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Adopting Industry 4.0 by leveraging organisational factors

Abstract

The manufacturing sector needs to focus on social, environmental and technological factors to integrate Industry 4.0 in production planning, logistics and supply chains. Technical education institutes can play a key role in achieving this ambition as they are responsible for the workforce of the digital future. To this end, a learning factory is often referred to as a realistic manufacturing environment. However, the existing research regarding the successful adoption of a learning factory based on Industry 4.0 is scant in the literature. We, therefore, aim to address this research gap by examining key factors that affect the decision to adopt Industry 4.0 in Technical Education Institutes (TEIs). We have adopted the theoretical lens of the Technology-Organisation-Environment (T-O-E) framework to study industry 4.0 adoption in TEIs. The findings based on 134 valid responses from TEIs in India indicate that the organisational dimension is critical in determining whether or not to adopt Industry 4.0. Our study shows that top management support, internal resources, and the capabilities of the teaching staff are vital for the adoption of Industry 4.0. Additionally, our findings indicate that significant differences exist between public and private TEIs concerning the adoption of Industry 4.0.

Keywords: Technical Education Institutes; T-O-E; Learning Factory; Industry 4.0; Empirical Study

1. Introduction

The business environment has undergone a significant transformation as the adoption of Industry 4.0 in manufacturing has revolutionised production processes and operations (Luthra and Mangla, 2018; deSousaJabbour et al., 2018) and this has led to an advancement in manufacturing systems (Li, 2018; Sung, 2018). Industry 4.0 is frequently used to refer to a collection of technologies such as artificial intelligence, robotics, quantum computing, cloud computing, the internet of things and 3D printing.

Industry 4.0 makes it easier to build a flexible, smart, cost-effective, environment-friendly and socially responsible manufacturing ecosystem (Wang et al.,2016a; Metallo et al.,2018). However, as Industry 4.0-based manufacturing becomes more prevalent, a need for extensive research on social and environmental issues is felt (Müller et al.,2018; Jabbour et al.,2019; Chen et al.,2020). Furthermore, progress in the field of digital manufacturing has highlighted the issues that are associated with the skills gap (Ekren and Kumar, 2020) and that are critical to dealing with the complexity created by the digital landscape.

Studies such as Hofmann and Rüsch (2017) and Jabbour et al.,(2019) show that rigorous research is required in managing social and environmental concerns in manufacturing systems. Training and continuing professional development are two of the most important areas that need to be focused on as part of the Industry 4.0 implementation process (Kagermann et al, 2013). One of the challenges is the need for employees to learn the demanding skills that Industry 4.0 requires (Baena et al., 2017). Hence, upgrading the traditional teaching pedagogy by incorporating Industry 4.0 technologies is critical.

Ekren and Kumar (2020) highlight that recent developments in Industry 4.0 pose a significant challenge in effectively dealing with the complex issues involved in advancing the current knowledge. They assert that a deep knowledge of Industry 4.0 in technical engineering disciplines and logical thought processes are required to prepare the future workforce. Ekren and Kumar (2020) hence suggest having a holistic view of product and system designs and making significant changes to the existing engineering curriculum. This is also echoed by Salah et al. (2019) who advocate for the integration of Industry 4.0 into engineering education. In the same vein, Hernandez-de-Menendez et al. (2020) emphasise the importance of understanding the competencies and skills that the future workforce will require to manage Industry 4.0. They also emphasise the role that universities can play in developing such a workforce by refreshing their courses in engineering and technology. This aligns with Ekren and Kumar's (2020) view that future engineering graduates should learn how to simplify the assumptions of a real, complex system so that a feasible solution can be constructed by which their knowledge can be transferred. Education in modern times would be impossible without a connection to practise and to be able to undertake hands-on work, and it should be altered to expose students to Industry 4.0-like production environment (Coskun et al. 2019).

To meet these challenges, education institutes have established learning factories based upon Industry 4.0, which has recently become popular in industry and academia (Mavrikios et al., 2017; Tisch et al., 2016). These learning factories are important for increasing understanding of Industry 4.0 and for developing competencies in digital manufacturing training and education (Wagner et al., 2012; Abele et al., 2015).

Furthermore, it has been demonstrated that learning factories are highly effective at providing learning in a real-world setting (Baena et al., 2017). Dassisti and Semeraro (2018) present and analyse the criteria adopted for the transformation of a real Italian company into an Industry 4.0 testing learning laboratory. They emphasise the critical role of the laboratory factory in developing new automation solutions and implementing Industry 4.0**.** With the increasing adoption of digitalisation within firms, the teaching pedagogy in education institutes is required to adapt to consequent changes that are being welcomed by firms around the globe. However, there is still much to be achieved with regards to training employees. Industry 4.0 represents a significant opportunity for emerging nations like India, which is also one of the leading manufacturing nations. While digitalisation and automation are occurring in a variety of industries, a collaboration between industry and academic institutes is critical for progress. Industry 4.0 adoption has spawned a slew of trends that are reshaping the future of work and fundamentally altering the job landscape in India (Bhat, 2020).

Existing studies such as Ekren and Kumar, (2020); Maisiri, Darwish, & Van Dyk, (2019) have shown there is significant skills requirements in meeting Industry 4.0 demands and hence to achieve digital manufacturing ambitions, the future technical workforce needs to have the digital skills. Graduates from institutes that have embraced Industry 4.0 would assist manufacturing companies in their transition to Industry 4.0. Since the learning factory is an emerging concept, its implementation has challenges (Wagner et al, 2014; Leal et al., 2020). Hence, understanding various factors that affect the adoption of Industry 4.0 in TEIs is essential. It would indirectly contribute to manufacturing sectors by way of filling the skills gap needed for digital transformation. The institutes adopting Industry 4.0, therefore, have the potential to convey this philosophy to their graduates and make an effective contribution to the corporate sector with ready and able graduates to lead the digital transformation. As a result, this study explores the essential factors impacting TEIs' adoption of Industry 4.0.

We, therefore, respond to the following research question:

What are the key factors affecting the adoption of Industry 4.0 technologies in TEIs?

The research objectives of this study are:

- To investigate the factors affecting the adoption of industry 4.0 technologies in TEIs
- To explore the theoretical framework that explains the relationship between the various factors and industry 4.0 adoption.
- To compare public and private TEIs in terms of industry 4.0 adoption.

This study aims to add to the existing literature in the following ways: firstly, findings provide a useful reference on the impact of ownership on Industry 4.0 adoption decisions by comparing public and private TEIs. Secondly, while several factors have been explored in previous research, this study empirically analyses the impact of these factors in a different context using the theoretical lens of the Technology-Organisation-Environment (T-O-E) framework, namely the education sector of an emerging country. The strength of this research is that it contributes to the adoption aspects of Industry 4.0 based learning factories by using the T-O-E framework which has yet to be empirically investigated in TEIs.

The rest of the paper is divided as follows: the next section deals with the hypotheses development, followed by methodology. Finally, discussions, conclusions, implications, limitations, and future scope of research are presented based on the research findings.

2. Theoretical Background and Hypotheses Development

Technology adoption models have been developed to investigate the users' decision-making process of specific technology adoption in the future (Louho, Kallioja and Oittinen, 2006). These technology adoption models emerge from different disciplines and perspectives such as psychological, managerial, operational, marketing and technical views. Some of the most common existing theoretical models used to examine the technology acceptance and adoption are Innovation Diffusion Theory (IDT) (Van den Berg and Van der Lingen, 2019), Theory of Reasoned Action (TRA) (Ajzen, 2005), Theory of Planned Behaviour (TPB) (Sniehotta, Presseau and Araújo-Soares, 2014), Technology Acceptance Model (TAM) (Gangwar, Date and Ramaswamy, 2015), Unified Theory of Acceptance and Use of Technology (UTAUT) (Williams, Rana and Dwivedi, 2015) and Technology- Organisation- Environment (TOE) (Gangwar, Date and Ramaswamy, 2015).

