The Educational Digital Ecosystem: A MICMAC Decomposition of the Reciprocal Influences Between Technological Platforms and Evaluation Methods

Piedad Mary Martelo Gómez, Raúl José Martelo Gómez, David Antonio Franco Borré

[1]Odontologist. Independent researcher. Professor of the Dentistry Program at the Universidad de Cartagena, Colombia. Email: pmartelog@hotmail.com.
[2]Specialist in Networks and Telecommunications; Master in Computer Science. Systems Engineer. Full-time Research Professor of the Systems Engineering Program at the Universidad de Cartagena. Leader of the INGESINFO Research Group. Cartagena de Indias, Colombia. E-mail: rmartelog1@unicartagena.edu.co
[3]Master in Computer Science. Systems Engineer. Full-time Research Professor of the Systems Engineering Program at the Universidad de Cartagena. Cartagena Colombia. E-mail: dfrancob@unicartagena.edu.co.

Abstracts

This study focuses on analyzing the interactions between technological platforms and evaluation methods in the educational digital ecosystem. The main objective is to identify the key variables that influence this environment and offer recommendations to improve the online educational experience. This is an exploratory study with a mixed approach, using the MICMAC technique to analyze the influence and dependence of the identified variables. The results reveal the importance of aspects such as the quality of content and technological infrastructure, as well as the need to improve usability and interactivity in online educational platforms. The conclusions highlight the complexity and interdependence of variables in the educational digital ecosystem, underlining the importance of addressing a variety of technical, operational, and pedagogical aspects to promote effective learning in the digital era.

Keywords: Technology, online learning, digital education, teaching methods, user experience, data analysis, pedagogical strategies.

Introduction

In the current field of education, the advancement of digital technologies has radically transformed the style of learning and teaching. The exponential growth of educational technology platforms has generated a complex and dynamic ecosystem that offers new

opportunities and challenges for students, educators, and instructional designers (Alam, 2021). In this context, the present study focuses on the exploration and analysis of the educational digital ecosystem, with a specific focus on the interactions between technological platforms and evaluation methods.

The educational digital ecosystem encompasses a diverse set of tools, resources, and practices that are used to facilitate and enhance the teaching and learning process through digital media (Hrynevych, Morze, Vember, & Boiko). This digital environment offers a variety of technological platforms, from learning management systems to mobile applications and virtual learning environments (Kovtoniuk, Kosovets, Soia, & Tyutyun, 2022), which are designed to support different instructional modalities and boost the active participation of students in their educational process. Within the broad spectrum of the educational digital ecosystem, this study specifically focuses on investigating the reciprocal influences between technological platforms and evaluation methods.

This study is based on previous research that has explored specific aspects of the educational digital ecosystem, such as the usability of technological platforms in (Pinho, Aguiar, & Amaral, 2023), the effectiveness of online evaluation methods in (Castro & Tumibay, 2021) and the impact of technology on learning in (Naik, Chitre, Bhalla, & Rajan, 2020), among others. However, this study is distinguished by its focus on analyzing the dynamic and multifaceted relationships between the key variables that make up the educational digital ecosystem, providing a more complete and detailed understanding of this complex environment.

The relevance of this study lies in its ability to provide valuable information on how to optimize the design and implementation of educational technology platforms and online evaluation methods to improve the quality and effectiveness of digital learning. The findings of this study may have significant implications for educators, instructional designers, educational technology developers, and policymakers in developing innovative student-centered educational strategies and practices.

Therefore, the purpose of this study was to analyze the reciprocal influences between technological platforms and evaluation methods in the educational digital ecosystem, identifying the key variables that affect its operation and effectiveness. Through a multidisciplinary and methodological approach, it is sought to provide a deeper understanding of the complexity and dynamics of this digital environment and generate practical recommendations to improve the online educational experience.

Methodology

This research is framed within the exploratory study type, with a mixed research design that combines qualitative and quantitative elements. Exploratory due to the emergent and multifaceted nature of the phenomenon studied (Creswell & Creswell, 2017), in this case, the reciprocal influences between technological platforms and evaluation methods in the educational digital ecosystem. Through an exploratory approach, the aim is to generate ideas, identify patterns and trends, and establish a solid base of knowledge that can guide future research and

decision-making (Neuman, 2021). While the mixed design is considered appropriate to address the complexity of the phenomenon investigated and to generate significant knowledge that can inform both theory and practice in the field of digital education.

