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Review Article

Hybrid Learning and Blended Learning in the Perspective of Educational Data Mining and Learning Analytics: A Systematic Literature Reviews

Pratya Nuankaew[1], Phaisarn Jeefoo[2], Patchara Nasa-Ngium[3], Wongpanya S. Nuankaew[4]

[1,2,4]*School of Information and Communication Technology, University of Phayao, Phayao, Thailand.*
[3]*Faculty of Science and Technology, Raja Maha Sarakham University, Maha Sarakham, Thailand.*

[4]*Corresponding Author : wongpanya.nu@up.ac.th*

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Abstract *- Rapid societal and technological changes have driven enormous educational developments in learning styles and assessment. Due to the Coronavirus 2019 (COVID-19) epidemic, the world's education system has recognized distance education's importance in dealing with and solving asynchronous learning. Consequently, hybrid and blended learning have been proposed to support a learning process through a combination of face-to-face (onsite) and online learning. The learning process and activities arise from a more versatile and flexible teaching strategy than traditional learning patterns; however, the reliance on educational technology results in the dissemination and collection of massive amounts of data called big data. Thus, educational data mining and learning analytics have been applied for statistical and qualitative data analysis in hybrid learning and blended learning. Although these methods can be optimized for distinctive learning formats, the implementation varies depending on course structure and dataset characteristics. Therefore, this study analyzes and reviews different educational data mining and learning analytics methods and applications in hybrid and blended learning aspects.*

Keywords *- Blended learning, Educational data mining, Hybrid learning, Learning analytics, Learning styles.*

1. Introduction

1.1. Educational Trends in Hybrid and Blended Learning

At the beginning of spring 2020, more than 1300 schools surrounding 50 states in the United States canceled classrooms and moved to online learning platforms. [1]. Conducting the physical classroom or onsite class has inevitably changed after the outbreak of Coronavirus 2019 (COVID-19). Many educational institutions developed a hybrid model for distance learning at the end of the year. To reduce the risk of infection caused by face-to-face learning and support the educational system under this circumstance, the classroom and learning style design in the new normal era must be sufficiently consistent with the functionalities of interactive learning [2]. In the education sector, the development of analytical thinking processes, communication enhancement, technology adoption, participation in learning activities, and examination management are important factors in enhancing learner performance [3-6]. Consequently, adaptive learning styles such as hybrid and blended learning can meet the needs of distance education at the current [7-8].

1.1.1. Hybrid Learning

Typically, the hybrid model for learning management offered different levels of achievement for each institution [9-11]. According to the College Crisis Initiative report, US institutions performed 27% of the onsite classes, 44% of online classes, and 21% of the hybrid model [1]. In late 2021, several institutions conducted the class to be more fully integrated as in Thailand. 20% of college students had difficulty accessing efficient technology such as high-speed internet and capable performance devices [12]. Due to a lack of discipline and self-study, some students also experienced learning issues in many online classes.

Consequently, there were typical announcement plans to support students by extending libraries' opening hours and providing a cellular plan for online class access. Many schools worldwide have switched grading systems from fixed-range scores to 'pass' and 'fail' to help students temporarily. However, institutions still need to find a solution to avoid the long-term problems associated with transferring college and university credit. In this circumstance, hybrid learning has been adopted to deal with future crises, either new epidemics or disasters and threats. In general terms, hybrid learning is a practical learning scheme that includes efficiency and socialization, combining traditional face-to-face and online learning platforms [13], as shown in Fig. 1.