TOE framework emerges as a widespread theoretical perspective that brings both human and non-human actors into the network which helps handle the illusion of accumulated traditions and techno-centric predictions that are found as the weakness of other technology adoption frameworks such as TAM, TRA, UTAUT, and TPB (Awa, Ukoha and Emecheta, 2016). The T-O-E framework is frequently used in studies of information technology adoption (Iacovou et al. 1995; Lin and Lin, 2008), and it has both theoretical and empirical support (Oliveira and Martins,2011). Tailoring the T-O-E framework to fit within a different research context is appropriate, since "innovation adoption decisions must be studied within appropriate contexts and with variables tailored to the specificity of the innovation" (Chau and Tam, 1997, p. 3). Hence, the T-O-E framework can be used in the context of the education sector also. This framework is a good fit for the study as it addresses the main factors that are crucial to adopting Industry 4.0 in TEIs.

In previous studies, the T-O-E framework has been used to adopt Industry 4.0. Lian et al. (2014) and Qasem et al. (2020) for example, used it to examine the factors that influence cloud computing adoption in Taiwanese hospitals. Ghobakhloo and Ching (2019) examine the adoption of digital technologies for smart manufacturing in SMEs. Lin et al. (2018) identify critical factors influencing the Chinese automotive industry's adoption of Industry 4.0. Prause (2019) examines the adoption of Industry 4.0 in Japanese SMEs, whereas Masood and Sonntag (2020) examine the adoption of Industry 4.0 and its associated challenges in SMEs.

Additionally, research on the adoption of other technologies bolsters the T-O-E framework. Teo et al. (2009) investigate the adoption of e-procurement in Singapore based firms whereas Hassan et al. (2017) analyse the effects of various factors on the breadth and depth of electronic procurement in New Zealand based SMEs. Awa et al. (2015) examine the role of various factors in the adoption of enterprise resource planning in SMEs and Saldanha and Krishnan (2012) examine factors that influence Web 2.0 adoption.

Lin (2014) examines factors affecting the adoption of e-SCM in Taiwanese firms. Aboelmaged (2014) investigates the factors affecting manufacturing firms' readiness for e-maintenance technology. Leung et al. (2015) identify factors influencing Internet and communication technologies (ICT) adoption within hotels in Hong Kong. Ramanathan and Iyer (2015) examine the factors affecting the adoption of open-source software (OSS) in outsourcing firms. The following sections discuss the T-O-E framework's dimensions and the development of the hypotheses that will be tested in this study.

2.1 Technology Dimension

Considering the nature of Industry 4.0, variables, such as relative advantage from the adoption of technology and compatibility of technology with existing infrastructure, are considered. Relative advantage occurs if the adoption of Industry 4.0 in TEIs can reduce their operating costs and give an advantage over that of their competitors in terms of a good and robust reputation, strong industry connections and the enhancement of the efficiency of internal operations**.** Relative advantage from technology adoption is a significant factor within previous studies; for example, Hassan et al. (2017) find perceived relative advantage affects the depth of e-procurement while Tan et al.(2009) identify that it influences the use of ICT. Prause (2019) shows that the adoption of technologies is affected by perceived relative advantages. Similarly, AlBar and Hoque, (2019), find that a relative advantage of technology will determine a firm's intention to adopt new technology. Alkhalil, et al. (2017) reveal that perceived relative advantage affects Industry 4.0 adoption. Therefore, the following can be hypothesised:

H1: The perceived relative advantage of Industry 4.0 affects the adoption of Industry 4.0 in TEIs.

Compatibility of existing infrastructure with Industry 4.0 is to be considered when making an adoption decision (Premkumar and Ramamurthy, 1995; Premkumar and Roberts, 1999). TEIs need to consider how to integrate existing IT systems with Industry 4.0, and how the compatibility of the TEI's systems and applications with Industry 4.0 is likely to make the adoption of Industry 4.0 feasible.

Prior studies suggest that the perception that technology is compatible with the organisation will support the adoption. Wang et al., (2016b) find compatibility affects the adoption of the mobile reservation system in Taiwanese hotels. Ghobakhloo and Ching (2019) identify perceived compatibility as a significant factor to the Smart Manufacturing-related Information and Digital Technologies adoption. According to Prause (2019), the more sophisticated that manufacturing technologies are, the more likely it is that they will be deemed to be compatible with current infrastructure, hence they will be more likely to be adopted. Other research, such as Aziz and Wahid (2020); Masood and Egger (2019); Qasem et al., (2020); Shi and Yan (2016), discover that technological compatibility influences an organisation's willingness to adopt new technology. Therefore, the following can be hypothesised:

H2: The perceived compatibility of Industry 4.0 affects the adoption of Industry 4.0 in TEIs.

2.2 Organisation Dimension

The organisation dimension includes the support of top management, internal resources and capabilities of teaching staff, all of these being factors affecting the adoption of technology. Here, top management support refers to whether the TEI's leadership supports the adoption of Industry 4.0, which is typically a significant financial commitment. There have been many studies stressing the importance of top management support. Prause (2019), for example, claims that the greater the support from the management at the top for new manufacturing technologies, the more probable it is that these technologies will be deployed. Top management support influences cloud computing adoption, according to Qasem et al. (2020). Shi and Yan (2016) discover that senior management's positive attitude towards RFID adoption has a beneficial impact on whether it is adopted. Other studies, such as Premkumar and Roberts (1999); Grover and Goslar (1993); Jeyaraj et al. (2006) have found the role of top management support in technology adoption. These studies indicate that top management support is vital for industry 4.0 adoption in organisations. Therefore, the following can be hypothesised:

H3: The top management support affects the adoption of Industry 4.0 in TEIs.

The Resource-Based View (RBV) contends that a company's valuable, rare and inimitable resources are a source of competitive advantage (Barney,1991; Melville et al.,2004). Internal resources include financial, technological, and overall infrastructure, all of which assist TEIs to adopt and use Industry 4.0 more effectively. Existing research suggests that the availability of resources can aid in adoption of Industry 4.0. Hwang (2016), for example, find that organisational resources affect green supply chain adoption choice. Other research has backed up the importance of internal resources in technology adoption (Heung, 2003; Anckar and Walden, 2001; Khemthong, and Roberts, 2006). Therefore, the following can be hypothesised:

H4: Availability of internal resources affects the adoption of Industry 4.0 technologies in TEIs.

The adoption of Industry 4.0 could also be related to the teaching staffs' capabilities and skills. The essence of organisational capability is knowledge integration (Grant, 1996). There is a relationship between new technologies and employees' skills as they are the only ones who implement such technologies (Piva et al., 2005). Teaching staff should also be able to manage and handle Industry 4.0; installing and maintaining a learning factory necessitates a more capable and skilled teaching team.

The absorptive capacity of the organisation influences the ability to adapt to the innovation (Joo, 2011), which is affected by the willingness of employees to familiarise the technology (Buchanan et al., 2013). Cohen and Levinthal (1990), define "absorptive capacity as the ability of a firm to recognise the value of new, external information, assimilate it and apply it to commercial ends" (p. 128). Studies show that qualified employees are needed for innovation and management, as well as the adoption of new technologies (Gómez and Vargas,2012). Knowledge base, in the case of the TEIs, depends on the capabilities of qualified teaching staff. It can be argued that teaching staff can easily accept and conform to Industry 4.0 technologies if they have the necessary capabilities. Maduku et al.'s (2016) study on SMEs in South Africa shows that the IT capability of employees was an important driver for mobile marketing adoption intention. Therefore, the following can be hypothesised:

H5: Capabilities of teaching staff affects the adoption of Industry 4.0 in TEIs.

2.3 Environment Dimension

The proclivity of an organisation to innovate is often shaped by the opportunities and threats within its environment (Raymond, 2001). The environment dimension represents the operating context of TEIs that includes government policies and demand for skills in the job market that force TEIs to make the student industry-ready and employable.

The government of India has launched the "Make in India" and "Digital India" programs to promote innovation in the manufacturing sector by way of capitalising on Industry 4.0 technologies. Recently, a new education policy has also been released by the government which envision the role of modern technologies in pedagogy. Previous studies have advocated government support in the adoption of technology. For example, Osakwe et al. (2016) examine adoption issues of corporate websites in Nigeria based micro-enterprises. They discover that perceived government support is a significant determinant. Pan and Jang (2008) identify government support as a factor influencing Taiwanese communications companies' decision to adopt ERP. Therefore, the following can be hypothesised:

H6: Government support affects the adoption of Industry 4.0 in TEIs.

