to 4IR for both students and faculty. Another possible way to promote students' readiness for 4IR is to establish a partnership between HEIs and industry (Halim *et al.*, 2019; Mian *et al.*, 2020). The HEIs should cooperate with the industry by discussing their training needs and offering training for students and graduates by establishing online learning platforms and encouraging them to take these courses. The HEIs should also work hard to start Massive Open Online Courses (MOOCs) in fields related to 4IR technologies, enabling students and graduates to increase their skills and stay updated with the latest trend and knowledge associated with 4IR. HEIs should also collaborate with the industry to develop mobile apps that offer online training for students and graduates in 4IR technologies. This will significantly help improve their skills and capabilities and positively impact their performance when different companies and organizations recruit them (Mian *et al.*, 2020; Umachandran *et al.*, 2018).

The HEIs should also initiate extra-curricular activities for students to become more aware of different aspects and applications of 4IR, such as organizing events, conferences and competitions to disseminate knowledge related to 4IR, which will assist in nurturing students' talents and be exposed to different implementations of IR related-technologies in real-life situations (Sackey *et al.*, 2017).

The HEIs should provide advanced technological infrastructure for working and teaching in the 4IR era, including strong Internet coverage, virtual labs and equipment to digitalize learning and teaching. More funds can be allocated for research related to 4IR to familiarize students and staff with 4IR-related technologies, especially the literature shows that one of the challenges encountered by HEIs is the lack of sufficient funds to develop their infrastructure to cope with 4IR requirements (Mian *et al.*, 2020).

## 6. Conclusion

The 4IR, characterized by technology automation, requires HEIs to initiate changes in line with the digital transformation so that their students will not be left behind in this digital era.

Therefore, this study investigated the factors affecting university students' perception of their readiness for 4IR. A conceptual model was introduced, and hypotheses were tested using data collected by an online survey.

Results revealed that students' characteristics, knowledge of 4IR technology and organizational dimensions significantly impact their preparedness for the 4IR. The study also found that organizational dimensions have the highest impact on students' preparedness. Furthermore, the organizational dimension significantly influences students' knowledge of 4IR technology. Moreover, students' characteristics related to 4IR are significantly affected by their knowledge of 4IR technology and organizational dimension. The results revealed that characteristics, organizational dimension and awareness impact students' perception of being prepared for 4IR.

The findings suggest that HEIs are responsible for increasing the adoption of 4IR and, therefore, ensure that 4IR skills and characteristics required for the successful implementation of the 4IR are integrated well into the curriculum. Furthermore, the organizational dimensions such as the programs, the infrastructure and others are all critical to preparing students for a better future. The study results suggested that the HEIs should offer their students education and training programs aligned with 4IR demand to increase their employability opportunities in the future since most of the studies asserted that the job market would be looking for students who are knowledgeable and acquainted with various 4IR-related technologies (Tilak and Singh, 2018; Shahroom and Hussin, 2018). Needless to say, students must experience the application of 4IR technology in the on-campus environment by providing smart facilities and services for them, such as using IoT-enabled building management systems to have more efficient buildings and using sensor-generated data to enhance user experience. Students should experience being in a smart campus while using a high level of digitization of services and utilizing smart business solutions on university campuses.

### *6.1 Limitation and further research*

There are some limitations associated with this study which one can benefit from them for further research. First, this study has used academic programs and training to measure the organizational dimension. However, other important factors should be considered, such as technological infrastructure, leadership and governance of HEIs. Second, the current research depends on quantitative data, so future research should implement a mixed methodology (questionnaires, depth interviews, document analysis and focus group) to understand the factors affecting students' readiness for 4IR clearly. Third, the study focuses on exploring students' preparedness from their perceptions only; hence, future research should investigate factors affecting students' readiness for 4IR from other stakeholders' perspectives, such as the HEIs leaders, staff and the industry/employer, which will provide a more comprehensive picture of the factors that help to prepare students for the 4IR era. Fourth, the research was conducted with a specific group of students; therefore, study results highly depend on the context of HEIs in Oman. Hence, we are unsure if the same findings would exist if conducted in another context. Finally, although the 4IR has numerous benefits, it also has challenges in its implementation, so future studies should focus on challenges encountered by different stakeholders in implementing 4IR-related technologies.

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