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Developing Interpretive Structural Model for Technology Framework in Higher Education's Quality and Sustainability

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INTRODUCTION

Critical Success Factors (CSFs) are key elements or conditions necessary for the success and effectiveness of a specific goal or objective. In the context of higher education and its quality enhancement, several CSFs play a crucial role in ensuring an effective and impactful educational experience. There are some of these critical success factors like Faculty Quality and Expertise, Curriculum and Program Design, Student Engagement and Support, **Technology**, Learning Resources and Facilities, Assessment and Evaluation, Research and Innovation Culture, Collaborations and Industry Engagement, Quality Assurance and Accreditation, Student-Centric Approach, Ethical and Inclusive Practices. Addressing these critical success factors collectively ensures a comprehensive approach to enhancing the quality of higher education and ultimately preparing students for success in their chosen fields. [1]

Quality in higher education refers to the overall excellence, effectiveness, and appropriateness of educational programs, services, and outcomes provided by institutions of higher learning. It encompasses various elements that contribute to a positive educational experience and the successful development of students. Some key aspects related to quality in higher education include Academic Excellence, Faculty Competence, Research and Innovation, Infrastructure and Facilities, Student-Centric Approach, Accreditation and Compliance, Assessment and Continuous Improvement, Inclusivity and Diversity, Stakeholder Engagement, Ethical and Professional Standards. Overall, quality in higher education is a multidimensional concept that requires a holistic approach, encompassing academic, social, and administrative aspects to provide a well-rounded and impactful educational experience.[2]

Sustainability in higher education refers to the integration of environmental, social, and economic considerations into the core functions of universities and colleges. It involves fostering a culture of responsible resource management, promoting environmental stewardship, addressing social equity, and ensuring economic viability. Sustainable practices in higher education aim to minimize negative impacts on the environment, society, and economy while preparing students to be responsible global citizens. This includes incorporating sustainable principles into curriculum, research, campus operations, community engagement, and partnerships, all with the goal of creating a more sustainable future for all.[3]

Technology in higher education refers to the integration and utilization of various technological tools, applications, and platforms to enhance the teaching, learning, research, and administrative processes within the higher education sector. This integration is aimed at improving educational outcomes, increasing accessibility, fostering collaboration, and streamlining administrative tasks. Key components of technology in higher education includes: Online Learning Platforms, E-Learning and Digital Content, Blended Learning, Virtual Classrooms and Webinars, Flipped Classroom Approach, Adaptive Learning, Educational Apps and Gamification, Data Analytics and Learning Assessment, Collaborative Tools and Communication Platforms, Virtual Reality (VR) and Augmented Reality (AR). Integration of these technologies empowers educators to cater to diverse learning styles, promote critical thinking and problem-solving, increase engagement, and prepare students for a technology-driven future. Additionally, it allows higher education institutions to expand their reach and offer flexible learning options, including online and hybrid programs.[4]

The ISM (Interpretive Structural Modeling) method is a structured approach used for analyzing complex systems and understanding relationships among various elements within the system. It originated in the field of operations research and management science. ISM focuses on depicting the interdependencies and hierarchical relationships among different components or elements in a system. Key features of the ISM method include: Element Identification, Pair wise Comparison, Relation Matrix, Reachability Matrix, Structural Self-Interaction Matrix, ISM Hierarchy, Final Model and Interpretation. ISM is often used in various fields, including strategic management, organizational analysis, policy formulation, technology management, and more, to aid decision-making and understanding of complex systems.[5]

In this paper an empirical study was conducted to develop a structural model (ISM) with level of importance to different enablers of technology indentified to achieve quality & sustainability in higher education. Based on the literature review and pilot test with opinion from eminent academicians certain elements, indicators and strategic issues in technology were identified. The ISM was applied to prioritize these elements qualitatively, and thereby propose a hierarchical structure based on sequencing, and categorization.

