Modeling the Enablers and Barriers to Effective E-learning: A TISM Approach

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Abstract—The drastic change in the technological environment has transformed the entire world including the education sector which was and is largely dominated by classroom teaching. In the last decade, a new entrant in the education sector has been e-learning. The COVID-19 pandemic has forced educational institutes to look at e-learning as a path to continue the learning process. The present paper aims to propose a model highlighting the enablers that encourage the smooth and effective delivery of e-learning process and highlight the barriers that cause hurdles in the effective delivery of e-learning. The researchers have followed the Total Interpretive Structural Modelling and Fuzzy Matriced' Impacts Croise's Multiplication Appliquée a UN Classement (MICMAC) analysis approach of extant literature review, expert opinion and multiple iterations to arrive at the proposed model. The findings of the present research study show the linkages between the identified enablers: institutional culture, institutional capability and support, flexibility in the teaching-learning process, e-readiness, motivation, knowledge management practices, and technology. Knowledge management practices that include practices of capturing knowledge and sharing knowledge have emerged as the most significant enabler of e-learning. The model on barriers to e-learning shows the relationship between lack of required skills, lack of access to technology, quality concerns, time as a barrier, learner engagement as barriers to effective e-learning. Modelling of enablers and barriers and effective e-learning is a less explored area, particularly in the Indian context with special emphasis on the pandemic. The study was carried out to address this research gap.

Keywords—e-learning, enablers, barriers, TISM, fuzzy MICMAC

1 Introduction

1.1 E-learning

E-learning involves the usage of information technology to deliver educational material and resources online [1], [2] defines e-learning as "instruction delivered electronically wholly by a web browser, through the Internet or an intranet, or through CD-ROM or DVD multimedia platforms." On the basis of whether e-learning is bound

by place or time it usually takes two forms—synchronous and asynchronous. Synchronous e-learning allows the interaction between the teacher and the learner on a real-time basis [3]. It enhances the efficiency of the teaching-learning process by enabling the exchange of information and ideas between the participants during the same period [4]. In the case, of asynchronous e-learning, the teaching and learning happen at two different times, and mediums such as emails or discussion forums are used for communication [5]. Many learners opt for e-learning due to its asynchronous nature [6]. The asynchronous form provides flexibility and convenience in terms of time. Learning is self-paced and involves no interaction with other learners in real-time. Applications such as email, discussion forums, pre-recorded videos, audios, etc. are used and learners complete the content at their own time and pace. It is important to note that both these forms have their pros and cons. As per a study conducted in Japan by [7], students found e-learning effective for nurturing academic literacy. E-learning is a powerful tool to spread learning and increase literacy. Although e-learning offers huge opportunities, the challenges associated with it cannot be ignored. While access to the traditional classroom is limited by space, time, and place; access to e-learning is limited by good internet connection and availability of technical infrastructure. [8] documented three components of the e-learning system: technology, learning content, and e-learning design. Another big challenge for effective use of e-learning is to make the content dynamic and engaging. E-learning may not be effective if the learners view the content as an old-fashioned and outdated mode of teaching [9].

1.2 E-learning and India

India is a country with a substantial youth population. As per Census 2011; 34% of India's population is in the age group of 15–34 years. In India, the higher education system has grown at a rapid pace to become one of the biggest systems in the world. The student enrolment statistics by the All India Survey on Higher Education (AISHE) 2018–19, show that the highest number of students are enrolled for programs at the Under Graduate level which is 79 percent out of the total students enrolled. In a country like India where the literacy rate is 74% and with literacy rate in some states being as low as 64% and distance enrolment is only 10.6% of total enrolment in higher education; e-learning can be a useful tool to provide access to education to masses [10].

COVID-19 has had an adverse impact on every country and has put a standstill on many activities in different sectors. Also, human behavior drastically changed in just a brief period of time [11]. The education sector in India too faced the impact of COVID-19. As per UNESCO [12], the education of 320 million students of India was affected by COVID-19. In such times, institutes were required to look at alternate options so that the learning process would not get affected. E-learning provided a good alternative to support continued learning during this period. The pandemic has transformed "the traditional teaching model to the educational technology (EdTech) model where teachers and students were exposed to new innovative educational methodologies" [13]. It acted as a catalyst for education institutes to explore different platforms and methods for e-learning. There have been multiple initiatives taken up by the Government of India to promote e-learning during the past few years. SWAYAM and

e-PG Pathshala are some notable initiatives from the Government of India to encourage e-learning. These digital initiatives have helped and supported e-learning during the pandemic. India is viewed as the second largest online market in the world but the internet penetration rate stood at only 50% in 2020 [14]. The figure is significant as it highlights the existing divide and the challenges associated with the smooth implementation of e-learning in India.

Thus, it becomes imperative to understand the barriers as well as enablers to e-learning especially in the Indian context with emphasis on the pandemic. Therefore, the present study aims at exploring and modelling the enables and barriers considering the Indian perspective. This will not only help the higher education institutions to design their e-learning policies but will also reveal the factors that drive the successful implementation of e-learning.

1.3 Supporting theories for the study

The study was grounded on theories that are well researched, discussed, and accepted. The theories below formed the building blocks to understand, predict, and explain phenomena associated with e-learning. They helped shed light on the virtual learning environment, technology acceptance, and the process of transition to the digital environment. This laid the foundation to identify enablers and disablers discussed in the literature review section.

Theory of connectivism. Connectivism is a conceptual framework that views modern day learning as a phenomenon which occurs via network connection affected by the virtual learning environment and by the process of socialization [15]. Connectivism reflects rapid changes in society. According to the theory, advancements in technology helped to cope with these changes and uncertainties in society. The theory discussed the ability to connect different information sources to ensure smooth and continual learning. The theory proposed that there should be systems and processes to synthesize this change. Another important aspect of Connectivism is the individual learner. The learner in the virtual learning environment gain from well-established systems. These systems helped to continue the cycle of knowledge management. Learners could help promote a well-organized flow of knowledge [16].