In this sense, the research focused on analyzing the reciprocal influences between technological platforms and evaluation methods in the educational digital ecosystem. To achieve this, a review of the academic literature was carried out, considering publications from the year 2000 to 2023 in databases and information resources such as Google Scholar, PubMed, and Scopus. Additionally, institutional repositories, digital libraries, and websites of educational organizations were explored to obtain a broad and diverse coverage of relevant literature. The search used a combination of key terms related to the educational digital ecosystem, technological platforms in education, and evaluation methods. Boolean operators were used to refine the results and maximize the relevance of the search.

The selected articles were reviewed in detail to extract and synthesize relevant findings and conclusions. Special attention was paid to the theoretical frameworks, conceptual models, and methodological approaches used in the reviewed studies, as well as the variables and relationships discussed in the literature. The relevant variables were extracted from the literature review. These include characteristics of technological platforms (usability, interactivity, accessibility, among others), types of evaluation methods (formative, summative, authentic, among others), and contextual factors (type of educational institution, educational level, etc.).

The MICMAC (Multiplex Influence and Influence Capacity Matrix) decomposition methodology was applied to analyze the reciprocal influences between the identified variables. A matrix was constructed that shows the relationships between the variables and classifies their impact according to their influence and capacity to be influenced. Secondary information available in the reviewed literature and academic databases was used. Qualitative and quantitative analysis techniques were applied to examine the secondary data collected, including content analysis and statistical methods.

The results acquired from the secondary data analysis were interpreted in the context of the reviewed literature and the theoretical framework. Patterns, significant relationships, and potential implications for theory and practice in the educational digital ecosystem were identified. The main conclusions of the study were summarized and practical recommendations were provided for technology platform designers, educators, and policymakers. These conclusions and recommendations were based on the findings obtained throughout the study and the synthesis of the reviewed literature.

Results

Below are the results acquired from the analysis of the variables relevant to the study on the educational digital ecosystem, focusing on the relationships between technological platforms, evaluation methods, and educational contexts. The findings presented here are derived from a rigorous analysis of data collected through a review of specialized literature and documentary analysis relevant to the field of study. As shown in Table 1, the first column indicates the number

of the variable, the second column shows the code corresponding to the variable, followed by the third column that presents the name of the variable, and finally the fourth column offers a description detailed of it.

As can be seen, variable number 1 is identified by the code USA, called Usability, and is described as the ease of use of the platform for both teachers and students. Likewise, variable number 2 is identified with the code INT, it is called Interactivity and is described as the degree of interaction and participation offered by the platform. In this sense, the data in Table 1 can be interpreted in a similar way.

Table 1. Variables related to technological platforms, evaluation methods, and the educational context

#	Code	Variable	Description
Variables related to technological platforms			
1	USA	Usability	Ease of use of the platform for teachers and students.
2	INT	Interactivity	Degree of interaction and participation offered by the platform.
3	ACC	Accessibility	Accessibility level for users with different abilities and devices.
4	CUS	Customization	Platform's ability to adapt to individual preferences and needs.
5	QC	Quality of content	Relevance, accuracy, and topicality of the educational material provided by the platform.
Variables related to evaluation methods			
6	TEV	Type of evaluation	Formative, summative, diagnostic, among others.
7	AUT	Authenticity	The degree to which assessments reflect real-world situations and contexts.
8	VF	Variety of formats	Diversity of evaluation methods used, such as written exams, projects, online discussions, among others.
9	VR	Validation and reliability	Rigor and consistency of the evaluation methods used.
Contextual variables			
10	TEI	Type of educational institution	Primary school, secondary school, university, distance education, among others.
11	EL	Educational level	Elementary, secondary, higher education, postgraduate education, etc.
12	TECI	Technological infrastructure	Availability and access to technology in the educational environment.

Source: Authors

With the list of variables selected previously, a joint reflection process was carried out to identify the relationships of influence and dependence between each of the variables, using a MICMAC matrix as an integral part of the second stage of the method, the values in the matrix range from zero (0) to three (3), where zero (0) indicates a null relationship, one (1) indicates a weak relationship, two (2) indicates a moderate relationship, and three (3) indicates a strong relationship. Figure 1 displays the matrix of direct influence and dependence of 12x12 dimensions, which has been completely filled. As can be seen, the relationship of the variable ACC (Accessibility) with itself is null (0), with the variable AUT (Authenticity), it is weak (1), with the variable QC (Quality of content) the relationship is null (0), which shows that accessibility does not influence or depends on the quality of the content. Similarly, the direct influence/dependence relationship between each variable is detailed in Figure 1, which illustrates the matrix of direct influence/dependency.

