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Using of Interpretive Structural Modeling Technique to Design a Technological Learning Model Focused on Emerging Metaverse Technology for Schools

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ABSTRACT

Objective: Metaverse has gained increasing interest in education, with much of literature focusing on its great potential to enhance both individual and social aspects of learning. This study aimed to design a technological learning model focused on emerging metaverse technology for schools in Iran in 2024.

Methods: The research was conducted using a mixed methods approach (qualitative-quantitative), with the target group consisting of experts in educational sciences and information technology. In the qualitative part, data was collected through in-depth interviews based on focus groups and analyzed using thematic analysis and grounded theory. In the quantitative part, the interpretative structural model was used.

Results: The qualitative findings included a systematic theoretical model that identifies causal, strategic, contextual, intervening and consequential factors. In the quantitative part, a structural interpretation model was categorized into three levels. All factors included in the model were statistically significant, with p-values ranging from <0.001 to 0.04, confirming the validity and reliability of the hierarchical structure. The driving factors at the first level included the creation of interactive and technological educational environments and the development and strengthening of skills. The enabling factors at the second level included assessing and improving educational progress, the digital revolution in education and learning, and optimizing teachers and administration. The outcome factors identified at the third level were skills development and teacher training, innovation and progress in management and education, process improvement and optimization, educational development and empowerment, and transformation in education and learning.

Conclusions: Therefore, it can be concluded that the implementation of a technology-enhanced learning model focused on emerging technologies can contribute to the advancement and development of the national education system. It is recommended that the model proposed in this study be piloted and, if proven effective and efficient, be implemented more broadly.

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Introduction

From a global perspective, educational innovations have become one of the requirements of the 21st century to solve the current crisis of education systems around the world (Sánchez & Gutiérrez-Esteban, 2023). In today's world, education systems face numerous challenges that highlight the need for fundamental changes in teaching and learning methods. One of the biggest challenges is the lack of commitment to educational contents and curricula courses in schools and the inability to capture students' attention and encourage their active participation. This problem is particularly pronounced in Iranian schools, where traditional teaching methods and a lack of modern teaching materials have led to a decline in motivation to learn. Nevertheless, establishing innovations in schools proved to be a real challenge in terms of educational improvements and problem solving (Kuril et al., 2023). Thus, schools are encountering difficulties to implement innovation processes that truly have an impact on the educational success of students (Andriani et al., 2018).

Globally, educational research on COVID-19 and emerging technologies such as artificial intelligence (AI) has raised awareness of the need for better use of digital technologies to improve learning and teaching, as well as a solid understanding of the digital and data-intensive world (Chiu, 2022). Evidence on the necessity to promote the digital competence development of young students worldwide is obvious in this digital age. They must continuously improve their digital competence from the standpoint of lifelong learning (Comission, 2020).

Digital education has become an increasingly important component of school education. However, the majority of in-service teachers lack digital competency in teaching and learning as well as knowledge of emerging technologies such as AI. In Hong Kong, the European Union, and the United States, for example, approximately 36%, 39%, and 38% of teachers felt well-prepared to use digital technologies in online teaching, respectively (Hamilton et al., 2020). Furthermore, AI education in schools is a critical global strategic undertaking for educating the next generation. The majority of in-service teachers have not had any necessary official training, and as a result, they are less qualified and confident in teaching with AI, which includes legal and ethical considerations, privacy, and security (Chiu, 2022). Digital education should be a core ability for all school teachers today, more than ever, and should be included in all disciplines of teacher professional development, including basic teacher education (Falloon, 2020).

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With the COVID-19 pandemic declared in 2020, humanity was forced to live in a society being non-face-to-face with each other (Lee et al., 2022). In particular, a range of activities in the physical world has transited into the virtual world. Telecommuting, online meetings, distance learning, online shopping, etc., have become a natural part of human life. Due to the quarantine of COVID-19, the metaverse has provided the ability to run off physical time and space limitations, using non-face-to-face services. (Suzuki et al., 2020). The metaverse can be used successfully by E-Learning (we use the term e-learning to denote the educationaland learning application types, i.e., E-Learning, M-Learning, Blended Learning, VirtualLearning, Distance Learning, and Online Learning) as a solution for the subjects that depend totally on convergence and cannot be taught online or in distance learning, such as medical and engineering courses (Kim, 2021). Although E-Learning environments have many different types, metaverse-based systems can also be used to provide safe and efficient environments for education and business by applying virtual reality technologies and continuously studying and endeavoring to expand learning experiences (Jeon, 2021). As a result, in the metaverse, all known learning systems will depend on the virtual learning environment (VLE). In addition, the metaverse is not just a virtual reality (VR) environment, but it also merges the Internet and web technologies and extended reality (XR)(Lee, 2021). Owing to the breakthrough of VR (virtual reality), AR (augmented reality), AI (artificial intelligence), blockchain, etc., the metaverse, a 3D digital space with collapsed virtual and real boundaries, has provoked increasing attention. It has been recognized as the next generation of the Internet (Hwang & Chien, 2022), which is about to dramatically change how we interact with the world.

