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A SYSTEMATIC REVIEW ON EXPLORING THE ROLE OF CLUSTERING ALGORITHMS IN EDUCATIONAL DATA MINING

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Abstract

The review examines the objectives, datasets, algorithms, and application areas of studies, with specific attention to student performance analysis, learning conduct identification, personalized learning, and educational decision support systems. The outcomes reveal that K-means is the most used clustering algorithm due to its ease and effectiveness, while tools such as Weka, SPSS, and learning analytics platforms are commonly employed. The study features the efficacy of clustering techniques in segmenting students, predicting academic performance, and supporting instructional strategies. This exam specifies effective perceptions into current trends, trials, and future directions in applying clustering algorithms within EDM, highlighting their prospective to enhance educational characteristic and understanding experiences. The review examines the objectives, datasets, algorithms, and application areas of studies, with specific attention to student performance analysis, learning conduct identification, personalized learning, and educational decision support systems. The outcomes reveal that K-means is the most used clustering algorithm due to its ease and effectiveness, while tools such as Weka, SPSS, and learning analytics platforms are commonly employed. The goal of data mining is to extract knowledge from massive amounts of data. Among the data mining algorithms are clustering, regression, summarization, association rules, and detection of irregularities. A variety of private and open-source data mining tools are used. Using the MCLUST method, predict a system for educational data mining using ensemble and filtering techniques. The results show that the e-learning style algorithm is the most widely employed algorithm. An automatic comparing method using spectral clustering, OPTICS, TOPSIS, k-medoids, and BSCAN. This work conducts the same experiment on a controlled version of the datasets based on the findings. To use data mining to examine pupils' accomplishments, CGPA was used to create groups using the K-means algorithm and to use data clustering and predictive modeling to track pupils' progress.

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Introduction

Data mining identifies concealed trends in enormous data sets. Data mining is divided into several stages: data selection, pre-processing, dataset transformation, use of data mining tools, and analysis. Classification, clustering, rules of association, regression analysis, anomaly detection, and summarizing all data mining approaches [1]. Educational Data Mining is examining and analyzing data collected while teaching to enhance learning results. As in science and business, education researchers see the potential to improve. Learning just got a whole lot easier with this type of

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research. Gathering data to figure out best practices used to be a real challenge, but now it's easy to collect and work with big data. There's a field of research called Educational Data Mining, or EDM for short that uses data mining and machine learning to analyze educational data. It's all about extracting useful information and insights from large datasets to improve education, student learning, and teaching methods. EDM has the potential to make a big impact on education by providing valuable insights that can inform teaching practices, make learning more personalized, and support decision-making in schools. One of the cool things about EDM is that it uses clustering algorithms to group similar students, courses, or educational resources together based on certain characteristics or patterns. These algorithms help identify hidden structures in educational data, giving educators and researchers a better understanding of how students learn, what they need, and how to design curricula. For example, clustering algorithms can be used to identify students who are struggling with similar concepts, so teachers can provide targeted support. To get a better sense of how clustering algorithms are being used in education, a systematic search was conducted across major databases using specific search terms. The search included studies published between 2013 and 2023 that focused on applying clustering algorithms in educational settings. The goal was to identify research articles and conference papers that explored the use of clustering algorithms for things like student grouping, personalized learning, and educational decision-making. This paper takes a closer look at various forms of data mining, including educational data mining, as well as clustering techniques, algorithms, and approaches. The authors reviewed a bunch of research papers and examined the studies based on certain criteria. They presented the goals, characteristics, and techniques of some key publications in a table of clustering algorithms. By exploring how clustering algorithms are being used in education, we can gain a better understanding of how to improve teaching and learning.

1. Educational Data Mining

When we look at how Educational Data Mining, or EDM, works, we see that it uses a lot of different methods like statistics, machine learning, and data mining to get useful information and trends from educational data. This involves looking at big datasets from education, like how students do on tests, how they interact with online learning tools, and how they use educational software, to understand how students learn, how teachers teach, and how the whole education system works. By analyzing this data, researchers and teachers can do things like predict how well a student will do, find out what teaching methods work best, make learning more personal, discover things that affect learning that aren't immediately obvious, and see if educational programs are working. Data mining is a way to find patterns in huge amounts of data. There are a lot of practical problems that come up when trying to group similar data points together in real-world applications. The term EDM refers to the techniques, tools, and research that help us get insights from large datasets that come from people's educational activities. This data is often very detailed, precise, and comprehensive. When trying to predict how well a student will do using EDM, there are several factors that can affect how accurate and effective the prediction models are. These factors can include things like the quality of the data, the methods used to analyze it, and how well the models are designed. By understanding these factors, educators and researchers can build better models that help them make more informed decisions about teaching and learning. This can lead to better outcomes for students and more effective use of educational resources.