Other environmental factors, such as industry pressure, can influence the adoption decision. Increasing adoption of Industry 4.0 by the corporate sector has pushed the Indian education system to align teaching pedagogy and curriculum as per the market need. This also presents a strong case for the Indian TEIs to reform their curriculum and resonate with the demand for the business environment. Students are expected to work in a new environment, as employment, skill and recruitment patterns shift across industries and geographies.

Studies have found industry pressure is a factor contributing toward technology adoption. According to Jia et al. (2017), competitive pressure affects an organisations' intention to renew its enterprise systems to Enterprise 2.0. McKinnie, (2016) find that competitive pressure positively influences cloud computing adoption. Ghobakhloo and Ching (2019) identify competitive pressure as a key factor in Smart Manufacturing-related Information and Digital Technologies adoption. Shi and Yan (2016) report that competitive pressure affects RFID adoption. Hassan et al. (2017), however, identify external pressure as a factor affecting the use of electronic procurement by manufacturing-based SMEs in New Zealand. Therefore, the following can be hypothesised:

H7: Increased industry pressure affects the adoption of Industry 4.0 in TEIs.

Because the data for this study were gathered from the teaching staff of TEIs located in various states throughout India, the TEIs were established at varying ages. To avoid misinterpretation or discrepancies arising from the results, it was important to incorporate control variables. Therefore, we included two control variables in this study: (1) age and (2) ownership).

The age of TEIs may have an impact on industry 4.0 adoption, as old and new TEIs adapt at different rates. The ownership type of a firm reveals its institutional constraints (Li 2010a, Li 2010b). Further, priorities and cost structures for public and private higher education institutes can be somewhat different (Cohn, et al, 1989). As a result, TEI ownership may have an impact on Industry 4.0 adoption, with public and private TEIs adopting at varying rates.

The dependent variable of our model is the adoption of an industry 4.0 based learning factory. Figure 1 illustrates a proposed research model based on the preceding discussion. Following the T-O-E framework (Drazin, 1990), this study employs a three-dimensional model to analyse the decision to adopt Industry 4.0 in TEIs.

[Insert Figure 1 here]

3. Methodology and Data Collection

As this study proposes several hypotheses that are to be tested empirically, following the positivism philosophy a quantitative approach was deemed more appropriate. The study adopts a survey/questionnaire-based approach. Figure 2 shows the research process followed in this study. The survey data was drawn from the teaching staff within technical education institutes (TEIs) located in different parts of India. In the end, a total number of 700 respondents across the various

TEIs were contacted, out of which 134 valid responses to the questionnaire were obtained, thus representing a response rate of 19.14 percent.

[Insert Figure 2 here]

With the exception of age and ownership, all variables were evaluated using a five-point Likert scale, with values ranging from 1 (extremely unimportant or strongly disagree) to 5 (very important or extremely agree). A higher value indicates the respondents' perception of greater significance or agreement. The use of a Likert scale is justified because a response to Industry 4.0 is evaluated based on respondent perception, which requires cognitive understanding (Byrch et al., 2007). A continuous variable representing the number of years since the TEI's inception is used to estimate age. Ownership is a binary variable that refers to either public or private TEIs.

Pre-testing of the questionnaire was carried out with two senior experts who had an understanding of Industry 4.0. Their suggestions were primarily around the wording of the questions. The questionnaire's wording was hence refined according to their suggestions and some items were rephrased. The survey was administered to the senior teaching staff involved in some decision-making processes. Since Industry 4.0 is an emerging concept, it is common for respondents to be unsure of what Industry 4.0 entails. Hence, an overview of Industry 4.0 was included on the questionnaire's cover page. The teaching staff who participated in the survey belong to publicly and privately funded TEIs located in different parts of India. These TEIs were well established; the average year of their establishment was 26 years. The profile of TEIs is summarized in Table 1.

[Insert Table 1 here]

3.1 Validity and reliability assessment

The principal component method (varimax rotation) was applied to test the validity of the constructs. The items with the factor loading of 0.50 or more were taken in further analysis (Keong, 2016). The perceived cost item ("The cost is a major factor in establishing and maintaining Industry 4.0 technology in the TEIs") in the technology dimension could not meet such a requirement (0.129); hence, it was dropped. Cronbach's alpha values of dimensions were more than 0.60, showing adequate reliability (Taber, 2018; van Griethuijsen et al. 2015). Table 2 summarises the factor analysis and reliability results. using Cronbach's alpha.

[Insert Table 2 here]

4. Findings

The survey resulted in 134 valid responses from Indian technical education institutes(TEIs). The data was first subjected to correlation analysis(Table 3). The analysis shows that most of the constructs were found to be significantly correlated. However, relative advantage (T1) was not found to be significantly correlated with the two internal resources (O2) and teaching staff capability (O3). No significant correlation was observed between teaching staff capabilities (O3) and industry pressure (E2) as well as between government support (E1) and industry pressure (E2). The adoption of Industry 4.0 (A1) did not correlate with relative advantage and industry pressure

(E2). The correlation analysis supports hypotheses H2, H3, H4, H5, and H6. However, it did not support H1 and H7.

[Insert Table 3 here]

Multiple regression analysis was used to verify the outcomes from the correlations. Table 4 summarises the results of multiple regression analysis, which is significant (R= 0.689, R Square= 0.474, Adjusted R Square= 0.436, F=12.427(.000)), which indicates the fit of the data to the conceptual model of the study.

[Insert Table 4 here]

Though the T-O-E framework implies that the technological context, organisational context and environmental context of the firm does influence its adoption of new technology, in contrast to the correlation analysis the multiple regression analysis confirmed only the effects of organisational factors on Industry 4.0 adoption. Organisational factors including support of top management, internal resources and capabilities of teaching staff are significant (Table 4). The findings indicate that organisational factors influence the decision to adopt Industry 4.0 in TEIs. Hence following three hypotheses related to the organisation dimension are accepted where the p-value is significant.

- The top management support affects the adoption of Industry 4.0 in TEIs (H3)
- Internal resources affect the adoption of Industry 4.0 in TEIs (H4)
- The capabilities of teaching staff affect the adoption of Industry 4.0 in TEIs (H5)

Furthermore, an ANOVA test was applied in the order that the difference could be known between public and private TEIs for Industry 4.0 readiness (Table 5). In the sample, 77 private and 57 public TEIs have participated. Their mean scores for readiness were 3.53 and 2.79 respectively. The readiness was measured based on to what extent they have adopted Industry 4.0. The ANOVA results are shown in Table 5, where the F-value is 18.84, which is significant. The findings indicate that there is a significant difference in the adoption of Industry 4.0 in public and private TEIs.

[Insert Table 5 here]

Additionally, we detect the existence of bias on the data set to explore the reliability of the results. We apply the Common Method Bias (CMB) method, for this purpose. Inadequate consideration of CMB may have some detrimental effects on the research outcomes. CMB occurs when response variability is caused by the method used to collect data. As a consequence, the results would be tainted by the 'noise' introduced by the biased instruments. If there is any biased estimate, then it may affect the interpretations of the hypothesis being tested. One of the simplest procedures to test whether or not CMB exists in the analysed data set is Harman's single factor score (Miguel et al., 2019). This method loads all items (measuring latent variables) into a single common factor, and if the total variance for a single factor is less than 50 percent, CMB had no effect on the data (Miguel et al., 2019). Table 6 shows the test results applied by the SPSS statistics tool. In that analysis, we include all Table 4 dimensions. Namely, there are nine components in Table 6. As a result, since from Table 6, it is observed that the cumulative are less than the recommended threshold of 50 percent (i.e., 32.95), we assume that there is no bias in the data set.

[Insert Table 6 here]

5. Discussions

Discussions of the findings based on the T-O-E framework is presented in this section.