THEORITICAL BACKGROUND

Technology has significantly impacted higher education, enhancing both the quality and sustainability of academic programs and institutions. This impact can be understood through several key dimensions like:-

1) **Access and Inclusivity:** Technology has expanded access to education by breaking down geographical barriers and enabling remote learning. Online courses, virtual classrooms, and digital libraries provide opportunities for students from diverse backgrounds and locations to participate in higher education.
2) **Personalized Learning:** Adaptive learning technologies utilize data analytics and machine learning to tailor learning experiences to individual student needs. Personalized learning paths, adaptive assessments, and customized content delivery help students learn at their own pace and in alignment with their specific learning styles and abilities.
3) **Collaborative Learning:** Educational technology fosters collaboration and interaction among students and educators. Virtual classrooms, online discussion forums, and collaborative document editing tools facilitate teamwork, knowledge sharing, and peer learning.
4) **Enhanced Teaching and Learning Resources:** Digital platforms offer a plethora of educational resources such as e-books, open educational resources (OERs), interactive simulations, multimedia content, and educational apps. These resources enhance the learning experience by providing diverse and engaging materials.
5) **Assessment and Feedback:** Technology enables efficient and timely assessment through automated grading, online quizzes, and instant feedback. Learning analytics provide insights into student performance, allowing educators to identify areas for improvement and tailor their teaching strategies.
6) **Efficiency and Cost-Effectiveness:** Learning management systems (LMS) streamline administrative tasks, course management, and communication, resulting in cost savings and operational efficiency for educational institutions. Virtual classrooms reduce the need for physical infrastructure and associated expenses.
7) **Research and Innovation:** Advanced technologies, such as big data analytics, artificial intelligence (AI), and virtual reality (VR), enhance research capabilities and promote innovation in higher education. Researchers can analyze vast amounts of data, simulate complex models, and conduct virtual experiments.
8) **Sustainability:** Technology supports sustainability efforts in higher education through the reduction of paper usage, energy-efficient infrastructure, and remote collaboration. Digital platforms minimize the need for physical resources and contribute to environmental conservation.
9) **Professional Development:** Online platforms offer continuous professional development opportunities for educators, enabling them to enhance their skills and stay updated with the latest advancements in their respective fields.

10) **Global Learning Communities:** Technology facilitates the creation of global learning communities, allowing students and educators to connect with peers and experts worldwide, fostering a diverse and inclusive educational environment.

In summary, technology plays a crucial role in shaping the quality and sustainability of higher education by improving access, personalizing learning, enhancing collaboration, providing rich learning resources, enabling efficient assessment, promoting research and innovation, supporting sustainability efforts, and fostering a globalized educational landscape.[6]

EMPIRICAL STUDY

A. **Objective of the study**

This study has been conducted with the objectives of finding the role of technology in the quality and sustainability of higher education in Indian context with identification, sequencing categorization and prioritizing technology characteristics and structuring into a systematic model.

B. **Methodology**

a. Scope of the study: The study was confined to the city of Dehradun, India. On the basis of random and convenience sampling institutions imparting graduate and post graduate degrees/diplomas were chosen. Within such institutions, the respondents were selected by stratified random sampling.
b. Variable conceptualization: Various theoretical and empirical studies of technology role in the quality & sustainability of higher education were reviewed and measures and indicators of educational performance were identified. The pilot study was conducted to examine the validity and reliability of the scale facilitated the identification of quantitative and statistically proven items and attributes. Qualitative validity was tested through the theoretical study as well as through expert comments. The focus of the study is on "technology system framework," which is essentials that an educational institution must possess in order to satisfy the needs and wants of the stakeholder and customer groups.
c. *Technique used for the study*: Interpretive Structural Modeling (ISM) technique was applied on these quality characteristics to establish linkage between them and identify them as enablers.

INTERPRETIVE STRUCTURAL MODELING (ISM)

Interpretive structural modelling (ISM) is an analysis method proposed by Professor J. Warfield of the USA in 1973 [11]. Interpretive Structural Modeling (ISM) is an effective methodology for dealing with complex issues. It has been used for over 25 years to understand complex situations and find solutions to complex problems. ISM is often used to provide fundamental understanding of complex situations, as well as to put together a course of action for solving a problem. ISM can be used for identifying and summarizing relationships among specific variables, which define a problem or an issue. Based on these identified relationships, the overall structure is extracted ISM structure from the complex set of variables. It is intended as a group learning process; however, in some cases, ISM is used individually. [10]. It provides us a means by which order can be imposed on the complexity of such variables.[7] In this research, technology system in higher education, in Indian institutes has been analyzed using the ISM methodology, which shows the interrelationship of different enablers of technology system in higher education and their levels. Higher education institutions (HEIs) have been regarded as the essential party for accomplishing sustainable development (SD) [8]. These are also categorized depending on their driving power and dependence. After a review of the literature and expert opinion of the survey response from higher education institutes in education hub of the central India, Dehradun following 14 enablers has been identified. The literature review, together with the experts' opinion, was used in developing the relationship matrix, which is later used in the development of an ISM model. Figure 1 clearly shows flow diagram for the methodology adopted for the ISM.