Technology acceptance model. The technology acceptance model (TAM) was proposed by Davis (1986) [17] to provide a framework for the adoption and usage of computer technology. This model has also made a substantial contribution to the understanding of the e-learning process [18]. Theory on TAM considers the end-user perceived usefulness of the technology and the end-user perceived ease of use as important predictors for the success of the technology. The theory further focused on the behavioral intention aspect and social norms that would regulate the acceptance of new technology among end-users. An individual's intention to use technology is affected by an individual's attitude and social norms. Social norms are the informal rules of a group that influenced one's decision to accept or reject behavior.

1.4 Research gap and questions

E-learning–both synchronous and asynchronous can be used to enhance the reach of education to the larger section of Indian society. According to [6], synchronous, and asynchronous e-learning complement each other, and instructors or teachers should use a combination of both for an effective teaching-learning process. Studies in the past have revealed that both synchronous and asynchronous e-learning, increased the achievement and skill acquisition among learners [4]. Researchers in the past have also discussed the use of innovative technologies in e-learning courses [18]. Few studies in past have explored the barrier to e-learning [5] [20] [21] [22]. However, with the pandemic of COVID-19 the education system landed in deep trouble. Also, there was drastic increase in the adoption of e-learning. This also raises lot of challenges for learners as well as teachers. Therefore, it becomes very important to identify and understand the factors (enablers as well as barriers) affecting e-learning.

Modeling of enablers, as well as barriers to effective e-learning, is less explored especially in the Indian context with emphasis on the pandemic. The present study aims at exploring and modelling the enables and barriers considering the Indian perspective. This will not only help the higher education institutions to design their e-learning policies but will also reveal the factors that drive the successful implementation of e-learning.

To fill this research, gap the present study is carried out and researchers seek answers to the following research questions:

RQ1: What are the important enablers and barriers to e-learning?
RQ2: What is the nature of linkages and relations between these identified enablers and barriers?

The objectives of this study accordingly are:

O1: To understand the factors that enable and pose as barriers to effective implementation of e-learning during the pandemic.
O2: To arrive at a model using Total Interpretive Structural Modelling to explain the nature, importance, and interactions within the identified enablers and barriers.

2 Theoretical background

The following section presents an insight into the theoretical background of the key areas relevant to the present study.

2.1 Enablers for e-learning

The e-learning paradigm has provided access to information that is not bounded by any boundaries and facilitates the creation and progression of the knowledge society [23]. Multiple factors decide and contribute to the success of e-learning. The major enablers or drivers of e-learning are discussed as follows:

Institutional culture and e-learning (E1). Institutional culture promoting the dissemination of knowledge and information act as an enabler of e-learning. Past studies have reinforced the direct association between the supportive organizational culture and success concerning knowledge sharing [24] [25]. There have been radical changes in social, economic, and technological environment and therefore an institutional culture that embraces these changes is a precursor for the success of e-learning [26]. The same was also reinforced by [27] in their study where they stated that institutional culture that supports technological advancement and encourages flexibility is a key factor for e-learning success. Also, in the last decade, education institutions have witnessed a rise in student demand for flexibility, convenience, and distance learning programs. This has also led to the growth in e-learning and virtual platforms [28].

Institutional capability and support (E2). The implementation and promotion of e-learning involved institutional support [29] in various aspects such as adequate infrastructure facility, availability of e-learning platforms, IT support, network security, favourable policies, etc. A strong and efficient technical infrastructure ensured the success of e-learning and thus acted as one of the critical success factors in the case of e-learning [30]. Institutions need to provide adequate support to their faculty to integrate digital technology [31]. In other words, technical support and guidance are the precursors for successful e-learning [32]. Also, the institution readiness concerning finances involved, infrastructure facility, cultural, and content readiness should be analysed [33], so that a proper blueprint could be developed before the actual execution of e-learning [34]. Training and development of all the stakeholders was a vital enabler of the successful execution of the e-learning program. As human resource is involved in every aspect of e-learning, systematic training ensures that necessary skill and knowledge are imparted to drive e-learning [35].

Flexibility in the teaching-learning process (E3). One of the major advantages of e-learning is the flexibility it provides to the entire teaching-learning process. Learning can happen at the pace selected by the learner and without any geographical and time-related barriers. Also, the learner has the flexibility to access reading material anytime and anywhere [36]. Attempts should be made to blend e-learning into the present curricula [37]. This would "facilitate independent, interactive, and collaborative learning due to its flexible and technologically rich format" [36]. Also, in the case of e-learning, learners have access to richer resources as compared to the traditional classroom [38].

E-readiness (E4). The characteristics of learners such as involvement of learners, ability to make use of resources or e-readiness, motivational level, persistence in learning, technical competency, word-processing skills, positive attitude, etc. are vital for the success of e-learning. The presence of these characteristics enables and enhances e-learning. For example- 'E-readiness' is a term which is used in the context of e-learning which explains learners "ability to make use of e-learning resources and multimedia technologies to improve the quality of learning" [39] [29] [40]. Similar to all teaching-learning endeavours, the instructor plays a vital and principal role in e-learning [29]. Few researchers also opined that the effectiveness of e-learning depends on how the instructor implements IT in his or her instructional process. E-learning empowers teachers or instructors and provides them with an array of technical and pedagogical tools to teach effectively and efficiently [41]. Also, teachers play a major

role in organizing and arranging the content of a course to ensure the effective and efficient delivery of the content [42] which boosts the motivation and satisfaction of the learners. Commitment, investment of effort and time, and motivation of the instructor also impact the process [43].

Motivation (E5). Motivation is a key driver for successful e-learning as it has a significant impact on the attitude of the learners and facilitator. This attitude would further impact behaviours, engagement levels, and levels of interaction in a virtual environment [44]. It would impact the desired levels of learning; low learner motivation would result in low levels of learning. Similarly, the low level of motivation among the facilitators will result in poor delivery of the course as they act as the "frontline workers" for any teaching-learning organization [13]. This will also affect learner's behaviors. Motivation to learn reflected students' desire to attend sessions and learn [45]. Intrinsically motivated students get involved in the learning process due to the interest generated by the facilitator, they had the desire to increase their domain knowledge and achieve personal objectives [46]. Extrinsic motivation looked at rewards and gains out of the e-learning process. This could be in the form of recognition, better marks, certificates, etc. [47]. It is important to understand intrinsic and extrinsic motivators to facilitate effective e-learning.