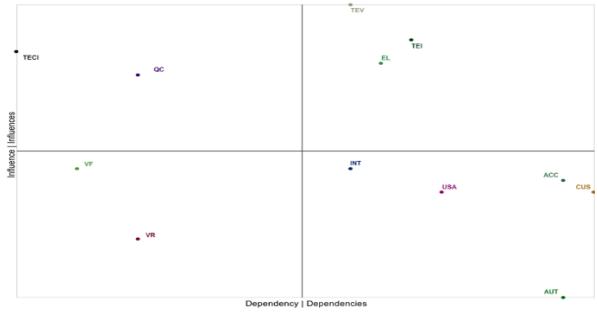
Figure 1. matrix of direct influence/dependency

Influence ↱	ACC	AUT	QC	INT	TECI	EL	TEI	TEV	USA	VR	VF	CUS
ACC	0	1	0	2	0	2	3	3	3	0	0	3
AUT	1	0	0	1	0	0	0	0	1	0	1	3
QC	3	3	0	1	1	3	3	3	1	3	2	3
INT	3	3	0	0	0	3	2	3	2	0	0	2
TECI	3	3	3	3	0	2	3	3	3	1	1	3
EL	3	3	3	2	3	0	3	3	3	1	0	3
TEI	1	2	3	3	3	3	0	2	3	3	3	3
TEV	3	3	3	3	3	3	3	0	2	3	3	3
USA	3	3	0	3	0	0	0	3	0	1	0	3
VR	2	3	2	0	0	2	1	0	1	0	1	0
VF	3	1	0	3	0	1	2	1	2	2	0	3
CUS	3	3	0	0	0	3	3	0	3	0	1	0

Source: authors

Once the matrix was completed, the processes of classification and localization of each variable were carried out in one of the four quadrants of the plane of direct influence/dependence, as illustrated in Figure 2. From the structural analysis, the presence of three key variables was established, which were positioned in the first quadrant (upper right corner): TEV (Type of evaluation), TEI (Type of educational institution), and EL (Educational level). In the second quadrant (upper left corner) two determinant variables were identified: QC (Quality of Content) and TECI (Technological infrastructure). In the third quadrant (lower left corner) two variables classified as autonomous were located: VR (Validation and reliability) and VF (Variety of formats), finally, in the fourth quadrant (lower right corner) five variables were classified as result: INT (Interactivity), USA (Usability), ACC (Accessibility), CUS (Customization) and AUT (Authenticity).

Figure 2. Plane of direct influence/dependence



Source: Authors

To better explain, these same results are shown in Table 2.

Table 2. Classification of factors by direct influences and dependencies

Type of Variable	Variable	Code
Key, strategic or challenge factors	Type of evaluation	TEV
	Type of educational institution	TEI

	Educational level	EL
Determinant or "influencing" factors	Quality of content	QC
	Technological infrastructure	TECI
Autonomous or independent factors	Variety of formats	VF
	Validation and reliability	VR
Dependent or result factors	Usability	USA
	Interactivity	INT
	Accessibility	ACC
	Customization	CUS
	Authenticity	AUT

Source: Authors

When observing the classification table of the variables, the Type of evaluation appears as a key variable. This classification is due to its high influence and high dependence on the educational digital ecosystem. The type of evaluation used has a relevant impact on the learning experience of the students and can influence the motivation, commitment, and academic performance of the students. According to Rahman et al (2022), the type of evaluation used often dictates the style of learning and teaching the content. For example, formative evaluations may require a more focused approach to feedback and ongoing skill development, while summative evaluations may focus on assessing content mastery at the end of a study period.

For Makri, et al. (2021), the choice of the type of evaluation is closely related to the educational objectives and the pedagogical approach used. On the other hand, Link, et al. (2022) state that the type of evaluation can determine the nature and frequency of the feedback provided to students, which is effective and is essential to improve learning and to promote academic development. In this sense, given its central role in the design and implementation of the educational process, as well as its impact on the student's experience and performance, the variable Type of evaluation is classified as key in the educational digital ecosystem.