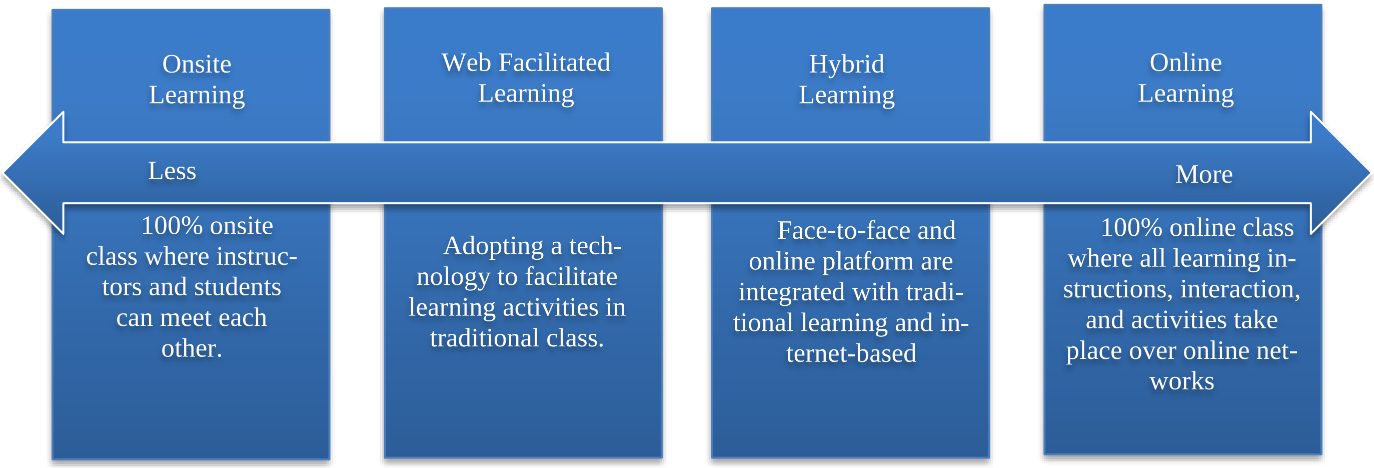

Fig. 1 Hybrid learning and traditional learning methods

According to Fig. 1, this learning method offers a flexible and scalable learning model in a combination of synchronous (real-time) and asynchronous learning connected by telecommunication networks for live streaming with onsite class. Characteristics of this approach include student-centered teaching. Each student can actively participate in the content and learning activities to increase opportunities for interaction between groups of students. Hybrid learning is a unique educational delivery method that combines traditional face-to-face instruction with online learning activities. It is an option for students and instructors who want to replace some portion of traditional face-to-face meeting time with online instruction [14]. The terms “hybrid” and “blended” are often used interchangeably in higher education and refer to courses that include both online and face-to-face instruction. Hybrid courses are defined as those that include 30% to 79% of content delivered online, with at least 20% of face-to-face interaction [15]. Hybrid education is a form of blended learning that reduces face-to-face classroom time, replacing it with out-of-class online learning activities [14]. Such courses provide flexibility and convenience to learners while maximizing learning in both environments [14-15]. In hybrid learning, online learning can be synchronous or asynchronous, while face-to-face time may be replaced with online learning activities. The outcomes of hybrid/blended courses are the same or superior to face-to-face instruction, making it an effective form of educational delivery [15]. Hybrid learning has been widely adopted in higher education, resulting in high satisfaction, enhanced learning and technical skills acquisition, and decreased attrition rates in nursing education. It has also been successfully implemented in healthcare education [16]. To ensure successful implementation and student learning, a hybrid curriculum must be based on sound theoretical frameworks such as constructivism, which emphasizes active learning, problem-solving, collaboration, and drawing on experience to construct meaning [17]. It meets the requirements and appeals of student assessments with different learning styles. Moreover, hybrid learning provides learners the opportunity to learn on their own at a convenient time in the new normal era upon the changing conditions of society, and the environment can occur all the time [18]. Classroom design is tailored to the learning style through a collaborative online classroom, primarily with quizzes and assignments, then entering the classroom to meet the instructors [19]. In hybrid learning, switching between groups of learners in regular, distance learning along with online learning for other groups of students simultaneously is possible. In addition, instructors can continuously follow up and provide either advice or suggestions before and during self-learning [20].

1.1.2. Blended Learning

Blended learning, also known as hybrid learning, is a combination of teaching practices applied in both face-to-face and online learning environments. It can be defined as a learning mode where parts of traditional educational procedures have been replaced by online modes of knowledge transmission [21]. Blended learning offers alternative possibilities for user-learners and creates flexible online learning environments [21]. Colleges and universities worldwide aim to provide scalable information in a modern, lifelong educational system through blended learning. However, there is ambiguity about what is meant by blended learning [22]. It can be described as any combination of face-to-face and online learning [22]. The quantity conceptualization emphasizes that a substantial part of the course should occur in both face-to-face and online settings, while the quality conceptualization focuses on thoughtfully integrating the benefits of face-to-face and online learning to improve quality or achieve other positive effects [22]. Successful blended learning programs require a sound institutional strategic plan; best practices are available as a reference for instructors to plan and implement a successful blended learning program [23].

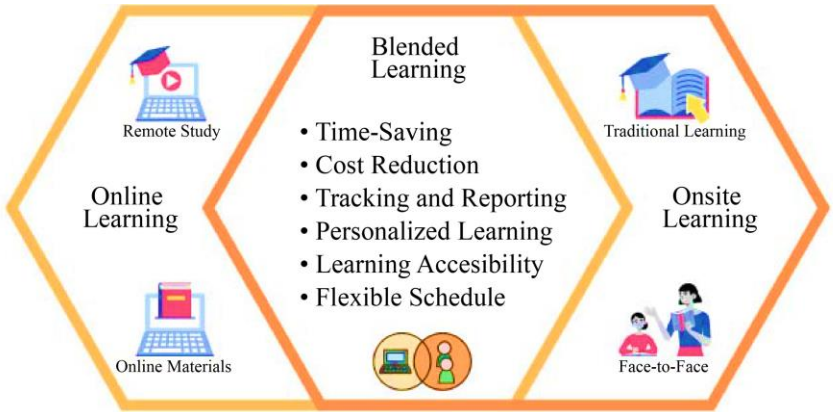

Fig. 2 Beneficial features of blended learning

Moreover, blended learning involves the perspectives of instructors, students, and administrators and can affect budgetary and support issues for institutions depending on the perspective model used [23]. Blended learning can be complemented or replaced with more specific, descriptive terms [22]. In this situation, adaptation is extremely important, especially for education. Online materials enhance the learning experience through cutting-edge e-learning features through the common learning mode called blended learning. Blended learning combines physical learning in the classroom with scattered online course content through a Learning Management System (LMS) [24]. This practical approach refers to the learning process that combines various learning styles, both digital communication and face-to-face, in the same classroom [25]. This learning model can apply various learning resources over online networks [10, 26]. The learning process and activities arise from various teaching and learning strategies aimed at assisting learners to achieve their goals [27], as the beneficial features in Fig. 2.

To perform a blended learning model, instructors can adopt multiple course materials. For example, instructors deliver lesson content through technology combined with face-to-face teaching and track instructional activities through e-learning and LMS. In 2009, the US Department of Education introduced a meta-analysis of online learning, indicating improved learner engagement and efficiency [28]. It can be concluded that this approach is a truly transformative approach to the education system. However, factors affecting classroom and online learning must be identified to make a difference and change for learners [29].

It appears that blended learning will only be successful if the right strategy is placed between the teaching strategy and the learning objective [30]. In a nutshell, due to the variety and flexibility of learning methods, instructors can tailor strategies to suit the needs of each topic. The academic synergy generated by deploying blended learning can offer a completely different and transformative learning experience [31]. Students will be engaged in research for further insights through various technologies.

Nevertheless, online learning may reduce student enthusiasm due to a lack of interaction and discussion [32]. Besides, large groups or enormous numbers of students resulted in a lack of individual responses. In contrast, blended learning enhances the engaging classroom experience for learners by synchronizing communication channel technology. Social media are also used to mediate conversations between groups or individuals. Although blended learning is more complex than traditional teaching and learning styles, this approach has been recognized as a factor that can encourage learners to be more involved in the classroom [33].

1.1.3. Challenges of Hybrid and Blended Learning

Basically, hybrid learning is a learning approach in which students can participate in both virtual and face-to-face classes at the same time. It is a flexible learning style where learning is not restricted to attending onsite classes. This learning style increases learners' convenience and supports access to course resources outside the classroom all the time via video conference and cloud library.

