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RESEARCH ARTICLE

Analyzing Teaching Effects of Blended Learning With LMS: An Empirical Investigation

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ABSTRACT The development of modern science and technology has had a significant impact on the traditional teaching methods of higher education institutions. The utilization of technology-mediated learning approaches has provided universities and other higher education institutions with an opportunity to promote blended learning. This research aims to empirically analyze the learning effects of blended learning using the machine learning algorithm CART (Classification and Regression Tree) and regression analysis models, with Learning Management Service (LMS, using Rain Classroom as an example in this paper). It explores whether different dimensional factors in blended learning on the Rain Classroom platform are associated rules for English proficiency, while specifically focusing on their correlation with scores in the English proficiency test (CET-4, College English Test Band 4). The study identifies which association rules within these factors contribute to the improvement of students' scores. Additionally, it classifies students based on their scores and learning effects using a decision tree structure. Based on the classification results, a multiple linear regression model is constructed to quantitatively assess the learning effects of using Rain Classroom for English language learning among students with different English proficiency levels. These analytical results enable educators, during the later stages of using Rain Classroom for blended learning, to adjust teaching decisions based on individual situations of students in different categories. They can design teaching materials and activities tailored to each student, leveraging the tool capabilities of Rain Classroom as an LMS and the advantages of blended learning. This approach aims to create more profound and meaningful learning experiences for students, assisting them in achieving educational goals and unlocking their full potential in academics.

INDEX TERMS Blended learning, learning management system (LMS), rain classroom, technology-mediated learning.

I. INTRODUCTION

Undoubtedly, information technology like Artificial Intelligence (AI) is changing the world around us [1]. As Frank Pasquale [2] stated in his seminal book "The Black Box Society", decisions that used to be based on human reflection are now made automatically. Software encodes thousands of rules and instructions computed in a fraction of a second. With the backdrop of technology empowerment, diverse educational approaches have emerged, going beyond the traditional institutionalized education paradigm. The outbreak and spread of the COVID-19 virus in 2020 acted as a catalyst for the widespread application of technology in the field of education. As described by Vivek Goel, the President of the University of Waterloo, this was a "once-in-a-century chance to reset" for institutions of higher education. Educational institutions worldwide, including universities and colleges, have increasingly adopted online teaching. Information technology is being extensively utilized in various aspects, such as organizational operations, teaching content design, overall instructional structure, and the facilitation of teaching activities. The field of education resonates with the progress of technology, as technology-mediated learning enhances learning effectiveness and empowers the entire

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education system. This profound integration reshapes pedagogical concepts, giving rise to new instructional approaches and promoting structural changes in the education ecosystem primarily driven by technology and algorithms. This transformation has not only empowered educators with greater autonomy and creativity but facilitated personalized and diversified learning experiences for students. Researchers and educators in various higher education institutions have begun to adopt technology-mediated teaching and learning methods, such as blended learning, in their specific instructional practices.

The continuous and deep integration of technology and education has posed higher demands and challenges on the flexibility, interactivity, and convenience of learning methods. This has led to the emergence of numerous Learning Management Systems (LMSs) as auxiliary teaching tools, introduced by higher education institutions and educational technology organizations, thereby increasing the diversity and richness of choices available to educators and learners. According to a joint report entitled ''Shock to the System'' [3] released by Educate Ventures, an education venture capital company, and Cambridge University, educational technology organizations hold a considerably optimistic outlook regarding the future development of the industry. This indicates the growing recognition of the potential impact and opportunities that technology can bring to the field of education.

The emergence of Learning Management System, as a new educational tool, leveraging information technology, has transformed traditional face-to-face teaching methods, breaking through the constraints of time and space, and enabling the delivery of instructional content online. Within the LMS, the presence of educators creates an engaging learning environment. Students can maintain their autonomy, enthusiasm, and motivation by utilizing LMS [4]. The improved educational experience generated by LMS has the potential to positively impact various aspects of learning and teaching, ultimately contributing to the advancement of academic research.

Indeed, blended learning, facilitated by LMSs, enables the collection and extraction of teaching data. The data can be used to accurately identify weak points in learners' knowledge, enabling adjustments to the learning content and its presentation method. As a result, dynamic matching of more optimized learning paths becomes achievable, forming a new instructional ecosystem that can be automatically migrated and intelligently adjusted. By harnessing the power of LMSs and the data they provide, educators can offer personalized learning experiences that cater to individual learners' needs and preferences. This dynamic and adaptive approach to education enhances the overall learning process, making it more efficient, effective, and engaging for students. Furthermore, blended learning through LMSs also enables the tracking of learners' academic progress, which helps educators determine when and in which aspects they should intervene in learners' learning processes to provide timely and relevant assistance. Through the utilization of machine learning, cluster analysis, and learning analytics, educators can unearth the key characteristics of various educational components within the LMS. By identifying patterns in the data, they can construct an explanatory framework based on relevant relationships. This data-driven approach empowers educators to make informed decisions and tailor their instructional strategies to address the specific needs and learning progress of individual students, ultimately enhancing the effectiveness and personalized nature of the learning experience.

Blended learning, as a representative of technology-mediated learning, diminishes the emphasis on collective and standardized learning behavior among students. Its dynamic nature allows for continuous adjustments based on educational data mining, which enables the analysis and assessment of learners' capabilities, learning strategies, and preferences. Through learning analytics, personalized learning resources can be accurately recommended, and individualized learning models can be constructed, fostering a more accurate approach to personalized learning. This process is conductive creating a self-adaptive learning system that caters to the unique needs of each learner, enhancing the overall learning experience and outcomes. Blended learning, supported by LMSs, bridges the gap between traditional instruction and online learning, capitalizing on the strengths of both modalities to create more comprehensive learning experiences [5]. This transformation in the educational ecosystem further clarifies the core essence of education, as advocated by UNESCO. Education is no longer something imposed externally on learners or forced onto others; it must originate from the learners themselves. As advocated by Andreas Schleicher [6], educational innovation is not just about introducing more technology into more classrooms, but about changing teaching methods to equip students with the skills necessary to thrive and flourish in the fiercely competitive global economy. By embracing this shift towards personalized and adaptive learning, education can better meet the diverse needs of individual learners, nurturing their growth and development more effectively.