5.1 Technological Dimension

The technology dimension includes relative advantage and compatibility with existing infrastructure. Surprisingly, the relationship between the factors of technology dimension and adoption are not found to be significant. This is opposed to the findings of Shi and Yan (2016); Aziz and Wahid (2020)), who all demonstrated that compatibility with existing infrastructure would support Industry 4.0 adoption. Most of the Industry 4.0 technologies are compatible with basic IT infrastructure, hence, compatibility was not found to be an issue that affects the Industry 4.0 adoption. Similarly, the perceived relative advantage of adopting Industry 4.0 was not found to be significant. This is also opposed to the findings of other studies such as Alkhalil, et al. (2017); and Arnold et al.(2018), all of whom advocate the importance of relative advantage as a key factor for Industry 4.0 adoption. A possible explanation for this finding is that compared to other emerging nations, India has better adoption of information technology in TEIs because of the size of the education sector and the growth of the IT industry. This finding is partially consistent with a previous study by AlBar and Hoque, (2019), which found that the relative advantage of using ICT influences adoption decisions, whereas compatibility with existing infrastructure has no significant impact on ICT adoption and with a study of Aziz and Wahid (2020), which found that technology compatibility affects adoption while relative advantages have no significant impact.

5.2 Organisation Dimension

The organisation dimension captured top management support, available resources and capabilities. The adoption of Industry 4.0 is strongly linked to all three factors of the organisation such as top management's support, internal resources and teaching staff capabilities, all of which affect the decision to adopt Industry 4.0 in TEIs. When technology is adopted, it must be used in conjunction with the TEI's existing knowledge base. As a result, the teaching staff's capabilities may be able to help TEIs adopt and exploit Industry 4.0 more efficiently. The findings are consistent with those of Abed (2020); Henao Ram-rez and López-Zapata (2021); Lorente-Martnez et al., (2020), who found that organisational context does influence technology adoption decisions. Prause (2019) and Qasem, et al., (2020) have emphasised the role of top management support with regard to the adoption of Industry 4.0. The study by Maduku et al.'s (2016) further supported our findings that internal resources are one of the key factors of technology adoption. Other studies, such as Alsaad et al., (2017); AlBar and Hoque, (2019); Chandra and Kumar, (2018), show that technology adoption is influenced by organisational technological capabilities, employee technological experience and capabilities and financial and technological resources. Therefore, the capability of the teaching staff could help TEIs to adopt and exploit Industry 4.0 more effectively.

The findings are equally beneficial for other sectors such as manufacturing who often struggle in their digital transformation journey and lack of staff capability is often seen as a significant challenge.

5.3 Environment dimension

The environmental dimension includes government support and industry pressure. The result shows an insignificant relationship between the environment dimension and the adoption of Industry 4.0 in TEIs. This is in sharp contrast to the findings of Petrillo et al. (2018) who emphasise that Government and its policies play a critical role in the adoption of Industry 4.0. Whereas Jia et al. (2017) and Ghobakhloo and Ching (2019) advocated that industry pressure is an enabler for Industry 4.0 adoption. It appears that TEIs view Industry 4.0 as an enabling set of technologies, thus showing that the environment dimension does not have any significance. This means that Industry 4.0 adoption is an inner requirement and is deemed to be more important than any external pressure. To this end, it is shown that TEIs are concerned more about the available resources and the capability to adopt Industry 4.0. The findings are in line with such as Arnold et al. (2018); Ali et al (2021); AlBar and Hoque (2019) where the authors found that the external environment is not significantly linked with the adoption of technology. The age of TEIs does not affect industry 4.0 adoption. This finding is similar to the studies of Ben Khalifa (2016), who found no significant link between firm age and technology adoption. The study discovered that ownership has a significant influence in TEIs adopting Industry 4.0, which is consistent with Li's (2010 a, b) finding that firm ownership has an impact on e-business assimilation. Furthermore, the findings show that privately-owned TEIs are more likely than publicly-funded TEIs to have adopted Industry 4.0. The number of private TEIs has expanded over the previous two decades, and these TEIs tend to be more proactive in adopting Industry 4.0 in order to boost their brand and visibility.

6. Conclusions

The study contributes to the literature on technology adoption by offering useful empirical evidence of Industry 4.0 adoption in TEI. Only a few studies have investigated the adoption of Industry 4.0 and the learning factory approaches. These studies have limited explanatory power in emerging nations such as India. The present study examines Industry 4.0 adoption from a holistic perspective, considering factors relating to technology, organisation and environment.

Out of the three dimensions identified in the model, the organisation is shown to be the most important when deciding to adopt Industry 4.0 in TEIs. TEIs that have top management support, internal resources and capabilities of teaching staff are more receptive to Industry 4.0 adoption. The study emphasises the role of organisational factors, such as internal resources and teaching staff capabilities, in the process of Industry 4.0 adoption. This study advances the resource-based view, which is widely accepted in the literature by arguing that the competitive advantage of a firm is based on its unique set of resources (Barney, 1991; Peteraf, 1993; Maduku et al. 2016).

Validating the T-O-E framework statistically in a different context, namely the education sector of an emerging country, is a significant contribution to the literature. Although the Covid-19 epidemic has accelerated the adoption of digital technology, there is still a need to improve the technology infrastructure in TEIs and change the way education is delivered and material is developed. The Indian government recently released a new National Education Policy (NEP)-2020 that emphasises modernization and technological integration in education. There are more than 9000 institutes, with an overall intake of 3 million students, that award degrees to their students every year[1]. A large number of students pursuing technical programmes in various fields and will be joining the workforce soon. In this context, aligning the programme structure with Industry 4.0 has become inevitable. Since not much literature is available on Industry 4.0 in the Indian context, the study can be used as a reference.

The study adds to the literature on Industry 4.0 in the Indian context of technical education institutes (TEIs) by introducing approaches that can be used by these TEIs to induce Industry 4.0 in the form of a learning factory and support the government efforts in the process of undertaking successful digital transformation.

7. Implications

Our findings provide several implications for theory and practice. Theoretically, our findings add to the limited literature on industry 4.0 adoption in TEIs context. Moreover, this study also adds to the limited empirical evidence on industry 4.0 adoption in an emerging nation. Our findings highlight that for a successful transition to the digital manufacturing era, it is essential to address the skills gap where TEIs can play an important role. This study highlights the fact that socioeconomic factors in the workplace are essential for the successful adoption of Industry 4.0 technologies. This finding is important for TEIs but also equally applicable for other sectors such as manufacturing sectors who are also facing challenges in digital transformation.

From a practical perspective, our study provides TEIs with insights into the learning factory based on Industry 4.0, which would assist the understanding, learning and application of such modern technologies. TEIs may use the findings to analyse the adoption of Industry 4.0. Integration of Industry 4.0 with education increases training and research. It may help ease the transition to new digital manufacturing trends within an academic environment. When TEIs are ready for Industry 4.0 adoption, the first priority should be to emphasise organisational factors to ensure that they would be used effectively. Specifically, top management should be involved throughout the adoption process. Our study demonstrates the critical role of top management in Industry 4.0 adoption. Additionally, TEI should focus on internal resources and staff capabilities. This has an important implication also for manufacturing industries who often struggle with digital transformation.

From a policy standpoint, the empirical findings can assist decision-makers in developing targeted policies to accelerate the adoption of Industry 4.0 in the education sector. This finding may provide

[1] https://facilities.aicte-india.org/dashboard/pages/dashboardaicte.php

useful recommendations for promoting Industry 4.0 adoption across diverse ownership TEIs. Government, in particular, can encourage and assist publicly funded TEIs in adopting Industry 4.0 by establishing the necessary environment in the first instance. This is also vital for meeting the broader digital shift agenda of the government. TEIs can make an important contribution by the adoption of Industry 4.0 and preparing the future workforce supporting the digital transformation. Studies from other sectors such as manufacturing have also shown that government policies can support digital transformation and hence such policies can act as a significant enabler of industry 4.0 adoption.

8. Limitations and future scope of research

Although there are certain limitations to the study, they do not diminish the value of the findings; rather, they propose future research directions. To begin, the study solely focuses on TEIs in India. As a result, we must be cautious when extrapolating the findings geographically. A comparative study of TEIs in different nations could be useful.