In contrast, blended learning is conducted in the physical classroom with different online course materials through the LMS. This online material enhances students' learning experience through cutting-edge e-learning features with relevant information. Blended Education in the United States reported that the definition of blended learning, sometimes called hybrid learning, is offered through blended courses that account for between 30 percent and 79 percent of online content [34]. Meanwhile, 0 to 29 percent of online content comprises original content facilitated through the website. Additionally, online learning provides at least 80 percent of online content. Although the course delivery methods used by general instructors vary greatly, the different classifications of courses used in education can be summarized in a nutshell as Table 1.

Regarding a fundamental distinction, online learning encourages face-to-face learning in distinctive classrooms in hybrid learning. Hybrid learning and blended learning are often used interchangeably to refer to the same concept despite some differences in philosophy and implementation. Both are characterized by a combination of online and in-person instruction, with online tools being integrated into the learning experience to varying degrees. Hybrid learning specifically combines face-to-face education with access to online learning tools, and asynchronous online material is considered part of the main lesson plan [35]. On the other hand, blended learning involves integrating technology into traditional classroom settings, with online tools being used to supplement face-to-face instruction. Despite these subtle differences, the terms hybrid learning and blended learning are often used synonymously to describe any learning environment that combines online and in-person instruction. Therefore, it is important to understand that while there are some differences in philosophy and implementation, the overarching concept of hybrid and blended learning combines online and in-person instruction in a cohesive manner [33].

In contrast, online learning is an alternative to classroom patterns in blended learning. As for the aspect of learning relationship, some differences are associated between hybrid learning and blended learning, listed in Table 2.

Table 1. Learning method classification and online content proportion [29]

Learning Method	Online Content Proportion	Remarks
Onsite Learning	0	Traditional classes are offered through paper-based learning without online technology and online content.
Web Facilitated Learning	1-29	Web-based class conducted with the technology facilitation for support face-to-face course.
Blended/Hybrid Learning	30-79	Blended learning or hybrid learning integrated with online content and face-to-face meetings.
Online Learning	80-100%	Online class that completely offers online materials and courses without onsite meetings.

Table 2. Differences between hybrid learning and blended learning

Hybrid Learning	Blended Learning
Combination of face-to-face and virtual learning platforms.	Implementation of technology to support face-to-face and distance learning.
Synchronous communication opportunities.	Asynchronous communication opportunities.
Students can meet the instructors on a face-to-face schedule, either in-person or digitally.	Students can work on online exercises and access course materials at flexible times.
Students who learn in-person and online lessons are different people.	Students learn both in person and using online tools and materials.

Blended learning has been around for a while and has taken on various forms [36]. It is widely used in most classroom settings, and the advantages and disadvantages of this mode of learning have been thoroughly explored [36]. Educator presence in online settings, interactions between students, teachers and content, and designed connections between online and offline activities, as well as between campus-related and practice-related activities, seem to be factors that affect e-learning and blended learning in relation to learning outcomes, student satisfaction, and engagement in collaboration in higher education and professional education [37]. In the quest to determine which learning format provides the highest learning outcomes, creates the most satisfied students, or has the highest course completion rate, several studies have compared face-to-face teaching to online learning and/or blended learning [37]. Existing research on synchronous hybrid learning suggests cautious optimism. It creates a more flexible and engaging learning environment compared to fully online or fully onsite instruction [38]. However, hybrid and blended learning have pedagogical and technological challenges that must be addressed.

Furthermore, most of the existing literature on this topic is exploratory and qualitative in nature, focusing primarily on descriptions of students' experiences. In addition, another difference between the two learning patterns is the focus on distance learning along with traditional learning and the lack of asynchronous learning, where students receive the same information simultaneously. Although hybrid learning facilitates students by focusing face-to-face, in-person, or digitally, students are required to attend physical classes to participate and interact in the learning process [19]. In fact, students who are unable to participate in classes need to learn virtually through lecture records. Consequently, blended learning is more flexible in terms of interaction, participation, and distance learning by asynchronously performing online tools and materials [35]. Hence, blended learning delivers the optimal content to students, whether online or offline platforms.

To compare the similarities and differences between hybrid learning and blended learning, a study was conducted using the “Adopt a Microorganism” project at IFSP, Sorocaba campus, in which both models were applied to high school students [33]. In the study, the students’ discourse richness was evaluated using the Shannon Diversity Index, normally used in biology to comprehend community dynamics and species diversity [33]. To analyze the data, the Shannon index was chosen to verify potential changes in the content richness of the participating students in both teaching models [33]. The classes were suspended due to the COVID-19 pandemic in 2020, and the project was developed entirely remotely, relying only on the activities and virtual discussions that took place on Facebook® [34]. In blended learning, the internet is combined with traditional face-to-face classes, considered its cornerstone [35]. The study aimed to assess potential differences and similarities between both education models. While hybrid learning replaces parts of physical, educational procedures with online modes of knowledge transmission, blended learning requires two or more different kinds of things that can then be mixed. Thus, the breadth of interpretations means that almost anything can be regarded as blended learning. The point of blended learning is that it means different things to different people. However, despite these differences, it was found that both models showed similarities in terms of students’ discourse richness throughout the “Adopt a Microorganism” project [33]. Recently, educational institutions adopted one of two learning styles based on their benefits [18]. While there are some disadvantages and challenges to both approaches, leveraging information technology can reduce accessibility issues and allow future access to education for everyone.

1.2. Educational Data Mining and Learning Analytics

Due to the complexity and diversity of data that changes with society and technology, the process of acquiring the body of knowledge from big data is applied to increase business or organizational values. Based on the fundamental concept of the nature of data, data science techniques are used to solve research and organizational problems comprehensively and realistically. In addition to structural issues, the amount of data affects traditional research processes. Big Data is the collection of massive amounts of data, which can be structured data such as tables, semi-structured data such as data logs, and unstructured data such as social network interactions [39]. It is highly complex and might not be in a form that is adequately usable by an organization, though it may contain concealed variables that are beneficial to the organization.

Most people around the world are likely to learn and understand digital systems that are increasingly connected to daily lives, including trading, investing, communicating, commuting, and educating [40]. Modern databases that run through technology are entirely managed and stored. Thus, analyzing organizational impacts and benefits is driven by database reference and the widespread utilization of big data analysis [41]. In businesses, big data gathered from actual behaviors and activities become an important factor in enabling operations to acquire useful insight or body of knowledge. In addition, it creates a new understanding of the correlation of statistical factors, leading to more in-depth consumer behavior predictions than traditional data analysis.