This research takes the example of 102 students from three majors in the 2019 cohort in a Chinese university using the widely adopted LMS, Rain Classroom, as the teaching platform for blended learning in English. We collect process-related unstructured data such as text data, behavioral data, and interaction data during students' use of Rain Classroom. The research assesses students' learning outcomes by examining their scores in the national College English Test Band 4 (CET-4) as a parameter. To ensure that the empirical analysis results are more targeted and reliable, the data undergo cleaning, with 32 student records containing original data deficiencies being excluded. In the end, a total of 70 students' valid samples are obtained for analysis. We seek to explore how blended learning, facilitated through Rain Classroom, impacts students' English language proficiency. And we will identify which factors within these dimensions are correlated with improvements in students' academic performance and identify the specific rules that contribute to enhancing students' learning outcomes. This analysis will contribute to a better understanding of the potential benefits and challenges

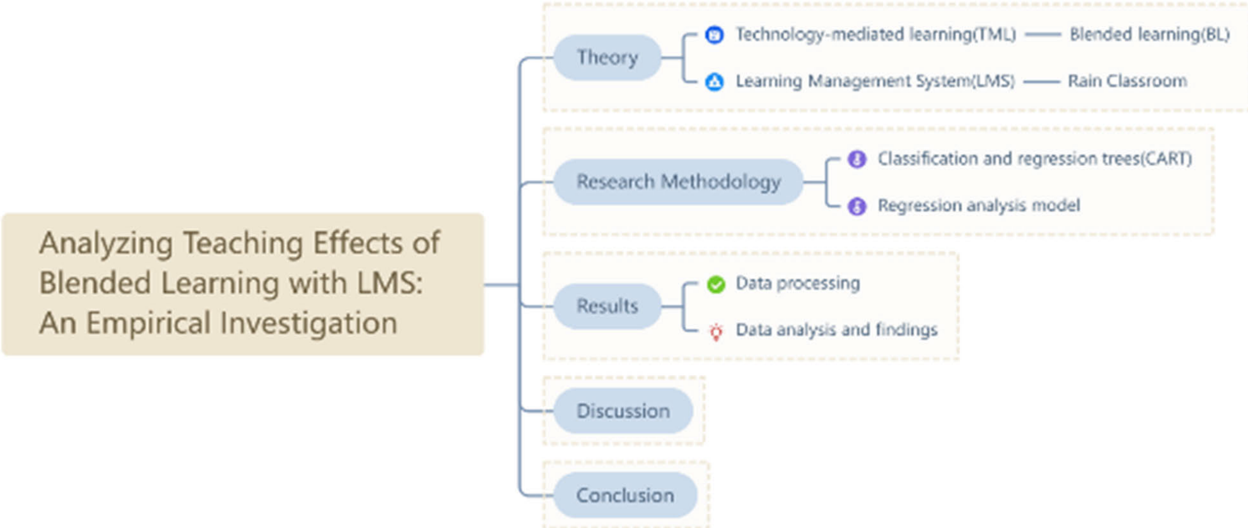

FIGURE 1. Flowchart.

of utilizing LMSs for blended learning in higher education institutions. The insights gained through data analysis enable educators to make informed instructional decisions in subsequent pedagogical design activities. They can tailor their teaching approaches according to the individual needs of students, thereby cultivating a more profound and meaningful learning experience. This personalized approach aids students in achieving educational objectives and unleashing their full potential throughout their academic journey.

The structure of this paper is as follows. Section II provides an overview of the fundamental theories and relevant literature related to the research topic. Section II-B describes the research methods and approaches used in the research. Section III presents the process of data analysis, data processing, and the findings obtained from the research. Section IV provides a comprehensive discussion and interpretation of the results. Section V summarizes the main findings and conclusions drawn from the research and offers suggestions for further research.

II. THEORY AND METHOD

A. TECHNOLOGY-MEDIATED LEARNING

Technology-mediated learning is a comprehensive term that primarily refers to the interaction between learners and instructors using technology as a mediator in the process of teaching and learning. It involves the transmission of learning materials, as well as discussions and exchanges among learners and peers. It typically encompasses online learning, E-learning, blended learning, open distance learning, computer-assisted learning (CAL), computer-mediated communication (CMC), and other related approaches, all of which contribute to the advancement of modern educational practices. Bower [7] consolidates various research and theories that were previously approached independently, aiming to facilitate a comprehensive analysis and investigation of situations where technology mediates learning. Roth and Moencks [8] conduct a study to explore the effective integration of technology-mediated learning within the industrial context. Nussbaumer et al. [9] introduce technology-mediated strategies and proposes a technical infrastructure design to facilitate self-regulated learning in open responsive learning environments that learners can individually customize and compile. Henrie et al. [10] examine the strengths and limitations of technology-mediated learning, aiming to help researchers and instructors identify effective methods for measuring student engagement in technology-mediated learning. Howard et al. [11] suggest how teachers can address diverse experiences in technologically integrated learning. Mayer [12] conduct researches on multimedia learning, offering valuable insights into the design of technology-enhanced learning experiences. Aulakh et al. [13] explore the role of Educational Data Mining (EDM) in improving e-learning environments, focusing on commonly-used techniques, student performance prediction, and identifying priority areas for future e-learning development. Goos et al. [14] demonstrate the potential of technology in enabling collaborative inquiry, fostering engagement in both small group interactions and whole class discussions.

In general, technology-mediated learning utilizes various technological tools such as LMS, Augmented Reality, Virtual Reality, online forums, and others to provide learners with multimodal learning resources. These resources include images, sound, text, audio, video, and interactive multimedia, among others, offering learners a diverse range of interactive experiences and engaging learning content. By simply having internet access and necessary devices, learners can engage in self-directed learning anytime and anywhere. They are not constrained by time or space and can access learning materials at their convenience. Learners have the flexibility to choose their preferred learning environment and engage in personalized learning based on their individual preferences and needs. As the learning progresses, they can experience a customized and adaptive learning process tailored to their unique learning process. Zhong et al. found that the integration of technology-mediated learning has a significant positive impact on student's academic achievement and learning experience through the analysis of selected literature [15].

In summary, technology-mediated learning manifests in the following aspects:

1. Increased Interactivity and Collaboration: Technology provides more opportunities for interaction and collaboration in the learning process, fostering active engagement among learners. This interaction and collaboration can help learners gain a deeper understanding of subject matter and facilitate the learning process among peers.
2. Personalized Learning Experience: The application of technology allows learners to study at their own pace, accommodating their individual needs and learning preferences. Personalized learning experiences contribute to improved learning efficiency and outcomes for learners.
3. Enhanced Accessibility: Technology ensures that learning resources and opportunities are accessible to learners without barriers, irrespective of their physical location or other constraints. This accessibility enables more learners to access educational resources, regardless of their geographical location.

Sarker et al. found that integrating technology into the teaching process can effectively cultivate both learners and educators, leading to better learning and educational outcomes [16] Technology-mediated learning has advantages in interactivity, collaboration, personalization, and accessibility. It breaks through the limitations of time and space, changing the educational landscape, expanding the audience of traditional education, and providing numerous opportunities for lifelong learning and ubiquitous learning.