Knowledge management practices (E6). Knowledge management practices included systems and processes to capture information, store it, and effectively use it. Digital library tools that help to locate resources, learning management systems, e-library, etc. are practices for knowledge management in a virtual learning environment. These practices should aid the end-user to search, browse, and discover exhibits [48]. Educational systems are similar to knowledge management (KM) systems. Both these systems collect, integrate, and utilize information. These tools help learners acquire information and learn in the digital space [49]. Institutes that have Learning Management Systems (LMS) permit this process and allow smooth communication between teachers and students [50] [51].

Technology (E7). Technology has changed the outlook towards learning, it has impacted how learners learn and what learners can learn [52]. During the pandemic, technology has played a vital role in aiding the learning process in the virtual space. Technology has ensured that learning does not stop, learners and facilitators can connect, interact, and carry forward the learning process. Technology has a role to play in e-learning by supporting interactivity, association, and on-time delivery of online education. It has helped to conduct teaching-learning activities across the globe and connect even remote areas through the Internet [53]. Advancement in information technology makes e-learning more prevalent. Technology such as learning management systems, collaborative tools, communication tools has enhanced the effectiveness of e-learning. They facilitate knowledge sharing and are beneficial to both the online instructors and as well as the e-learners [54]. Also, technology-related aspects such as system speed, reliability, flexibility, ease of use, security play a major role in the success of e-learning [55].

Table 1. Enablers of e-learning in the pandemic COVID-19

Serial Number	Identified Enabler	Author (Year)
E1	Institutional Culture	[28] [24] [25] [26] [27]
E2	Institutional Capability and Support	[29] [30] [32] [33] [34] [35]
E3	Flexibility in the teaching-learning process	[36] [37] 38]
E4	E readiness	[40] [39] [29] [41] [42] [43]
E5	Motivation	[44] [45] [46] [47]
E6	Knowledge Management Practices	[48] [49] [51] [50]
E7	Technology	[52] [53] [54]

2.2 Barriers to e-learning

Novel technologies have amalgamated with the present learning process and have become inevitable [23] and a new normal of the present teaching-learning environment. E-learning has opened new doors of opportunities to the educational institution and thus has "vital strategic importance" in most of the institutions around the globe [56]. However, there are factors that act as a barrier towards the effective adoption and implementation of e-learning. The major barriers of e-learning are discussed below:

Lack of required skills (B1). The outbreak of the pandemic had forced schools and higher education institutes to explore online teaching and learning processes. Institutes with limited or no experience in this area faced the challenge of faculty members who were not compatible with this new method of teaching. [57] in their study identified that inadequate IT skills were the primary barriers that hindered the successful implementation of e-learning. [58] in their study classified the barriers that impacted the successful delivery of e-learning as policy challenges, technological challenges, insufficient skills, and cultural challenges. A big challenge faced was the inadequate skills required to design and develop e-content and deliver lectures effectively in the virtual space [59]. Many instructors preferred the traditional teaching-learning platform and were reluctant to develop new skills [60]. Faculty delivering a course is a crucial stakeholder for effective e-learning. However, e-learning in the prima facia is still in the initial stage of development and until the pandemic was not a regular practice in most institutes. Hence, faculty members were not acquainted with the synchronous and asynchronous mode of delivery [5]. Lack of skills also covered an inadequate understanding of e-learning, learners' need, and lack of knowledge, skills, and abilities on the part of faculty members to effectively deliver [61].

Lack of access to technology (B2). Technology is the backbone of effective e-learning, lack of technology or technological constraints has been identified as a barrier by various researchers. Technological constraints included lack of integrated computer technology (ICT) infrastructure, accessibility, and poor network connections. [62] stated that barriers to e-learning could be classified as material and nonmaterial barriers. In the study, material barriers were defined as a lack of ICT resources. This could be due to a lack of accessibility, financial constraints, internet bandwidth, and connectivity issues in remote areas [63]. Many higher education institutes did not have the required hardware and software for the smooth implementation of e-learning.

Similarly, learners would be in remote areas with limited access to computers, servers, networks for learning. Another challenge was the ability to upgrade technology, maintenance of infrastructure, and technical assistance to end-users [60]. The challenges associated with the adoption of technology related to e-learning were related to the attitude of faculty members, inaccessibility and unavailability of ICT tools, and the lack of support [64].

Quality concerns (B3). Another barrier that has been identified is the quality and credibility of e-learning. There has always been a debate on the quality and efficiency of an e-learning system as compared to the traditional classroom teaching-learning process [60]. Some researchers have argued that the effectiveness of online learning sessions exceeded that of traditional classroom learning [65], however, the quality of e-learning content and delivery is still a topic of huge debate [66]. There is a need to improve teaching-learning strategies to improve the quality of online classes. Quality concerns are reflected in knowledge limitations and assessment challenges. Further, the lack of a universally accepted definition of quality in e-learning and a standardized process of pre or post-assessment equates to poor quality [67]. Quality concerns related to data protection, the integrity of data were important security issues that affected the quality of e-learning [68]. Ambiguity in the curriculum, poor quality, and insufficient evaluation are other areas that raise concern on the quality of e-learning [61]. According to [69] the e-quality framework is influenced by social aspects of learning.

Time as a barrier (B4). The COVID-19 pandemic was a major reason that educational institutes looked at practices to adopt e-learning. The switch from traditional class settings to an online environment was sudden and did not give sufficient time for faculty members to get well acquainted with this new mode of delivery. Due to workload and other responsibilities along with teaching faculty members faced time constraints to devote time for developing good e-content. Due to work from home practices, faculty also found it difficult to concentrate on their domicile with all the other familial distractions [70]. Managing this challenging work-life balance and contributing to a virtual learning environment resulted in individual faculty members making constant decisions about their priorities and participation levels [71]. The introduction of e-content especially asynchronous classes demanded higher levels of discipline, dedication, and time management from learners. Many times, improper time management from learners probed to be a challenge [72].