Big data generally have three essential attributes: volume, variety, and velocity [42 43]. Traditional data or statistical analysis is too slow in data processing based on the essential characteristics of big data. Data mining is to analyze and discover hidden correlations from big data, whether statistically or qualitatively [36]. This technique deploys a pattern classification to indicate relevant information and probabilities that can be used to make decisions in various fields. Moreover, growing interest in data analytics in education has raised the priority and improvement in high-quality research. This educational assessment trend focuses on a convergence between the applications of advanced statistical methods and big data analysis for optimizing the learning process. Educational Data Mining (EDM) and Learning Analytics (LA) have converged on an increasing focus on educational data assessments and student cognitive engagement over the last few years [44-47].

EDM is a subsection of data mining based on big data analysis but particularly related to education systems and learning processes [48-49]. This technique only deals with methods for developing classification and surveying data types that come from the management of the education sector. In general, the application of this method supports the assessment of students’ potential to enhance the classroom environment and more relevant course materials. EDM focuses on developing new tools and algorithms for finding data patterns. To analyze data collected during the learning process, statistical techniques, machine learning, and data mining are offered through EDM [50]. EDM proves to learn predictions and informs educational practices based on databases. In addition, it can also be used for research that includes computational methods, psychology, and various research approaches under learning prediction circumstances.

Additionally, interactive learning methods through information technology systems, simulators, and digital games can also be used to collect and analyze student data. The discovery of data patterns can demonstrate the hypothesis and prediction in the appropriate learning method for the individual student. Furthermore, data gathered from online learning systems can dramatically shorten the collection time and increase the amount of data. It consists of many variables that data mining algorithms can explore to create efficient models. Accordingly, EDM covers education, statistics, and informatics through data mining analytics and machine learning, shown in Fig. 3.

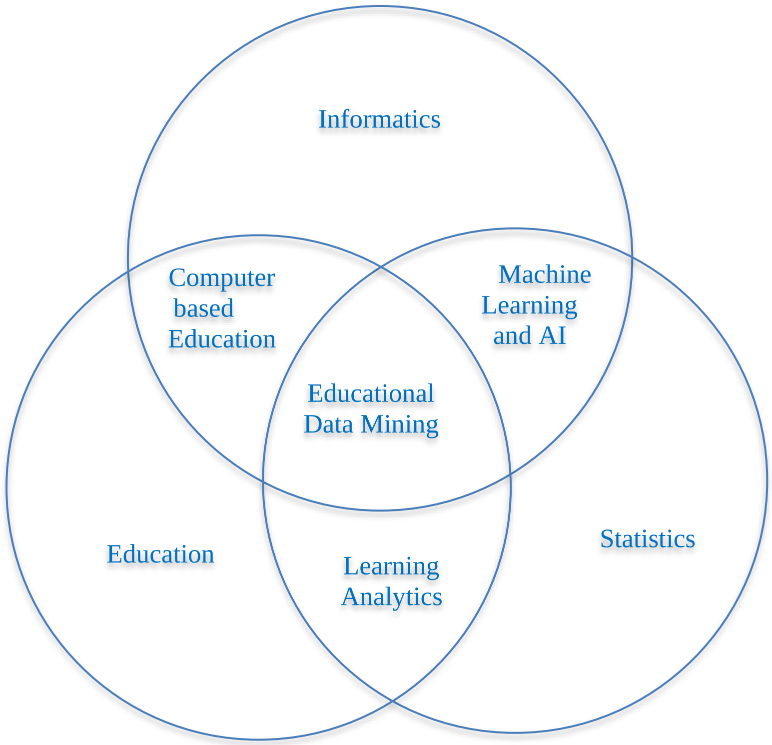

Fig. 3 Intersection of educational data mining

From a broader perspective, this technique is aimed at addressing problems. It is related to different phases in the LMS, whether it is a formal or informal educational activity. EDM can be considered the intersection of education, statistics, and informatics [51]. The main parts of EDM consist of machine learning and AI, Informatics, and Computer Based Education (CBE). Data science theory and design are presented through psychology, sociology, and computational philosophy methods. Data model design includes learning design, interaction design, and educational design. Analytics is the science of examining data to make decisions and deliver operational guidelines. From this point of view, learning analytics is defined as a specific case of data analytics, a decision to improve learning and education. LA is a data science that combines the applications of big data and educational data analysis. This approach involves developing control over educational datasets to support the learning process. Typically, LA is interdisciplinary, requiring competence in computer science, cognitive psychology, and philosophical teaching. It utilizes a variety of computer science and computational methods, including statistics, big data, machine learning, data mining, image processing, etc. According to Fig. 4, LA consists of four steps: descriptive analytics, diagnostic analytics, predictive analytics, and prescriptive analytics, respectively.

The first stage, descriptive analysis, is used to collect and analyze learners' profiles and teaching materials used [52]. The purpose of using descriptive analysis in Learning Analytics is to improve learning outcomes. Descriptive analytics involves collecting and analyzing data to understand past and current learning performance [53]. The second stage of Learning Analytics is diagnostic analytics, which involves identifying the causes of learning difficulties or successes. Predictive analytics, the third stage of Learning Analytics, involves using data to anticipate future learning outcomes and trends. The final stage of Learning Analytics is prescriptive analytics, which involves using data and insights to recommend actions and interventions for improved learning outcomes. LA helps organizations make suitable interventions, which increases the success of the initiative [54]. The method of Academic Analytics involves descriptive and predictive analyses to improve learning and teaching methods. The method provides faculty members with important factors to improve students' levels [52]. LA is presented with practical experiences acquired and validated by 16 institutions [54]. The text provides a comprehensive overview of the four key stages of Learning Analytics: Descriptive, Diagnostic, Predictive, and Prescriptive Analytics [53]. Various techniques are used in LA, such as Bayesian modeling, natural language processing, and predictive modeling. Furthermore, data is collected from various sources in all LA methods. In healthcare studies, descriptive analytics is the most used type of analytics, followed by predictive analytics. Clinical decision support had the highest application of predictive analytics. Evidence of prescriptive analytics was found in public healthcare, administration, and mental health but was very uncommonly used [55]. LA aims to improve and predict learners' success; however, the forms of learning analytics depend on creating large enough databases and the reliability of analytics based on data science principles.