A survey methodology is used in this study. In the future, a study might be undertaken to employ structured interviews with various TEI stakeholders to evaluate diverse perspectives on Industry 4.0. One of the study's limitations is that the research model did not explicitly distinguish between the various sorts of Industry 4.0 technologies. As a result, it is also possible to research the adoption of specific technology in TEIs. Future research could look into other aspects of Industry 4.0 adoption using different theoretical lenses. It is also possible to conduct longitudinal research to determine the usability of various contextual factors and Industry 4.0 adoption. Future research could look into the link between the challenges of digital transformation and TEI's readiness for Industry4.0. While this study focuses on technological, organisational and environmental factors, social factors, in particular, has not been fully explored in this study. Hence, future studies can look at the role of social, environmental and technological factors in digitalization. Future studies can also look beyond the TEIs and explore this in the context of other sectors such as the manufacturing.

References

Abed, S.S., (2020). Social commerce adoption using TOE framework: An empirical investigation of Saudi Arabian SMEs. *International Journal of Information Management*, 53, 102118, https://doi.org/10.1016/j.ijinfomgt.2020.102118.

Abele, E., Metternich, J., Tisch, M., Chryssolouris, G., Sihn, W., ElMaraghy, H., Hummel, V., Ranz, F., (2015). Learning factories for research, education, and training. *Procedia CiRp*, 32, 1-6, https://doi.org/10.1016/j.procir.2015.02.187.

Aboelmaged, M.G., (2014). Predicting e-readiness at firm-level: an analysis of technological, organizational and environmental (TOE) effects on e-maintenance readiness in manufacturing firms. *International Journal of Information Management*, 34 (5), 639-651, https://doi.org/10.1016/j.ijinfomgt.2014.05.002.

Ajzen, I., (2005). Attitudes, Personality and Behaviour. 2nd Ed., Open University Press, NY, ISBN: 0335217044, 09780335217045.

AlBar, A.M., Hoque, R. (2019). Factors affecting the adoption of information and communication technology in small and medium enterprises: a perspective from rural Saudi Arabia. *Information Technology for Development*, 25 (4), 715-738, https://doi.org/10.1080/02681102.2017.1390437.

Ali, O., Shrestha, A., Osmanaj, V., Muhammed, S. (2021). Cloud computing technology adoption: an evaluation of key factors in local governments, *Information Technology & People*, 34 (2), 666-703, https://doi.org/10.1108/ITP-03-2019-0119.

Alkhalil, A., Sahandi, R., John, D., (2017). An exploration of the determinants for decision to migrate existing resources to cloud computing using an integrated TOE-DOI model. *Journal of Cloud Computing*, 6 (1), 1-20, https://doi.org/10.1186/s13677-016-0072-x.

Alsaad, A., Mohamad, R., Ismail, N.A., (2017). The moderating role of trust in business to business electronic commerce (B2B EC) adoption, *Computers in Human Behavior*, 68, 157-169, https://doi.org/10.1016/j.chb.2016.11.040.

Anckar, B., Walden, P., (2001). Introducing web technology in a small peripheral hospitality organization. *International Journal of Contemporary Hospitality Management*, 13 (5), 241-250, https://doi.org/10.1108/09596110110395938.

Arnold, C., Veile, W.J., Voigt, K., (2018). What Drives Industry 4.0 Adoption? An examination of technological, organizational, and environmental determinants. *Proceedings of the International Association for Management of Technology (IAMOT) Conference*, Birmingham, UK.

Awa, H.O., Baridam, D.M., Nwibere, B.M., (2015). Demographic determinants of electronic commerce (EC) adoption by SMEs: A twist by location factors. *Journal of Enterprise Information Management*, 28 (3), 326-345, https://doi.org/10.1108/JEIM-10-2013-0073.

Awa, H.O., Ukoha, O., Emecheta, B.C. (2016). Using T-O-E theoretical framework to study the adoption of ERP solution. *Cogent Business & Management*, 3 (1), 1196571, https://doi.org/10.1080/23311975.2016.1196571.

Aziz, A. S. A., Wahid, N. A., (2020). Do new technology characteristics influence intention to adopt for manufacturing companies in Malaysia? *Proceedings of the First ASEAN Business, Environment, and Technology Symposium* (ABEATS 2019), 30-35. Atlantis Press.

Baena, F., Guarin, A., Mora, J., Sauza, J., Retat, S., (2017). Learning Factory: The Path to Industry 4.0. *Procedia Manufacturing*, 9, 73-80, https://doi.org/10.1016/j.promfg.2017.04.022.

Barney, J. B., (1991). Firm resources and sustained competitive advantage. *Journal of Management* 17 (1), 99-120, https://doi.org/10.1177/014920639101700108.

Khalifa, A.B., (2016). Determinants of information and communication technologies adoption by Tunisian firms. *Journal of Innovation Economics & Management*, 20 (2), 151-177. https://doi.org/10.3917/jie.020.0151

Bhat, T.P., (2020) India and Industry 4.0**,** ISID working paper 218**,** https://isid.org.in/wp-content/uploads/2020/07/WP218.pdf

Buchanan, T., Sainter, P., Saunders, G. (2013). Factors affecting faculty use of learning technologies: Implications for models of technology adoption. *Journal of Computing in Higher Education*, 25, 1 – 11, https://doi.org/10.1007/s12528-013-9066-6.

Byrch, C., Kearins, K., Milne, M., Morgan, R., (2007). Sustainable "what"? A cognitive approach to understanding sustainable development. *Qualitative Research in Accounting & Management*, 4 (1), 26-52, https://doi.org/10.1108/11766090710732497.

Chandra, S., Kumar, K.N., (2018). Exploring factors influencing organizational adoption of augmented reality in e-commerce: Empirical analysis using technology–organization–environment model. *Journal of Electronic Commerce Research*, 19 (3), 237-265.

Chau, P.Y.K., Tam, K.Y., (1997). Factors affecting the adoption of open systems: an exploratory study. *MIS Quarterly*, 21(1), 1–21, https://doi.org/10.2307/249740.

Chen, J., Gao, M., Mangla, S. K., Song, M., Wen, J., (2020). Effects of technological changes on China's carbon emissions. *Technological Forecasting and Social Change*, 153, 119938, https://doi.org/10.1016/j.techfore.2020.119938.

Cohen, W., Levinthal, D., (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 35 (1), 128-152. https://doi.org/10.2307/2393553.

Cohn, E., Sherrie L. W. Rhine, Santos, M., (1989). Institutions of Higher Education as Multi-Product Firms: Economies of Scale and Scope. *The Review of Economics and Statistics,* 71 (2), 284-290, https://doi.org/10.2307/1926974.

Coşkun, S., Kayıkcı, Y., & Gençay, E. (2019). Adapting engineering education to industry 4.0 vision. *Technologies*, 7 (1), 10, https://doi.org/10.3390/technologies7010010.

Dassisti, Michele; and Semeraro, Concetta (2018). Smart sustainable manufacturing: a new Laboratory-Factory concept to test Industry 4.0 principles. *Proceedings of the 8th International Conference on Information Society and Technology*, ICIST 2018, Kopaonik, Serbia.

de Sousa Jabbour, A. B. L., Jabbour, C. J. C., Foropon, C., Godinho Filho, M., (2018). When titans meet–Can industry 4.0 revolutionise the environmentally-sustainable manufacturing wave? The role of critical success factors. *Technological Forecasting and Social Change*, 132, 18-25, https://doi.org/10.1016/j.techfore.2018.01.017.

Ekren, B.Y., Kumar, V., (2020). Engineering education towards industry 4.0. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, Dubai, UAE, March 10-12, 2886- 2893.

Gangwar, H., Date, H. and Ramaswamy, R. (2015). Understanding determinants of cloud computing adoption using an integrated TAM-TOE model. *Journal of Enterprise Information Management*. 28 (1), 107-130, https://doi.org/10.1108/JEIM-08-2013-0065.

Ghobakhloo, M., Ching, N. T., (2019). Adoption of digital technologies of smart manufacturing in SMEs. *Journal of Industrial Information Integration*, 16, 100107, https://doi.org/10.1016/j.jii.2019.100107.