Metaverse is a compound word combined with “meta-” (beyond; transcending) and “verse” (the root of “universe,” cosmos; the whole world), which denotes a new virtual universe created beyond the real world. The term “metaverse” was first coined in the 1992 cyberpunk science fiction novel Snow Crash written by American novelist Neal Stephenson (Joshua, 2017). In this novel, humans could freely access a 3D space that reflects the real world through digital agents (avatars) and interact with each other. Over the next three decades, the metaverse concept was more vividly depicted in science fiction movies, such as Ready Player One, Lucy, and The Matrix (Zhao et al., 2022). Similarly, (Siyaev & Jo, 2021) claim that metaverses will play a crucial role in the industry as well as many other activities such as education, culture, entertainment and communication. Virtual experiences associated with the Metaverse are enabled by various types of interconnected technologies, such as: Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), 3D representations, Artificial Intelligence (AI), Machine Learning, and Deep learning (Siyaev & Jo, 2021). Metaverse is a virtual world and closely related to the real life. It aims to build a digitized world that consists of digital media. The combination between the real and virtual world shows that virtuality is capable of acting on reality through daily activities and economic life (Mystakidis, 2022).

As indicated by scholars, education is one of the most significant applications of the metaverse with great potential in the coming future. We believe that the presence of the metaverse can be served as a new educational environment (De la Fuente Prieto et al., 2022). Therefore, the metaverse in education can be regarded as an educational environment enhanced by metaverse-related technologies which fuse with the elements of the virtual and the real educational environment. It enables learners to use wearable devices to enter the educational setting without being limited by time and locations and allows them to use digital identities to have real-time interactions with different forms of items (e.g., avatars, intelligent NPCs, or virtual learning resources). As a result, they can feel present as if they are in a real-world educational setting. From this standpoint, it can be seen that applying the metaverse in education can unlock a variety of fantastic learning experiences for learners. The Metaverse has numerous distinctive features and key elements that distinguish it from other digital technologies. The Metaverse is a shared virtual space where users can be present and interact with each other simultaneously. These interactions can include conversations, games, education and even trading. The Metaverse often uses virtual reality and augmented reality technologies to provide users with an immersive and interactive experience. These technologies allow users to navigate virtual environments and interact with digital objects and other users. One of the key elements of the metaverse is digital avatars that represent users in the virtual world. These avatars can be customized to personalize the user's digital identity. The Metaverse provides a platform for diverse social interactions, allowing users to meet in virtual environments, join groups and participate in shared activities.

(Khadivi, 2024) in his study titled “Exploring the Applications and Challenges of the Metaverse in Education,” analyzed the applications of the Metaverse in educational processes and identifies the existing challenges in this domain. The findings showed that the metaverse can create new opportunities for interactive and experiential learning. However, the metaverse also presents challenges such as high costs, the need for appropriate infrastructure, and social and ethical issues. (Moradi et al., 2023) conducted a study to examine the role of the metaverse in improving educational processes in the field of medicine. This research aimed to analyze the various applications of the metaverse in clinical learning and educational simulations. The methodology included a literature review and an examination of practical experiences in using the metaverse in medical education. The results showed that the metaverse can help improve experiential learning, increase learning interactions, and improve access to educational resources. In this context, the paper also highlights challenges such as the need for technological infrastructure and educational issues.

(Lee & Hwang, 2022) in their study titled" Technology-Enhanced Education through VR-Making and Metaverse-Linking to Foster Teacher Readiness and Sustainable Learning" documented the experiences of pre-service English teachers in instructional Virtual Reality (herein, VR) content design of K–12 English digital textbooks. The study findings showed that such transformative experiences of VR-Making (herein, VRM) for instructional contents are conducive to capacitate pre-service teachers' technological readiness, 4Cs (Critical Thinking, Creativity, Collaboration, Communication) in digital citizenship, and perceived pedagogical benefits.

(Balat et al., 2023) in their research titled "Using Metaverse in Education: Bibliometric and Content Analysis on Applications, Tools and Impacts" investigated the impact of metaverse technologies in the field of education. The analysis identified higher education and secondary education as the primary contexts for metaverse application. The recommendations presented in this study were categorized into five groups: to ensure a quality learning experience, to improve student experience, for skill development, to support education activities, and for material use. Finally, regarding the limitations of metaverse technology in education, a six-category structure was identified, encompassing technical problems, high cost, ethical and safety concerns, learning requirements, limitations of the technology used, and health problems.

The present study has several innovative aspects that distinguish it from previous studies. The first innovative aspect is the focus on using the metaverse as a teaching tool. While many studies have examined the impact of traditional digital technologies such as online learning and learning management systems, this research examines the use of interactive virtual environments that offer unique features such as multi-party interaction and realistic simulations. These learning environments can provide students with richer learning experiences that go beyond the confines of traditional classrooms.

The second innovation aspect of this research is the identification and analysis of specific obstacles and challenges that may exist in implementing Metaverse in the Iranian education system. Given the cultural, social and economic differences that exist in different countries, understanding these challenges can help design educational programs tailored to local contexts and create appropriate infrastructure for the introduction of new technologies.

The third aspect of innovation in this research is the emphasis on interactive and collaborative learning methods. The Metaverse offers students the opportunity to learn in a virtual environment and under simulated conditions, in a group setting and using the latest technologies. This type of learning not only helps deepen the understanding of concepts but also strengthens students' social and communication skills in virtual environments. This research can help teachers develop more effective assessment tools to measure student learning and progress in virtual environments. Assessment in the Metaverse can include hands-on activities, group projects, and the use of innovative learning assessment technologies that can help improve the quality of education. Examining educational innovation, particularly in the context of the metaverse, revealed several significant gaps that need to be addressed. These gaps highlighted the challenges and opportunities associated with integrating metaverse technology into education systems. There is a need for innovative assessment tools that can effectively measure student learning and progress in metaverse environments. Traditional assessment methods may not be appropriate for assessing the interactive and collaborative learning experiences that the metaverse offers. While existing research recognizes the potential of the metaverse in education, much of it focuses on general applications or specific fields such as medicine. This study aims to delve deeper into the use of the Metaverse specifically as a teaching tool and explore its unique features such as multi-party interaction and realistic simulations to improve pedagogical practices. This study aimed to fill these gaps by providing a targeted investigation of the metaverse as a teaching tool in the specific context of the Iranian education system, with a focus on interactive and collaborative learning and the development of appropriate assessment strategies. This targeted approach distinguishes it from

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broader investigations of metaverse applications in education and contributes to a more nuanced understanding of its potential and challenges in specific real-world settings.