EDM and LA have optimal esthetic reliabilities and crucial mechanical properties to support educational data assessment in producing a body of knowledge, as shown in Fig. 5. EDM adopts that data for data mining and forwards it to the LA process for data science analysis [43]. The data from this analysis are passed through the data preprocess and interpretation method until instructors or students acquire knowledge. The distinction between EDM and LA was of concern to many studies. EDM covers both learning analysis and academic analysis. At the same time, LA is the collection of selected institutional data for statistical analysis and predictive modeling for supporting and developing learners based on desirable academic behaviors. The difference between EDM and LA lies in its origins. EDM encompasses intelligent teaching paradigms and analytical learning-focused learning systems of organizations such as learning content management systems.

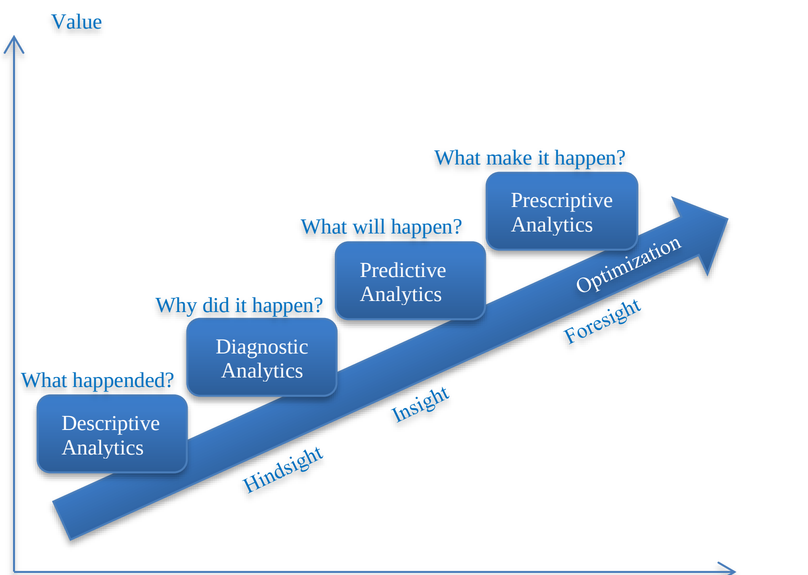

Fig. 4 Forms of learning analytics

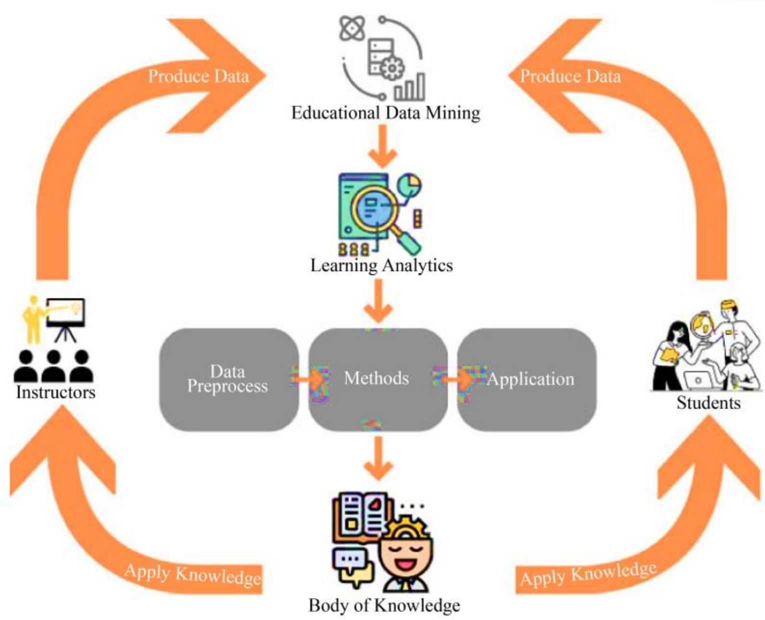

Fig. 5 Educational data mining and learning analytics schemes

EDM and LA have significant overlaps in the investigator's objectives and the methods and techniques used in the evaluations. In general, LA is essential in cases where datasets resulting from EDM are highly complex and require data science analysis before deployment in several knowledge acquisition methods.

1.3. State of Problems

Hybrid learning and blended learning have become increasingly prevalent in education, particularly in the wake of the COVID-19 pandemic. However, as more institutions adopt this approach to education, challenges related to designing and implementing Blended Learning Environments (BLE) are surfacing [56]. The literature on blended learning environments has identified both benefits and challenges related to this mode of instruction. Though the common challenges faced in hybrid and blended learning are not explicitly mentioned in the text, an overview of common challenges related to using blended learning environments can be gleaned from the research literature. For instance, inadequate faculty training and support, difficulty in developing quality materials, assessing student learning, and maintaining student engagement are some of the most common challenges faced by instructors in blended learning environments [57]. In addition, students may face technical difficulties accessing online materials or participating in online activities [58]. As such, it is crucial for institutions to provide adequate support to both instructors and students to address these challenges and ensure the success of hybrid and blended learning initiatives.

Therefore, this study aims to systematically prepare and review the related existing methods based on hybrid learning and blended learning. The perspective of educational data mining and learning analytics was designed in the scope of systematic reviews relying on the JBI Critical Appraisal Checklist [59]. Although the learning processes and resources have been published regarding educational system purposes, the expected outcomes from the study plans can be consistently prepared in a systematic review. In the case of an academic study, conducting a systematic review can address the issues of learning platforms and interacting limitations over beneficial incrementation in remote learning supports.

2. Materials and Methods

This study reported the systematic review following the critical appraisal checklist for systematic reviews and research synthesis from JBI essential appraisal tools [59].

2.1. Focused Question

The systematic review focused on preparing and analyzing the different characteristics and perspectives of hybrid learning and blended learning in several educational aspects of educational data mining and learning analytics. In this review, the focus question was based on the PICO (population or problem, intervention, comparison, and outcome) strategy dedicated as following descriptions.

2.1.1. Population (P)

Students who study in universities and schools.