Enablers

1) Access to Learning Resources
2) Personalized Learning
3) Interactive Learning
4) Collaborative Learning
5) Real-world Simulations
6) Data Analytics and Learning Insights
7) Remote Learning and Access to Experts
8) Multimodal Content Delivery
9) Flipped Classroom Approach
10) Assessment and Feedback
11) Augmented and Virtual Reality (AR/VR)
12) Mobile Learning
13) AI-Powered Tutoring and Support
14) Digital Citizenship and Safety

A. ISM Methodology & Model Development

In this section, a rendition of the steps taken towards model development based on the ISM methodology is provided [9]. The methodology of ISM is an interactive learning process. In this a set of different and directly related variables affecting the technology system under consideration is structured in to a comprehensive systematic model. The beauty of ISM model is that it portrays the structure of complex issues of the problem under study, in a carefully designed pattern employing graphics as well as words. The methodology of ISM can act as a tool for imposing order and direction on the complexity of relationship among elements of a system These criteria have also been categorized depending on their driver power and dependence. The ISM can be judiciously employed for getting better insights into the present case of strategic information modeling. The ISM methodology is interpretive from the fact that as the judgment of the group decides whether and how the variables are related. It is structural too, as on the basis of relationship; an overall structure is extracted from the complex set of variables. It is a modeling technique in which the specific relationships of the variables and the overall structure of the system under consideration are portrayed in a digraph model. ISM is primarily intended as a group learning process, but it can also be used individually. [7]

The steps suggested by reference [7] for implementing for implementing ISM methodology are

Step 1: Variables affecting the system under consideration are listed, which can be objectives, actions and individuals etc.

Step 2: From the variables identified in step 1, a contextual relationship is established among variables with respect to which pairs of variables would be examined.

Step 3: A Structural Self-Interaction Matrix (SSIM) is developed for variables, which indicates pair wise relationships among variables of the system under consideration.

Step 4: Reachability matrix is developed from the SSIM and the matrix is checked for transitivity. The transitivity of the contextual relation is a basic assumption made in ISM. It states that if a variable A is related to B and B is related to C, then A is necessarily related to C.

Step 5: The reachability matrix obtained in Step 4 is partitioned into different levels.

Step 6: Based on the relationships given above in the reachability matrix, a directed graph is drawn and the transitive links are removed.

Step 7: The resultant digraph is converted into an ISM, by replacing variable nodes with statements.

Step 8: The ISM model developed in Step 7 is reviewed to check for conceptual inconsistency and necessary modifications are made