Material and Methods

This study employed an exploratory mixed-methods approach, initially gathering and prioritizing qualitative data, followed by the collection of quantitative data to validate the themes or instruments developed during the qualitative phase (Creswell, 2008). In the qualitative part of this research, data were collected through in-depth interviews and focus groups with experts in the fields of information technology and education. These methods allow us to gain a deeper understanding of participants' experiences and perspectives. Qualitative analysis helps us explore the different aspects of the topic and examine different perspectives in the process of technological learning, focusing on the metaverse. Thematic analysis method and grounded theory strategy were used to analyze these data. The second phase of the research is quantitative and uses structured questionnaires to measure and validate the components extracted from the qualitative phase. The questionnaires consist of closed questions that are intended to be answered quickly and easily. This phase examines the degree of agreement between managers, experts and educational specialists with the hypotheses derived from the qualitative part, as well as the degree of collaboration between experts and educational specialists with the relevant educational organizations and schools. In the present study, the sample consisted of 12 faculty members in the education field. The selection of these faculty members was based on their familiarity and expertise in the areas of educational technologies and technology-enhanced learning. The selected faculty members were from reputable universities with extensive experience in education and technology so that their perspectives and experiences could be thoroughly explored. Ethical considerations were also carefully considered throughout the research process. The inclusion and exclusion criteria for the sample were carefully defined to ensure that participants were appropriate and aligned with the research objectives. These criteria included factors such as technical expertise, professional experience, social roles and the influence of participants on information and communication technologies in the education system.

In quantitative research on structural interpretive modeling, the sample size is typically assumed to be at least 5 to 10 respondents (Kline, 2023). Therefore, the sample size in the quantitative part is 14 faculty members in the education field. Similar to the qualitative section, this section also utilized experts in the field of educational technology and technology-enhanced learning. This selection was made to collect quantitative data and conduct accurate statistical analyses. Given the consultations with experts and professors in research methodology, as well as taking into account the nature of the interactive matrix questionnaire and the expected analyses, this sample size appears appropriate for conducting preliminary analyses. To ensure the validity and reliability of the data collection instruments, questionnaires and interview questions, a pilot test was conducted by sending them to a small group of participants after the design phase. This was done to ensure the understandability and accuracy of the questions. In addition, the use of relevant literature and consultation with subject matter experts contributed to content validity. Various methods were used to assess reliability, such as Cronbach's alpha for the questionnaires and effective techniques for the interviews.

Results

Qualitative Section

In the qualitative part, semi-structured interviews were conducted with 12 experts to collect data and obtain reliable results. The research findings have identified key central categories and codes, which include causal conditions, contextual conditions, intervening conditions, and consequential conditions.

Table 1. Axial coding: combination of codes extracted from open coding and formation of categories

Dimensions of the model	Optional category	Axial codes	Open source
Causal factors	Transformation in teaching and learning	Teaching and learning	**Improving learning processes**
			Improving educational content
			Education based on critical thinking
		Flexibility and adaptation to technological changes	**Empowering teachers**
			Promoting the culture of creativity
	Optimizing teachers and administrators	Empowering teachers	**Flexibility and adaptation to technological changes**
			Strengthening global skills
		Planning and management	**Proper planning and management**

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			Improving technical infrastructure
Strategic factors	Digital revolution in education and learning	Upgrading technology and educational processes	**Promoting the culture of using Metaverse technology**
			Promotion of interactive and multimedia educational environments
		Developing teachers' skills in digitization	**Improving the digital skills of teachers**
			Improving digital and technological skills
		Improving and upgrading educational processes	**Evaluation and continuous improvement of learning processes**
			Improving the quality of educational content
		Flexibility and development of educational platforms	**Creating flexible educational platforms**
			Creating interactive and dynamic educational platforms
	Innovation and progress in management and education	Development of educational resources and strategies	**Creating suitable conditions for research and development**
			Development of interactive educational resources
		Strengthening and improving educational infrastructure	**Improved initial support and engagement**
			Improving access to Metaverse technology
			Improving the technical infrastructure of schools
		Development and empowerment of teachers	**Training teachers for optimal use of Metaverse technology**
			Empowering teachers for the best performance and use of Metaverse technology
		Management strategies and innovation	**Developing appropriate management strategies**
			Developing innovative strategies
			Upgrading technical infrastructure

Background factors	Educational development and empowerment	Improving infrastructure and educational platforms	**Creating flexible educational platforms**
			Improving technical infrastructure
			Development of flexible educational platforms
		Skills development and teacher training	**Improving digital and technological skills**
			Teacher training
			Developing digital skills of teachers
	Evaluating and improving educational progress	Improving learning processes	**Evaluation and improvement of learning processes**
		Development of educational resources and strategies	**Creating suitable conditions for research and development**
			Creating a suitable educational environment
			Improving educational content
			Development of interactive educational resources
Intervening factors	Skills development and teacher training	Creating interactive and technological educational platforms	**Creating interactive and dynamic educational spaces**
			Development of interactive educational resources based on Metaverse technology
		Evaluation and improvement of teaching and learning processes	**Evaluation and improvement of teaching and learning processes**
			Development of interactive educational content
		Upgrading technical and educational infrastructure	**Upgrading the technical infrastructure of schools**
			Improving the technical infrastructure of schools
			Development of flexible educational platforms
	Creating interactive and technological educational platforms	Skills development and teacher training	**Improving the digital skills of teachers**
			Training teachers to run classrooms
			Training teachers for optimal use
		Empowering managers and teachers	**Empowering managers and teachers**
			Developing digital and technological skills of teachers

