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Research Paper

Innovative Strategies and Student Academic Performance: Machine Learning Insights on International Students in Chinese Universities

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Abstract. The higher education sector in China has faced unprecedented challenges recently due to the global COVID-19 pandemic. The influx of international students, a vital component of the nation's academic landscape, presented distinct challenges, including maintaining academic achievements through various online platforms, which necessitated innovative strategies to ensure that their educational pursuits remained rewarding despite these challenges. This study aims to explore the innovative strategies adopted by Chinese higher education institutions in response to the COVID-19 pandemic and examine their impact on the academic achievements of international students. This study employs a comprehensive approach that incorporates questionnaire surveys and dominant Machine Learning Algorithms, such as Multiple Linear Regression (MLR), Decision Tree Model (DTM), Support Vector Regression Model (SVRM), and K-nearest neighbors (KNN). By employing rigorous data-gathering approaches, our study aimed to address a set of particular questions: How did these innovative strategies improve students' academic performance in the face of environmental emergencies? To what extent did international students benefit from these adaptations? Through investigation of these concerns, our research provides insight into the effectiveness of these strategies and their possible significance for future educational methodologies. Innovative strategies positively correlated with student academic performance during the COVID-19 pandemic in Chinese higher Education. This research highlights how overcoming these challenges can have broader implications for shaping resilient global education systems in future crises. The study accurately predicted academic performance, highlighting the importance of innovative teaching approaches in the context of the COVID-19 pandemic. This study might influence educational policies and practices. Educational institutions can make informed decisions about emergency preparedness and development by assessing results using a creative approach. Our findings bring depth to the global conversation on higher Education under challenging circumstances, showing how Innovation might alleviate the adverse impacts on international students' learning experiences.

Keywords: COVID-19, Innovative Strategies, Student Academic Performance, Global Environmental Emergency, Learning Outcomes, Digital Media Technology, Machine Learning.

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Introduction

This paper aims to investigate the effects of innovative strategies on students' psychological well-being, academic health, and performance, with a particular focus on international university students in China. The research employs a machine learning approach to investigate the adoption of innovative strategies by University students in China during the global environmental emergency and the students' learning outcomes following the global environmental emergency in 2023. To achieve this, we will adopt a methodology for evaluating the most adapted innovative strategy among international university students in China. The conclusions are significant for the applicability, and others can assume that an innovation strategy has a huge influence on a student's academic performance. Probe the innovative strategies implemented by Chinese institutions to overcome the challenges caused by the worldwide environmental emergency of COVID-19. These strategies serve as a model for educational resilience worldwide, assuring every student's success in the face of challenges. Discover how these strategies effectively influence the learning experiences of international students, offering significant insights for overcoming challenges in Education on a global level. The challenges that have been identified refer to effectively managing the rising tide of international students during the COVID-19 pandemic while ensuring their educational experiences in the Chinese higher education sector are enriching through the implementation of innovative strategies.

Furthermore, it is essential to prioritize the accurate prediction and improvement of academic performance in the face of the environmental emergencies of COVID-19. The COVID-19 pandemic is considered a case study of a real-world environmental emergency that impacted global education mechanisms. While the primary focus is on the pandemic, the study's insights are framed within the broader context of environmental emergencies to enhance the applicability of its findings for future crises.

The Greeks devised the strategy, which lent it a militaristic connotation.

The concept "strategic" is derived from the Greek word "strategos," meaning "a general in command of forces," "the skill of a general," or "a strategy to kill opponents by making efficient use of resources"[1-3]. This word encompasses goals to be achieved and strategies to be implemented based on the enemy's response in various circumstances[4].

At the time of Pericles (450 BC), the strategy was already seen as an organizational competence, thus management skills, as per [5], including Administrative, leadership, public speaking, and power. The commercial world, which has grown considerably, needs directions, divisions, and approaches to be pursued through all structures [1], and fully adopted strategy after World War II. Because of the complexity of the organizations created by this development, as well as the pace of climate change, organizations have been pushed to allocate more facilities to design and implement strategies that would assist them in addressing challenges in the current and achieving their objectives within the short, moderate, and long term [6]. [7] believes that only in the 1980s were approaches undergoing significant change.

The advancement of transportation and communication technologies inspired trends like corporate restructuring, collective decisions, and actions affecting the organizational structure, financing, and

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portfolio management [8], and since then, interactive dynamics and connectivity on a global scale have gained prominence.

Today, whether a firm is run for profit or not, leadership and management require the ability to think strategically [9]. After all, the strategy discusses the connection between the business's internal and external environments [10].

According to [11], improving performance is one of the major causes for organizations to adopt innovative strategies. Although mainly associated with the challenges of organizations, inventiveness has emerged as the main driver behind such a nation's socio-economic well-being and economic growth [12]. As a response, most nations strive to achieve a competitive gain in the environment of global innovations [13]. To improve economic growth and prosperity, established and developing economies are putting great importance on Innovation [14, 15].

In this study, 'Innovative Strategies' are defined as a comprehensive range of adaptive methods implemented by higher education institutions to maintain academic continuity during crises like as the COVID-19 epidemic. These strategies include innovative technologies (e.g., Learning Management Systems, Google Meet, ZOOM Meeting, VOOV Meeting etc.), pedagogical transitions to online and blended learning models, faculty development programs for digital instruction, curriculum modifications for remote learning contexts, and adaptive academic policies in response to crises. This multi-faceted approach demonstrates a comprehensive awareness of Innovation, incorporating technological, pedagogical, and institutional elements to uphold educational quality in challenging environments. According to many authors, the definitions of strategy and strategic management are as follows. These conceptions assist organizations in accomplishing their long-term goals and objectives and long-term comparative edge in the markets in which they compete. [16], defined strategy as the method of assessing the current environment and making changes as necessary. Identifying one's resources and how they must be being an element. According to [17], an organization's strategy defines its fundamental long-term goals in addition to implementing strategic planning and allocating resources needed to accomplish those goals. "Strategy formulation can only build competitive gain to a level that the method can convey direction to employees in the ranks," says [18]. By establishing and influencing actions rather than just reacting to them, strategic management enables an organization to take complete control over its future and become more proactive than reactive in developing it. The benefits of strategic management have been recognized and appreciated by small business proprietors, presidents, chief executive officers, and managers of numerous nonprofit and for-profit organizations.

On the other hand, long-range planning aims to maximize today's modern developments for tomorrow. Strategic management seeks to capture and build new and different prospects for tomorrow. A crucial skill for strategists is choosing the best strategies to help an organization or business. An organization can operate as a competitive team with the support of strategic management. Most small organizations and some large businesses have only the corporate and functional levels; they need divisions or departments of the business.

This study has the following sections: the second is about a Review of the Literature, and Section three is about the study's Methodology, including data collection methods and data analysis techniques. Section Forth, Discussions, Section Fifth, Conclusion; Section Sixth, Acknowledgement; and Section Seventh, References.

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1. Review of the Literature

1.1. Innovative Strategies and Conceptual Framework

The objective of assessing an enormous body of literature is to provide encouragement for this research's conceptual framework and corroborate using Multiple Linear Regression (MLR) methods, Decision Tree Model (DTM), Support Vector Regression Model (SVRM), and K-Nearest Neighbors (KNN) the relationship between the innovative strategies and student academic performance. A conceptual framework for online Education, such as learning management systems, Google Meet, Zoom Meet, Online Mooc Lectures, VOOV Meeting, Ding Talk, and WeChat, are additionally offered. These systems prove that causality exists in pandemic disruption. They were adhering to the innovative strategies conceptual framework. Implementing innovative strategies is essential to effectively navigate the distinct challenges caused by the COVID-19 pandemic and facilitate the continued academic achievements of international students enrolled in Chinese higher education institutions. These strategies assist in navigating the sudden interruptions triggered by the global environmental emergency while ensuring that Education remains of the highest quality.