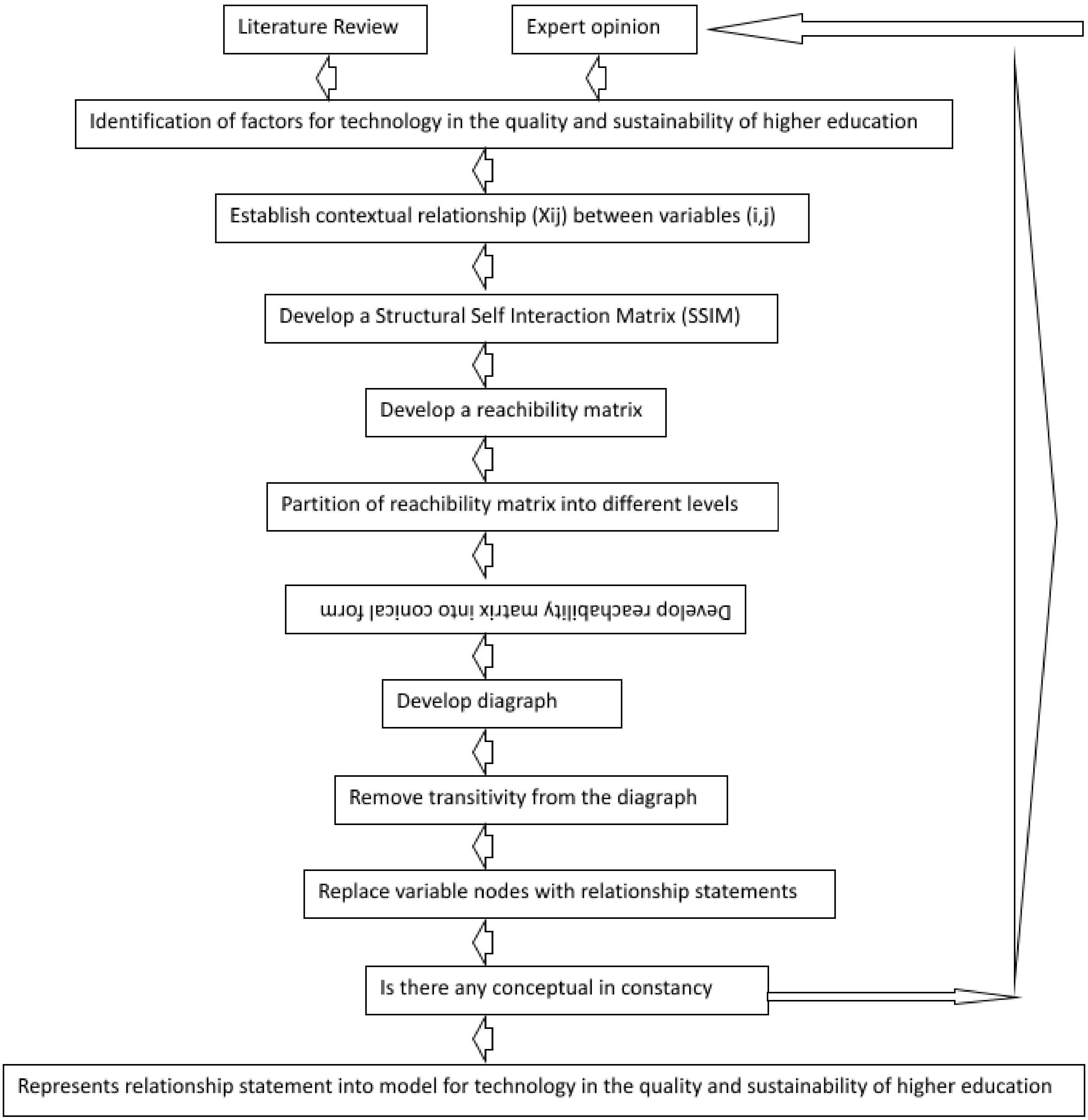

Fig.1 ISM based methodology

B. Structural Self-Interaction Matrix (SSIM)

ISM methodology suggests the use of the expert opinions based on various management techniques such as brain storming, nominal technique, etc., in developing the contextual relationship among the variables. Thus, in this research for identifying the contextual relationship among the technology system variables academia, were consulted for the same. These experts from the academia were well familiar to the use of technology in higher education.

1) For analyzing the technology variables in higher education, a contextual relationship of b leads to Q type is chosen. This means that one variable leads to another variable. Based on this, contextual relationship between the variables is developed (Table I). Keeping in mind the contextual relationship for each variable, the existence of a relation between any two variables (i and j) and the associated direction of the relation is questioned. As suggested by Sage (1977), four standards symbols (i and j) are used to denote the direction of relationship between the variables.

V: Variable i will help alleviates j ;

A: Variable j will be alleviated by Variable i ;

X: Variables i and j will help achieve each other; and

O: Variables i and j are unrelated.

2) Reachability matrix was developed from the SSIM by expressing the information in each cell entry of the SSIM into 1s and 0s (Table II).
3) The reachability matrix was partitioned on the basis of the reachability and antecedent sets for each of the variables, and, through a series of iterations, these were grouped into various levels [Tables III(A) and III(B)].
4) The reachability matrix was then converted to a conical form, based on the 0and 1 relationship (i.e. absence and presence of relationships) (Table IV).
5) A directed graph, was drawn portraying direct and indirect relationships through arrows, and then converted into an ISM, by replacing elements/codes with the statement of the respective design characteristics (Figure 2).