B. BLENDED LEARNING

Blended learning is a subset of technology-mediated learning, and its precise definition has been somewhat ambiguous in the academic community. Generally, it is considered a methodology that combines both synchronous (real-time) and asynchronous (self-paced) learning experiences. Lawless [17] maintained that blended learning refers to an educational approach that integrates online educational materials and interactive opportunities with traditional methods of teaching that take place in physical settings. Other definitions perceive blended learning as a form of mixed methods learning [18] or a deliberate integration of face-to-face and online experiences [19]. It can also be seen as an instructional approach that combines online and traditional classroom methods [20], [21], a combination of various technologies utilized to facilitate teaching and learning [22], a learning system that enhances traditional teaching methods through the incorporation of new technologies [23], an interactive online learning combined with offline learning to provide students with greater control over the timing, location, and path of their learning [24].

In a blended learning environment, students are responsible for actively constructing and engaging in various cognitive activities. They are actively engaged in thinking, discussing, creating, questioning, investigating, collaborating, and reflecting. Typically, blended learning encompasses various forms of integration. Firstly, there is the blending of learning environments, which can take place either in the physical classroom or online, incorporating a combination of synchronous video conferencing and asynchronous learning or a hybrid format involving person-to-person classroom instruction and online learning. Secondly, there is the blending of learning resources, which combines traditional classroom teaching materials, such as textbooks, with diverse learning resources available in the digital learning environment, such as various audio, video, and online webinars, among others. Furthermore, there is the blending of learning approaches, where learners have the flexibility to engage in self-directed inquiry-based learning, collaborative group learning, as well as real-time synchronous educator-led instruction. The specific combination and integration of these teaching modes may vary based on the learning context and learning objectives. The asynchronous nature of the blended component of blended learning courses helps to expand the time students invest in course materials. Online discussions encourage reflection, and participation rates usually reach 100%. As a result, face-to-face time can be utilized more effectively. Students in blended learning courses establish richer connections between what they are learning and what they already know, creating a robust scaffold to organize information [25].

Compared to the traditional educators-centered approach, blended learning offers several advantages, including:

1. Empowering students to take active responsibility for their learning and make important decisions.

2. Facilitating personalized instruction more consistently and effectively to meet individual student needs.

3. Collaborating with students to personalize their learning paths, tailoring educational experiences based on their unique strengths and interests.

4. Granting students control over the pace of learning to empower them to tailor their learning progress according to their individual learning styles and preferences.

These advantages make blended learning a promising educational approach that fosters student engagement, self-directed learning, and personalized educational experiences. As technology advances with time, educational landscapes experience continuous shifts and transformations. Courses that utilize blended teaching have advantages over traditional courses, enhancing student engagement and providing opportunities for them to review information and practice skills iteratively in a comfortable environment [25]. It is essential for educators to develop versatile skills and utilize adaptive tools to effectively address various teaching and learning landscapes. In the process of designing and facilitating interactive blended learning that emphasizes student engagement, educators need to create inspiring and impactful instructional content, encourage meaningful online discussions, and foster a dynamic and engaging learning environment.

During the specific teaching and learning activities involved in implementing blended learning, LMS serves as a powerful technological tool and instructional platform. Popular LMSs adopted by universities in China include Rain Classroom, Chaoxing and Treenity, etc. We employ Rain Classroom developed by Tsinghua University for the teaching practices.

C. LEARNING MANAGEMENT SYSTEM (LMS)

As a widely employed educational tool in higher education institutions across the globe in recent years, Learning Management Systems typically encompass functionalities such as registration, course scheduling, delivery of teaching materials and learning resources, synchronous and asynchronous communication between learners and educators, examinations, assessments, and more. These features significantly support teaching activities and further enhance the convenience and sustainability of the learning process. Lonn and Teasley [26] propose that an LMS is a web-based system that facilitates online communication between learners and educators. It allows them to engage in interactive discussions, share learning materials, and submit assignments, among other collaborative activities. According to Chao and Chen [27], Learning Management Systems free learners from the constraints of time and space, allowing them to access educational materials asynchronously. This asynchronous access to learning resources provides alternative and substitutable learning opportunities with multiple advantages. Additionally, educators and educational institutions can save time and reduce associated costs through the implementation of LMS. Karagöz et al. [28] highlight that Learning Management Systems exhibit strong usability as they have the capability to store access information of various users, including learners, educators, system administrators, and visitors. Due to this feature and its many benefits, LMS has been widely adopted and extensively utilized in numerous universities worldwide. According to Muñoz et al. [29], the potential of LMS is immense, especially in the context of enhancing the overall educational experience. Their utilization in education can lead to substantial benefits for academic research and development. Alturise [30] conducts a survey to assess challenges, constraints, faculty members' experiences, and student satisfaction with the implementation of Blackboard Learning Management System (LMS) for on-campus full online courses. Iuliana [31] provides a theoretical research-based overview of the available options for Learning Management Systems (LMSs) in Higher Education Organizations. Aldiab et al. [32] examine various features of commercially available and widely used modern Learning Management Systems (LMS), accompanied by a comparative analysis. Additionally, they conduct a case study centered on the universities. Saito and Ulbricht [33] conduct a study within the context of Learning Management Systems (LMS) to assist in selecting an appropriate LMS to facilitate bilingual education in face-to-face classes.

LMS possesses an irreplaceable level of flexibility, primarily utilized for designing, implementing, and evaluating specific educational activities and facilitating the learning process of individual learners. It seamlessly integrates traditional classroom teaching with online learning tools, offering learners a blended learning experience. LMS complements traditional instructor-led classroom teaching by providing customized digital educational materials, thereby enabling educational activities to be conducted more efficiently and effectively. In blended learning, common forms of LMS typically consist of two essential elements: the server responsible for executing basic functionalities; the user interface designed for learners, educators, and system administrators. Generally, LMS provides learners with learning materials and interactive features, while offering educators the ability to create and deliver educational content, monitor learners' engagement, collect learning behavioral data, and assess learners' performance.