1.2. Machine Learning Techniques in Educational Research

Regression analysis is a statistical approach to analyzing and modeling variables' relationships. Its main objective is to determine the values of the unknown parameters in the regression model [19]. The application of multiple linear regression involves determining the relationships between variables, building confidence intervals for regression coefficients, and performing hypothesis tests to assess the statistical significance of these coefficients [20]. The primary purpose of Decision Tree Models (DTMs), as stated by [21], is to facilitate predictive modeling by systematically representing data. In this representation, nodes correspond to features, and branches designate decision rules. DTMs are designed to identify patterns and relationships in datasets, allowing for accurate classification or regression objectives by dividing the feature space into smaller sections to forecast the target variable. Consequently, the Support Vector Regression Model (SVRM) algorithm is a supervised learning technique commonly employed in data mining and text categorization [22]. The support vector regression model (SVRM) approach is practical in domains with many parameters. It is not at risk of overestimation, provides reliable outcomes under challenging settings, can be adjusted to different situations, utilizes resources effectively, and is especially useful for analyzing sparse data, such as text categorization. However, its effectiveness for a particular task depends on the specific requirements of that activity. According to [21], the primary purpose of the K-Nearest Neighbors (KNN) algorithm is to classify or regress data points based on the similarity of their neighboring instances in the feature space.

1.3. Innovation Types and Organizational Strategies

The Innovation of newer services or products can be thought of as Innovation [23, 24]; Various business strategies [25, 26], the advancement of novel knowledge [27]; and a unique way of transmission are all possible [28]. According to [29], organizational Innovation refers to implementing an innovative concept that encompasses all organizational activities, such as a new and more effective product, service,

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or procedure. The various types of innovations that are the focus of this research study are (Learning Management System, Google Meet, Zoom Meet, Online Mooc Lectures, VOOV Meeting, Ding Talk, and WeChat) as Digital Media Technology. According to [29], the introduction of new products and services to meet market and customer demands is known as product and service innovation. According to [30], this process involves integrating new technologies into production methods to boost profits [31]. This Innovation highlights the need for an updated and remodeled end product to maintain its market position [31]. Process innovation is the addition of new components to existing processes and operations, such as new materials or machinery [29]. This procedure modifies how the company produces its goods and services [32]. Innovative strategies adopted during the global environmental emergency in China by international students strengthened the academic performance of the university's international students during the COVID-19 pandemic.

1.4. Pandemic-induced Educational Disruptions and Responses

Suppose a more dependable remedy for the global environmental emergency has yet to be discovered, and the disease's spread persists. In that case, the disturbance carried on by the environmental emergency in the educational sector usually lasts beyond what was expected. According to [33], the Director-General of UNESCO, "the global size and speed of the educational disturbance due to coronavirus are unprecedented and, if extended, could endanger the right to education," according to a VOA News report from 2020. Unexpected education cuts can cause significant problems for students, teachers, parents, and society. It might hurt pupils' academic achievement and interest. Suppose the students need to participate more intimately in their learning. In that case, it may result in passivity, which may cause adolescent involvement in crimes, a loss of interest in Education, and inferior academic performance. The US Center for Disease Prevention and Control (CDC) also expressed concerns regarding the effects of school closures. More prolonged shutdowns "may cause more students to gather outside of schools," according to the CDC [34]. According to [35], closing a school is particularly controversial and may significantly impact a large population of students in neighboring schools. Particularly for students with special needs or those who have learning disabilities who frequently require more physical attention and assistance from the teachers, it can affect the quality of teaching and learning and academic performance. Technology can help with some of the effects of school shutdowns, but it cannot compensate for the value of in-person interactions between students and instructors. The unprecedented COVID-19 pandemic compelled educational institutions worldwide to transition rapidly to digital technologies for the delivery of teaching and learning, marking a significant shift in educational practices [36]. Digital collaboration and technology interfaces play a vital role in enhancing student engagement and satisfaction. Digital technologies enable students to work together on projects, share resources, and communicate effectively, irrespective of their physical location [36, 37]. The difficulties associated with online learning during the pandemic and internship challenges further compound the academic challenges faced by international students in China. The shift to online learning, necessitated by the COVID-19 pandemic, presented numerous obstacles for students, including limited access to technology, unreliable internet connectivity, and a lack of face-to-face interaction with instructors and peers [38]. This abrupt shift presented both challenges and opportunities for educators and students alike, requiring adaptation to new modes of instruction and engagement. While some

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institutions were well-prepared for the transition, others faced significant hurdles in terms of infrastructure, resources, and training.

Additionally, many students need access to supplementary technologies, making it more challenging to utilize the learning technology during breaks from school. Strategic education cuts during the global environmental emergency remain one of the most appropriate strategies that can be used to lessen the impact of epidemic disease; mathematical models and empirical analyses of reactive education cuts in past pandemics indicate that it reduces the total number of cases in the community by 25% and delays the pandemic's peak by a week or two [39].

"Online education" refers to online teaching and learning using various platforms and technology resources. The success of distance learning depends on several elements, such as solid internet connections, educational software, digital talents, affordability, and availability of technology. Online education platforms and essential resources support online learning and educational services. Distance learning and the development of digital technologies are the origins of Online Education. Online education platforms can be fully utilized to resolve the learning gap and lower the rate of worldwide illiteracy due to the widespread use of mobile and internet technologies. Numerous platforms and tools for online Education are available, especially during pandemics like the one caused by the coronavirus.

Adopting innovative strategies also improves universities' and students' performance, usefulness, expertise, assurance, and Innovation while preparing them for the future. Existing literature consistently emphasizes the importance of innovative strategies, digital tools, and pedagogical innovations in mitigating the impact of global crises like COVID-19 on student academic performance. However, variations in technological readiness, institutional support, and resource availability result in diverse outcomes across contexts. Prior studies also underline the growing relevance of machine learning models in educational research for performance prediction. Despite this progress, gaps remain in understanding how innovative strategies specifically influence international students' academic success within the unique setting of Chinese higher education institutions during environmental emergencies. This study addresses this gap by integrating machine learning approaches with an analysis of innovative educational strategies.

2. Material and methods

This research explores the innovative strategies adopted by the higher education sector in China during the global environmental emergency and the learning outcomes of international students in 2023. The research methodology incorporates survey-based data collection with a quantitative analysis approach to study the perspectives and experiences of international students in Wuhan City; who had experienced the transition to innovative learning strategies during the COVID-19 pandemic. Due to the accessibility and availability of international students in Wuhan, the data was collected through a convenience sampling method, so as to facilitate the collection of data within the given time frame. This technique may constrain the sample's representativeness, as it targets easily accessible respondents from specific universities in Wuhan. Furthermore, self-selection bias may influence replies, as students with deeper opinions and experiences may be more motivated to participate. These considerations may limit the applicability of the findings to the broader population of international students in China or worldwide.

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Further research with more diverse and randomized populations would improve external validity. This method was chosen because it enabled the researcher to get quick and effective insights into the relevant aspects of the situation, and in the face of the challenges posed by the pandemic, such as limited mobility and poor access to the broader population. This study adhered strictly to international ethical research standards. Ethical approval was obtained, ensuring that all procedures complied with relevant ethical guidelines. Participants were informed about the purpose of the study, and their voluntary participation was ensured. Measures were taken to protect confidentiality and anonymity, safeguarding participants' rights throughout the research process.

2.1. Sample and Data Collection Method

For this study, the population is international students in different universities in Wuhan City, China who have been studying since 2019. The primary source of information for these students aligns with the study's educational objectives of learning outcomes and experiences during the COVID-19 pandemic. The sample is made up of international students from a few public universities in Wuhan City who responded to questionnaires distributed through Google Forms and other contact methods including WeChat Video Calls. To make this accessible and inclusive, we selected this approach to ensure that the physical interactions were restricted. The survey had 343 students, from all kinds of nationalities and countries. The 343 respondents sample size is sufficient to support the study findings. Further data could be collected through additional interviews, however, some requirements and stipulations provided did constrain the range of further data collection.