2.1.2. Intervention (I)

Hybrid learning and blended learning structures in educational data mining and learning analytics.

2.1.3. Comparison (C)

Hybrid learning and blended learning structures in educational data mining and learning analytics.

2.1.4. Outcome (O)

Functional and structural outcomes.

2.2. Search Strategy

The IEEE Xplore, SCOPUS, Web of Science, ScienceDirect, Springer, and MDPI were dedicated as the research databases in this systematic review. The main keywords that were mechanically used in the searching processes were hybrid learning, blended learning, remote learning, distance learning, and educational systems. This study analyzed and grouped the relevant research works and other publications, including conference papers, journals, and books in the field of education. The search process was fulfilled and completed manually in the analyzing methods.

2.3. Inclusion and Exclusion

The inclusion criteria for the study were hybrid and blended learning in educational data mining and learning analytics. The exclusion criteria were technological tools and other learning styles, such as Physical (Kinesthetic) Learning, Visual (Spatial) Learning, Auditory Learning, Verbal (Read/Write) Learning, Logical (Mathematical) Learning, and Musical Learning. In addition, there are English-based language research restrictions. Neither non-English nor unrelated studies indicated in the inclusion criteria were excluded.

2.4. Screening Method

This study independently performed a manual search of the existing works' research titles, keywords, and abstracts. The full texts were mainly downloaded from the research databases and the open-source literature reviews, including IEEE Xplore, SCOPUS, Web of Science, ScienceDirect, Springer, and MDPI.

2.5. Data Extraction

The relevant data used in this review were extracted from the selected paper through a document and spreadsheet applications. The extracted data comprised the algorithms, samples, settings, learning modes, focus questions and outcomes. The algorithms indicated the main methods, techniques, and tools applied to each study. The samples represented the types and numbers of participants in the experiments and study cases. Settings stated the specific details in factors, variables, and other associated values, while learning modes involved the learning styles only. In addition, the focus questions determined each study's achievements and goals. Also, the outcomes indicated the scientific results, whether it is a specific value or parameter.

2.6. Quality Assessment

The Critical appraisal tool, the Joanna Briggs Institute (JBI) Critical Appraisal Checklist, was applied as the quality evaluation criteria and assessment method for conducting systematic reviews in unique evidence-based information, education, software, and training designs [59]. JBI provided review guidelines for conducting umbrella reviews, qualitative evaluation, scoping reviews, qualitative research, and mixed-method reviews in the JBI Manual for Evidence Synthesis [60-61].

3. Results

3.1. Inclusion and Exclusion of Articles

This study searched 82 research works related to educational data mining and learning analytics and was screened and filtered manually. The full text of 10 research works was analyzed and selected as the suitability of articles matched the inclusion and exclusion criteria described in the next section.

3.2. Description of Selected Articles

The selected ten articles consisted of 5 blended learning, four hybrid learning, and one mixed learning (VLE and hybrid learning) implementing different EDM and LA techniques. Two research works are presented in educational data mining and machine learning and visualization assessment approach [53, 62]. Eight studies focused on applying classification algorithms [63-70]. Even if the presented methods come along with similar algorithms, they refer to different focus questions that led to specific outcomes, as shown in Table 3.

3.3. Quality Evaluation Criteria

The JBI critical appraisal checklist for systematic reviews and research syntheses contains 11 questions to guide the systematic review and the literature analysis, as shown in Table 4. Each question should be answered as "yes", "no", or "unclear". Not applicable, or "NA" denotes an optional choice for complicated instances.

3.4. Mechanical Outcomes of Hybrid Learning and Blended Learning in Educational Data Mining and Learning Analytics

The mechanical outcomes reflect the achievements and goals of each study in different scenarios, including classroom environment, class participation, cumulative scores, and performance predictions, as shown in Table 5.

3. Discussion

Data mining refers to techniques, tools, and research designed to assess the body of knowledge from large data sets. This information generally pertains to people living, working, and learning in different environments [58]. Learning analytics (LA) tracks information directly related to student learning and education systems [38, 74]. It can access and analyze course material access frequency and learning quality in less time than a traditional method. In addition to real-time analysis, periodic data recording can be used for accurate statistical predictions. As instructors and educators benefit from this technique and sustainably improve the quality of educational systems, data mining has gained immense popularity in the education sector. Educational data mining (EDM) evaluates scientific data related to the application of data mining, machine learning, and statistics generated by analyzing educational data. EDM encompasses data analytics across all levels of the education sector regardless of different educational systems or teaching methods. In practice, this technique provides a diverse aspect with multiple levels of meaning to uncover new insights to suit the educational environment better [45, 63]. In this case, EDM supports learning theories in educational psychology and learning science [74]. These fields are closely linked to comparative learning in different scenarios, e.g., hybrid learning and blended learning.

The objective of this present systematic review was to evaluate, analyze, and compare the existing methods, algorithms, and tools covered in the perspective of Educational Data Mining (EDM) and Learning Analytics (LA). This study mainly focused on how EDM and LA were incorporated into hybrid learning and blended learning in several situations. The comparison results indicate that most existing studies focused on machine learning and classification methods, such as EDM and LA, where statistical tools and artificial intelligence schemes were applied [63-70]. Two research works were examined using different machine learning algorithms, such as SVM, Naïve Bayes, Decision tree, Neural Networks, etc., dedicated to blended learning and hybrid learning schemes [63-70]. The exploration of those existing methods focused on students' learning performance and success rate prediction through online platforms such as Moodle and SIS. Besides, visualization assessment was applied in blended learning among programming and information technology via synchronous and asynchronous participation in a mixed education [45]. Although the proposed methods focused on EDM and LA in different methods and scenarios, they aimed to predict student educational success rates. Assessment of learning competency through educational data analysis effectively measured the characteristics or behaviors desirable to meet the specified instructional objectives. The results of these assessments will be applied to decision-making to prioritize learning content and improve the education systems in the future.