The second key variable is Type of educational institution, this is due to its high influence and high dependence on the educational digital ecosystem. First, different types of educational institutions, such as primary schools, secondary schools, universities, and higher education institutions, may have different capabilities and approaches to implementing educational technologies. These differences can influence the selection and use of technological platforms, as well as the evaluation methods used. According to Pradana et al. (2020), each type of educational institution has its own educational and pedagogical objectives. For example, a primary school may focus on developing basic skills, while a university may prioritize research and specialization.

On the other hand, Alam & Mohanty (2023) state that the type of educational institution can be associated with different socioeconomic and cultural contexts. That is, schools located in urban areas may have access to different technological and financial resources than schools in rural areas, which may influence the technological infrastructure available and the teaching and learning strategies used. Likewise, according to Kahu, et al. (2020), the nature and educational focus of the educational institution can affect the student experience, in the sense that students may experience different levels of technological support, resources, and opportunities of learning according to the type of educational institution attended.

The last variable that was classified as key was Educational level, whose classification is due to its high influence and high dependence on the educational digital ecosystem. In this sense, each educational level, whether primary, secondary, higher education, among others, has unique characteristics and educational needs. For example, primary school students may require a more playful and visual approach to their learning, while university students may require greater autonomy and research capacity.

According to Hayat, et al. (2020), the educational level influences the teaching and learning strategies used. That is, the pedagogical methods used in primary education can differ significantly from those used in higher education. Therefore, the educational level affects the selection and design of learning activities, as well as the educational resources used. Likewise, Newman & Gough (2020) state that the type of evaluation and evaluation criteria vary depending on the educational level. For example, while evaluation in primary education may focus on mastery of basic concepts and fundamental skills, evaluation in higher education may include the practical application of knowledge and critical analysis skills.

Continuing with the classification of the variables, the focus is now on the variables classified as determinants. In this sense, the variable Quality of content was classified as such, due to its high influence, but low dependence within the educational digital ecosystem. The quality of educational content has a relevant impact on the effectiveness of the learning process because high-quality content can facilitate students' understanding, retention, and application of knowledge.

According to Bakker, et al. (2021), high-quality educational content is characterized by being relevant and pertinent to educational objectives and student needs. That is, well-structured and evidence-based content can improve the understanding and applicability of knowledge. While for Kwangmuang et al. (2021), quality educational content can promote learners' analytical skills and critical thinking by presenting accurate, up-to-date, and objective information, which can stimulate debate and reflection among learners. On the other hand, although the quality of content has a significant impact on the learning process and institutional reputation, its implementation and improvement can be managed independently of other variables within the educational digital ecosystem. Therefore, it is classified as a determining variable in the research.

On the other hand, Technological infrastructure was classified as a determinant variable due to its high influence, but low dependence on the educational digital ecosystem. The technological infrastructure provides access to digital resources and tools that are fundamental to the educational process, which include computers, mobile devices, educational software, high-speed internet access, among others. According to Jannah, et al. (2020), adequate technological infrastructure is essential to facilitate the effective implementation of technology-based teaching and learning strategies. In addition, it allows the creation and distribution of digital educational content, the implementation of interactive and collaborative activities, and access to online resources.

Likewise, Moldavan, et al. (2022), state that technological infrastructure can play a significant role in reducing digital divides and promoting educational equity and provides all students, regardless of their geographic location or economic resources, the opportunity to access quality

education and online educational resources. While for Troussas & Sgouropoulou (2020), a solid technological infrastructure provides the necessary environment for the implementation of innovative educational practices, such as adaptive learning, virtual reality, artificial intelligence, and game-based learning. These technologies can improve the educational experience and promote more effective and meaningful learning. In this sense, given its importance in facilitating access to education, supporting learning and teaching, promoting educational equity, and encouraging innovation, the variable Technological infrastructure is considered a determinant one.

Continuing with the classification of the variables, the focus is now directed towards those identified as autonomous. The first of these was Variety of formats this is due to its low influence and low dependence on the educational digital ecosystem. Although the variety of evaluation formats can offer benefits in the educational process, their specific impact may vary depending on the context and individual preferences. Therefore, its influence on the overall success of the educational digital ecosystem may be limited. According to Vykydal, et al. (2020), the implementation of a wide variety of assessment formats can present logistical and administrative challenges for educational institutions, which could limit their widespread adoption and, therefore, their influence on the educational ecosystem.