D. RAIN CLASSROOM

Rain Classroom is a LMS developed by Tsinghua University and is widely utilized by universities across China. It is an integrated LMS that combines pre-class information dissemination, real-time Q&A during classes, and multi-screen interaction. For students, it also serves as a mobile learning tool. It deeply integrates with PowerPoint and WeChat (a mobile app and communication software) to provide educators with intelligent support and comprehensive data recording capabilities throughout the three stages of teaching: "pre-class, in-class, and post-class." It enables intelligent functions, personalized reports, and visualization of teaching data, facilitating the teaching process. Facilitated by the internet and mobile devices, the constraints of time and location in learners' studying have been overcome. Learners can participate in every stage of the instructional process, allowing them to unleash their subjective initiative to the maximum. This greatly enhances teaching efficiency and maximizes the engagement of learners in their learning journey. In simple words, Rain Classroom is a plugin installed in PowerPoint, which is connected through the Rain Classroom official account on WeChat. It serves as a bridge for communication and interaction between educators and learners, increasing the frequency of interactions. This integration makes teaching more efficient and convenient, resulting in a more effective and enjoyable learning experience. Yuan et al. [34] merge Rain Classroom with the BOPPPS model and implements their principles in the teaching practice of the data structure course. They make use of mobile apps like Rain Classroom to create smart educational materials, establish a smart teaching platform, create a flipped classroom-style intelligent teaching approach, and conduct smart teaching for general education courses enhanced by smartphones. Lu et al. [35] make use of Rain Classroom to create educational materials, create a flipped classroom-style intelligent teaching approach, and conduct smart teaching for general education courses enhanced by smartphones. Wang and Xia [36] elucidate the methodology of employing the Rain classroom-based hybrid teaching model for conducting instruction within university online classrooms based on analysis of the hybrid teaching model. Liu [37] adopts a novel approach known as the 3D Blended Teaching Mode, which is built upon Rain Classroom. This approach provides a comprehensive overview of its precise implementation and is then applied in the context of the operations management course. Li et al. [38] examine the attributes of the Rain Classroom, investigate issues within the flipped classroom teaching approach, devise a fresh flipped classroom teaching method grounded in Rain Classroom, and implement this innovative approach in a computer-aided landscape design course.

In an academic context, the steps for educators and students to use Rain Classroom for teaching and learning primarily include:

1. Pre-class: Before the class, educators create new courses and classes on the Rain Classroom educator platform. They prepare pre-class learning materials and upload them using the Rain Classroom plugin for PowerPoint. Subsequently, these materials are distributed to the students who have enrolled in the corresponding course. Upon receiving the learning resources, students can engage in pre-class study using the Rain Classroom student platform on their mobile devices or computers, gaining a grasp of the knowledge framework. They also have the option to mark those specific parts they find difficult as ''not understood''. On the Rain Classroom educator platform, educators can access specific information, such as the duration of time students spent previewing courseware and the number of pages reviewed, as well as data collected from students' markings of ''not understood''. By gathering and analyzing this information, educators can integrate the classroom teaching content effectively and arrange the instructional plan accordingly.

2. In-class: During the in-person classroom session, educators utilize the Rain Classroom educator platform on their computer to activate the teaching function, synchronizing the instructional courseware. Students can simultaneously access the course materials online and follow the educator's instructions offline. This allows them to integrate their learning by taking notes and consolidating key concepts and challenging points. Furthermore, educators can engage students through interactive questioning during the class. By presenting questions to the students, they encourage active participation and critical thinking. Students can participate in discussions and raise their own questions through the Rain Classroom student platform using real-time bullet screen messages. This approach of participating in discussions and asking questions through bullet screen messages can significantly enhance students' enthusiasm and involvement in the learning process. It also allows educators to gain valuable insights into the students' level of comprehension and identify areas where clarification or further explanations are needed. This provides an opportunity for educators to address individual learning needs more effectively and tailor their answers to match the specific requirements of the students. By fostering a collaborative learning environment where students can actively interact with their peers and the educator, this approach not only improves student engagement but also creates a more dynamic and inclusive classroom atmosphere. Additionally, the instant nature of bullet screen messages facilitates efficient and timely communication, leading to more productive classroom discussions and a deeper understanding of the course content.

3. Post-class: After class, the Rain Classroom platform automatically generates a class summary, which includes information such as student attendance, participation in class quizzes and discussions, as well as the content of bullet screen messages. By collecting and analyzing these instructional process data, educators can identify any areas in need of further explanations. They can compile and summarize student queries and then provide comprehensive and unified explanations to address their doubts. The automatic generation of class summaries on the Rain Classroom platform streamlines the post-class review process for educators. It enables them to have a comprehensive overview of the students' engagement and learning performance during the session. This data-driven approach helps educators to fine-tune their teaching strategies, ensuring that the learning objectives are effectively met and that students' questions are adequately addressed. It also allows for a more personalized and targeted approach to follow-up discussions and remedial measures based on each student's individual needs.

In addition, Rain Classroom provides a variety of exercise design features, including single-choice or multiple-choice questions, fill-in-the-blank questions, and subjective questions. Educators can utilize these features to design custom exercises according to their teaching objectives. Moreover, Rain Classroom provides a test paper creation function that allows educators to arrange key concepts and challenging topics into electronic test papers. Then these test papers will be distributed to the Rain Classroom student platform as post-class assignments and tests. The diversity of exercise types and the ability to create electronic test papers on Rain Classroom empower educators with flexible assessment tools. They can design comprehensive evaluations to assess students' knowledge, critical thinking, and problem-solving skills. By incorporating a range of question formats, educators can effectively gauge students' understanding and proficiency across different subjects. Through Rain Classroom's seamless integration of assessment tools, students receive well-structured and thought-provoking post-class assignments and tests on their student platform. This fosters a conducive learning environment where students can review and apply what they have learned, thus promoting deeper comprehension and reinforcing knowledge retention. The research by Li et al. indicates that learning in the Rain Classroom can enhance students' interest in learning, stimulate their initiative in learning, and promote better learning [38]. The research findings of Yu et al. indicate that

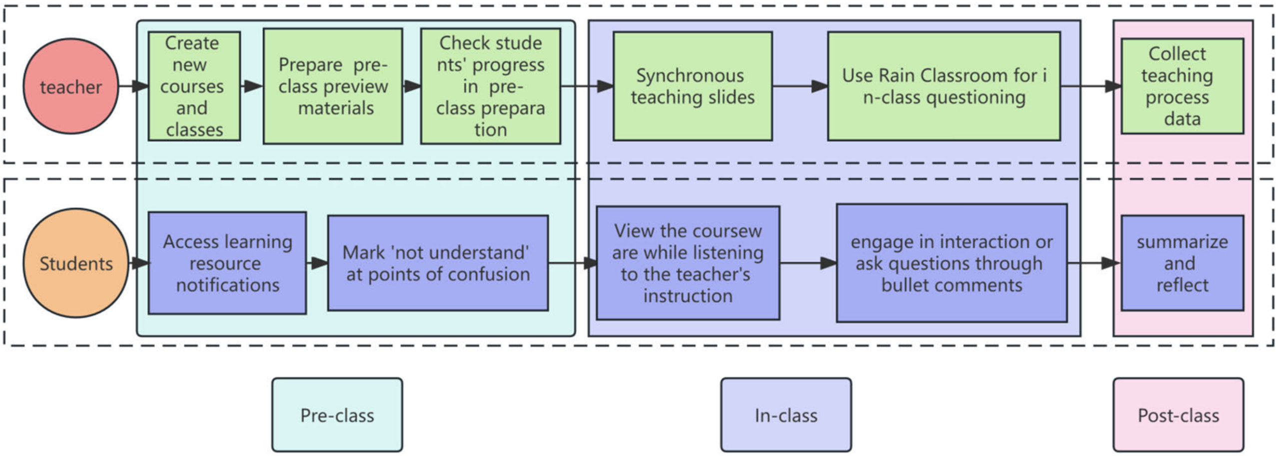

FIGURE 2. Three phases of blended learning with rain classroom.