Consequence factors	Developing and strengthening skills	Developing skills and tools	**Improving students' decision-making and problem-solving skills**
			Improving classroom management and lesson organization skills
			Developing students' critical and creative thinking skills
		Development of technology and digital skills	**Creating facilities for education and advanced research in the field of technology**
			Developing digital and technological skills of teachers
			Development of flexible and adaptable educational platforms
		Motivation and empowerment	**Improving students' motivation and interest in learning**
			Facilitating the monitoring and evaluation of students' progress
			Empowering teachers to make optimal use of technology tools
	Improvement and optimization of processes	Improving access and educational processes	**Making it possible to access wider educational resources**
			Improving students' access to educational resources and information
			Facilitating students' access to personalized educational resources
		Enhance experience and communication	**Creating dynamic and interactive learning spaces**
			Improving communication and interaction between teachers, students and parents
			Improving communication and coordination between family and school
		Improve processes and collaboration	**Improving communication processes and cooperation between teachers and administrators**
			Improving the interactive capabilities and educational experiences of students

			Improving the quality and efficiency of educational processes
		Development of partnership and social cooperation	**Creating suitable conditions for independent learning and group cooperation**
			Developing cooperation and social interaction skills of students

Quantitative Section

The Interpretive Structural Modeling (ISM) technique was used for quantitative data analysis. The ISM methodology was first introduced by Sage in 1977. This approach focuses on classifying factors and identifying relationships between criteria. The interpretive structural modeling approach is an effective and efficient methodology for situations in which qualitative variables at different levels of importance have mutual effects on each other (Pathania & Tanwar, 2024).

The main idea of the interpretive structural modeling technique (ISM) is to use the experience and knowledge of experts to create a multi-level structural model, which is extracted by dividing a complex system into multiple subsystems (Nemati & Momeni, 2013). This method is an interactive learning process in which a number of different and interrelated elements are structured into a comprehensive systematic model. This methodology helps to create and control complex relationships between the elements of a system. The model obtained using this methodology represents the structure of a complex problem or topic, a system or a field of study, which is a carefully designed model (Wu et al., 2021). As a result, we can say that interpretive structural modeling not only provides insights into the relationships between different elements of a system, but also provides a structure based on the meaning or effect of the elements together (depending on the nature of the substantive relationship). This is a method of interpretation because the judgment of a group of people determines whether or not relationships exist between these elements. This method is structural because the basis of relationships is an overall structure extracted from a complex set of elements. This method is a modeling technique in which the specific relationships and the overall structure are represented in a diagram model. Therefore, the Interpretive Structural Modeling (ISM) method first identifies the effective and essential factors and then presents the relationships between these factors. The way in which progress can be made through these factors helps in identifying the internal relationships of variables and is an appropriate technique for prioritizing and analyzing the effect of one variable on other variables (Hasteer et al., 2023).

The steps to implement the ISM technique are described in Figure 1.

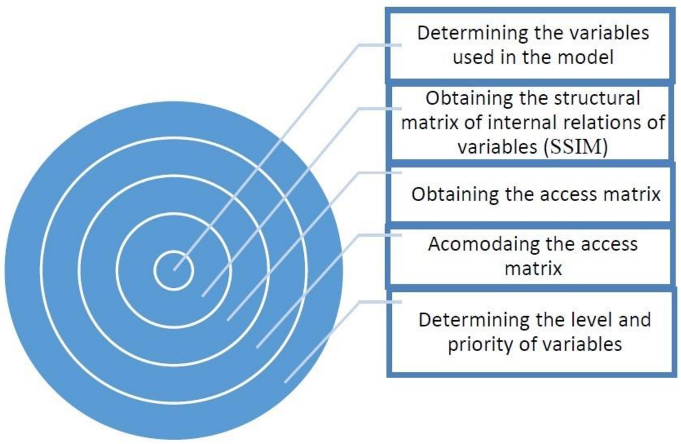

Figure 1. Steps to implement the interpretive structural modeling (ISM) technique

First step: Determining the variables used in the model: The interpretive structural modeling technique (ISM) begins with identifying the variables that are relevant to the topic of discussion. In this research, our variables for designing the model are extracted from the qualitative phase.

Table 2. Variables are extracted from the qualitative phase.

row		variables	Symbol
1		Transformation in teaching and learning	C1
2		Optimizing teachers and administrators	C2
3		Digital revolution in education and learning	C3
4		Innovation and progress in management and education	C4
5		Educational development and empowerment	C5
6		Evaluating and improving educational progress	
7		Skills development and teacher training	C7
8		Creating interactive and technological educational platforms	C8
9		Developing and strengthening skills	C9
10		Improvement and optimization of processes	C10

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Second step: Forming the structural self-interaction matrix (SSIM): After identifying the variables, it is time to enter these variables into the structural self-interaction matrix (SSIM). This matrix is a matrix with the dimensions of the variables, with the variables listed in order in the first row and column. Then the two-by-two relationships of the variables are indicated by symbols. The structural self-interaction matrix is formed by the dimensions and indices of the study and their comparison using four modes of conceptual relationships. This matrix is completed by process-oriented experts and specialists and the resulting information is summarized based on the interpretive structural modeling method. The matrix obtained in this step shows which variables a variable affects and from which variables it is affected. The states and signs used in this conceptual relationship are:

V: The row factor (i) can be the basis of reaching the column factor (j) (one-way connection from i to j).