Figure: 1 Factors for Prediction [3]

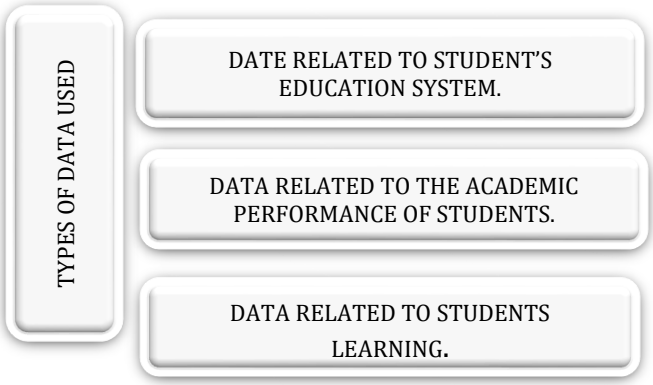

Figure 2: Types of data analyzed for educational purposes.

2. CLUSTERING ALGORITHMS

These algorithms aim to identify patterns, similarities, or groupings without knowing the class labels or predefined categories. The most common categories that are mostly used are: K is a user-defined parameter in the widely recognized clustering algorithm K-means, which partitions the data into K distinct clusters. With either agglomerative (top-down) or divisive (bottom-up) methods, hierarchical clustering constructs a structured hierarchy of clusters. The DBSCAN acronym stands

for density-based spatial clustering of applications with noise. The iterative algorithm Mean Shift begins by assigning data points at random and then updates the centroids to reflect the meaning of the data points. A probabilistic model called the Gaussian Mixture Mode assumes that a variety of Gaussian distributions were used to create data points. Spectral clustering considers data points as nodes in a graph. And uses spectral techniques to achieve dimensionality reduction. It then applies K-means or another clustering algorithm to the reduced-dimensional representation of the data. Because many of the clustering algorithms overlap, it is challenging to classify them precisely. Traditionally, hierarchical and partitional clustering techniques have been broadly categorized into two categories. However, it's crucial to comprehend the subtle distinction between cluster analysis (the unmonitored classification) and understanding the individual (or discriminant analysis) before we talk about these types. In supervised classification, a set of labeled (or pre-classified) observations are provided to us. The goal is to decide how to label a newly discovered unlabeled dataset. The challenge in clustering is to organize the data sets with no label into informative classified with labels trends or clusters [4]. Clustering algorithms have several applications in educational data mining like Student Segmentation, Course and Curriculum Design, Learning Analytics, Recommender Systems, Dropout Prediction, Early Warning Systems, and Educational Data Visualization.

3. EDUCATIONAL DATA AND CLUSTERING METHODS

Educational data clustering is a tool that helps us understand student behavior by analyzing educational data using special techniques and algorithms. It looks for patterns and predictions in how students learn. A summary of this can be found in Table II, which shows the main studies that use clustering to analyze educational data. Clustering is a technique that helps us understand unique things about education. It's been used to look at many different educational variables. Many sources were used in this study, including five big databases: IEEE, ACM Digital, Google Scholar, Journal of Educational Data Mining, and Science Direct. The rules for choosing which papers to include are in Table I. Most of the papers reviewed were about educational data mining. Authors have written many papers on topics like e-learning, educational data mining, and other learning styles. Some papers were about clustering in education, student performance, technology, and other related topics. We grouped together many different studies that used clustering algorithms to look at academic attributes. By using clustering algorithms, we can now get a detailed picture of many educational characteristics. To predict how well students will do, two data mining models (Decision Tree and Random Forest) were used on student data. The results showed that Decision Tree was better than Random Forest, with an accuracy score of 66.9%. This means we can use Decision Tree to make pretty good predictions about student performance. Clustering is an important technique in educational data mining because it helps us find patterns and relationships in student data. By using clustering algorithms, we can identify groups of students with similar characteristics and predict their academic performance. This information can be used to improve education and help students succeed. The study used a variety of clustering algorithms to analyze educational data and found that Decision Tree was the most accurate model. The results of the study can be used to inform educational policy and practice, and to help teachers and administrators make data-driven decisions. By using educational data clustering, we can gain a better understanding of how students learn and how to support their academic success. Overall, educational data clustering is a powerful tool for analyzing educational data and predicting student performance. By using clustering algorithms and