2.2. Research Model of the study

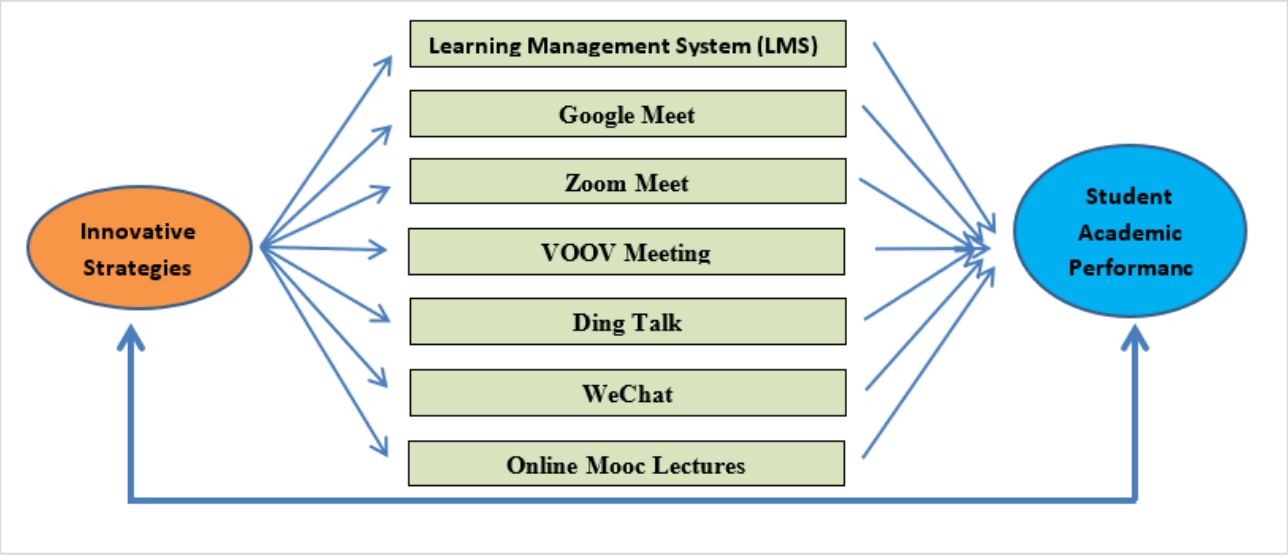

Figure 01. Research model shows how innovative strategies drive student academic performance

2.3. Measures of the study

First, the questionnaire has six questions to identify an organization's general state. Next, six questions evaluate the institution's teaching and learning state. Finally, there are six questions to discover the

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university's innovative strategy implementation approach. This methodological framework in Figure 02, was meticulously designed to align with the study's aims of evaluating the impact of innovative strategies on international students' academic performance, with each machine learning model selected to provide robust, data-driven insights into the relationship between the strategies and performance outcomes, ensuring precision and reliability in achieving the research objectives.

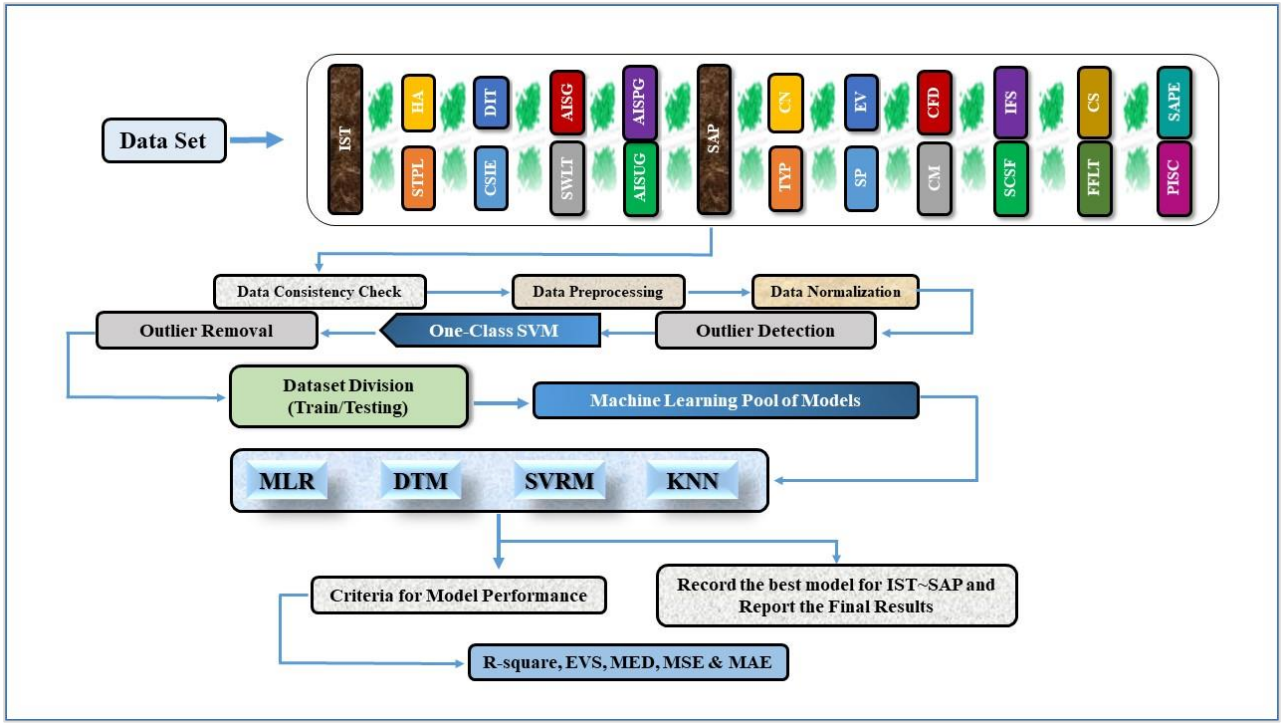

Figure 02. Methodological Framework.

2.4. Questionnaire Design and Validation

The questionnaire utilised in this study was constructed after a comprehensive literature assessment of previous research on innovative techniques, digital learning adoption, and student academic performance during situations of emergency. Items were carefully adapted to represent the context of international students in Chinese higher education institutions during the COVID-19 pandemic. The questionnaire, analysed using a 5-point Likert scale, yes/no, and categorical, was validated via a pilot study involving 30 international students in Wuhan, enhancing item clarity and relevance. The reliability analysis produced a Cronbach's alpha of 0.86, indicating robust internal consistency. The parameters consistent with the research model, Table 02; facilitated systematic assessment of innovative tactics, distance learning, crisis management, and academic achievement, hence augmenting the study's methodological rigour and empirical validity. The final survey was then distributed to 343 students for the main analysis.

2.5. Pre-processing of the Data

Exploratory data analysis (EDA) is an essential tool for understanding the data collected, as it demonstrates the distribution pattern of each variable and identifies correlations among features [40]. Before doing exploratory data analysis (EDA), purify the dataset by removing any data with missing

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values [41]. Normalization is an essential step in preparing the dataset features variables [42], a dataset in the study that significantly differs in magnitude for machine learning models. Various normalization methods are utilized for data scaling, including sigmoid normalization, Z-Score normalization, Min-Max normalization, and statistical column normalization. This study used the Min-Max normalization method (Eq. 01).

$$\boldsymbol{Data_{Norm}} = \frac{(\boldsymbol{Data_{Original}} - \boldsymbol{Data_{min}})}{(\boldsymbol{Data_{max}}) - (\boldsymbol{Data_{min}})} \tag{01}$$

Where, the $Data_{Norm}$represents the data normalization.

In the next stage of preliminary data analysis, we executed outlier detection on the datasets by identifying abnormal values that significantly deviate from the other values. We removed these outliers by establishing standard value ranges for the features. Unsupervised machine learning methods were employed to find patterns in the data that humans may not readily identify. Studies have utilized unsupervised algorithms to detect outliers, as exemplified by [43]. This study adopted an unsupervised outlier detection algorithm to demonstrate how washout-affected data can be autonomously detected.

The next phase involves partitioning the data into training and testing datasets. Overfitting during data training and ensuring the model's generalizability is a common issue. The study employed a cross-validation method to address this issue by partitioning the training dataset into testing and training subsets. According to the defined rules, 80% of the dataset was allocated for training, while the remaining 20% was designated for testing to train and test our machine learning algorithms.