A: The column factor (j) can be the basis of reaching the row factor (i) (one-way connection from j to i).

X: There is a two-way relationship between the row factor (i) and the column factor (j). In other words, both can be the basis of reaching each other (two-way connection from i to j and vice versa).

O: There is no relationship between two elements (i j).

The logic of Interpretive Structural Modeling (ISM) is based on non-parametric methods and the mode in frequencies. For this purpose, a questionnaire was first designed by placing 9 selected factors in the rows and columns of a 9 × 9 matrix and asking the respondent to determine the nature of the two-by-two connections of the factors corresponding to those introduced Symbols (V, A, X, O). In other words: In this matrix, the experts look at the criteria in pairs and react accordingly to the pairwise comparisons.

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Table 3. SSIM structural self-interaction matrix

SSIM C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Transformation in teaching and learning A	A	A	A	A	V	V	O	V	V
Optimizing teachers and administrators	V	V	V	V	V	V	V	V	V
Digital revolution in education and learning		O	O	O	V	V	V	V	O
Innovation and progress in management and education			V	V	V	V	V	V	V
Educational development andempowerment				V	V	V	V	O	X
Evaluating and improving educational progress					X	X	X	V	A
Skills development and teacher training						V	V	V	A
Creating interactive and technological educational platforms							V	V	A
Developing and strengthening skills								V	A
Improvement and optimization of processes									A

The third step: Forming the Reachability matrix (RM): The reachability matrix is obtained by transforming the structural self-interaction matrix into a two-valued matrix of zero and one. In the reachability matrix, the entries of the main diameter are equal to one. To extract the reachability matrix, in each row of the self-interaction matrix the number one is used instead of X and V symbols and zero is used instead of A and O symbols. The obtained matrix is called the initial reachability matrix. Also, to be sure, the secondary relationships must be controlled. That is, if A leads to B and B leads to C, then A must lead to C. Therefore, if the direct effects should have been included based on the secondary relationships, but this did not happen in practice, the structural self-interaction matrix table 6 should be corrected and the secondary relationship should also be shown.

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Table 4. Reachability matrix (RM)

RM C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Transformation in teaching and learning 1	1	0	0	0	1	1	0	1	1
Optimizing teachers and administrators 1	1	1	1	1	1	1	1	1	1
Digital revolution in education and learning 1	1	0	1	0	1	1	1	1	0
Innovation and progress in management and education 1	1	0	1	1	1	1	1	1	1
Educational development andempowerment 0	0	0	0	0	1	1	1	0	1
Evaluating and improving educational progress 0	0	0	0	0	0	1	1	1	0
Skills development and teacher training 0	0	0	0	0	0	0	1	1	0
Creating interactive and technological platforms 0	0	0	0	0	0	0	0	1	0
Developing and strengthening skills 0	0	0	0	0	0	1	1	1	1
Improvement and optimization of processes 0	0	0	0	0	0	1	1	1	1

Fourth step: Creating the final access matrix (TM): After the initial access matrix is obtained, the final access matrix is obtained by transferability in the relationships of the variables. It is a square matrix, that each of its entries is one when the element to element has access of any length, and otherwise zero. The way of obtaining the access matrix is by using Euler's theory, in which we add the adjacency matrix to the unit matrix. Then, if the entries of the matrix do not change, we raise this matrix to the power of n. The following formula shows the method of determining accessibility using adjacency matrix.

Equation (1): Determining the final access matrix

$$A + I$$

$$M = (A + I)^{n} \tag{1}$$

Matrix A is the initial access matrix of the identity matrix and of the final access matrix. The operation of raise to the power of the matrix is done according to Boolean rules (relationship). Relationship (2): Boolean laws

$$1 \times 1 = 1; 1 + 1 = 1 \tag{2}$$

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Therefore, secondary relationships should be controlled to be sure. That is, if A leads to B and B leads to C, then A must lead to C. That is, if direct effects should have been included based on secondary relationships, but did not occur in practice, then the table of reachability matrix 7 should be corrected and the secondary relationship should also be shown.

Table 5. The final access matrix

TM	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Transformation in teaching and learning	1	0	0	0	1	1	1*	1	1	1
Optimizing teachers and administrators	1	1	1	1	1	1	1	1	1	1
Digital revolution in education and learning	1	0	1	1	1	1	1	1	1	1*
Innovation and progress in management and education	1	0	1	1	1	1	1	1	1	1
Educational development andempowerment	0	0	0	1	0	1	1	1	1*	1
Evaluating and improving educational progress	0	0	0	0	0	0	1	1	1	0
Skills development and teacher training	0	0	0	0	0	0	0	1	1	0
Creating interactive and technological platforms	0	0	0	0	0	0	0	0	1	0
Developing and strengthening skills	0	0	0	0	0	0	1	1	1	1
Improvement and optimization of processes	0	0	0	1	1	1	1	1	1	1

Fifth step: Determining relationships and dimension levels: In order to determine the relationships and leveling of dimensions and indices, the outputs set and inputs set for each dimension/index of the reachability matrix should be extracted. The set of outputs includes the dimension/index and the dimensions/indices that are affected by it. The set of inputs includes the dimension/index and set of dimensions/indices that are affecting it. Then, the set of two-way relationships of each dimension/index is determined; i. e. the number of dimensions/indices that are repeated in two sets of input and output. The dimensions/ indices are leveled based on the resulting sets. Normally, the dimensions/indices that have the same output set and the two-way relations set constitute the dimensions/indices of the upper level of the hierarchy. Therefore, the dimensions/indices of the top level will not be the source of any other dimension/ index. Once the

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top level is defined, it is separated from other dimensions/ indices. Then, through a similar process, the next levels are determined.