Table I. Structural Self-Interaction Matrix

	14	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
1	X	V	O	A	V	X	O	V	X	A	X	V	V	
2	X	V	A	A	V	V	A	V	V	V	V	V		
3	V	V	A	A	V	A	A	X	V	X	X			

Table II. Reachability Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1	1	1	1	0	1	1	0	1	1	0	0	1	1
2	0	1	1	1	1	1	1	0	1	1	0	0	1	1
3	0	0	1	1	1	1	1	0	0	1	0	0	1	1
4	1	0	1	1	0	1	1	0	1	1	0	0	1	1
5	1	0	1	1	1	1	0	0	0	1	0	0	1	1
6	1	0	0	1	0	1	1	0	0	1	0	0	1	1
7	0	0	1	0	0	1	1	0	0	1	0	0	1	1
8	0	1	1	0	0	1	1	1	1	1	0	0	1	1
9	1	0	1	1	0	1	0	0	1	1	0	0	1	1
10	0	0	0	0	0	0	0	0	0	1	0	0	1	1
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	0	1	1	1	1	1	1	1	1	1	1	1	1	1
13	0	0	0	0	0	0	0	0	0	0	0	0	1	1
14	1	1	0	0	0	0	0	0	0	0	0	0	1	1

Table III (A). Level of elements (Partitioning the reachability matrix based on 10 iterations)

Enablers	Reachability	Antecedents	Intersection	Level
1	1,2,3,4,6,7,9,10,13,14	1,4,5,6,9,11,14	1,4,6,9,14	VII
2	2,3,4,5,6,7,9,10,13,14	1,2,8,11,12,14	2,14	VI
3	3,4,5,6,7,10,13,14	1,2,3,4,5,7,8,9,11,12	3,4,5,7	IV
4	1,3,4,6,7,9,10,13,14	1,2,3,4,5,6,9,11,12	1,3,4,6,9	IV
5	1,3,4,5,6,10,13,14	2,3,5,11,12	3,5	VII
6	1,4,6,7,10,13,14	1,2,3,4,5,6,7,8,9,11,12	1,4,6,7	III
7	3,6,7,10,13,14	1,2,3,4,6,7,8,11,12	3,6,7	III
8	2,3,6,7,8,9,10,13,14	8,11,12	8	VII
9	1,3,4,6,9,10,13,14	1,2,4,8,9,11,12	1,4,9	V
10	10,11,13,14	1,2,3,4,5,6,7,8,9,11,12	1,10	II
11	1,2,3,4,5,6,7,8,9,10,11,12,13,14	11	11	IX
12	2,3,4,5,6,7,8,9,10,12,13,14	11,12	12	VIII
13	13,14	1,2,3,4,5,6,7,8,9,10,11,12,13,14	13,14	I
14	1,2,13,14	1,2,3,4,5,6,7,8,9,10,11,12,13,14	1,2,13,14	I

Table III (B). Level of elements (Partitioning the reachability matrix based on 10 iterations)

Enablers	Reachability	Antecedents	Intersection	Level
13	13,14	1,2,3,4,5,6,7,8,9,10,11,12,13,14	13,14	I
14	1,2,13,14	1,2,3,4,5,6,7,8,9,10,11,12,13,14	1,2,13,14	I
10	10,11,13,14	1,2,3,4,5,6,7,8,9,11,12	1,10	II
6	1,4,6,7,10,13,14	1,2,3,4,5,6,7,8,9,11,12	1,4,6,7	III
7	3,6,7,10,13,14	1,2,3,4,6,7,8,11,12	3,6,7	III
3	3,4,5,6,7,10,13,14	1,2,3,4,5,7,8,9,11,12	3,4,5,7	IV
4	1,3,4,6,7,9,10,13,14	1,2,3,4,5,6,9,11,12	1,3,4,6,9	IV
9	1,3,4,6,9,10,13,14	1,2,4,8,9,11,12	1,4,9	V
2	2,3,4,5,6,7,9,10,13,14	1,2,8,11,12,14	2,14	VI
1	1,2,3,4,6,7,9,10,13,14	1,4,5,6,9,11,14	1,4,6,9,14	VII
5	1,3,4,5,6,10,13,14	2,3,5,11,12	3,5	VII
8	2,3,6,7,8,9,10,13,14	8,11,12	8	VII
12	2,3,4,5,6,7,8,9,10,12,13,14	11,12	12	VIII
11	1,2,3,4,5,6,7,8,9,10,11,12,13,14	11	11	IX