Learner engagement (B5). A traditional classroom setup permitted faculty to gauge the engagement levels of learners through their expressions, responses, class participation. In a virtual environment keeping learners engaged and measuring learner engagement poses to be a challenge. In a virtual set up it is difficult to recognize individual differences and meet the diverse needs of students. As per [73], it was important to focus on environmental characteristics, satisfaction levels of learners, and learners' characteristics for effective e-learning. A learner can be engaged only if the facilitator identified the learner's characteristics and can differentiate between different learning styles [74]. The attention span of a learner is limited, it was important to understand this and actively engage the learner. There is a need to plan the curriculum, document it in detail so that it could be available easily for different learners. [75] in their study observed that e-learners found it difficult to track their academic needs, hence it was important to provide a well-designed faculty support system [76]. A high

degree of faculty involvement and peer student support was important to keep learners engaged [66].

Table 2. Barriers to effective e-learning in the pandemic COVID-19

Serial Number	Identified Barriers	Author (Year)
B1	Lack of Required Skills	[5] [57] [58] [59] [60] [61]
B2	Lack of access to technology	[62] [63] [60] [64]
B3	Quality Concerns	[60] [65] [66] [67] [68] [61] [69]
B4	Time as a barrier	[70] [71] [72]
B5	Learner Engagement	[66] [73] [74] [75] [76]

3 Research methods

The research method had three major steps: The enablers and barriers to e-learning were identified based on extant literature review by thoroughly studying papers published in the journal of repute in Scopus, J-Stor, Emerald, Springer, Inderscience, etc. Both national and international studies were considered. Through this process, seven enablers and five barriers were identified. (Tables 1 and 2).

i. As a part of the ISM methodology, the identified enablers were validated through a survey with experts in the domain. Focus group discussions, semi-structured interviews and semi-structured questionnaire to gather expert opinions.
ii. Total Interpretive Structural Modelling (TISM) and the Matriced' Impacts Croise's Multiplication Appliquée a UN Classement (MICMAC) analysis were used to develop a model and understand the nature of linkages between the enablers and barriers to effective e-learning.

The Interpretive Structural Modelling (ISM) technique proposed by [77] in 1974 is a technique grounded in literature. It is quite often used to predict the relationship among the identified variables. ISM is an effective tool that is used to create logical links between the identified variables which helps in a holistic visual representation of the problem at hand. ISM as a technique is interpretive as it is based on the opinion of subject experts. It is structural as mathematical iterations are used to arrive at linkages between the identified variables. And the outcome is a Model that represents these linkages. ISM starts with the development of the structural self-interaction matrix (SSIM). For the development of the SSIM, the ISM methodology suggests that expert opinion should be used for defining the contextual relationship among the identified enablers and barriers to e-learning. This relation is denoted by V, A, X, O represented in Table 4. The SSIM was then converted into the initial reachability matrix using the rules laid down by ISM. The principle of transitivity was tested to arrive at the final reachability matrix. Total Interpretative Structural Modelling (TISM) is an extension of ISM proposed by [78]. It helps to overcome some of the key limitations of ISM by answering all the three key questions of theory building, i.e. what, how, and why while defining the relation between the identified variables.

3.1 Data collection

For the study, as per the ISM technique data was collected through expert opinion. The experts were categorized into three groups—students who are learners and the end receivers of the e-learning process, faculty members who are facilitators, and researchers who have contributed to the area of e-learning, and the third category included IT staff that support the process of e-learning. 50 experts were identified out of which 30 were undergraduate students located in different parts of India. The 30 students were e-learners who attended sessions in the virtual environment during the pandemic. 15 experts were faculty members and researchers who were conducting e-learning lectures or were researchers who have contributed significantly to the research area of e-learning. The remaining 5 experts were support staff who helped in processes, IT infrastructure, and digital infrastructure for e-learning. The data was collected with a focus on all key stakeholders involved in the process of e-learning. The sample size selected permitted the researchers to explore the research objective in-depth through in depth participation.

The methodology employed a thorough analysis of the research questions being explored. [79] proposed that for qualitative and studies that explore the depth of the topic under consideration the expert opinion should be of limited size as this would help get deeper insights into the study for both the participant and the researcher. 50 experts were selected for the study considering the depth of information required for the study. The experts were contacted from July 2020 to September 2020. Consent was taken from the experts before collecting data. Researchers used methods such as Focus groups, semi-structured interviews and semi-structured questionnaire to gather expert opinions. Focus group studies were conducted with students with discussions focussed on their experiences with e-learning. The group of 30 students were divided into three sub groups. During the discussions, the researchers posed questions related to the learner's experiences, perceptions, and views on the identified enablers and barriers. The prompts for the focus group discussions included accessibility, infrastructure used, inclination and motivation to learn online and time management. For example, one of the discussions revolved around whether and how technology impacted the motivation to learn, e readiness, knowledge sharing practices and flexibility to learn. Further prompts were given to identify the nature of the relation between technology and the identified enablers which were then translated into the structural self-interaction matrix. A semi-structured questionnaire was designed with a focus on the identified enablers and barriers and the nature of linkages between them. The questionnaire was floated among the faculty and support staff. The faculty and support staff were asked to fill questions that represented the V, A, X, O relation of the Self-Structured Interaction Matrix (SSIM). These symbols indicate the degree of association between the pairs of the variables. Once the questions were filled, in-depth interviews helped to understand the nature of relation which were translated into Table 11: transitive links of enablers and Table 12: transitive links of barriers. The tools were designed bearing in mind the TISM methodology to get responses on the nature of linkages between the identified enablers and barriers.

Table 3 shows the demographics of the identified group of experts.

Table 3. Demographics of the experts

Variable	Category	Respondents
Age (years)	15–25	30
	26–50	18
	Above 50	2
Gender	Male	18
	Female	32
Designation	Students (E Learner's)	30
	Faculty (E Facilitator's)	15
	Support Staff	05

3.2 Data analysis

The expert opinion was translated into the Structural Self Interaction Matrix. In this matrix, i and j represented the two parameters for which the relation had to be checked. The relationship was denoted by V, A, X, and O. Table 4 represents the relation between i and j.