Table 6. Inputs and outputs set to determine the level

Dimension	Output: affected		Input: affecting	Sharing	Level
Transformation in teaching and learning	C1		C1, C2, C3, C4	C1	1
Optimizing teachers and administrators	C1, C2, C3, C4, C5,	C6, C7, C9 C10	CC1, C2, C3, C4 2, C3	C2, C5	3
Digital revolution in education and learning	C2-C3-C6-	C4, C5, C6	C6-C8-C9	C1, C2-C3-C6-	3
Innovation and progress in management and education	C4		C1, C2, C3, C4	C4	2
Educational development and empowerment	C5		C5-C6-C8-C9	C5	1
Evaluating and improving educational progress	C1,	C2-C3-C6	C2-C3-C6-C7	C1, C2, C5	4
Skills development and teacher training	C7	C6, C8	C1, C2, C3, C4	C7	2
Creating interactive and technological platforms	C1,	C2-C4, 4C3-	C1, C2, C5	C2-C3-C6	3
Developing and strengthening skills	C4, C5	C2-C3-C6	C3, C4	C8-C9	5
Improvement and optimization of processes		C2, C10	C6-C8-C9	C2, C10	1

Analysis of the power of penetration dependence (MICMAC Chart)

Process-oriented indexes can be based on the penetration power of each index in other indexes, and the degree of dependence of each index on other indexes can be divided into four levels: autonomous, dependent, linked (interface) and independent.

Autonomous: Autonomous variables have a low degree of dependence and directional strength. These criteria are generally not connected to the system because they have weak connections to the system. Changing these variables does not lead to a serious change in the system.

Dependent: Dependent variables have strong dependence and weak direction. Basically, these variables have both high and low influences on the system.

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Independent: independent variables have low dependence and high direction, in other words, high affecting and low affectability are the characteristics of these variables.

Linked: Link or interface variables have high dependence and high direction power, in other words, the affecting and affectability of these criteria is very high, and any small change on these variables leads to fundamental changes in the system.

Table 7. The power of penetration and the degree of dependence of research variables

Research Variables	Symbol	Degree of dependence	Power of penetration
Transformation in teaching and learning	C1	6	1
Optimizing teachers and administrators	C2	6	10
Digital revolution in education and learning	C3	5	9
Innovation and progress in management and education	C4	5	2
Educational development and empowerment	C5	7	1
Evaluating and improving educational progress	C6	5	10
Skills development and teacher training	C7	6	2
Creating interactive and technological platforms	C8	4	8
Developing and strengthening skills	C9	4	10
Improvement and optimization of processes	C10	7	2

Validation of the model using partial least squares method: Partial least squares method was used to validate the model. In the partial least square method, several points are very important: the strength of the relationship between the factor (hidden variable) and the observable variable, indicated by the factor loading. The factor loading is a value between zero and one. The reliability of each item refers to the value of the factor loadings of each of the observed variables and was used to determine how acceptable the measurement indices (observed variables) are for measuring hidden variables. The minimum acceptable value is 0.3 and factor loadings of 0.4 indicate an average level of significance. In confirmatory factor analysis, values with a factor loading greater than 0.5 indicate a strong level of significance and high correlation between the observed variables and the factor, and also indicate that the structure is well defined.

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To assess the validity of the external model, three indices of convergent validity, composite reliability, and Cronbach's alpha were used. Convergent validity (CV) shows how the variables of a construct are aligned with each other. Convergent validity is checked using the external model and by calculating the average variance extracted (AVE). The AVE measure represents the average variance of each construct with its indices. In simple terms, AVE shows the degree of correlation of a structure with its indices. The higher the correlation, the better the fit. (Fornell & Larcker, 1981) believed that the measurement model had convergent validity when the AVE criterion was higher than 0.5. Composite reliability (CR) in structural models is considered a better and more valid criterion than Cronbach's alpha because when calculating Cronbach's alpha for each structure, all indices are calculated with the same importance. However, when calculating composite reliability, the indices with higher factor loadings are more important and determine the CR values, the indices with higher factor loadings are more important, and the CR values of the constructs have a more realistic and accurate measure than Cronbach's alpha.

The following relationships should hold for convergent validity and composite reliability:

(CR): $CR > 0.7$; $CR > AVE$; $AVE > 0.5$

Table 8. Internal validity of research constructs

Main Constructs	Convergent Validity (AVE)	Composite Reliability (CR)	Cronbach's alpha
Transformation in teaching and learning	0.892	0.674	0.842
Optimizing teachers and administrators	0.927	0.808	0.871
Digital revolution in education and learning	0.918	0761	8.874
Innovation and progress in management and education	0.914	0.725	0.847
Educational development and empowerment	0.805	0.520	0.658
Evaluating and improving educational progress	0.851	0.596	0.749
Skills development and teacher training	0.936	0.548	0.761
Creating interactive and technological platforms	0.854	0.518	0.752
Developing and strengthening skills	0.844	0.536	0.728
Improvement and optimization of processes	0.861	0.542	0.744

The average variance extracted (AVE) is greater than 0.5, so there is convergent validity. Cronbach's alpha of all variables is greater than 0.7, so reliability is confirmed. The composite reliability (CR) value is also greater than the AVE and is above the threshold of 0.7 in all cases, so the third condition is also met.