	13	**14**	**10**	**6**	**7**	**3**	**4**	**9**	**2**	**1**	**5**	**8**	**12**	**11**	**Driving Power**
13	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2
14	1	1	0	0	0	0	0	0	1	1	0	0	0	0	4
10	1	1	1	0	0	0	0	0	0	0	0	0	0	0	3
6	1	1	1	1	1	0	1	0	0	1	0	0	0	0	7
7	1	1	1	1	1	1	0	0	0	0	0	0	0	0	6
3	1	1	1	1	1	1	1	0	0	0	1	0	0	0	8
4	1	1	1	1	1	1	1	1	0	1	0	0	0	0	9
9	1	1	1	1	0	1	1	1	0	1	0	0	0	0	8
2	1	1	1	1	1	1	1	1	1	0	1	0	0	0	10
1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	10
5	1	1	1	1	0	1	1	0	0	1	1	0	0	0	8
8	1	1	1	1	1	1	0	1	1	0	0	1	0	0	9
12	1	1	1	1	1	1	1	1	1	0	1	1	1	0	12
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
Dependent	14	14	12	11	9	10	9	7	6	7	5	3	2	1	

Table IV. Conical Form of Reachability Matrix

C. **Formation of ISM-based Model**

From the final reachability matrix, the structural model is generated. If the relationship exists between the variables *j* and i, an arrow pointing from *i* to j shows this. This resulting graph is called a digraph. The digraph is finally converted into the ISM model as shown in Figure 2. It is observed that Augmented and Virtual Reality is a very significant variable for the technology system in the quality and sustainability of higher education in the central Indian educational institutes at Dehradun as it comes as the base of the ISM hierarchy. AI-Powered Tutoring and Support & Digital Citizenship and Safety are appeared at the top of the hierarchy.