Table 4. V, A, X, O interpretation for SSIM

Connotation	Indication	Implication
V	Indicates i influences j but j does not have an influence on i.	One way relation between the two variables.
A	Indicates i does not influence j but j influences i.	One way relation between the two variables.
X	Both i and j influence each other	Two way relation between the two variables.
O	Neither i nor j influence each other	No influence between the identified variables.

The SSIM derived for the enablers and barriers of effective e-learning is shown in Tables 5 and 6.

Table 5. SSIM for enablers (Authors contribution)

I/j → ↓	E7	E6	E5	E4	E3	E2	E1
E1	V	X	V	V	X	X	
E2	A	X	V	V	V		
E3	A	X	V	A			
E4	A	X	A				
E5	A	X					
E6	A	X					
E7	X						

Table 6. SSIM for barriers (Authors contribution)

I/j → ↓	B5	B4	B3	B2	B1
B1	V	A	V	A	
B2	V	X	X		
B3	A	A			
B4	X				
B5					

The SSIM is converted into the initial reachability matrix by converting V, A, X, O into binary digit form using the ISM guidelines. Tables 7 and 8 illustrate the initial reachability matrix for the enablers and barriers to effective e-learning.

Table 7. Initial reachability matrix for enablers (Authors contribution)

I/j → ↓	E1	E2	E3	E4	E5	E6	E7
E1	1	1	1	1	1	1	1
E2	1	1	1	1	1	1	0
E3	1	0	1	0	1	1	0
E4	0	0	1	1	0	1	0
E5	0	0	0	1	1	1	0
E6	1	1	1	1	1	1	1
E7	0	1	1	1	1	1	1

Table 8. Initial reachability matrix for barriers (Authors contribution)

I/j → ↓	B1	B2	B3	B4	B5
B1	1	0	1	0	1
B2	1	1	1	1	1
B3	0	1	1	0	0
B4	1	1	1	1	1
B5	0	0	1	1	1

Transitivity principle. The transitivity principle is applied to maintain the consistency of the derived model [80]. This principle helps to eliminate gaps in the variables. The final reachability matrix after taking care of transitivity is shown in Tables 9 and 10. The nature of the relationship is explained in Tables 11 and 12.

Table 9. Final reachability matrix for enablers (Authors contribution)

I/j → ↓	E1	E2	E3	E4	E5	E6	E7
E1	1	1	1	1	1	1	1
E2	1	1	1	1	1	1	0
E3	1	0	1	0	1	1	0
E4	0	0	1	1	0	1	0
E5	0	0	0	1	1	1	1*
E6	1	1	1	1	1	1	1
E7	0	1	1	1	1	1	1

Table 10. Final reachability matrix for barriers (Authors contribution)

I/j → ↓	B1	B2	B3	B4	B5
B1	1	0	1	0	1
B2	1	1	1	1	1
B3	0	1	1	0	0
B4	1	1	1	1	1
B5	0	0	1	1	1

Table 11. Transitive links of enablers from expert opinion and literature review (Authors contribution)

	E1	E2	E3	E4	E5	E6	E7
E1		Culture of learning, development, growth and support.	Promotes transparency, trust	Provides required support, infrastructure	Incentives, appraisal, intrinsic and extrinsic motivation	Encourages knowledge sharing practices	Investments in infrastructure
E2	Culture of learning, development, growth and support		Transparency and increased trust in the system	Opportunities for development	Improves morale of employees	Provides basis for knowledge capture and transfer.	
E3	Employee autonomy, flexibility				Improves intrinsic motivation	Flexibility is supported by access to knowledge.	
E4			Willingness to accept change			Creates strong inventory	
E5				Gain expertise and increase in extrinsic motivation			Facilitates e-learing by connecting to the end users.
E6	Encourages knowledge transfer		Access of information at any point of time.		Sense of cohesion and belonging		
E7		Facilitates training process		Provides access to various aps and tools.		Provides infrastructure for capturing and sharing information.	

Table 12. Transitive links of barriers from expert opinion and literature review (Authors contribution)

	B1	B2	B3	B4	B5
B1			Inability to design suitable curriculum for e content, improper evaluation		Inability to use tools to map learner engagement.
B2	Incompetence to learn and adopt new technology			Time management issues	Inability to use collaborative tools.
B3		Challenges in recording and measuring output.			
B4	Lack of time to prepare asynchronous content		Time to take in time feedback and correct action.		Time to understand learner requirement, learing styles and preferences.
B5			Inability to give timely feedback and engage with the learner.		

Level partitioning. The final reachability matrix helps in deriving the antecedent and reachability set. The intersection of the two sets is considered to perform a series of iterations to arrive at the different levels of the model. Tables 13 and 15 demonstrate the iteration performed to identify level 1 of enablers.

Table 13. Level partitioning of level 1 enablers (Authors contribution)

	Antecedent Set	Reachability Set	AS$\frown$RS	Level
E1	(1,2,3,4,5,6,7)	(1,2,3,6)	(1,2,3,6)	
E2	(1,2,3,4,5,6)	(1,2,6,7)	(1,2,6)	
E3	(1,3,5,6)	(1,2,3,4,6,7)	(1,3,6)	
E4	(3,4,6)	(1,2,4,5,6,7)	(4,6)	
E5	(4,5,6,7)	(1,2,3,5,6,7)	(5,6,7)	
E6	(1,2,3,4,5,6,7)	(1,2,3,4,5,6,7)	(1,2,3,4,5,6,7)	Level 1
E7	(2,3,4,5,6,7)	(1,5,6,7)	(5,6,7)	

The final levels are depicted in Tables 14 and 16.