For Eradze, et al. (2021), preferences and priorities regarding evaluating formats may change over time and may be affected by external factors, such as technological advances or changes in pedagogical practices. This can reduce the dependence of the variable on the general functioning of the educational digital ecosystem. In this sense, given its ability to promote adaptability, equity, creativity, and motivation in the educational process, the variable Variety of formats is considered autonomous in the educational digital ecosystem.

The other variable that was classified as autonomous was Validation and reliability, which means that it has a low influence and a low dependence on the educational digital ecosystem. The validation and reliability of evaluations can be considered as technical and administrative aspects of the evaluation processes. Although they are important to ensure the quality of evaluations, their specific impact on the overall success of the educational digital ecosystem may be limited. According to Cañadas (2023), educators and instructional designers can focus mainly on aspects such as the relevance of the content, the variety of evaluation formats and feedback, relegating validation and reliability to the background. This could indicate a lower influence of this variable on the educational ecosystem.

On the other hand, Conrad et al. (2022), evaluation validation and reliability may be normative requirements or quality standards in some educational contexts, but their influence may be more limited compared to other variables that directly affect student experience and performance. In this sense, due to its technical and administrative nature, as well as its possible relegation to the background compared to other educational considerations, the variable Validation and reliability is classified as autonomous on the educational digital ecosystem.

Moving forward in the classification of variables, the focus is now directed towards those identified as results. Usability was classified as a results variable, due to its high dependence, but low influence on the educational digital ecosystem. Usability is an important aspect of the

user experience on educational technology platforms; its direct influence on the general success of the educational ecosystem may be limited compared to other more central variables, such as the quality of content or types of evaluation. According to Pal & Vanijja (2020), usability mainly refers to the ease of use and efficiency in interacting with a technological platform. Although this variable is crucial to guarantee a positive user experience, its impact on the achievement of educational objectives can be indirect and conditioned by other factors, such as the quality of content and the effectiveness of the teaching methods.

For Miraz, et al. (2021), usability can largely depend on other aspects of the design and implementation of technological platforms, such as user interface, navigation, and accessibility. Therefore, its success and effectiveness may be conditioned by the influence of these variables. While for Vlachogianni & Tselios (2022), usability can be considered more as a result observed after the implementation of a technological platform, rather than a determining factor in the design or initial adoption. That is, its importance becomes evident as users interact with the technology and provide feedback on their user experience. Therefore, although usability is a critical aspect of the user experience in the educational digital environment, its direct impact on the general success of the educational ecosystem may be limited compared to other more central variables.

On the other hand, the variable Interactivity was classified as a results variable, due to its high dependence, but low influence on the educational digital ecosystem. In this sense, although interactivity is a fundamental aspect to promote the participation and commitment of learners in the educational process, its direct impact on the achievement of educational objectives may be limited compared to other more central variables, such as quality of content or evaluation methods. According to Ahshan (2021), interactivity refers to the ability of technological platforms to enable the active participation of users through various activities, such as discussion forums, collaborative activities, and feedback tools. Therefore, although it is crucial to promote active learning focused on the student, its impact on the achievement of educational objectives can be indirect and conditioned by other factors.

Tao, et al, (2022), state that interactivity can depend largely on other aspects of the design and implementation of technological platforms, such as usability, accessibility, and quality of content. Therefore, its success and effectiveness may be conditioned by the influence of these variables. While for Akour et al. (2022), interactivity can be considered more as a result observed after the implementation of a technological platform, rather than a determinant factor in the design or initial adoption. Like usability, its importance becomes evident as users interact with the technology and participate in interactive activities. Although interactivity is a crucial aspect to foster the participation and engagement of learners in the digital educational environment, its direct impact on the achievement of educational objectives may be limited compared to other more central variables.

Regarding Accessibility, it was classified as a results variable, due to its high dependence, but low influence on the educational digital ecosystem. Although accessibility is essential to ensure that all users, regardless of their disabilities or abilities, can access and use educational technology platforms, its direct impact on the achievement of educational objectives may be limited compared to other more central variables, such as the quality of content or the types of

evaluation. For Botelho (2021), accessibility refers to the ability of technological platforms to be used by people with different abilities and disabilities, including visual, auditory, motor, and cognitive.