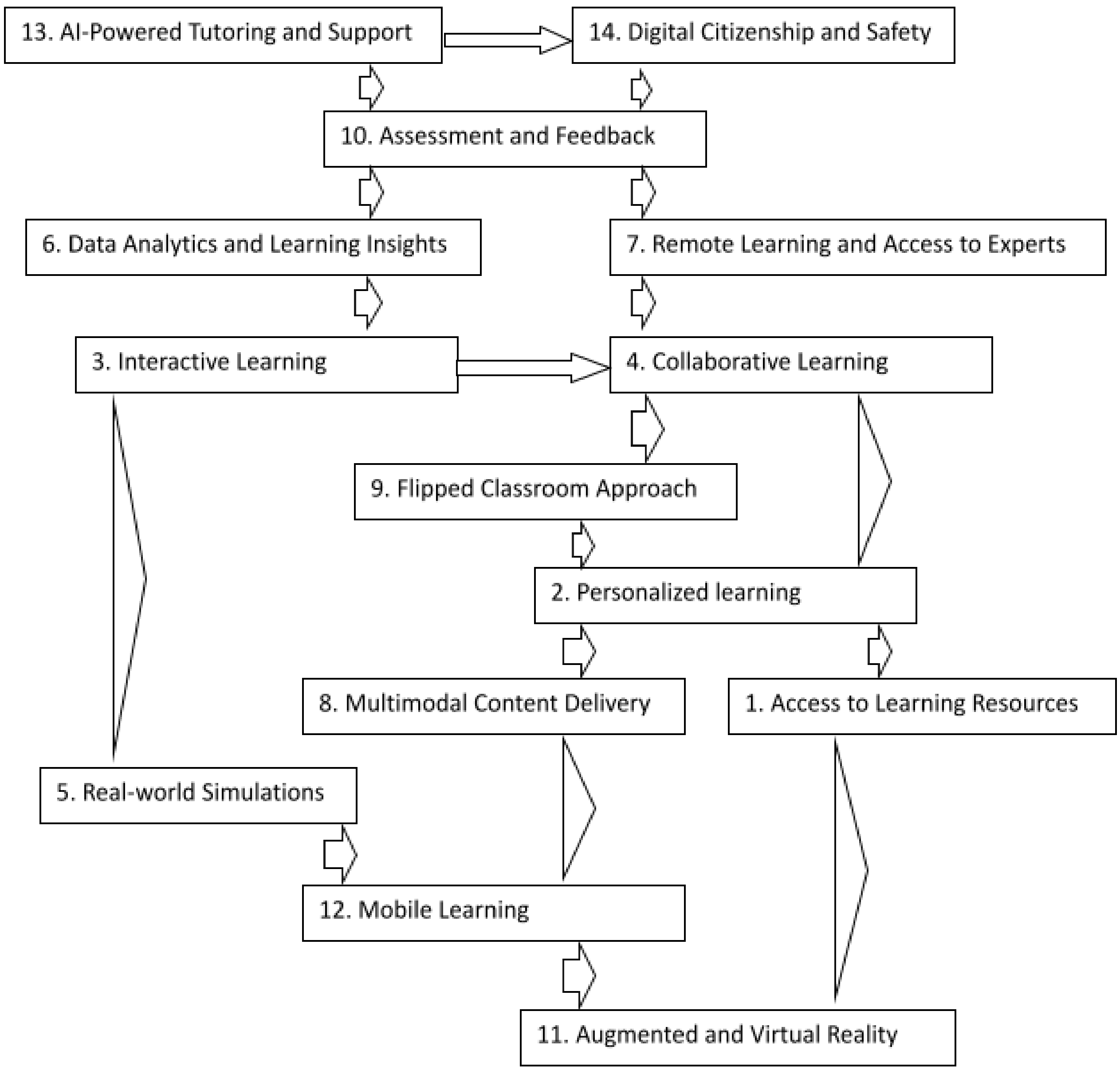

Fig.2 Interpretive Structural Modeling

D. Micmac Analysis

It is called the *Matrice d'Impacts Croisés Multiplication Appliquée á un Classeement*, (cross impact analysis) or MICMAC Analysis, developed by Michel Godet in 1975.The objective of the MICMAC analysis is to analyze the driver power and the dependence power of the variables [12]

The variables are classified into four clusters (Fig.3). The first cluster consists of the autonomous variables T that have weak driver power and weak dependence. These variables are relatively disconnected from the system, with which they have only few links, which may be strong. Second cluster consists of the dependent variables that have weak driver power but strong dependence. Third cluster has the linkage variables that have strong driving power and also strong dependence. These variables are unstable in the fact that any action on these variables will have an effect on others and also a feedback on themselves. Fourth cluster includes the independent variables having strong driving power but weak dependence. It is observed that a variable with a very strong driving power called the key variables, falls into the category of independent or linkage variables. The driving power and the dependence of each of these variables are shown in Table: IV. In this table, an entry of 1' along the columns and rows indicates the dependence and driving power, respectively. Subsequently, the driver power dependence diagram is constructed which is shown in Figure. 3.

Driving Power

14	11												
13													
12		12	**IV**							**III**			
11													
10				5		2	1						
9			8					4					
8							9			3			
7											6		
6								7					
5			**I**							**II**			
4													14
3												10	
2													13
1													
1		2	3	4	5	6	7	8	9	10	11	12 13 14	

Dependence

Fig.3 MICMAC Analysis

- **I-** Autonomous **II-** Dependent **III-** Linkage **IV-** Independent (Driver)

IV- Driver

2) Personalized Learning
5) Real world Simulations
8) Multimodal Content Delivery
11) Augmented and Virtual Reality

III- Linkage

1) Access to Learning Resources
3) Interactive Learning
4) Collaborative Learning
9) Flipped Classroom Approach

II- Dependent

6) Data Analytics & Learning Insights
7) Remote Learning and Access to Experts
10) Assessment and Feedback
13) AI-Powered Tutoring and Support
14) Digital Citizenship and Safety

CONCLUSION

Technology based practices in an educational institute can be very well derived in the form of structural model through ISM. The derived hierarchical relationship among various identified variables shows that it is the higher education with Augmented and Virtual reality and effective use of Mobile learning plays critical role in the success of technology based management system for higher education. There has been a paradigm shift in the manner in which customer interests in education are viewed today, with the ultimate objective of "delighting the customer." A satisfied stake-holder which comes out from quality & sustainability enhancement and assurance are at the highest level of structure which can be achieved through access to learning resources, collaborative learning, interactive learning and flipped classroom approach. These variable works as linkage to achieve good quality enhancement along with digital citizenship and safety.

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