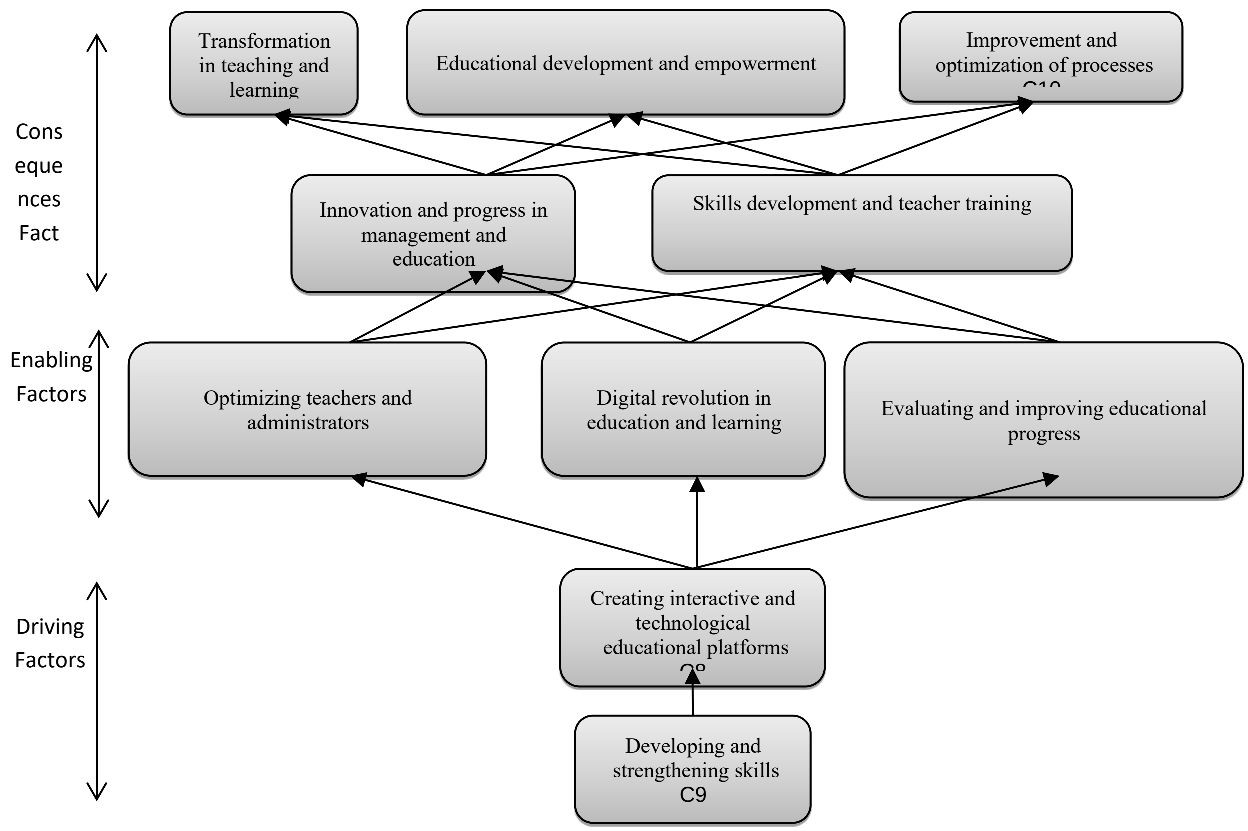

Figure 2. Model of ISM Research **(**source: research findings**)**

Discussion

This study aimed to design a technological learning model that emphasizes the integration of metaverse technology into educational settings. The research identifies key variables and factors that influence this integration, focusing on their roles in transforming teaching and learning processes. The core variables identified through a combination of qualitative and quantitative analysis fall into four categories: causal conditions, contextual conditions, intervening conditions, and consequential conditions. These categories help to map out the critical elements that contribute

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to a successful technological learning model. To achieve this goal, the influencing factors and effective indexes for the technological learning model focusing on the emerging metaverse technology were first identified and then these factors and indices were evaluated and reviewed. The library method and document studies were used to collect the theoretical information base for explaining the research literature.

This study provides a model to determine the causal relationships in designing a technological learning model focused on emerging metaverse technology for schools. This model is used to systematically determine cause-effect relationships between factors. According to this model, transformation in teaching and learning (C1), educational development andempowerment (C5), and improvement and optimization of processes (C10) are on the first level or dependent, innovation and progress in management and education (C4) and skill development and teacher training (C7) are on the second level, optimizing teachers and administrators (C2), digital revolution in education and learning, and creating interactive and technological platforms (C8) are on the third level, evaluating and improving educational progress (C6) at the fourth level, and finally developing and strengthening skills (C9), at the fifth level. The model not only shows the relationships between the elements, but also classifies the factors into four categories. The first category includes "autonomous variables" that have low penetration and dependency. In the current study, no variable was included in this category; "Dependent variables" are the second category, which have low penetrating power but strong dependence.Educational development , optimization of processes and skill development and teacher training fall into this category. These variables are mainly the result of the fact that many factors play a role in their formation and they themselves can rarely become the basis of other variables. The third category is "linked variables," which have high penetration and dependency. These factors are not static as any change to them can have an impact on the system and feedback from the system can eventually change these factors again. In this research, developing and strengthening skills, evaluating and improving educational progress, and optimizing teachers and administrators are included in this category. In today's world most factors are not static and dynamic. The factors used in this research are not excluded. The fourth category includes "independent variables" that have strong penetration but weak dependence. These categories form the basis of the model and should be highlighted before system operation begins. This category includes creating technological platforms and digital revolution in education and learning.