2.6. Evaluation Criteria for Model's Performance

Evaluating the performance of machine learning models in predicting the impact of IST is an integral part of model development. It involved a comprehensive analysis of the correlation between actual and predicted data. Statistical measures have been used to assess the accuracy of machine learning models by correlating the expected and observed impacts. Six necessary statistical measures are used, consisting of the coefficient of determination (R^2), mean absolute error (MAE), minimum euclidean distance (MED), root mean square error (RMSE), mean square error (MSE), and explained variance score (EVS). The mathematical equations for each of these measurements are presented below:

$$\boldsymbol{R^2} = \mathbf{1} - \frac{\sum(\boldsymbol{y_i} - \boldsymbol{\hat{y}})^2}{\sum(\boldsymbol{y_i} - \boldsymbol{\bar{y}})^2} \tag{02}$$

$$\boldsymbol{MAE} = \frac{\mathbf{1}}{\boldsymbol{N}} \sum_{\boldsymbol{i=1}}^{\boldsymbol{N}} |\boldsymbol{y_i} - \boldsymbol{\hat{y}}| \tag{03}$$

$$\boldsymbol{MED} = \frac{\mathbf{1}}{\boldsymbol{N}} \sum_{\boldsymbol{i=1}}^{\boldsymbol{N}} |\boldsymbol{y_i} - \boldsymbol{\hat{y}}| \tag{04}$$

$$\boldsymbol{RMSE} = \sqrt{\frac{\mathbf{1}}{\boldsymbol{N}} \sum_{\boldsymbol{i=1}}^{\boldsymbol{N}} (\boldsymbol{y_i} - \boldsymbol{\hat{y}})^2} \tag{05}$$

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$$\boldsymbol{MSE} = \frac{\mathbf{1}}{\boldsymbol{N}}\sum_{\boldsymbol{i=1}}^{\boldsymbol{N}}(\boldsymbol{y_i} - \boldsymbol{\hat{y}})^{\mathbf{2}} \quad (06)$$

$$\textbf{Explained Varriance } (\mathbf{y} - \boldsymbol{\hat{y}}) = \mathbf{1} - \frac{\boldsymbol{Var}\,(\boldsymbol{y} - \boldsymbol{\hat{y}})}{\boldsymbol{Var}\,(\boldsymbol{y})} \quad (07)$$

Where, $\boldsymbol{N}$, $\boldsymbol{y_i}$, $\boldsymbol{\hat{y}}$, and $\boldsymbol{\overline{y}}$ are the overall data points, the measurement values, and the predicted IST~SAP, respectively.

3. Empirical results

Descriptive Statistics

Demographics	N	Min.	Max.	Mean	Std. Dev.	Skewness		Kurtosis	
	Stats	Stats	Stats	Stats	Stats	Stats	Std. Error	Stats	Std. Error
TYP	343	1	3	1.1195	0.46547	3.728	0.132	12.152	0.263
CN	343	1	7	3.4577	2.23942	0.424	0.132	-1.31	0.263
SP	343	1	3	1.6764	0.5699	0.135	0.132	-0.646	0.263
EV	343	1	6	3.9388	1.61835	-0.396	0.132	-1.098	0.263
Valid N (listwise)	343								

Table 01. Demographics' Descriptive Statistics
Source: Author's calculations

Table 01 presents the descriptive statistics of key demographic variables. The majority of respondents were from public institutions (Mean = 1.12) and represented diverse nationalities (Mean CN = 3.46). The data distribution shows acceptable skewness and kurtosis values, supporting the suitability of the dataset for regression analysis.

To determine the Machine Learning Algorithms of the dimensions of both measuring variables in this study. Multiple Linear Regression (MLR) methods, Decision Tree Model (DTM), Support Vector Regression Model (SVRM), and K-Nearest Neighbors (KNN) analysis methods have been undertaken to find the adoption of the predictor variables; that is an innovative strategy; Digital tool, such as (Learning et al. Meet, Zoom Meet, Online Mooc Lectures, VOOV Meeting, Ding Talk, and WeChat). The dependent variable, a Student's Academic Performance, has been investigated using machine learning algorithms.

The average statistical parameters for the training and testing sets for different methods of Student Academic Performance (SAP) prediction are presented in Table 02. The evaluation metrics considered are Mean Absolute Error (MAE), Mean Squared Error (MSE), Median Error (MED), Explained Variance Score (EVS) and the R^2 (coefficient of determination). MAE is the average magnitude of errors in predictions, and it is easy to understand how accurate the predictions were. MSE simply calculates the average squared errors, putting larger errors more into the spotlight. In R^2, the values closer to 1 imply better performance of predictive model. The evaluation metrics, such as MAE, MSE, and R^2, were utilized to assess model performance. MAE shows the average difference between predicted and actual values, helping understand how close predictions are to reality. MSE highlights larger errors by squaring them,

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showing the overall accuracy of the model. R^2 measures how well the model explains the data. Fig. 03 visually compares predictions to actual values for clarity.

Data Set	Method	Average statistical Parameters between (Training Set 80% and Testing Set 20%)				
		MAE	**MSE**	**MED**	**EVS**	**R^2**
SAP	**MLR**	0.075	0.012	0.042	0.887	0.883
	DTM	0.042	0.011	0	0.859	0.859
	SVRM	0.072	0.009	0.064	0.907	0.905
	KNN	0.056	0.019	0	0.757	0.757

Table 02. Average Statistical Parameters
Source: Author's Calculation

The dependent variable "Student Academic Performance" (SAP) is displayed in the table above by using machine learning algorithms (MLA) to extract empirical results from data collected through questionnaire surveys. The table demonstrates the average statistical parameters for each method between the training and testing sets.

According to the methods in the table, the sample comprises the students' academic performance at higher education institutions in China.

The MLR algorithm's predictions include some inaccuracies because of its moderate MAE, MSE, and MED values. However, with an EVS of 0.887 and R^2 of 0.883, it performs satisfactorily, indicating a good fit for the research topic. Compared to MLR, the DTM method displays greater accuracy with lower MAE, MSE, and MED values. A satisfactory fit for the study's data is indicated by its EVS and R^2 results of 0.859 and 0.859, respectively. With relatively better MAE and MED, SVRM succeeds favorably to MLR. A lessened MSE performs better than MLR and indicates greater accuracy. Additionally, SVRM yields higher EVS (0.907) and R^2 (0.905) results, indicating a better match for the investigation's data. Compared to MLR, KNN exhibits a lower MAE but a higher MSE and MED. This shows that KNN has more average oversights overall but fewer extreme errors. Compared to the other methods, it achieves a lower EVS of 0.757 and R^2 of 0.757, indicating a substantially weaker fit. Typically, an R^2 value above 0.7 is considered indicative of a strong model fit, while lower MAE and MSE values signify higher predictive accuracy. In this study, the SVRM's R^2 of 0.905 and low MSE of 0.009 reflect superior performance, while the MLR's R^2 of 0.883 remains within acceptable thresholds for predictive modeling.

In a nutshell, the Decision Tree Model (DTM) and Support Vector Regression Model (SVRM) perform better than Multiple Linear Regression (MLR) and K-Nearest Neighbours (KNN) based on the specified statistical parameters. Lower error metrics (MAE, MSE, MED), higher explained variance scores (EVS), and higher R-squared (R^2) values are obtained by DTM and SVRM, suggesting improved accuracy and fit for the particular research subject matter.

DOI: 10.21791/IJEMS.2025.14.

		IST	***SAP***
Correlation	***IST***	1.000	0.26
	SAP	0.26	1.000

Table 03. Correlation Coefficient Matrix
Source: Author's Calculation

The following insights describe the current relationship between innovative strategies and student academic performance, as portrayed in Table 03.

Innovative Strategies have a perfect correlation score of 1.000, while Student Academic Performance has a score of 0.26. The table indicates a perfect correlation between these two variables. Moreover, amid the global environmental emergency, executing innovative strategies resulted in students' remarkable academic performance, as evidenced by scores of 1.000 and 0.26 for Student Academic Performance and Innovative Strategies, respectively.