Gómez, J., Vargas, P., (2012). Intangible resources and technology adoption in manufacturing firms. *Research Policy*, 41 (9), 1607–1619, https://doi.org/10.1016/j.respol.2012.04.016.

Grant, R.M., (1996). Toward a knowledge-based theory of the firm. *Strategic Management Journal*, 17 (2), 109-122, https://doi.org/10.1002/smj.4250171110.

Grover, V., Goslar, M.D., (1993). The initiation, adoption, and implementation of telecommunications technologies in U.S. organizations. *Journal of Management Information Systems*, 10 (1), 141-164, https://doi.org/10.1080/07421222.1993.11517994.

Hassan, H., Tretiakov, A., Whiddett, D., (2017). Factors affecting the breadth and depth of e-procurement use in small and medium enterprises. *Journal of Organizational Computing and Electronic Commerce*, 27 (4), 304-324, https://doi.org/10.1080/10919392.2017.1363584.

Henao Ram-rez, A.M. and López-Zapata, E. (2021). Analysis of the factors influencing adoption of 3D design digital technologies in Colombian firms. *Journal of Enterprise Information Management*, Vol. ahead-of-print No. ahead-of-print, https://doi.org/10.1108/JEIM-10-2020-0416.

Hernandez-de-Menendez, M., Díaz, C. A. E., Morales-Menendez, R., (2020). Engineering education for smart 4.0 technology: a review. *International Journal on Interactive Design and Manufacturing*,14 (3), 789-803, https://doi.org/10.1007/s12008-020-00672-x.

Heung, V.C.S., (2003). Barriers to implementing E-Commerce in the travel industry: A practical perspective. *International Journal of Hospitality Management*, 22 (1), 111-118, https://doi.org/10.1016/S0278-4319(02)00075-0.

Hwang, B.N., Huang, C.Y., Wu, C.H., (2016). A TOE approach to establish a green supply chain adoption decision model in the semiconductor industry. *Sustainability*, 8 (2), 168-197, https://doi.org/10.3390/su8020168.

Iacovou, C.L., Benbasat, I. and Dexter, A.S. (1995) Electronic data interchange and small organizations: Adoption and impact of technology, *MIS Quarterly*, 19 (4), 465-485, https://doi.org/10.2307/249629.

Jabbour, C.J.C., de Sousa Jabbour, A. B. L., Sarkis, J., Godinho Filho, M., (2019). Unlocking the circular economy through new business models based on large-scale data: An integrative framework and research agenda. *Technological Forecasting and Social Change*, 144, 546-552, https://doi.org/10.1016/j.techfore.2017.09.010.

Jeyaraj, A., Rottman, J.W., Lacity, M.C., (2006). A review of the predictors, linkages, and biases in IT innovation adoption research. *Journal of Information Technology*, 21 (1), 1-23, https://doi.org/10.1057/palgrave.jit.2000056.

Jia, Q., Gao, Y., Staurt, J.B., (2017). Enterprise 2.0 post-adoption: extending the information system continuance model based on the technology-organization-environment framework. *Computers in Human Behavior*, 67, 95-105, https://doi.org/10.1016/j.chb.2016.10.022.

Joo, J., (2011). Adoption of Semantic Web from the perspective of technology innovation: A grounded theory approach. *International Journal of Human-Computer Studies*, 69 (3), 139-154, https://doi.org/10.1016/j.ijhcs.2010.11.002.

Kagermann, H., Helbig, J., Hellinger, A., Wahlster, W., (2013). Recommendations for Implementing the Strategic Initiative Industry 4.0: Securing the Future of German Manufacturing Industry. Final Report of the Industry 4.0 Working Group Forschungsunion. https://www.din.de/blob/76902/e8cac883f42bf28536e7e8165993f1fd/recommendations-for-implementing-industry-4-0-data.pdf

Keong, W. E. Y. (2016). The determinants of mobile shopping mall apps adoption intention in Malaysia: An empirical investigation. Proceeding of the 11th IEEE International Conference on Computer Science & Education (ICCSE), 341-346, https://10.1109/ICCSE.2016.7581604.

Khemthong, S., Roberts, L., (2006). Adoption of internet and web technology for hotel marketing: A study of hotels in Thailand. *Journal of Business Systems, Governance, and Ethics*, 1 (2), 51-70, https://doi.org/10.15209/jbsge.v1i2.74.

Leal, F.L., Fleury, A., Zancul, E., (2020). Starting up a Learning Factory focused on Industry 4.0, *Procedia Manufacturing*, 45, 436-441 https://doi.org/10.1016/j.promfg.2020.04.049.

Leung, D., Lo, A., Fong, L.H.N., Law, R., (2015). Applying the technology-organization-environment framework to explore ICT initial and continued adoption: an exploratory study of an independent hotel in Hong Kong, *Tourism Recreation Research*, 40 (3), 391-406, https://doi.org/10.1080/02508281.2015.1090152.

Li, D. H., Chau, P.Y.K., Lai, F., (2010a). Market orientation, ownership type, and e-business assimilation: evidence from Chinese firms. *Decision Sciences*, 41 (1), 115–145, https://doi.org/10.1111/j.1540-5915.2009.00261.x.

Li, D., Lai, F., Wang, J., (2010b). E-business assimilation in China’s international trade firms: the technology-organization-environment framework. *Journal of Global Information Management*, 18 (1), 39–65, https://doi.org/10.4018/jgim.2010091103.

Li, L., (2018). China's manufacturing locus in 2025: With a comparison of “Made-in-China 2025” and “Industry 4.0”. *Technological Forecasting and Social Change*, 135, 66-74, https://doi.org/10.1016/j.techfore.2017.05.028.

Lian, J.W., Yen, D.C., Wang, Y.T., (2014). An exploratory study to understand the critical factors affecting the decision to adopt cloud computing in Taiwan hospital. *International Journal of Information Management*, 34 (1), 28-36, https://doi.org/10.1016/j.ijinfomgt.2013.09.004.

Lin, D., Lee, C.K.M., Lau, H., Yang, Y., (2018). Strategic response to Industry 4.0: an empirical investigation on the Chinese automotive industry. *Industrial Management & Data Systems*, 118 (3), 589-605, https://doi.org/10.1108/IMDS-09-2017-0403.

Lin, H., (2014). Understanding the determinants of electronic supply chain management system adoption: using the technology-organization-environment framework. *Technological Forecasting and Social Change*, 86 (1), 80-92, https://doi.org/10.1016/j.techfore.2013.09.001.

Lorente-Martínez, J., Navío-Marco, J. and Rodrigo-Moya, B., (2020). Analysis of the adoption of customer facing InStore technologies in retail SMEs. *Journal of Retailing and Consumer Services*, 57, 102225, https://doi.org/10.1016/j.jretconser.2020.102225.

Luthra, S., Mangla, S. K., (2018). Evaluating challenges to Industry 4.0 initiatives for supply chain sustainability in emerging economies. *Process Safety and Environmental Protection*, 117, 168-179, https://doi.org/10.1016/j.psep.2018.04.018.

Maduku, D.K., Mpinganjira, M., Duh, H., (2016). Understanding mobile marketing adoption intention by South African SMEs: a multi-perspective framework. *International Journal of Information Management*, 36 (5), 711-723, https://doi.org/10.1016/j.ijinfomgt.2016.04.018.

Maisiri, W., Darwish, H., Van Dyk, L., (2019). An investigation of Industry 4.0 skills requirements. *South African Journal of Industrial Engineering*, 30 (3), 90-105, https://doi.org/10.7166/30-3-2230.

Masood, T., Egger, J., (2019). Augmented reality in support of Industry 4.0—Implementation challenges and success factors. *Robotics and Computer-Integrated Manufacturing* 58, 181-195, https://doi.org/10.1016/j.rcim.2019.02.003.

Masood, T., Sonntag, P., (2020). Industry 4.0: Adoption challenges and benefits for SMEs. *Computers in Industry*, 121, 103261, https://doi.org/10.1016/j.compind.2020.103261.

Mavrikios, D., Sipsas, K., Smparounis, K., Rentzos, L., Chryssolouris, G., (2017). A Web-based application for classifying teaching and learning factories. *Procedia Manufacturing*, 9, 222-228, https://doi.org/10.1016/j.promfg.2017.04.002.