Table 3. Details and descriptions of selected articles

Algorithms	Samples	Settings and Tools	Learning Modes	Focus Questions	Outcomes
Data Visualization [40]	Behaviors on asynchronous online learning behaviors (accountID, userID, courseID, click contentID, logTime, and exitTime), synchronous online learning (NAME (message publishers), message (message contents), live_broadcast_timestamp (broadcast-message timestamp), and Creat_time (message timestamps)), self-evaluation (namely, personal background, teaching platform, open questions, four major themes, curriculum design plan, and actual platform usage).	The Python programming course, the learning management system (course materials, weekly assignments, quizzes, and content clicks), message (message contents), NAME (message publishers), Facebook live platform, live_broadcast_timestamp (message timestamp), Facebook Graph API (creat_time (message timestamps), and 23 questionnaires for students.	Blended Learning	Evaluate the learning behaviors records generated by first-year university students in two classes of a blended learning course in Python programming.	Mid-Term Forecast via model evaluation and comparison between the three classification models (Decision Tree, Logistic Regression, Random Forest), Learning Behavior Grouping via hierarchical group heat map variable group (upper (G1), middle (G2), lower (G3), upper group (R1), and lower group (R2)), and Learning Attitude (Active Learning, Regular Learning, On-Demand Learning, Negative Learning)
Decision Trees, CART algorithm [49]	352 undergraduate students (student_ID, messages, ccc, quiz_efforts, files_viewed, and grade).	SPSS version 21, Gini index, Moodle LMS log file (Excel format or OpenDocument Spreadsheet (.ods)).	Blended Learning	Test the ability of the CART algorithm through web-based blended learning and online interaction via Moodle LMS log files.	Student failure or success classification on categorical variables via SPSS CART implementation
Decision Tree [50]	22 undergraduate students from Oman's private Higher Education Institution (x Student's Academic Information (CGPA, Term Exceed, High Risk, At-Risk, At-Risk SSC, Plagiarism Count, CW1, CW2, and ESE), and Student Activities (In Campus and Outside Campus))	WEKA Classifier, Moodle, Eight comparative Algorithms (Random Forest, REP Tree, Decision Stump, Hoeffding Tree, Naive Bayes, and Logistic Model Tree, SMO), and Classification Scale (Fail, Good, Average, Pass, and Excellent)	Virtual Learning Environments (VLE) and Hybrid Learning	explores student's academic performance using decision trees and comparative algorithms (REP Tree, Random Forest, Logistic Model Tree, Hoeffding Tree, Decision Stump, Naive Bayes, and SMO) through specific Student's Academic Information and the Student Activity.	Classifier prediction accuracy and kappa evaluation

Algorithms	Samples	Settings and Tools	Learning Modes	Focus Questions	Outcomes
SVM, Naïve Bayes, Decision tree, and Neural Network [51]	Students in higher educational institutions in Kerala, India	ID3 Decision Tree algorithm, MLP Neural Network, Academic Features (Topic, Grade ID, Stage ID, Section ID, and Semester), Demographic Features (Gender, Birth Place, Nationality, and Relation), Behavioral Features (Visited resources, Announcement view, Raised hands, and Discussion), and Extra Features (Parent school satisfaction, Parent answering survey, and Student absence days).	Hybrid Learning	Develop a machine learning model to evaluate students' academic performance through the real-time academic disciplines of higher educational institutions in Kerala, India.	Classification efficiency approaching results (precision, recall, F-score, and accuracy) for student features (Demographic, Academic, Behavioral, and Extra Features)
Neural Network [52]	885 undergraduate students in 3 courses under 16 different classes.	21 blended learning classes in three different courses (Engineering Management (EGR), Introduction to Statistics (MAT), and Basic Computing (COM)), classes conducted during the midterm (OctJan), Moodle log files (student full name, course, time, date, action, and IP address), action timestamps (AM+, AM-, PM+, and PM-) and Keras Python library.	Blended Learning	Develop a prediction model using the deep neural network for evaluating students' performance in the early phases of blended learning.	Accuracy percentage with ROC-AUC scores of Neural Network to assess and predict course outcomes in blended learning environments.
Multiple Linear Regression [53]	55 students from the Spring class and 72 students from the Fall class.	The flipped classroom, Small private online courses (SPOCs), massive open online courses (MOOCs), Student Behavioral Data (General Features (the time of the first access, Individualized teaching, Assignment Features (MCQ grades, timestamps for MCQ, study time, the number of posts), submission time, the number of submissions, and grade of subjective questions)), and Comparative Models (Gradient Boosted Decision Tree, Decision Tree, and K-Nearest Neighbor).	Blended Learning	Evaluate the impact of learning behavior in blended learning through a student-centered teaching method depending on the Small Private Online Course (SPOC) and the flipped classroom.	The predictability of student performance during the semester's 1/4, 1/2, and 3/4 phases using Multiple Linear Regression.

Algorithms	Samples	Settings and Tools	Learning Modes	Focus Questions	Outcomes
K-Nearest Neighbor and Random Forest [54]	182 college-level engineering students and 3 instructors from the Physics II course at the Technologico de Monterrey (Mexico).	Structured academic data (grades) and unstructured academic data (student ID and students' photo), Error measures (Mean Absolute Percentage Error (MAPE)), Mean Absolute Deviation (MAD), and T-Distribution).	Hybrid Learning	Assess the academic success rate of engineering students at the Technologico de Monterrey (Mexico).	Differences in the predictive and actual results between the control and the experimental group via average, mean absolute deviation and mean absolute percentage error.
Live and let live (L3) Classifier [55]	5000 students in the first-year courses.	Learning Management Systems (LMS), Student records (Student Id, Age, Gender, HM-loc, BH-loc, GRE-gr, HS-gr, and BS course), The first-year courses (Mathematical Analysis (MA), Science (CS), Chemistry (CH), Physics (PH)), and Computer Linear Algebra (LA)), and Course-Activities (Student Id, Course Id, Timepoint, MA-mat, and MA-str).	Blended Learning	Analyze learner-generated data acquired by our technical university in blended learning on the proposed explainable learning analytics and classification methods.	Evaluation results in the performance of the classification model and predicted per-student success rate assignments.
Ridge Regression and K-Means [56]	50 students in eighth grade	50 random samples (30 samples for the testing group and 20 samples for the validating group), namely, English learning data (attribute, excellent rate, qualified rate, scores, practice session number, practice time, and success rate. Type of Activity (Speaking, Listening, Reading, and Writing), Data Attributes on Hybrid Learning Platform (Learning achievements and Learning behaviors).	Hybrid Learning	Evaluate the eighth-grade student's English learning performance in hybrid learning through a prediction and alert model, Ridge Regression.	The proposed prediction-alert model and accuracy verification of students' performance prediction for alert and actual situations in hybrid learning.
Feedforward spiking neural networks [57]	55 19th-grade students on the Internet of Things at Shenyang University, Liaoning, China.	3976 entries records, 62 courses in 6 semesters, 26 variables student grades (grade), no. (student ID), gender, date of birth, place of origin, major, class, political status, graduate high school, and entrance examination score), and Comparative models (neural network, decision tree, XGBoost, random forest, and SVM).	Hybrid Learning	Predict the student's academic performances and achievements using the feedforward neural network on an online educational administration system.	Predicted results of percentile grades of students throughout the feedforward spiking neural network.