Codes	***Name of Parameter***	***Type of Parameter***	***Nature of Parameter***
IST	Innovative Strategies	Independent Variable	Main Measuring Variable
STPL	Strategic Plan	Input Parameter	Measuring parameter
HA	Holded Activities	Input Parameter	Measuring parameter
CSIE	Impact on students' enrollment	Output Parameter	Measuring parameter
DIT	Distance learning and teaching	Output Parameter	Measuring parameter
SWLT	Student's willingness to online learning and teaching	Input Parameter	Measuring parameter
AISUG	Adopted innovative strategy by under-graduates	Input Parameter	Measuring parameter
AISG	Adopted innovative strategies by graduates	Input Parameter	Measuring parameter
AISPG	Adopted innovative strategy by post-graduates	Input Parameter	Measuring parameter
SAP	Student Academic Performance	Dependent Variable	Main Predicted Variable
TYP	Type of Institute	Input Parameter	Measuring Parameter
CN	Country/Nationality	Input Parameter	Measuring Parameter
SP	Study Program	Input Parameter	Measuring Parameter
EV	Enrollment Volume	Input Parameter	Measuring Parameter
CM	Crisis Management	Output Parameter	Predicting Parameter
CFD	Collaboration between Faculty and Departments	Input Parameter	Measuring Parameter
SCSF	Successful communication between students and faculty	Output Parameter	Predicting Parameter
IFS	Internet facility for students	Input Parameter	Measuring Parameter
FFLT	Faculty familiarity with online learning and teaching	Input Parameter	Measuring Parameter
CS	Comprehensiveness of Study After Ecological Crisis	Output Parameter	Predicting Parameter

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PISC	Psychological impact and study consequences after ecological crisis	Output Parameter	Predicting Parameter
SAPE	Student academic performance evaluation	Output Parameter	Predicting Parameter
MAE	Mean Absolute Error	Indices	Base Model
MSE	Mean Squared Error	Indices	Base Model
MED	Median Absolute Error	Indices	Base Model
EVS	Explained Variance Score	Indices	Base Model
R^2	R-Squared	Indices	Base Model
MLR	Multi Linear Regression	Model	Main Model
DTM	Decision Tree Model	Model	Main Model
SVRM	Support Vector Regression Model	Model	Main Model
KNN	K-Nearest Neighbours	Model	Main Model

Table 04. Parameter's Descriptions

Source: Author's Compilation

Our study's Figure. 03 showcases visually stunning correlation coefficients between our independent variables and parameters, which are utilized to predict the dependent variable. For more accessible analysis, Table 04 offers comprehensive explanations of each parameter featured in the Figure.

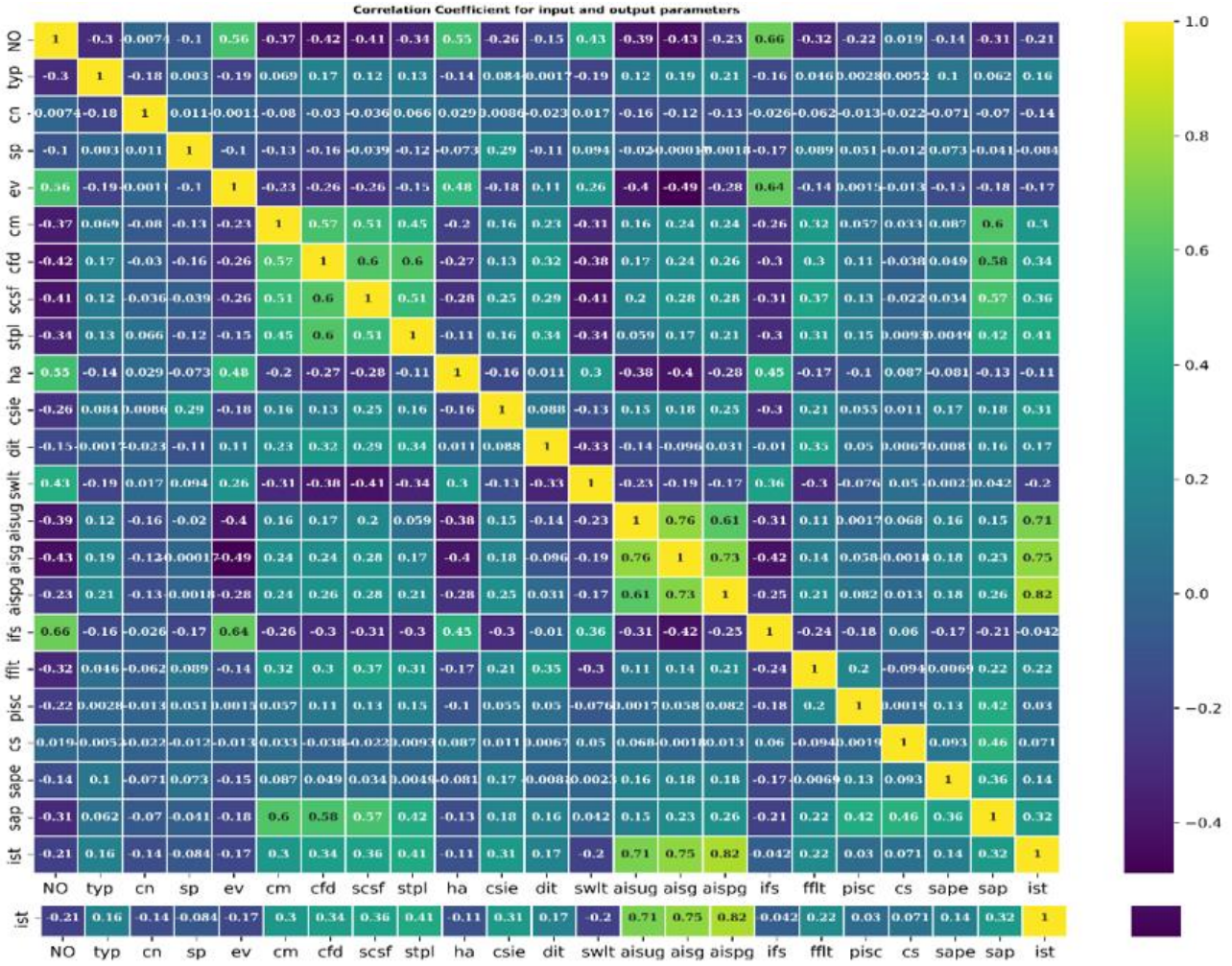

Figure 03. A heat map depicting the correlation coefficients ranging from -1 to 1 for NO, TYP, SP, CM, CFD and others with higher correlation in yellow and lower in purple.

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Figure 03 portrays the extent to which innovative strategies affect student academic performance during the global environmental emergency. The downward and left-to-right slope of the parametric shapes clearly explains why international students of Chinese higher education institutions adopted innovative strategies. The Figure provides a glimpse into the adoption trends at different academic levels. In the study mentioned above, the factor Innovative Strategies adopted by post-graduate students in various institutions was assigned an eigenvalue of 0.82, which was the highest level of adoption. The adoption level for graduate students was 0.75, slightly lower than that for the other two groups, and undergraduate international students had the lowest adoption level at 0.71. The heatmap distinctly highlights strong positive correlations between Innovative Strategies (IST) and Student Academic Performance (SAP). Key parameters such as Distance Learning and Teaching (DIT), Crisis Management (CM), Faculty Familiarity with Online Learning and Teaching (FFLT), and Successful Communication between Students and Faculty (SCSF) also show high correlations with SAP, with correlation coefficients exceeding 0.7. In contrast, parameters like Type of Institute (TYP) and Enrollment Volume (EV) exhibit weaker correlations, emphasizing the pivotal role of pedagogical and technological factors in driving academic outcomes.

A clear relationship between academic levels and the extent of strategy adoption is evident from the parameters plotted in the Figure, revealing the important role of innovative strategies in promoting learning outcomes for international students during difficult times. Understanding varying adoption of innovative strategies across academic levels guides effective interventions to support international students' learning in crises.