According to Senjam, et al. (2021), accessibility can depend largely on other aspects of the design and implementation of technological platforms, such as usability, interactivity, and quality of content. Therefore, its success and effectiveness may be conditioned by the influence of these variables. In this sense, although accessibility is fundamental to guarantee equity in access to online education, its direct impact on the achievement of educational objectives may be limited compared to other more central variables. Therefore, it is classified as a result variable with high dependence, but low influence.

On the other hand, Customization was classified as a results variable due to its high dependence and low influence on the educational digital ecosystem. Although customization is essential to adapt educational content and activities to the individual needs of learners, its direct impact on the achievement of educational objectives may be limited compared to other variables. In this sense, Alamri, et al. (2021) state that customization refers to the ability of technological platforms to adjust the content, presentation, and educational activities according to the individual preferences and characteristics of the students. While Shah (2023) points out that customization is largely related to other aspects of the design and implementation of technological platforms.

Finally, Authenticity was classified as a result variable, because even though authenticity is essential to guarantee the relevance and applicability of educational content in real life, its direct impact on the achievement of educational objectives can be limited. According to Radović (2021), authenticity refers to the ability of educational content to reflect real-world situations and contexts and to promote the practical application of knowledge and skills. For Hasan, et al. (2023), authenticity can be considered more as a result observed by users after interacting with educational content, rather than a determining factor in design or initial adoption.

Conclusions

In this exhaustive study of the educational digital ecosystem, various variables that influence its operation and effectiveness have been identified and analyzed. Through the application of the MICMAC technique, these variables have been categorized according to their degree of dependence and impact in the digital educational context. The conclusions obtained offer a comprehensive view of the key factors that shape the online educational environment and highlight important areas for continuous improvement and future development.

The variables identified as key, such as the Type of evaluation, the Type of educational institution, and the Educational level, emerge as fundamental pillars that shape educational practices and the student experience in the digital environment. These aspects are critical to adapt teaching and evaluation to the particular needs of learners and to ensure the effectiveness of online educational interventions. Likewise, it is revealed that variables such as Quality of content and Technological infrastructure exert a determining influence on the general success of the

educational digital ecosystem. These technical and operational aspects are fundamental to ensure the accessibility, reliability, and effectiveness of educational technological platforms and must be addressed as a priority to guarantee a high-quality digital educational environment.

On the other hand, despite their classification as autonomous, variables such as Variety of formats and Validation and reliability continue to be important to promote adaptability, equity, and quality in the educational process. These variables may require special attention to maximize their impact on the educational digital ecosystem and should be considered as areas of improvement for future research and educational practices. The analysis reveals that variables such as Usability, Interactivity, and Accessibility have a significant impact on the user experience, but their direct influence on the achievement of educational objectives may be limited. This suggests the need to improve these technical and operational aspects to ensure an optimal user experience and promote effective learning in the digital environment.

The relevance of promoting customization and authenticity in the design and implementation of educational technological platforms is also highlighted. These pedagogical and conceptual aspects are fundamental to foster meaningful, relevant, and lasting learning in the digital environment, and should be considered priority areas for the development of innovative educational strategies. In conclusion, this study offers a holistic and insightful view of the educational digital ecosystem, identifying key areas of strength and opportunities for improvement. The above provides valuable guidance for educators, instructional designers, and policymakers, and lays the foundation for future educational research and practice in the digital age.

Recommendations

Below are some recommendations based on the findings of this study:

-Improve the usability of technology platforms: Prioritize intuitive design and user-friendly navigation on online educational platforms to ensure an optimal user experience.

- Increase interactivity: Integrate interactive tools and activities that encourage active student participation and promote collaborative and meaningful learning.

-Enrich the quality of content: Develop diverse, relevant, and up-to-date educational content that adapts to the needs and preferences of students, and promotes a deep understanding of concepts.

-Personalize the learning experience: Implement customization strategies that allow the content and educational activities to be adapted according to the individual characteristics of the students, thus promoting more effective and student-centered learning.

-Diversify assessment methods: Offer a variety of assessment formats that encompass different abilities and learning styles, and that provide meaningful and timely feedback to students.

-Strengthen the authenticity of assessments: Design assessments that reflect real-world situations and contexts, and that promote the practical application of knowledge and skills in authentic contexts.

-Invest in technological infrastructure: Ensure reliable access to technology and stable connectivity for all students and educators, thereby ensuring equitable participation in online learning.

The above recommendations seek to improve the quality and effectiveness of learning in the digital educational ecosystem, promoting a student-centered approach and making the most of the potential of technology to transform education.

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