Table 14. Level matrix for enablers

Enabler	Name	Level
E6	Knowledge Management Practices	1
E1	Institutional Culture	2
E7	Technology	3
E5	Motivation	3
E4	E readiness	4
E3	Flexibility in teaching-learning process	4
E2	Institutional capability and support	4

Table 15. Level partitioning of level 1 barriers (Authors contribution)

	Antecedent Set	Reachability Set	AS⌒RS	Level
B1	(1,3,5)	(1,2,4)	1	
B2	(1,2,3,4,5)	(2,3,4)	(2,3,4)	Level 1
B3	(2,3)	(1,2,3,4,5)	(2,3)	
B4	(1,2,3,4,5)	(2,4,5)	(2,4,5)	
B5	(3,4,5)	(1,2,4,5)	(4,5)	

Table 16. Level matrix for barriers

Barriers	Name	Level
B2	Lack of access to technology	1
B4	Time as a barrier	2
B5	Learner Engagement	2
B1	Lack of required skills	3
B3	Quality concerns	3

4 Results and discussions

Through the study, the researchers have tried to identify the enablers and barriers to e-learning with special emphasis on practices that were followed during the pandemic. In the study, the researchers undertook an extensive literature review to give insights to published research in this area, and this formed the basis to identify the enablers and barriers to effective e-learning. TISM and Fuzzy MICMAC as a methodology was opted to identify the nature of linkages between the identified variables. The study is based on the opinion and experiences of the key players who were involved in the process of e-learning i.e. the faculty as facilitators, students as receivers, and staff as support providers for e-learning. Focus groups, semi-structured interviews and semi-structured questionnaire were used to gather expert opinions. Focus group studies were conducted with students with discussions focused on their experiences with e-learning. A semi-structured questionnaire was designed with a focus on the identified enablers and barriers and the nature of linkages between them. The questionnaire was floated among the faculty and support staff. In depth interviews were then conducted to understand the nature of

relation between the identified enablers and barriers to e- learning better. The analysis from the study has been divided into four sub-sections that discuss the TISM model on enablers that facilitate the process of e-learning (Figure 1), the TISM model on barriers that posed as challenges to smoothly implements e-learning during the pandemic (Figure 2). Fuzzy MICMAC analysis of enablers for e-learning (Figure 3) that depicts the classification of the identified enablers and Fuzzy MICMAC analysis of disablers for e-learning (Figure 4) that categorizes the identified disablers.

4.1 TISM model

TISM model on enablers for e-learning during the pandemic.

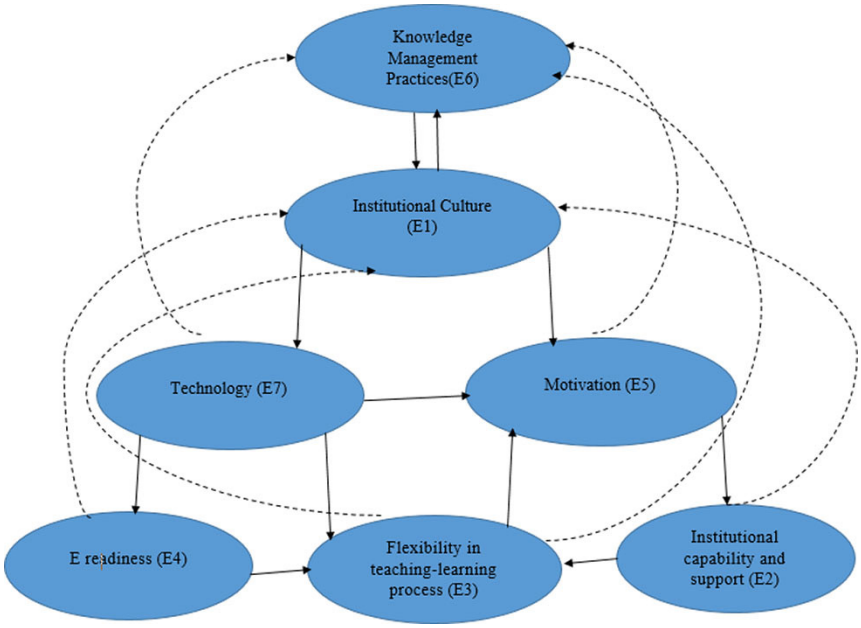

Fig. 1. TISM model of enablers of e-learning during the pandemic (Authors contribution)

E-learning or Electronic learning is now a vital component of the teaching-learning process in the majority of institutions worldwide. E-learning has opened new doors of opportunities to the educational institution and thus has "vital strategic importance" in most of the institutions around the globe. As shown in Figure 1, the TISM model shows that knowledge management practice is level 1 of the model. These practices are an important enabler for e-learning. Investment in infrastructure to capture knowledge, transfer knowledge is vital for the success of e-learning. Knowledge inventory, digital library, access to E-resources is necessary for the facilitators and end-users of e-learning. The institutional culture in level 2 is responsible for encouraging such practices. A culture of trust, transparency, and honesty is important to ensure that faculty are comfortable sharing knowledge. This culture impacts the degree to which an institute invests in technology. A culture that recognizes the efforts of both faculty and learners is important to increase the motivation to dwell in the e-learning environment.

This would subsequently impact the level of e-readiness i.e. the level that the faculty is willing to adapt to this new change in the pandemic, the extent to which faculty develop themselves to embrace this new mode of delivery. It would encourage flexibility in time, location for smooth delivery and would also help develop institutional capability.

TISM model of barriers to e-learning during the pandemic.