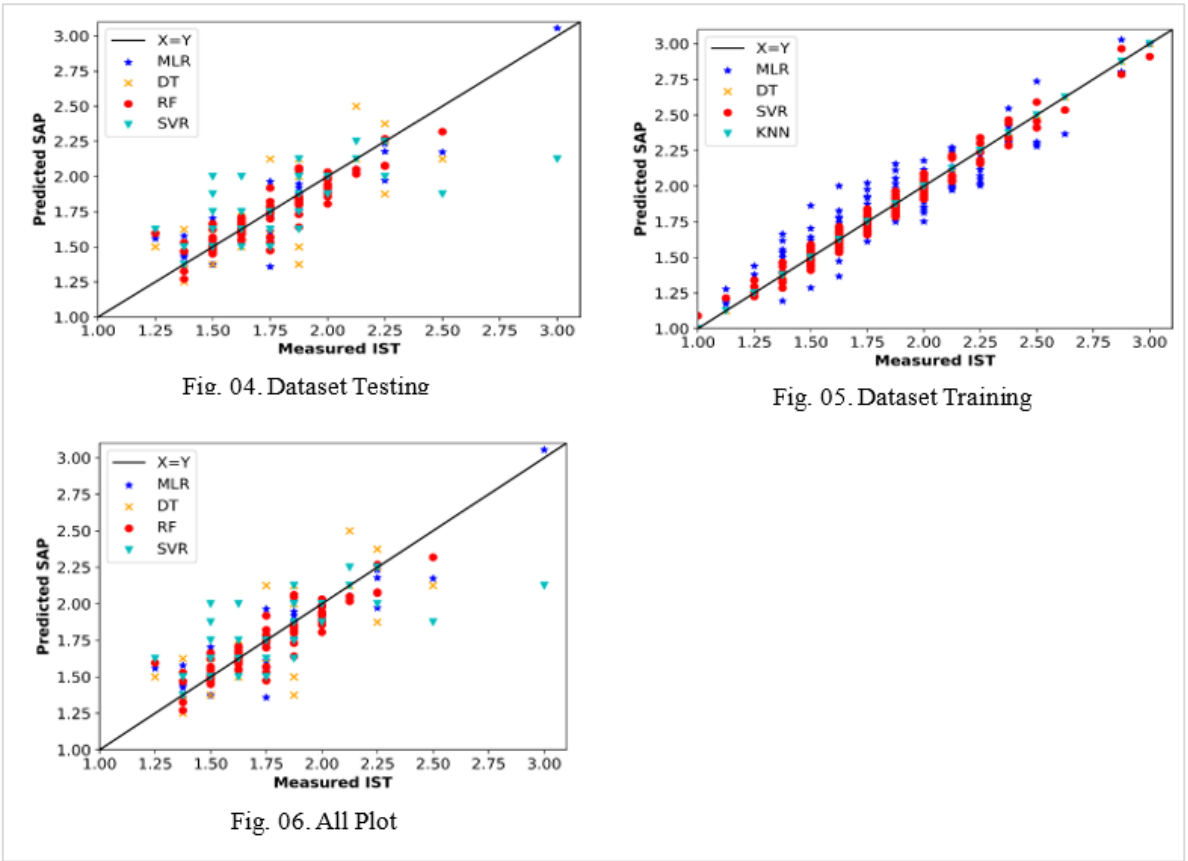

Fig. 04. Dataset Testing

Fig. 05. Dataset Training

Fig. 06. All Plot

Figures 04, 05 & 06. Machine Learning Algorithm (MLA) Model Plots: predicted SAP against the measured IST for models such as MLR, DT, RF, SVR, and KNN with the line of perfect prediction shown by X=Y.

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In the same initial context, 80% of the datasets serve the purpose of training, and 20% are employed for testing. It is clear from Table 02 that the SVRM and MLR give predictions that are more accurate than the other models in predicting student academic performance (SAP). [44], demonstrated that SVR provides superior predictive accuracy compared to MLR when modeling student GPA, particularly in complex, nonlinear educational datasets. Similarly, [45], utilized MLR to predict academic performance and highlighted its effectiveness, though acknowledging its limitations in capturing intricate relationships among educational variables. In our study, the SVRM achieved the highest R^2 value (0.905) and lowest MSE (0.009), outperforming MLR (R^2 = 0.883, MSE = 0.012) in predictive accuracy. This supports the notion that SVR's capacity to model nonlinear patterns and multidimensional interactions makes it a more robust method for predicting learning outcomes in educational research, especially when institutional, technological, and pedagogical factors are involved. The average EVS and R^2 values for the most effective prediction model were 0.907, 0.905, 0.887, and 0.883, respectively. In comparison to the other models, DTM mastered the second-best results. By producing figures, we may also assess the superior performance of models. Figures 04, 05 and 06 display the observed parameter for each model as IST (Innovative Strategies) and the predicted parameter as SAP (Student Academic Performance). The Support Vector Regression Model (SVRM) triumphs over the other models, as can be observed from the plot figures. Despite the competition in RF, K-Nearest Neighbours (KNN) performed the worst.

The above figures show a comparative analysis of machine learning algorithms (MLAs) predicting student academic performance (SAP) and measured innovative strategies (IST). For the sake of comparison with a perfect predictions baseline, each scatter plot has a reference line (X=Y). Support Vector Regression (SVRM) is the model with the strongest predictive capability, with points tightly clustered around the X=Y line in the middle range of measured IST values. This shows that it can generalize well over the dataset. However, Decision Tree Model (DTM) exhibits large deviations, especially for higher IST values, implying decreased precision. Multiple Linear Regression (MLR) does fairly well but it underestimates the higher values slightly. Random Forest (RF) is found to give a moderate prediction accuracy which is better than DTM but not as good as that of SVRM. On the other hand, K-Nearest Neighbors (KNN) has a larger spread particularly at low IST values, and exhibits shortcomings in managing nonlinearity. Therefore, there is an indication that SVRM is the most accurate model, though DTM and KNN perform much lower for extreme values.

Figure 07 depicts a histogram of student academic performance as seen from the scanner panel and in a questionnaire survey carried out under no-promotion configurations in response to implementing innovative strategies. Fig. 07 of the data from the MLA models reveals that international students in several higher-education institutions in Wuhan, China, are adopting a novel strategy.

This can be inferred from the SAP's frequency variation and nature. The MLA model data are distinguished by slightly more prevalent advancements, which, unlike those in experimentation as a questionnaire, may incorporate numerous digital technologies of innovative strategies simultaneously and are intended for higher education institutions.

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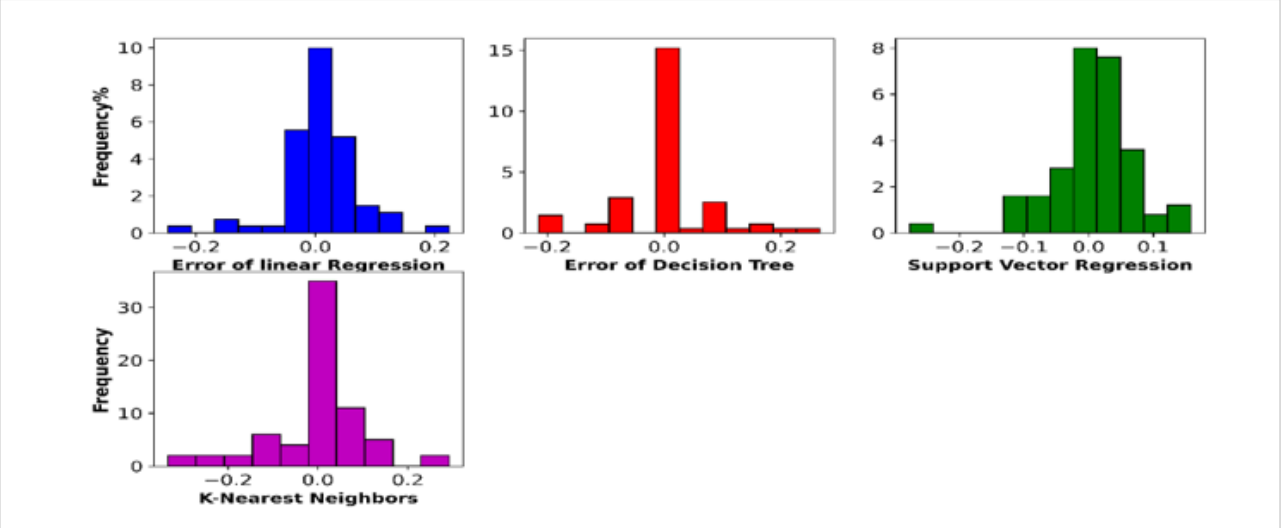

Figure 07. Histograms showing prediction error distributions for four regression models: Linear regression, decision tree, support vector machine regression, k-nearest neighbours.