Rain Classroom's acceptance is significantly higher than that of traditional multimedia projection systems in terms of performance expectations, effort expectations, social influence, convenience conditions, attitudes, etc. In comparison to traditional multimedia projection systems, Rain Classroom contributes significantly more to linguistic knowledge [39]. Overall, Rain Classroom' s array of exercise design features and test paper creation functionality contributes to a more dynamic and engaging learning experience, benefiting both educators and students in their educational endeavors.

Meanwhile, one of the key advantages of Rain Classroom for students is its mobile accessibility. With the access to review content and message notifications on their smartphones, students are no longer bound by time or location constraints. This enables them to engage in online, self-paced learning through the Rain Classroom student platform whenever and wherever they choose. By resorting to course materials, review content, and assignments on their mobile devices, students can conveniently integrate learning into their daily routines. They can utilize spare moments throughout the day to study, review, and complete post-class assignments and tests without the need to be physically present in a specific location. This flexibility empowers students to take ownership of their learning journey and adapt their study schedules to suit their individual preferences and needs. Moreover, the real-time nature of Rain Classroom's push notifications ensures that students stay informed about important updates, deadlines, and learning opportunities. This timely reminder system helps students manage their time effectively and stay on track with their academic responsibilities.

Overall, Rain Classroom's mobile capabilities enable students to experience continuous, adaptable learning, fostering a more independent and self-directed approach to education. By making education more accessible and personalized, Rain Classroom augments the learning experience and contributes to the overall academic success of students. By using Rain Classroom, a blended learning approach that combines online and offline learning modes is achieved. It assists both educators and learners in various teaching phases: before, during, and after teaching. This results in a more efficient teaching experience and creates a highly engaging learning environment.

III. RESEARCH METHODOLOGY

To empirically test the learning effectiveness of the Learning Management System (LMS), this paper plans to use first-hand data from students in the author's institution for quantitative analysis. Employing classification and regression algorithms in machine learning, the study will initially classify students based on their learning characteristics using the CART algorithm. Subsequently, regression analysis will be employed to examine the impact of different learning dimensions in Rain Classroom on academic performance. Finally, robustness testing will be conducted using Analysis of Variance (ANOVA).

A. CART (CLASSIFICATION AND REGRESSION TREES)

CART is a non-parametric statistical method to describe the conditional distribution of the target variable y given a given predictor variable x. The dependent variable can be either continuous or discrete, and when it is discrete, the generated tree is a classification tree. When facing challenges such as missing values and a large number of variables, CART proves to be highly robust and more easily interpretable than other models. It typically employs a binary recursive partitioning technique, dividing the prediction space into several subsets based on data features.

The regression tree generation algorithm for CART is as follows:

$$f_{(x)} = \sum_{m=1}^{M} c_m I\ (x \in R_m) \tag{1}$$

$f_{(x)}$ represents the output value of the regression tree model; the input space is divided into M partitions, and R_m denotes any one of these partitions. $I(\cdot)$ is an indicator function that reflects whether $\boldsymbol{x}$ belongs to a specific input partition. c_m represents the fixed output value for each partition. Typically, the optimal output value c_m for each partition is obtained using the criterion of minimizing the mean squared error, which is equal to the mean of the actual y_i values within R_m:

$$\hat{c}_m = ave(y_i \mid x_i \in R_m) \tag{2}$$

In this paper, a heuristic approach is used to partition the input space. Sequentially, each variable $\boldsymbol{j}$ is selected as the splitting variable, and any splitting point $\boldsymbol{l}$ generates two regions: $R_1(j,l) = \left\{x \mid x^{(j)} \le l\right\}$, $R_2(j,l) = \left\{x \mid x^{(j)} > l\right\}$. Equation (3) is employed to find the optimal splitting method (j^*, l^*):

$$\min_{j,l} Z = \left[\min_{c_1} \sum_{x_1 \in R_1(j,l)} (y_i - c_1)^2 + \min_{c_2} \sum_{x_i \in R_2(j,l)} (y_i - c_2)^2\right] \tag{3}$$

Firstly, for any given variable $\boldsymbol{j}$, the optimal splitting point is determined. The formulas to compute the optimal output values for the two regions on either side of the splitting point are $\hat{c}_1 = ave\,(y_i \mid x_i \in R_1(j,l))$, $\hat{c}_2 = ave\,(y_i \mid x_i \in R_1(j,l))$. The entire value range of variable $\boldsymbol{j}$ is scanned point-by-point, and the l^* point that minimizes the sum of squared differences between the two regions, denoted as Z, is identified. Subsequently, all input variables are traversed, and the Z values of the optimal splitting points for each variable are compared. The variable with the minimum Z value is selected as the optimal splitting variable, denoted as j^*.

Subsequently, for the two regions on either side of the optimal splitting point of the optimal splitting variable in the first layer, the above steps are repeated to determine the optimal splitting variable and splitting point for the second layer. This process is iteratively repeated for each subsequent layer until the termination condition is met, resulting in the construction of the least squares regression tree. Based on this algorithm, it is possible to conduct classification estimation for different students using the Rain Classroom usage data and their scores in the fourth level (e.g., language proficiency test scores).

The concept of coupling was first introduced to describe a physical phenomenon, which refers to the interaction between two or more objects or systems that influence each other, and then they gradually begin to correlate with each other. When conditions are ripe, they can be combined into a new structural body with higher level functions.

B. REGRESSION ANALYSIS MODEL

The multiple linear regression model is constructed based on the existing variables to examine the learning outcomes of students in different categories using the Rain Classroom software. The students' fourth-level proficiency scores (Score) are taken as the dependent variable, while Rain Classroom listening performance (Rainlistening), reading performance (Rainreading), and writing performance (Rainwriting) are used as independent variables. The model aims to investigate the association between different dimensions of Rain Classroom learning and English proficiency scores. The specific model is as follows:

$$Score_i = \beta_0 + \beta_1 Rainlisten_i + \beta_2 Rainread_i + \beta_3 Rainwrite_i + \varepsilon_i \tag{4}$$

In the above model, i represents the individual student's identification number. $\beta 0$ is the intercept term, and $\beta 1, \beta 2$, and $\beta 3$ are the estimated parameters, representing the specific impact of listening, reading, and writing on English proficiency scores, respectively. ε_i denotes the random error term, following a normal distribution N $(0, \sigma^2)$, where σ^2 represents the variance of the error term.