McKinnie, M., (2016). Cloud computing: TOE adoption factors by service model in manufacturing. Dissertation, Georgia State University, https://scholarworks.gsu.edu/bus_admin_diss/68.

Melville, N., Kraemer, K., Gurbaxani, V., (2004). Review: Information technology and organizational performance: An integrative model of IT business value. *MIS Quarterly*, 28 (2), 283-322, https://doi.org/10.2307/25148636.

Metallo, C., Agrifoglio, R., Schiavone, F., Mueller, J., (2018). Understanding business model in the Internet of Things industry. *Technological Forecasting and Social Change*, 136, 298-306, https://doi.org/10.1016/j.techfore.2018.01.020.

Miguel I., Aguirre-Urreta, Hu J., (2019). Detecting Common Method Bias: Performance of the Harman's Single-Factor Test. *ACM Sigmis Database*, 50 (2), 45-70, DOI:10.1145/3330472.3330477.

Müller, J. M., Kiel, D., Voigt, K. I., (2018). What drives the implementation of Industry 4.0? The role of opportunities and challenges in the context of sustainability. *Sustainability*, 10 (1), 247, https://doi.org/10.3390/su10010247.

Oliveira, T., Martins, M.F., (2011). Literature Review of Information Technology Adoption Models at Firm Level. *The Electronic Journal Information Systems Evaluation*, 14 (1), 110-121.

Osakwe, C.N., Chovancova, M., Agu, M.N., (2016). Can micro-enterprises leverage on the adoption of corporate websites to bolster their brand visibility? Examining salient adoption issues in Nigeria. *Information Development*, 32 (4), 904 - 919, https://doi.org/10.1177/0266666915573551.

Pan, M., Jang, W., (2008). Determinants of the adoption of enterprise resource planning within the technology-organization-environment framework: Taiwan's communications industry. *Journal of Computer Information Systems*, 48 (3), 94-102, https://doi.org/10.1080/08874417.2008.11646025.

Peteraf, M., (1993). The cornerstones of competitive advantage: A resource-based view. *Strategic Management Journal*, 14 (3), 179-191, https://doi.org/10.1002/smj.4250140303.

Petrillo, A., De Felice, F., Cioffi, R., Zomparelli, F. (2018). Fourth industrial revolution: Current practices, challenges, and opportunities. *Digital transformation in Smart Manufacturing*, 1-20, DOI: 10.5772/intechopen.72304.

Piva, M., Santarelli, E., Vivarelli, M., (2005). The skill bias effect of technological and organisational change: evidence and policy implications. *Research Policy* 34 (2), 141–157, https://doi.org/10.1016/j.respol.2004.11.005.

Prause, M., (2019). Challenges of Industry 4.0 technology adoption for SMEs: The case of Japan. *Sustainability*, 11 (20), 5807, https://doi.org/10.3390/su11205807.

Premkumar, G., Ramamurthy, K., (1995). The role of interorganizational and organizational factors on the decision mode for adoption of interorganizational systems. *Decision Sciences*, 26 (3), 303-336, https://doi.org/10.1111/j.1540-5915.1995.tb01431.x.

Premkumar, G., Roberts, M., (1999). Adoption of new information technologies in rural small business. *OMEGA*, 27 (4), 467–484, https://doi.org/10.1016/S0305-0483(98)00071-1.

Qasem, Y.A.M., Asadi, S., Abdullah, R., Jusoh, Y., Atan, R., Al-Sharafi, M.A., Yassin, A., (2020). A Multi-Analytical Approach to Predict the Determinants of Cloud Computing Adoption in Higher Education Institutions. *Applied Sciences*, https://doi.org/10.3390/app10144905.

Ramanathan, L., Iyer, S., (2015). A Qualitative Study on the Adoption of Open Source Software in Information Technology Outsourcing Organizations. Proceedings of the 11th International Conference on Open Source Systems (OSS), May 2015, Florence, Italy, 103-113, https://doi.org/10.1007/978-3-319-17837-0_10.

Raymond, L., (2001). Determinants of Web site implementation in small businesses. *Internet Research*, 11 (5), 411-424, https://doi.org/10.1108/10662240110410363.

Salah, B., Abidi, M. H., Mian, S. H., Krid, M., Alkhalefah, H., Abdo, A., (2019). Virtual reality-based engineering education to enhance manufacturing sustainability in industry 4.0, *Sustainability,* 11 (5), 1477, https://doi.org/10.3390/su11051477.

Saldanha, T., Krishnan, M.S., (2012) Organizational adoption of Web 2.0 technologies: an empirical analysis. *Journal of Organizational Computing and Electronic Commerce*, 22 (4), 301-333, https://doi.org/10.1080/10919392.2012.723585.

Shi, P., Yan, B. (2016). Factors affecting RFID adoption in the agricultural product distribution industry: empirical evidence from China. *SpringerPlus* 5, 2029. https://doi.org/10.1186/s40064-016-3708-x.

Sniehotta, F.F., Presseau, J., Araújo-Soares, V., (2014). Time to retire the theory of planned behaviour. *Health Psychology Review*, 8 (1), 1-7, https://doi.org/10.1080/17437199.2013.869710.

Sung, T.K., (2018). Industry 4.0: A Korea perspective. *Technological Forecasting and Social Change*, 132, 40-45, https://doi.org/10.1016/j.techfore.2017.11.005.

Taber, K.S., (2018). The Use of Cronbach's Alpha When Developing and Reporting Research Instruments in Science Education. *Research in Science Education* 48, 1273–1296, https://doi.org/10.1007/s11165-016-9602-2.

Tan, K. S., Chong, S. C., Lin, B., Eze, U. C., (2009). Internet-based ICT adoption: evidence from Malaysian SMEs. *Industrial Management & Data Systems*, 109 (2), 224-244. doi: 10.1108/02635570910930118.

Teo, T.S.H., Lin, S., Lai., K.H. (2009). Adopters and non-adopters of e-procurement in Singapore: An empirical study. *OMEGA*, 37 (5), 972–987, https://doi.org/10.1016/j.omega.2008.11.001.

Tisch, M., Hertle, C., Abele, E. Metternich, J., Tenberg, R., (2016). Learning factory design: a competency-oriented approach integrating three design levels, *International Journal of Computer Integrated Manufacturing*, 29 (12), 1355-1375, DOI: 10.1080/0951192X.2015.1033017

Drazin, R., (1991). The processes of technological innovation. *The Journal of Technology Transfer* 16, 45–46. https://doi.org/10.1007/BF02371446.

Van den Berg, J., Van der Lingen, E., (2019). An empirical study of the factors affecting the adoption of mobile enterprise applications. *South African Journal of Industrial Engineering*, 30 (1), 124-146, DOI:10.7166/30-1-1992.

van Griethuijsen, R.A.L.F., van Eijck, M.W., Haste, H., (2015). Global patterns in students' views of science and interest in science. *Research in Science Education* 45 (4), 581–603, https://doi.org/10.1007/s11165-014-9438-6.

Wagner, U., Algeddawy, T., ElMaraghy, H., Müller, E. (2014) Developing products for changeable learning factories. *CIRP Journal of Manufacturing Science and Technology*, 9,146-158, https://doi.org/10.1016/j.cirpj.2014.11.001.

Wagner, U., AlGeddawy, T., ElMaraghy, H., MŸller, E., (2012). The state-of-the-art and prospects of learning factories. *Procedia CiRP*, 3, 109-114, https://doi.org/10.1016/j.procir.2012.07.020.

Wang, S., Wan, J., Zhang, D., Li, D., Zhang, C., (2016a). Towards smart factory for industry 4.0: a self-organized multi-agent system with big data based feedback and coordination, *Computer Networks*, 101, 158-168, https://doi.org/10.1016/j.comnet.2015.12.017.

Wang, Y., Li, H., Li, C., Zhang, D., (2016b). Factors affecting hotels' adoption of mobile reservation systems: A technology-organization-environment framework, *Tourism Management*, 53, 163-172, https://doi.org/10.1016/j.tourman.2015.09.021.