Table 4. Quality evaluation criteria using JBI critical appraisal checklist [46]

Criteria	Hung et al. (2020)	Zacharis (2018)	Hasan (2018)	Francis & Babu (2019)	Raga & Raga (2019)	Xu et al. (2020)	Rincón-Flores et al. (2019)	Cagliero et al. (2021)	Zhuang et al. (2022)	Liu et al. (2022)
1. Is the review question clearly and explicitly stated?	✓	✓	×	×	×	×	×	✓	✓	✓
2. Were the inclusion criteria appropriate for the review question?	✓	✓	○	×	○	○	○	×	×	✓
3. Was the search strategy appropriate?	✓	○	○	○	✓	✓	✓	○	○	✓
4. Were the sources and resources used to search for studies adequate?	✓	✓	×	✓	✓	✓	✓	✓	✓	○
5. Were the criteria for appraising studies appropriate?	○	✓	✓	✓	✓	✓	○	✓	○	✓
6. Was critical appraisal conducted by two or more reviewers independently?	○	×	●	○	○	○	○	○	○	○
7. Were there methods to minimize errors in data extraction?	✓	●	×	×	○	○	×	✓	○	✓
8. Were the methods used to combine studies appropriate?	✓	×	✓	✓	○	✓	○	✓	✓	✓
9. Was the likelihood of publication bias assessed?	○	○	○	○	○	○	✓	○	○	○
10. Were recommendations for policy and/or practice supported by the reported data?	●	✓	✓	○	○	●	●	✓	✓	✓
11. Were the specific directives for new research appropriate?	✓	●	✓	●	○	✓	●	✓	●	✓

* ✓ denotes "yes", × denotes "no", ○ denotes "unclear", and ● denotes "NA" or not applicable.

Table 5. Mechanical outcomes and comparison results

Authors	Classroom Environments	Student Class Participations	Student Cumulative Scores	Student Performance Predictions
Liu et al. (2022)	-	Real classroom for the 19th grade in the Internet of Things major at a university in Shenyang City, Liaoning Province, China.	The total grade number in the courses.	Student achievement prediction.
Hung et al. (2020)	The degree of synchronous and asynchronous participation, the submission of assignments, and the discussion in the online forum.	Synchronous and asynchronous participation in a mixed-education environment of mixed face-to-face courses.	The total score of the semester, the student's grades, the 11 assignment scores, the number of un-submitted assignments, and the number of delayed submitted assignments.	A course successful interim prediction.
Zacharis (2018)	Web-based blended learning environments.	Moodle LMS for online course learning and discussion.	Grade Point Average (GPA) or grades across assignments, class quizzes and tests, lab work, and attendance scores.	Class successful prediction.
Hasan (2018)	-	Student Information System (SIS) and Moodle (VLE).	Student's Academic Information (Cumulative Grade Point Average (CGPA).	The ordinal scale prediction (Fail, Good, Average, Pass, and Excellent).
Raga & Raga (2019)	Moodle LMS for student activity reports.	The activity footprint of 11 unique action types of students.	-	-
Xu et al. (2020)	MOOC resources, SPOC, flipped classrooms, and student-centered teaching.	Videos watching, quizzes performing, collaborative learning, and group discussing.	The scores of MCQ in the Spring and Fall classes.	The behavioral data was collected in 4 periods during the semester periods, along with MCQ assignments and scores.
Rincón-Flores et al. (2019)	-	Student observation using the photograph and record inputs	Students' grades from the first and second evaluation periods of experiments.	Average scores of students in the second evaluation period for the control and experimental groups of the three instructors.
Cagliero et al. (2021)	The blended model relies on a massive educational video service.	Reserved courses for the first-year students enrolled in BS.	Examination scores	Exam Success Rate Prediction.
Zhuang et al. (2022)	Online and offline learning platforms.	English learning in a hybrid learning platform for eighth graders.	The submission time of the practice and dialogue scores.	English learning achievements and behaviors prediction.

4. Conclusion

In conclusion, this paper proposed a systematic literature review to analyze and review different Educational Data Mining (EDM) and Learning Analytics (LA) methods in distinctive circumstances of hybrid learning and blended learning aspects. Since hybrid learning and blended learning have been proposed to support a learning process in several cases regardless of the technological platforms, whether face-to-face (onsite learning) or online learning, the reliance on educational technology relied on the dissemination and collection of massive amounts of data could be resolved.

To perform the review, this study searched 82 research papers involving the EDM and LA techniques, where the assessment tools were defined in terms of machine learning and visualization methods. In this regard, the gathered documents were screened and filtered manually, relying on the inclusion and exclusion criteria. The full text of 10 research papers was selected and analyzed as educational data mining and learning analytics were adopted for statistical and qualitative data analysis. Furthermore, the JBI critical appraisal checklist was applied for systematic reviews and research syntheses using 11 specific questions during the review process.

The mechanical outcomes indicated that the achievements and goals of each study reflected in different environments, including classroom environment, class participation, cumulative scores, and performance predictions. Although the proposed studies differentiated the learning methods in terms of students' success rate prediction and assessment, the ways to implement these practical algorithms are varied depending on the educational system covering the offered course structure and learning dataset characteristics.

Finally, as a result, it can be concluded that the different educational data mining and learning analytics methods offered future benefits on educational prediction in several aspects of hybrid learning and blended learning regardless of the learning platforms.

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