It highlights how successfully international students in China adopted innovative strategies and how well they fit with data models. If the training datasets are typically distributed, the K-Nearest Neighbours ought to be very near to the normal distribution of the data. The models of the training dataset in Fig. 08 explain that If the K-Nearest Neighbours and Decision Tree models are close to the actual MMP, they are performing well in predicting the MMP based on the input features. A low MAE and MSE and a high R^2 and EVS values indicate that the predicted values are closer to the actual values. This suggests that K-Nearest Neighbours and Decision Tree models effectively predict MMP based on the input features in future cases.

Moreover, the models of the testing dataset in Fig. 09 explain that based on the statistical parameters mentioned above in Table 01, the Decision Tree Model (DTM) has the lowest MAE and MSE values, which means it is likely closer to the actual MMP values than the other ML models. However, the SVR Model has higher EVS and R^2 values, indicating better overall prediction performance for both MMP and SAP. It is essential to consider both the magnitude of the error (MAE and MSE) and the goodness of fit (EVS and R^2) when evaluating the performance of ML models.

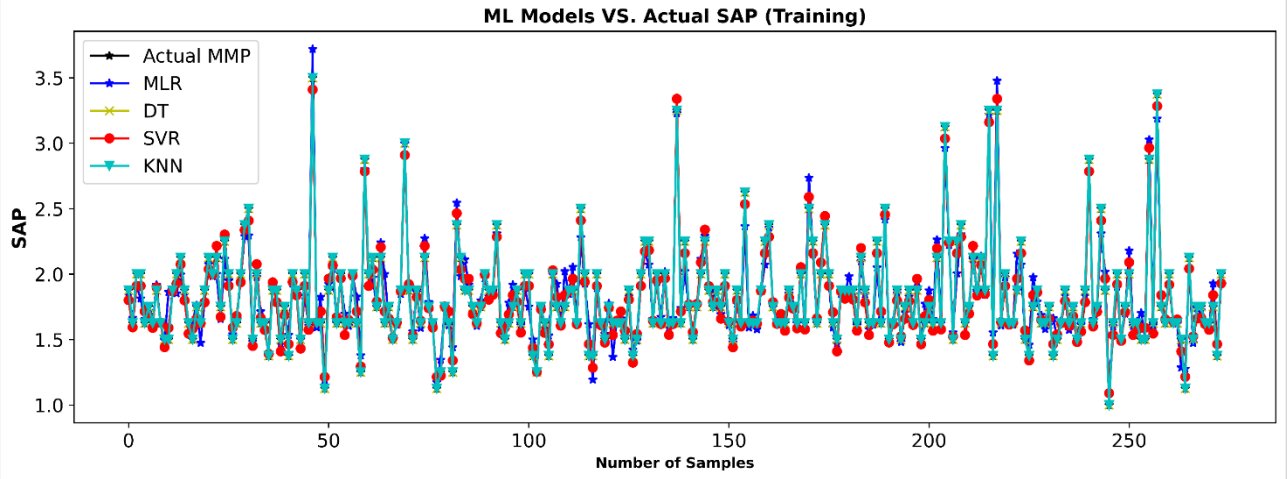

Figure 08. Line graph comparing actual SAP values to predictions from five machine learning models: MLR, DT, SVR, and KNN.

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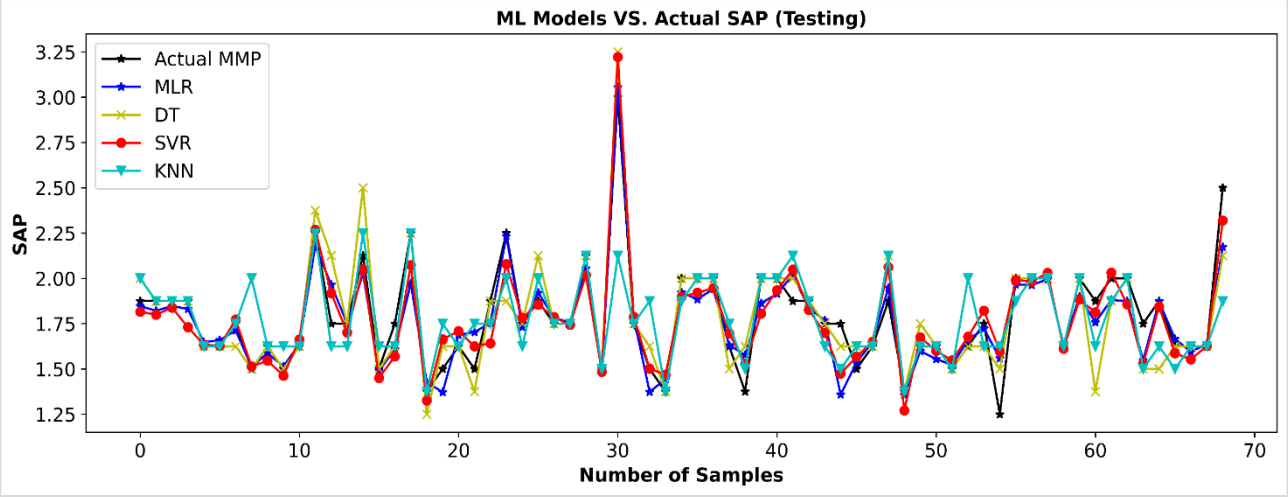

Figure 09. Line graph showing actual SAP values versus predictions from five machine learning models: Testing: MLR, DT, SVR, KNN.

The findings directly address the study's research questions by confirming that innovative strategies significantly influence student academic performance, as demonstrated by strong correlations and predictive modeling outcomes. The superior performance of SVRM aligns with expectations for handling educational data. These results are consistent with prior studies and highlight context-specific factors relevant to international students in Chinese universities.

4. Discussions

The superior impact of Distance Learning and Teaching (DIT) and Crisis Management (CM) strategies on student academic performance can be attributed to their direct influence on maintaining learning continuity and addressing immediate disruptions. DIT strategies, including robust online teaching platforms, ensured minimal academic interruption, while effective CM measures provided psychological and logistical support, reducing student stress and enhancing engagement. In contrast, strategies like Comprehensiveness of Study (CS) showed weaker correlations, likely due to their long-term orientation and indirect impact during the crisis phase. Our findings are consistent with [38], who emphasized the pivotal role of well-structured online learning systems in mitigating academic challenges during the pandemic. Similarly, [37]**,** highlighted that institutions with proactive crisis management frameworks reported higher student satisfaction and academic resilience. Our study extends this understanding by quantitatively demonstrating the relative effectiveness of these strategies among international students in Chinese universities.

4.1. Navigating the Digital Frontier: Education Amidst the Global Environmental Emergency COVID-19

As a result of the worldwide environmental emergency of COVID-19, especially during the period of 2020–2021, Chinese higher education institutions, particularly in Wuhan, are facing unprecedented challenges and require innovative solutions. Student-teacher interactions were revolutionized by online media and internet technology, leading to the establishment of a digital learning environment that was

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both significant and strategically important to Education and student services. This was a new age of learning, made possible by technological Innovation and digital adaptability. This educational evolution is what our study examines, and it explores the challenges and innovative strategies adopted to provide uninterrupted Education for international students.