IV. RESULTS

A. DATA PROCESSING

The data used in this research consists of independent variables selected from 102 undergraduate students across three majors, who utilized the Rain Classroom platform for learning English in the year 2020. The main variables encompass student behavior data, including the duration of viewing learning resources, frequency of access, and viewing patterns. Additionally, the data includes information on students' engagement with online exercises and quizzes, such as listening, reading, and writing tasks. The English College Test Band 4 (CET-4) scores of the students are employed as the dependent variable to assess the effectiveness of their learning outcomes. To enhance the specificity and credibility of the empirical analysis, it is necessary to clean the raw data containing missing and erroneous information. This process entails excluding data from students who were absent during the College English Test Band 4 (CET-4), those who did not complete the listening tests administered through Rain Classroom, individuals with missing writing exercise data, and those lacking recorded quiz scores. After cleaning the data and eliminating students with incomplete information, a total of 70 valid student samples were ultimately obtained for further analysis.

B. DATA ANALYSIS AND THE FINDINGS

After data cleansing, based on the organized summary results, the descriptive statistical information is presented in Table 1. Table 1 reveals that among the 70 students, the average score for the College English Test Band 4 (CET-4) is 451.1 points. The difference between the highest and lowest scores is 306, indicating a considerable range. The variance exhibits significant fluctuations. Additionally, the average duration of students' listening training on Rain Classroom is 54.19 minutes. Regarding the reading tests completed on the platform, students achieved an average score of 57.87 points. In contrast, the average score for writing exercises on Rain Classroom is the highest, reaching 81.19 points, with the least variation and a standard deviation of only 5.544.

TABLE 1. The descriptive statistical information.

VARIABLES	N	Mean	sd	Min	Max
Score	70	451.1	51.37	260	566
Rainlistening	70	54.19	13.85	15	80
Rainreading	70	57.87	14.99	20	88
Rainwriting	70	81.19	5.544	61	90

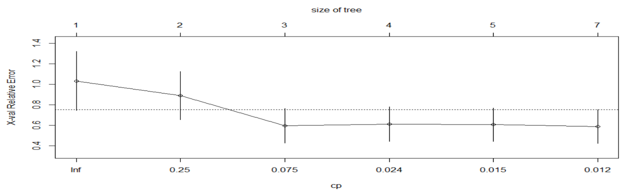

FIGURE 3. Dynamics of cross-validation error.

Using the CART algorithm, and based on Formula (1), the CET-4 scores are set as the target variable, while the variables representing the duration of listening, reading, and writing exercises on Rain Classroom are used as input variables. By employing the R software, a classification regression tree is constructed. The CART model has the capability to automatically ignore attributes that do not contribute significantly to the target variable. It also aids in assessing the importance of the attributes, thereby reducing the variable data to provide meaningful insights for the analysis.

To avoid over-fitting in the CART model, an automatic cost-complexity pruning technique can be employed to obtain a more parsimonious tree with stronger generalization capabilities. Cross-validation is used to determine the optimal generalization performance of the classification regression tree. In this case, R software's default 10-fold cross-validation is adopted. By using cost-complexity pruning and cross-validation, the CART model can achieve better generalization and avoid over-fitting, ensuring the model's reliability in predicting outcomes for unseen data.

In Fig. 3, the bottom horizontal axis represents the complexity parameter (cp), which controls the penalty strength on the model's complexity. The top horizontal axis represents the size of the decision tree. The vertical axis represents the relative cross-validation error (small circles) along with their standard error (vertical line segments). The dashed line indicates the position one standard error away from the optimal cp value, with the maximum cross-validation error normalized to 1. At a tree depth of 3, the cross-validation error is minimized, indicating that this tree structure is the most suitable. It is more concise compared to the default structure, with minimal loss in accuracy. Based on this analysis, a cp value of 0.075 is selected as the pruning standard, and the classification regression tree is pruned accordingly. By using the selected cp value for pruning, the resulting tree model achieves a better balance between model complexity and performance, making it more suitable for generalization to unseen data and avoiding potential overfitting.

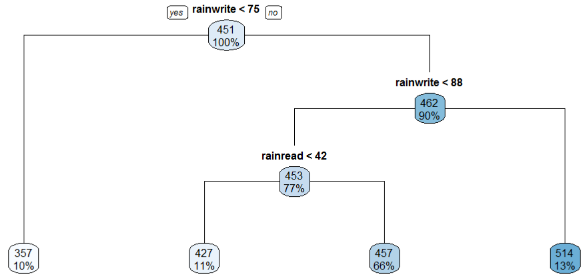

FIGURE 4. Classification regression tree.

Following the aforementioned algorithm for pruning, in Fig. 4, the pruned classification regression tree consists of 3 levels and 4 terminal nodes.

"Rainwriting," the writing component of the Rain Classroom platform, occupies both the root node and the initial internal node in the pruned classification regression tree. This indicates that it is the primary determinant factor influencing the English College Test Band 4 (CET-4) score. Among the pruned classification regression tree, the root node's splitting condition remains "Rainwriting," with the condition now being "Rainwriting < 75," accounting for 90% of the sample. This indicates that the writing exercises on the Rain Classroom platform have the most significant positive impact on students' English scores. If a student's writing score on "Rainwriting" is above 88 points, they belong to the group of outstanding students. In the third layer of nodes, the internal node's splitting condition is "Rainreading < 42." When a student's reading test score on Rain Classroom falls between 75 and 88 points (in the mid-range), reading becomes the primary criterion to distinguish between better and worse performance. The majority of students (66%) have a reading score above 42 points, with an average CET-4 score of 457 points, which is six times higher than the average score of students with reading scores below 42 points (average score of 427 points).

Following the path in Fig. 4, step by step, a complete set of criteria is established, resulting in the classification of the sample into four distinct categories.

According to the classification regression tree partition criteria in Fig. 4, regression analyses were performed on both the overall sample and each category using Equation (4). The results are presented in Table 2.

The regression results from Table 1 indicate that the reading and writing exercises and tests on Rain Classroom significantly contribute to improving English scores. Both of them show statistical significance at the 10% and 1% levels, respectively, as confirmed by the classification regression tree results. Among these factors, "Rainwriting" (the writing component) on Rain Classroom has the most noticeable impact on the improvement of the CET-4 scores.

Moreover, the "Rainreading" (the reading component) on Rain Classroom also demonstrates a significant promoting effect on the improvement of the scores. However, the

TABLE 2. The regression analysis results for different categories.