The interpretative structural modeling (ISM) results identified key factors at five levels specifically related to the structure and improvement of technological learning in Iranian schools. These factors represent, at different levels, the interrelationships and dependencies between variables that can contribute to strategic decision-making to optimize educational processes. Key factors at Level 1 include “the creation of interactive and technological educational environments” and “the development and strengthening of skills”. These factors are considered basic requirements for any change and innovation in the education system. The existence of appropriate infrastructure and the strengthening of technology-related skills will pave the way for subsequent changes in teaching and learning.

Level 2 includes “evaluating and improving educational progress”, “the digital revolution in education and learning” and “optimizing teachers and managers”. These factors are influenced by the Level 1 factors and at the same time act as important drivers of change at the first level. Continuous assessment and improvement of educational progress is the key to the successful implementation of new educational technologies. The digital revolution and the optimization of human resources in education play an important role in shaping modern educational processes. The key factors at level 3 include “developing skills and training teachers”, “innovation and progress in management and education”, “transformation in education and learning”, “pedagogical development and empowerment” and “process improvement and optimization”. These factors are considered secondary outcomes and long-term effects of actions taken at lower levels. The development of skills and innovations in management and education can lead to fundamental change in the education system and contribute to improving the quality of education and learning. The identification of "establishing interactive and technological learning platforms" and "developing and strengthening skills" as prerequisites is consistent with the findings of (Falloon, 2020) who emphasized the importance of providing appropriate infrastructure and empowering teachers for the adoption of new technologies. Furthermore, the factors "evaluation and improvement of educational progress," "digital revolution in teaching and learning," and "optimization of teachers and administrators" identified at this level are also consistent with the finding of (Sánchez & Gutiérrez-Esteban, 2023). This study particularly highlights the role of

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continuous evaluation and educational improvements in the successful implementation of new technologies. Finally, factors including "skill development and teacher training," "innovation and advancement in management and education," and "transformation in teaching and learning" are consistent with the research of (Balat et al., 2023) which emphasized the importance of innovation and continuous teacher skill development in enhancing educational quality. The findings of this study are consistent with previous studies, which have also emphasized the importance of educational transformation, learning, and the optimization of teachers and administrators. Studies have shown that the use of new technologies can improve the quality of education and better prepare teachers and administrators to address educational challenges. For example, research by (Anderson & Rainie, 2012) showed that the use of emerging technologies such as virtual and augmented reality can enrich educational experiences and make learning more interactive and engaging.

Despite the significant contributions of this research, certain limitations should be taken into account when interpreting and generalizing the results. The limited sample size may affect the robustness of some results and make them difficult to generalize to larger populations. Relying solely on in-depth interviews and focus groups to collect data may have limited the diversity of perspectives and experiences captured. Cultural and social factors within Iranian schools that could potentially influence results have not been fully examined. The study population focused primarily on information technology and education specialists and may have overlooked perspectives from other educational domains.

Conclusion

The findings of this study provided a comprehensive framework for integrating metaverse technology into schools, particularly within the Iranian context. By employing both qualitative and quantitative methodologies, the research has effectively identified key factors that contribute to the development of a technological learning model focusing on emerging metaverse technologies. The interpretative structural modeling (ISM) approach revealed five levels of factors influencing the educational system and their interrelationships, providing a clear roadmap for strategic implementation. At the core of the framework, Level 1 factors such as “creating interactive and technological educational platforms” and “developing and strengthening skills” serve as basic elements. These factors are prerequisites for any educational transformation and underscore the

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need for robust infrastructure and skills development as starting points for integrating metaverse technologies. Without these essential elements, further progress in digital education would be difficult to achieve. Level 2 factors, including “assessing and improving educational progress,” “the digital revolution in education and learning,” and “optimizing teachers and administrators,” highlight the importance of continuous assessment and optimization of both human and technological resources. These factors act as key drivers for the further development of the education system and ensure that the introduction of Metaverse technologies is not just a one-off effort, but part of a continuous improvement and adaptation process. The third level of the model focuses on long-term outcomes such as “competence development and teacher training”, “innovation and progress in management and education” and “transformation in teaching and learning”. These factors represent the broader impact that successful implementation of metaverse technologies can have on the education system. The introduction of new technologies promotes innovation, improves the quality of education and ultimately changes the way teachers and students interact with learning materials.

In summary, this study has developed a multi-level, interdependent model that not only identifies key factors for integrating metaverse technologies in schools, but also provides a clear guide to how these factors interact and influence each other. The results are significant because they provide practical insights for policymakers, education administrators and teachers. By following the layers and relationships outlined in the model, education systems can strategically implement metaverse technologies to enhance learning experiences, improve teaching practices, and prepare students for a future increasingly dominated by digital tools and platforms.

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Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries. can be directed to the corresponding author.

Ethics statement

All ethical principles are considered in this article. The participants were informed of the purpose of the research and its implementation stages. Principles of the Helsinki Convention were also observed.

Author contributions

All authors contributed to the study conception and design, material preparation, data collection, and analysis. All authors contributed to the article and approved the submitted version.

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Conflict of interest

This research did not receive any grant from funding agencies in the government, public, commercial, or non-profit sectors could be construed as a potential conflict of interest

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