These results align with the global educational policy that emphasizes the integration of technology and resilience in higher education systems. These measures are adaptable to various cultural settings, based on local technological infrastructure and training capabilities. Recommendations for enhancement include improving faculty members' use of digital platforms and enhancing internet accessibility, followed by regular training to help faculty members utilize digital tools effectively. To strengthen implementation, universities should establish structured faculty development programs focused on innovative digital platforms, emphasizing hands-on training and pedagogical integration. Critical preconditions include robust IT infrastructure, continuous technical support, and assessing faculty digital readiness. Institutional commitment to these factors ensures effective adoption of innovative strategies, ultimately improving student academic outcomes. These steps serve to reduce disturbances and lead to a sustainable and flexible education framework in the event of upcoming emergencies.

4.1.1. The Digital Learning Paradigm: From Offline to Online

Digital media has revolutionized the way students and instructors learn. This worldwide emergency-driven shift highlighted the strategic relevance of digital platforms. This paradigm shift helped keep Education going despite immense challenges.

4.1.2. Embracing Online Media: Tools and Technologies

Explore the various digital technologies that power education during times of emergency. From Google Meetings to Zoom Calls, these tools enabled real-time learning and connected teachers and students. Discover how these technologies formed a lively and engaging virtual classroom.

4.1.3. The Art of Innovation: Strategies That Worked

Discover Chinese higher education institutes' innovative strategies. We examined these methods to illustrate how certain teachers and students benefited from online learning. Discover the techniques that turned challenges into alternatives, laying the groundwork for crisis-ready Education.

4.1.4. Lessons for the Future: Shaping Education in the New Normal

Our research sheds light on the long-term effects of the crisis. How might Innovation learning influence Education's future? Explore remedies that can enhance educational policies and practices to better prepare institutions for future challenges better.

4.1.5. Empowering Institutions: Data-Driven Decision Making

Successful educational adaptation needs good administration. Explore the organization and assessment ties within education management. Discover how data-driven decision-making, accurate evaluations, and trustworthy information helped institutions manage the global environmental emergency, providing valuable lessons for future emergency response strategies.

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4.1.6. The Transformative Power of Innovation: Illuminating the Path Forward

This research demonstrates how Innovation enhances Education. Education remains resilient even under challenging conditions. Discover how digital technology enhanced learning experiences and demonstrated how to achieve educational excellence in unpredictable situations.

The research study examines the educational journey during the global environmental emergency of COVID-19 from multiple perspectives, offering a comprehensive understanding of the topic. The findings of this study give significant insights and propose innovative strategies for the future of Education in a dynamic and evolving world.

The research study examined the relationship between innovative strategies and student academic performance (SAP) in Chinese higher Education during the worldwide environmental emergency of COVID-19. As the perfect correlation scores show, innovative strategies and SAP have a strong positive relationship in global emergencies. The prediction was carried out using machine learning techniques, specifically the Support Vector Regression Model (SVRM) and Decision Tree Model (DTM), which indicated the highest effectiveness. The findings suggest a strong positive relationship between innovative strategies and Student Academic Performance (SAP), particularly during the COVID-19 pandemic. SVRM has shown exceptional precision in forecasting SAP, emphasizing its importance in educational settings. These findings suggest that the application of innovative strategies can have a substantial impact on student academic performance. The SVRM tool is a dependable method for predicting student academic performance in higher education settings, particularly during unpredictable circumstances.

To clarify methodological boundaries, we acknowledge that each machine learning algorithm (MLA) carries context-specific limitations. Multiple Linear Regression (MLR) assumes linearity and independence of predictors, which can lead to bias when relationships are nonlinear. Decision Tree Models (DTMs), though interpretable, are prone to overfitting small feature shifts, such as abrupt policy changes. Support Vector Regression (SVR) yields strong generalization but is sensitive to kernel and hyper-parameter selection, demanding computationally intensive tuning. K-Nearest Neighbours (KNN) performs well on locally smooth patterns but degrades with high-dimensional or noisy inputs and becomes inefficient as the cohort size grows. Recognizing these constraints enables a more nuanced interpretation of the reported accuracy metrics.

5. Conclusion

This research is a fundamental investigation of the innovative strategies that Chinese higher education institutions have implemented in addressing the worldwide environmental emergency of COVID-19. Through meticulous investigation, the objective is to provide practical suggestions to educational authorities to safeguard the enduring prominence of foreign Education in China during periods of uncertainty. Through an in-depth analysis of these fundamental elements, our study addressed the current deficiencies in knowledge and advanced the discourse regarding efficient emergency preparedness strategies within higher Education.

Higher education institutions in Wuhan, China, experienced severe disruptions due to the worldwide environmental emergency of COVID-19, which emerged in 2020-2021. The conventional method of in-

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person communication, which has historically been fundamental to the field of Education, has seen an important transition towards a digital landscape, whereby internet technology has emerged as an essential tool for ensuring the uninterrupted flow of educational practices. Nevertheless, this transition was not devoid of challenges. Educators and learners unfamiliar with digital media technologies and educational applications had immense challenges adjusting to this unprecedented educational environment.

Given these challenges, Chinese higher education institutions have promptly adopted, adapted, and incorporated a diverse range of digital media technologies and applications. E-learning has arisen as a critical tool for remote digital learning, utilizing computer- and internet-based electronic learning to facilitate Education without direct participation. Learning management systems (LMS) and other platforms, including Google Meet, Zoom, VOOV Meeting, Ding Talk, WeChat, and YouTube, as well as online lectures, have become essential elements of the learning experience, facilitating connections between students and instructors despite technological gaps. One of the primary subject matters was how these innovative strategies influenced student academic performance during the environmental emergency. The data showed the effectiveness of these strategies and the extent to which overseas students benefited. This study demonstrates how embracing Innovation can mitigate the adverse impacts of emergencies on students' learning experiences, revealing the future of Education.

This study has broad implications. Strategies employed by Chinese higher educational institutions can offer significant lessons to policymakers and institutions from around the world. The analysis of the triumphs and setbacks of international students in Wuhan may assist educational leaders in designing their emergency preparedness, online learning platforms, and faculty development programs based on the experience of Wuhan. During crises, faculty members will have no difficulty in transitioning to online Education with the strengthening of digital infrastructure, technological accessibility, and targeted faculty training. On the other hand, to ensure the effectiveness of innovative strategies, universities should establish continuous feedback loops involving students and faculty, enabling real-time assessment and refinement of teaching methods. Incorporating this feedback into decision-making promotes evidence-based implementation, ensuring that adopted strategies remain responsive, data-driven, and aligned with evolving educational needs.

This research also seeks to understand how Education has been able to adapt during unprecedented challenges. It shows how creativity, teamwork, and dedication to Education lead to change and Sustainability in unpredictable times. As a result, by introducing such measures, institutions increased students' achievements and performance, as well as access and support for the students. These outcomes demonstrate that Education is a tool for personal and social change and the world we live in. In this study, we hold out hope that Education can evolve and adapt during emergencies in the future, opening a new chapter of resilient and inclusive Education.

5.1. Practical Implications

Actionable steps for institutional practice emerge from the findings. First, we propose a continuous feedback loop: the weekly extraction of platform analytics (login duration, quiz scores, etc.) from the LMS, visualized in a dashboard reviewed bi-weekly by Programme teams, who then adjust pacing or intervention strategies. Second, a three-tier faculty development pathway is recommended, comprising

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baseline digital literacy workshops, peer-mentored micro-credentials in data-informed pedagogy, and competitive mini-grants rewarding demonstrable gains in student outcomes. These measures operationalize the study's insights while fostering resilient, data-driven teaching environments.

5.2. Limitations and Future Research Directions

While this study offers valuable insights into the role of innovative strategies in supporting the academic performance of international students, we encountered several research limitations. Firstly, the research relied on convenience sampling of international students from selected universities in Wuhan, which may limit the generalizability of the findings to a broader population. Additionally, the focus on Chinese higher education institutions may not fully represent experiences in other educational and cultural contexts.

Looking ahead, future research could benefit from adopting a longitudinal approach to explore how innovative strategies influence academic performance over time. Expanding the scope to include international comparisons across different regions and educational systems would also offer richer perspectives. Moreover, applying advanced machine learning techniques such as deep learning could further enhance predictive accuracy and provide deeper analytical insights.

Credit author statement

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Declaration of competing interest

The authors declare that there are no conflicts of interest.

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