VARIABLES	Overall sample	Category (1)	Category (2)	Category (3)	Category (4)
	score	*score*	*score*	*score*	*score*
Rainlistening	-0.398	0.573	3.672^{*}	-0.142	-1.483
	(0.295)	(1.750)	(1.428)	(0.235)	(1.051)
Rainreading	0.559^{*}	1.344	-0.783	-0.222	1.863
	(0.321)	(2.621)	(1.736)	(0.228)	(1.606)
Rainwriting	6.445^{***}	11.20^{***}	5.205	2.001^{**}	-13.13
	(0.796)	(1.208)	(7.180)	(0.956)	(11.25)
Constant	-82.90	-514.6	-160.1	316.3^{***}	1,636
	(71.16)	(224.2)	(590.5)	(74.77)	(956.1)
Observations	70	7	8	46	9
R-squared	0.571	0.572	0.640	0.102	0.332

"Rainlistening" (the listening component) does not exhibit a significant impact on the enhancement of the English scores.

When examining different categories, the results are as follows:

1. For students in Category (1), the writing exercises on Rain Classroom show significance at the 1% level and have the most noticeable impact on improving the CET-4 scores. However, the effects of reading and listening exercises are not significant.

2. For students in Category (2), the "Rainlistening" (the listening component) on Rain Classroom exhibits the most prominent impact on improving application scores. It becomes the only group among the four categories where listening significantly influences the CET-4 scores at the 10% significance level. Students in this category show significant potential for improving their English scores through listening practice.

3. Among students in Category (3), which has the largest sample size, "Rainwriting" (the writing component) on Rain Classroom shows the best effect in enhancing English CET-4 scores at the 5% significance level. The effects of the other two aspects (reading and listening) are not significant.

4. For students in Category (4), who already have a higher level of English proficiency, Rain Classroom exercises do not significantly improve their scores. None of the three independent variables demonstrate a significant effect on the dependent variable in this category.

In summary, the use of Rain Classroom for blended learning has the most noticeable impact on the improvement of students with intermediate to lower English proficiency levels. They display varying degrees of improvement in vocabulary, reading, listening, writing, with the most significant enhancement observed in the writing component, followed by reading, while listening proficiency shows the least improvement.

For students with advanced English proficiency levels, the use of Rain Classroom does not have a significant impact on improving their English scores. They do not show significant improvement in vocabulary, reading, listening, and writing; their overall proficiency levels remain relatively consistent with their previous abilities.

To verify the reliability of the results of classification and regression analysis and to avert bias caused by a single statistical method, this study further uses analysis of variance for robustness testing. Analysis of variance is used for significance testing of differences in means among two or more samples. Its basic idea is to analyze the contribution of variability from different sources in the study to the total variability, thus determining the magnitude of the influence of controlled factors on the research results. In this regard, this study examines the robustness of the results of CART classification and multivariate linear model regression using one-way analysis of variance.

In analysis of variance (ANOVA), the variation in the observed variable values is influenced by both controlled variables and random variables. Based on this, one-way ANOVA decomposes the total sum of squares (SST) of the observed variable into between-group sum of squares (SSA) and within-group sum of squares (SSE), mathematically represented as $SST=SSA+SSE$. Building upon this, the F-statistic (the ratio of between-group mean square MSA to within-group mean square MSE) is constructed to assess whether the means of different groups have significant differences.

Table 3 presents the results of the analysis of variance for different classification groups. The first part of Table 3 provides sample observations, means, and variances for each group, while the second table displays the results of the analysis of variance test. Intuitively examining the mean values for each classification, there is a significant difference in CART classification results, with between-group error much larger than within-group error. At a 5% significance level, the F-statistic value (29.43) significantly exceeds the critical value (2.74), with a P-value of $0.00<0.05$. Rejecting the null hypothesis that the mean scores are the same for all groups, this indicates a significant difference among students in different classified groups. The results suggest the robustness of the classification regression estimates.

V. DISUSSION

Compared to traditional face-to-face classroom teaching, leveraging LMS like Rain Classroom for blended learning offers significant advantages. Students can fully utilize smartphones to extend the classroom beyond its physical boundaries. The fragmented time and location of pre-class and post-class learning can be flexibly managed according to individual needs. Content that is not fully digested during class can be accessed anytime on the Rain Classroom

TABLE 3. Analysis of variance results (1). Analysis of variance results (2).

(1)

Classification	Observations	Summation	Mean	Variance
(1)	7	2501	357.29	4298.90
(2)	8	3414	426.75	2296.21
(3)	46	21033	457.24	479.25
(4)	9	4630	514.44	1806.78

(2)

Source of Variability	SS	df	MS	F	P-value	F crit
Between-Groups	104197.57	3	34732.52	29.43	0.000	2.74
Within-Groups	77887.52	66	1180.11			
Total	182085.09	69				

platform, facilitating review and reinforcement. Additionally, employing Rain Classroom for blended teaching diversifies the interaction between educators and students. Educators can provide learning assessments and feedback not only during face-to-face classroom sessions but also offer real-time feedback and evaluations on individual student participation and completion in pre-class discussions and post-class exercises. These efforts contribute to boosting student confidence and enthusiasm for learning. Notably, students with intermediate to lower English proficiency levels demonstrate the most significant improvement in grades. Their foundational English skills being weaker, utilizing Rain Classroom for previewing before class helps them to clarify learning tasks and objectives, providing a preliminary understanding of the knowledge to be studied. As a result of this preparatory work, they are better equipped to keep pace with the educator's progress during class, leading to improved learning efficiency and effectiveness. During the class, these students benefit from various interactive activities such as educator-led explanations, questioning, addressing doubts, and participating in group discussions with their peers. Through these engaging interactions, they deepen their grasp of the subject matter, experience an enhanced sense of achievement, and develop greater self-confidence. As a result, a positive feedback loop is formed, leading them to become more willing to utilize Rain Classroom for independent learning voluntarily. After class, when these students complete and submit exercises and tests on Rain Classroom, the platform's multi-layered and diverse evaluation methods come into play. As a result, educators can provide more timely and equitable feedback on their performance. This improved feedback mechanism enhances students' motivation, as they feel more engaged and acknowledged in the learning process. Consequently, they are no longer inclined to submit assignments hastily and perfunctorily, as they might have done in the past. Instead, they demonstrate increased diligence and commitment to their academic tasks.

Certainly, the integration of blended learning, incorporating both online and offline elements, along with the utilization of resources provided by Rain Classroom for blended learning, effectively compensates for the learning gaps experienced by students with intermediate to lower English proficiency. This approach not only addresses their weaknesses but also sparks enthusiasm for learning within them. Additionally, Rain Classroom serves as a bridge for those students who may feel hesitant to engage in face-to-face communication with their educators due to their limited English proficiency. It facilitates communication between students and educators, providing a comfortable and supportive platform for interaction. Moreover, Rain Classroom provides more ways of participating in classroom learning and discussions, thereby elevating their level of engagement in the learning process. Consequently, these students stand out as the ones exhibiting the most significant improvement in their academic performance.