Williams, M.D., Rana, N.P., Dwivedi, Y.K., (2015). The unified theory of acceptance and use of technology (UTAUT): a literature review, *Journal of Enterprise Information Management*, 28 (3), 443-488, https://doi.org/10.1108/JEIM-09-2014-0088.

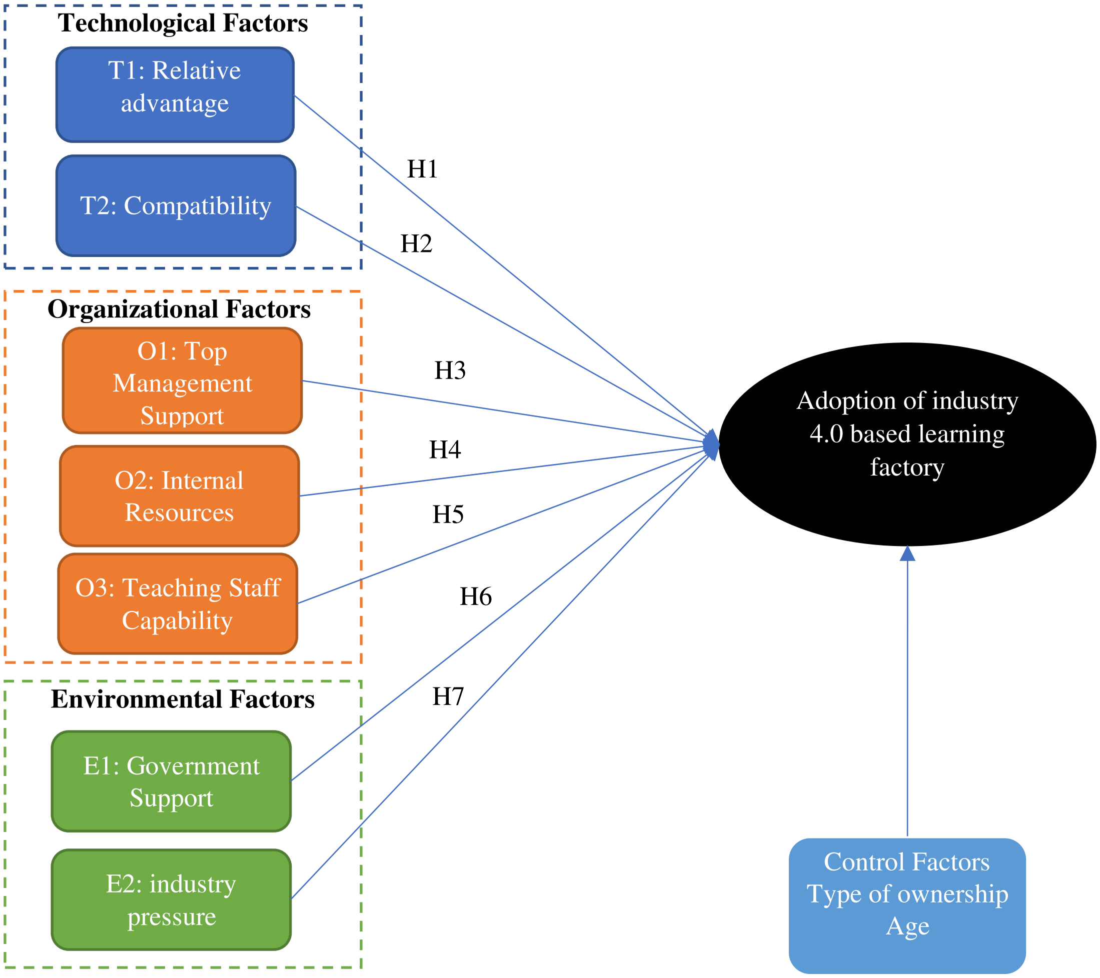

Figure 1: Research Framework

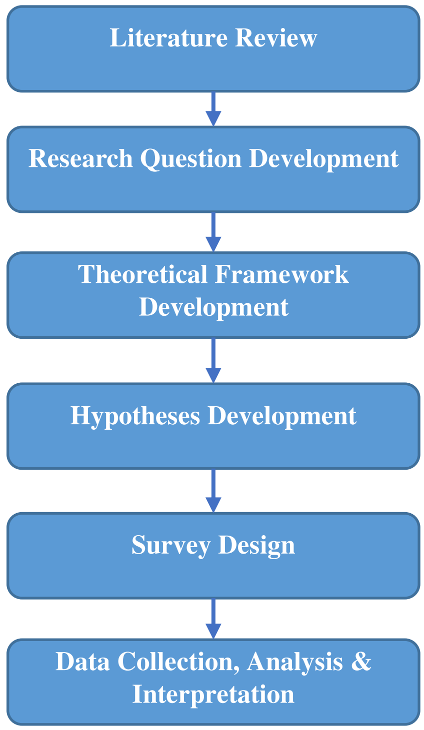

Figure 2: Research Process

Table 1: TEIs Profile

	Publicly Funded	**Privately Funded**
Number of TEIs	57	77
Average response	2.79	3.53

Table 2: Validity and reliability of the constructs

Dimensions/Items	**Factor Loading**	**Eigen Value**	**Cronbach Alpha**	**TVE**	**KMO**	**Bartlette Test**
Technology						
Adopting Industry 4.0 technology can give a relative advantage to the TEIs. (T1)	.847	1.435	.606	71.73	.50	.000
Adopting Industry 4.0 is compatible with our existing IT infrastructure (T2)	.847					
Organisation						
The top management of the institute is supportive of adopting industry	.817					

4.0 technologies (O1)		1.919	.712	63.96	.678	.000
We have enough internal resources to support the adoption of industry 4.0 (O2)	.789					
Our teaching staff has the capabilities to support the adoption of industry 4.0 (O3)	.793					
Environment						
The government supports to prepare the institute to meet the demand for industry 4.0 (E1)	.848	1.437	.608	71.8	.50	.000
We have to prepare our students for new job opportunities or skillsets, which are required because of the increased use of industry 4.0 by the manufacturing sector (E2)	.848					

Table 3: Correlation Analysis

	Relative Advantage (T1)	**Compatibility (T2)**	**Top management support (O1)**	**Internal resource (O2)**	**Teaching Staff capabilities (O3)**	**Government support (E1)**	**Industry pressure (E2)**	**Adoption of industry 4.0 (A1)**
T1	1							
T2	.435**	1						
O1	.223**	.275**	1					
O2	.100	.282**	.472**	1				
O3	.109	.273**	.477**	.429**	1			
E1	.197*	.311**	.462**	.400**	.479**	1		
E2	.378**	.304**	.291**	.274**	.388	.437	1	
A1	.044	.247**	.542**	.536**	.486**	.344**	.157	1
** Significant at the 0.01 level' *Significant at the 0.05 level								

Table 4: Multiple Regression Analysis

Dimension/hypotheses	**B**	**Significance**	**Hypotheses Accepted or Rejected**	
Constant **Control** Ownership Age **Technology** Relative Advantage	 -.421 .001 -.154	 **.**012 .642 .283	 **Rejected**	R= .689 R Square=.474 Adjusted R Square= .436 F=12.427.000)

Compatibility	.207	.156	**Rejected**	
Organization Top Management Support Internal Resources Teaching Staff Capabilities	.344 .247 .286	.001 .003 .006	**Accepted** **Accepted** **Accepted**	
Environment Government Support Industry Pressure	-.012 -.124	.917 .275	**Rejected** **Rejected**	

Table 5: ANOVA Results

	N	Industry 4.0 adoption Mean	Std. Deviation	Std. Error	F	Sig.
Private TEIs	77	3.53	.940	.107	18.846	.000
Public TEIs	57	2.79	1.031	.136		
Total	**134**	**3.22**	**1.043**	**.090**		

Table 6: CMB Analysis

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.965	32.949	32.949	2.965	32.949	32.949
2	1.576	17.516	50.465			
3	.965	10.718	61.182			
4	.844	9.382	70.565			
5	.750	8.331	78.896			
6	.581	6.450	85.346			
7	.502	5.580	90.925			
8	.440	4.886	95.812			
9	.377	4.188	100.000			

Extraction Method: Principal Component Analysis.