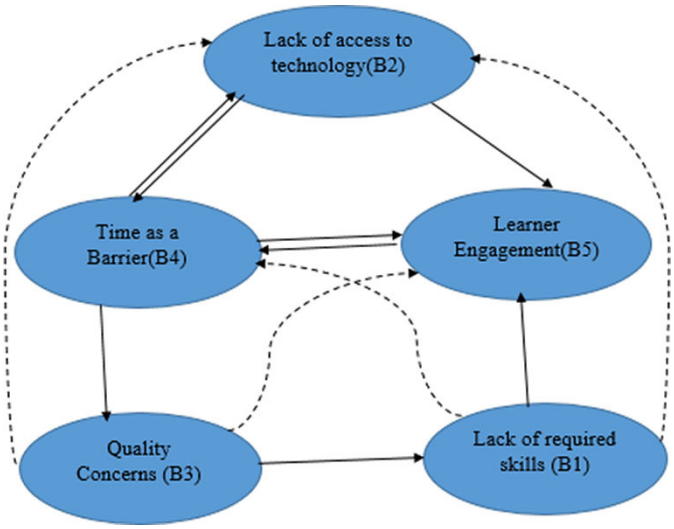

Fig. 2. TISM model of barriers to e-learning during the pandemic (Authors contribution)

Figure 2 represents the TISM model of barriers to e-learning during the Pandemic. Lack of access to technology has been identified as the most significant barrier. Technology is the backbone of e-learning. Due to the sudden pandemic and as a response to the switch to e-learning, not all institutes, faculty, and students were ready with the required technology to smoothly conduct and attend e-learning classes. This would include the physical infrastructure of systems, internet as well as software and tools required for e-learning. This has impacted the levels of learner engagement. Findings from various research studies have shown that technology has an impact on the engagement level of learners. Lack of access to basic infrastructures such as computers and the internet is a true reality for a significant fraction of students. The online mode demands higher levels of commitment, discipline, and time management. If time is not properly managed, the result would be backlogs in viewing the asynchronous content. This would have an impact on the overall quality of e-learning.

4.2 Fuzzy MICMAC (Matriced' Impacts Croise's Multiplication Appliquée a UN Classement) analysis

The traditional MICMAC analysis used binary digits from the final reachability matrix to arrive at the driving and dependent powers of variables. Based on the driving and dependence powers the variables are classified into four categories. An up-gradation to this approach is the Fuzzy MICMAC analysis that considers values in between the 0–1 scale. The group of experts was approached to rate on a scale shown in Table 17

the level of importance and associability between the identified enablers and barriers to e-learning. The multiplication of the fuzzy matrix is based on the principles of the Boolean matrix multiplication [81].

Table 17. Associability of values

Associability	No	Very Low	Low	Medium	High	Very High	Complete
Value	0	0.1	0.3	0.5	0.7	0.9	1

Tables 18 and 19 represent the fuzzy MICMAC analysis for Enablers and barriers of e-learning derived from the final reachability matrix. These tables are important in order to identify the driving and dependent powers of the variables.

Table 18. Fuzzy reachability matrix for enablers (Authors contribution)

I/j → ↓	E1	E2	E3	E4	E5	E6	E7	Driving Power
E1	0	0.9	0.5	0.5	0.9	0.7	0.7	4.2
E2	0.9	0	0.5	0.7	0.7	0.5	0	3.3
E3	0.5	0	0	0	0.3	0.5	0	1.3
E4	0	0	0.5	0	0	0.5	0	1.0
E5	0	0	0	0.7	0	0.3	0.7	1.7
E6	0.7	0.5	0.5	0.5	0.3	0	0.7	3.2
E7	0	0.5	0.7	0.7	0.7	0.7	0	3.3
Dependence Power	2.1	1.9	2.7	3.1	2.9	3.2	2.1	

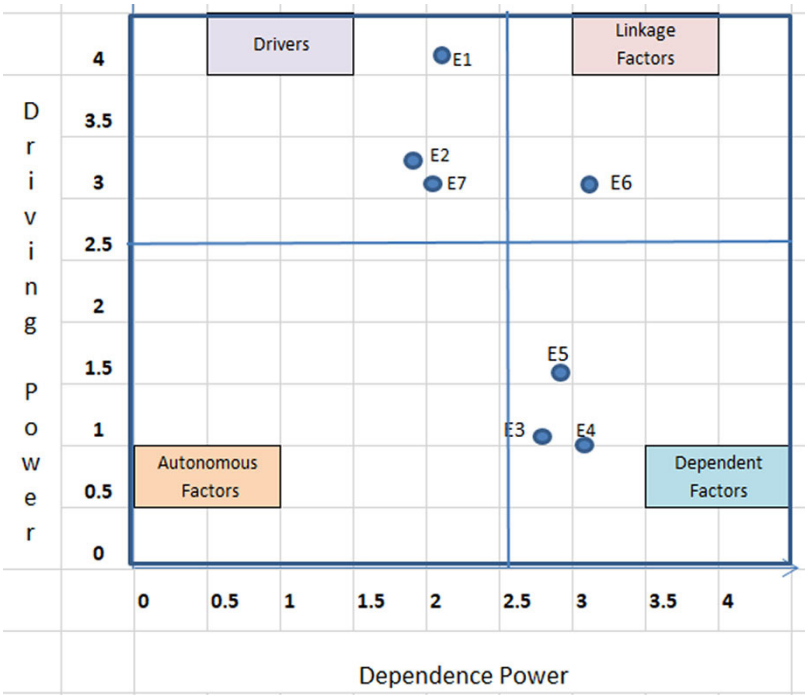

Fig. 3. Fuzzy MICMAC analysis of enablers for e-learning

The fuzzy MICMAC analysis in Figure 3 shows that Institutional Culture (E1), institutional capability and support (E2), technology (E7) are the drivers of the model. These are enablers that have strong driving power and weak dependence power. Institutional culture is a key driver that facilitates the smooth implementation of e-learning in an institute. In the TISM model as well, institutional culture holds significant importance. Knowledge management practices (E6) is a linkage variable that has high driving and dependence power. Flexibility (E3), E readiness (E4), and Motivation (E5) have been identified as dependent variables that have high dependence power and weak driving power. There are no autonomous variables in the model.