For students with advanced English proficiency levels, there is no noticeable improvement in their grades. The learning materials and tasks distributed on Rain Classroom mostly match the average level of students in terms of difficulty. These materials pose little difficulty for them, lacking challenge, and thus fail to stimulate their interest in learning, resulting in a lack of significant academic progress. The lack of challenging learning tasks fails to arouse their interest in learning, leading to a lack of evident academic improvement. High-achieving students typically require a higher level of difficulty to maintain interest and engagement in their studies. To address this issue, educators should consider adjusting the design of learning materials and tasks to accommodate the diverse levels of students, providing enough challenge to better meet the needs of high-achieving students. They can provide more advanced and intellectually stimulating content, offer opportunities for in-depth analysis and critical thinking, and encourage independent research and exploration. By challenging these students with more complex and engaging learning experiences, educators can inspire their curiosity and passion for learning, thereby fostering noticeable improvement in their academic performance. The goal is to keep them engaged and motivated to continually excel in their studies.

As demonstrated by the empirical study conducted by Manasrah et al., blended learning (based on intelligent learning environments) has a significant overall impact on enhancing college students' information literacy [40]. Technology-mediated blended learning expands the accessibility of learning resources, fostering active engagement and deep learning in the learning process. Technology-mediated learning promotes the possibility of continuous learning beyond formal educational settings, enabling individuals to remain involved in lifelong learning. It also allows learning to occur in diverse backgrounds and contexts, transforming education into an omnipresent experience beyond the traditional classroom boundaries. Ultimately, technology-mediated learning provides individuals with expanded opportunities for acquiring rich knowledge and skills, creating a more inclusive and dynamic educational environment.

From the perspective of educators, in the future use of Rain Classroom for blended learning, educators should dynamically adjust teaching auxiliary resources based on individual student situations when organizing teaching content, designing teaching activities, and selecting online supplementary teaching materials. They should make more precise teaching decisions, leveraging the tool functionality of the Learning Management System (LMS) to provide customized learning paths for students of different English proficiency levels, maximizing the effectiveness of blended learning. Educators should pay attention to the needs of high-achieving students and make necessary adjustments in teaching design and textbook selection. This can be achieved through the following ways:

1. Expand the depth and breadth of knowledge: Educators can explore more advanced and specialized topics within the subject area, providing opportunities for students to delve into complex concepts and ideas.

2. Increase knowledge density: Compressing information and presenting it in a concise yet comprehensive manner can challenge high-achieving students to process and synthesize information at higher cognitive levels.

3. Provide challenging learning tasks: Introducing more difficult and thought-provoking assignments can stimulate the curiosity and exploratory spirit of high-achieving students, encouraging them to actively seek solutions and deepen their understanding of the subject matter.

By employing these strategies, educators can effectively engage high-achieving students, nurture their enthusiasm for learning, and encourage them to continually pursue excellence in their academic pursuits. In doing so, Rain Classroom becomes a more versatile and effective tool to meet the diverse learning needs of all students, regardless of their proficiency levels.

Furthermore, in the process of using Rain Classroom for blended learning, we found that for educators accustomed to traditional face-to-face teaching methods, becoming familiar with and mastering the use of Rain Classroom for instructional activities posed significant challenges. Additionally, there is a higher demand for information technology skills from both educators and education administrators on how to effectively utilize the educational data generated during the teaching process. Therefore, educators not only need to continuously learn and stay informed about the latest research developments in their field but also actively embrace the opportunities brought by information technology to education. They should delve into understanding information technologies such as artificial intelligence and deep learning, incorporate interdisciplinary perspectives into future teaching and research, and integrate information technology and data-driven approaches into teaching practices. This way, educators become facilitators of personalized and data-driven learning experiences.

VI. CONCLUSION

Compared to the traditional face-to-face education model, blended learning provides learners with a more diverse and personalized learning experience by combining the advantages of traditional teaching and online learning, using technology to enhance the effectiveness of learning. Learners use LMS platforms as learning tools for blended learning, which includes taking online courses, completing learning tasks, participating in forum discussions, quizzes, and exams. Each learner's learning behaviors and performance are recorded and stored, generating a large amount of learning data. These massive datasets contain information such as learners' personal details, learning habits, learning progress, grades, and interactions with other learners. LMS also records the interaction between learners and learning content, such as the duration of watching videos, the level of participation in online discussions, and the timing of submitting assignments. For educational institutions and educators, the data is a valuable resource as it provides an opportunity for a deep understanding of learners' behaviors and learning processes. By analyzing and mining the data, educational institutions and educators can gain insights into learners' study habits, preferences, and difficulties to better understand students' learning needs and personalize teaching accordingly. Additionally, through the analysis of learning data, educational institutions can assess teaching effectiveness, improve teaching strategies, and optimize the allocation of educational resources.

In conclusion, the substantial data generated by learners using LMS for blended learning can provide valuable information to educational institutions and educators, aiding them in understanding learners better, refining teaching practices, and enhancing the overall learning experience. By fully utilizing the data collected through LMS, educators can gain a more profound insight into the strengths and weaknesses of individual learners, identify areas requiring additional support, and accordingly adjust their instructional strategies. This information allows them to provide personalized feedback, offer targeted interventions, and create a more adaptive and inclusive learning environment.

In future research, it is essential to explore and study how to better integrate data analysis into instructional practices, enabling educators to make more informed and wise educational decisions. By leveraging data-driven insights, educators can create more profound and meaningful learning experiences for students, helping them achieve their educational goals and unlock their full potential on their academic journey. The focus will be on investigating methods to effectively utilize educational data, analyze learning patterns, identify areas for improvement, and tailor instructional approaches to individual student needs. Moreover, research will delve into how data analysis can aid in assessing learning outcomes, monitoring progress, and optimizing the allocation of educational resources. By continually exploring these directions, education can be enhanced, and the role of data analysis in shaping personalized and impactful learning experiences will be further realized.

Due to the constraints of time and space, this study was unable to gather a sufficiently large sample of information data from students using Rain Classroom for blended learning. There were also difficulties in obtaining process data from students' usage of Rain Classroom in the pre-class, in-class, and post-class phases. To address this issue, we endeavor to take the following measures in future research, including expanding the sources of the sample, improving data collection methods, broadening the usage scope of Rain Classroom courses, increasing the number of observed subjects, and tracking the corresponding students' performance in the CET-4 in real-time. This is aimed at ensuring a better research outcome and deriving more comprehensive and systematic research conclusions.

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