Table 19. Fuzzy reachability matrix for barriers to e-learning (Authors contribution)

I/j → ↓	B1	B2	B3	B4	B5	Driving Power
B1	0	0	0.9	0.5	0.7	2.1
B2	0.7	0	0.5	0.7	0.7	2.6
B3	0.9	0.5	0	0.9	0	2.3
B4	0.5	0.7	0.9	0	0.7	2.8
B5	0	0	1	0.7	0	1.7
Dependence Power	2.1	1.2	3.3	2.8	2.1	

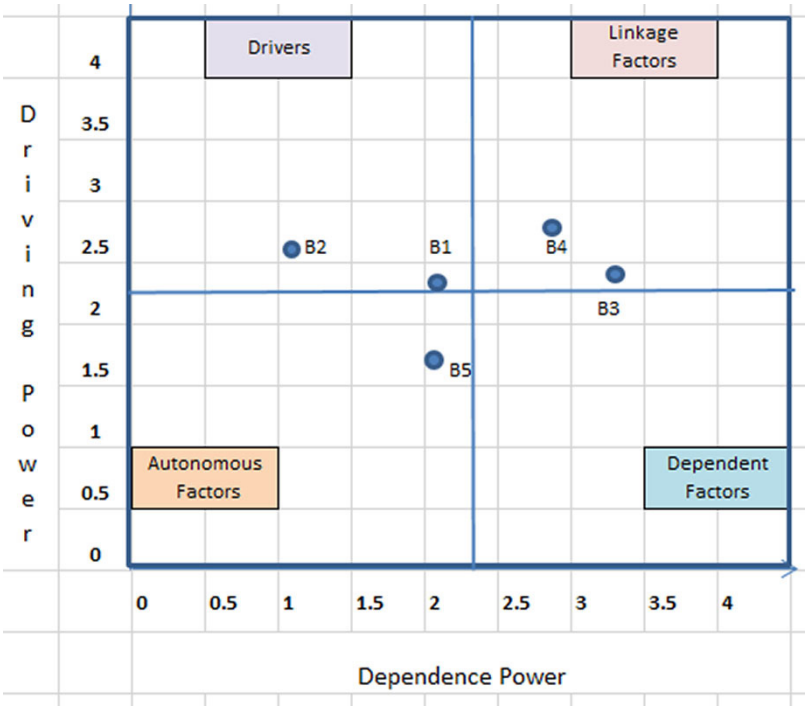

Fig. 4. Fuzzy MICMAC analysis of barriers to e-learning

The fuzzy MICMAC analysis as shown in Figure 4 demonstrates that the lack of required skills (B1), lack of access to technology (B2), are the drivers of the model.

These are the barriers that have strong driving power and weak dependence power. Lack of access to technology is the key barrier that impacts the delivery of e-learning. In the TISM model as well, lack of access to technology holds significant importance. Quality concerns (B3) and Time (B4) are linkage variables that have high driving and dependence power. Learner engagement (B5) has been identified as an autonomous variable that has low dependence power and low driving power. There are no dependent variables in the model.

4.3 Implication of the research

The study has attempted to identify the enablers and barriers to e-learning with an understanding of the nature of linkages between them. The first proposed model is a three-level TISM model that focuses on institutional culture, technology, knowledge management practices, motivation, e-readiness, and institutional capability as variables that would encourage the successful implementation of e-learning practices during the pandemic. The second proposed model focuses on the ill effects of lack and unequal access to technology, time as a barrier, engagement levels, lack of required skills, and quality concerns as challenges that obstruct the smooth implementation of e-learning.

The study highlights the need for policymakers of universities and higher education institutes to focus on these identified enablers and disablers. This would help drive the successful implementation of e-learning. The focus on support and training would enable faculty to derive the required skill set to successfully facilitate the e-learning process. There should be a robust system to encourage knowledge management practices that would enable knowledge capture and aid free knowledge transfer. This would benefit the University, institutes, faculty, and students. This would also enable students as primary learners to benefit from the synchronous and asynchronous mode of learning. The study shows that while formulating guidelines for e-learning during the pandemic, adequate emphasis should be laid on addressing diverse needs of students with different learning capabilities and there should be an emphasis on training required not only for faculty members but also support staff. Also, available technology must be used in an effective manner as this is one of the major issues faced by administrators [82]. The study would help the management of institutions in identifying areas in need of development and strategic decisions about e-learning directions for the institution as a whole.

5 Limitations and scope for further research

The paper has adopted the TISM methodology which is based on the experiences and expertise of experts. Biasness from experts cannot be ignored and is a challenge. The fuzzy MICMAC analysis is also based on expert opinion which could be biased based on the expert's perception. The derived models can be validated using a structured questionnaire followed by statistical analysis. The study is based on the opinion of 50 experts who belong to three different categories and could be further extended by further studying each group independently and assigning different weights to each sub-group in the model.

6 Conclusion

This research explores the role of e-learning in higher education institutions to facilitate continuous learning during the pandemic by examining the enablers and challenges using a literature review. The researchers have attempted to identify the nature of linkages and relations between these identified enablers and barriers to e-learning using TISM and fuzzy MICMAC analysis. The development of appropriate institutional policies is paramount. The policies should reflect flexibility, access, learning styles, and infrastructure support. This study has helped to highlight the factors that drive the successful implementation of e-learning. These include institutional culture, support and infrastructure, flexibility, E readiness, motivation, knowledge management practices and technology. The study has also raised many issues that need to be considered while framing policies around e-learning. Digital learning formats and elements can be used for enriching classroom teaching. A traditional university that follows the "brick and mortar" teaching principles needs to take steps towards e-learning initiatives to ensure that learning does not stop during the pandemic [83] which is believed to have created an environment of uncertainty in the present society [84]. E-learning provides the learner more comfort, flexibility and access to a variety of information [85]. The focus should be on removing hurdles such as lack of access to technology, lack of skills, quality issues, barriers to learner engagement, and time barriers to ensure the effectiveness of e-learning [36]. The framework proposed in the paper has attempted to shed light on the influential factors that contribute to the virtual learning environment. Policymakers in the area of higher education may choose to focus either in all or only on selective factors that could enhance the effectiveness of teaching and learning in the virtual environment. It is important for policy makers to understand the linkages between the different factors that affect e learning highlighted in the TISM models and fuzzy MICMAC analysis. This would help them understand the effect of the policy on different aspects of e learning. It may be concluded that the pandemic has been a major driver for institutes to switch to the new normal mode of learning i.e. e-learning. However, there is a need to look beyond and define strategies to incorporate e-learning through a blended learning approach even post the pandemic.

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