data mining techniques, we can gain a deeper understanding of student behavior and improve educational outcomes. The study's findings have important implications for educational practice and policy, and highlight the importance of using data-driven approaches to support student learning. In addition to its practical applications, educational data clustering also has the potential to contribute to our theoretical understanding of student learning and academic performance. By analyzing large datasets and identifying patterns and relationships, researchers can develop new insights into the factors that influence student success. This can help to inform the development of new educational interventions and policies, and to improve our understanding of how students learn and develop over time. Furthermore, educational data clustering can be used to support personalized learning and to help teachers tailor their instruction to meet the needs of individual students. By analyzing student data and identifying areas of strength and weakness, teachers can develop targeted interventions and support strategies to help students succeed. This can be especially helpful for students who are struggling or who have unique learning needs. In conclusion, educational data clustering is a powerful tool for analyzing educational data and predicting student performance. Its applications are diverse and far-reaching, and it has the potential to contribute to our theoretical understanding of student learning and academic performance. By using clustering algorithms and data mining techniques, we can gain a deeper understanding of student behavior and improve educational outcomes. As the field of educational data mining continues to evolve, it is likely that educational data clustering will play an increasingly important role in shaping our understanding of student learning and academic success.

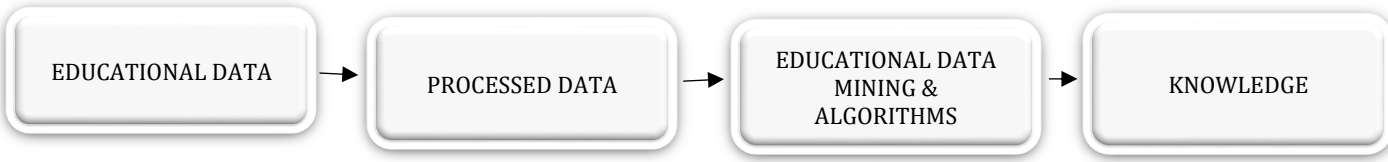

Figure 3: Educational Data and its Process.

4. Literature Search Procedure and Criteria

When conducting a literature search, it is important to follow a systematic procedure to ensure comprehensive coverage of relevant literature. The major steps are to define the research question(s) or topic, develop search terms and keywords, choose appropriate search tools, conduct the search, evaluate search results, inclusion, and exclusion criteria, read abstracts and full-text articles, Follow the reference lists, and stay up to date. The following are the main steps involved in conducting a literature search.

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5.1 Research Questions

- ✓ What are the applications of clustering algorithms in educational data mining?
- ✓ What types of data mining algorithms or models are commonly implemented to predict students' performance?
- ✓ What are the elements that play a role in student performance prediction through educational data mining?

a. *Constructing Search Terms:* The following terms are implemented in this paper for the research questions mentioned. Educational attributes: Clustering in educational data mining, e-learning, students profiling learning objectives, learning style, clustering databases, meta-analysis, hard and soft clustering, clustering in K-means, predicting student's performance, learning outcome, to monitor students' performance, educational problems, and automatic comparative approaches.

b. *Search Strategy*: To find the right information, we figured out what makes our search special and chose the right words to look for. We also found other words that mean the same thing and used those to help us search. Then, we looked through five big collections of information, or databases, and found the important papers we needed. You can see the names of these databases in Table I.

c. Publication Section To find the right articles, we need to look at certain types of papers. These include journal papers, early access articles, and technical reports. We will use these to identify the articles that are relevant to our study.

i. *Inclusion Criteria*: Research has looked into how the context of educational attributes affects the way we group students or schools together based on their educational characteristics.

- Studies include the worldwide population.
- Studies involve conference papers.
- Range of studies from 2013 to 2023.

ii. *Exclusion Criteria:* We'll leave out anything that isn't relevant to what we're studying. This means we'll exclude criteria that don't have a bearing on the literature we're looking at.

- Studies not in the English Language.
- Studies not based on Education.
- Research questions that are not relevant to the studies.

Table 1: Data source and results for literature search.

No.	Data Source	Total Results	Primary selections	Final selections
a.	IEEE	25	20	10
b.	ACM Digital	17	15	03
c.	GOOGLE SCHOLAR	28	25	04
d.	SCIENCE DIRECT	30	25	06

iii. Selecting Primary Sources: Here's how we picked the main sources for our study. We broke it down into two parts: first, we looked at the titles, summaries, and keywords of the papers that had already been published. Then, we narrowed it down further by reading the whole text of the ones that made the cut. The person in charge of reviewing everything was responsible for making the final choices. Out of 100 papers we found that were relevant to what we're studying, we chose 23 of them.

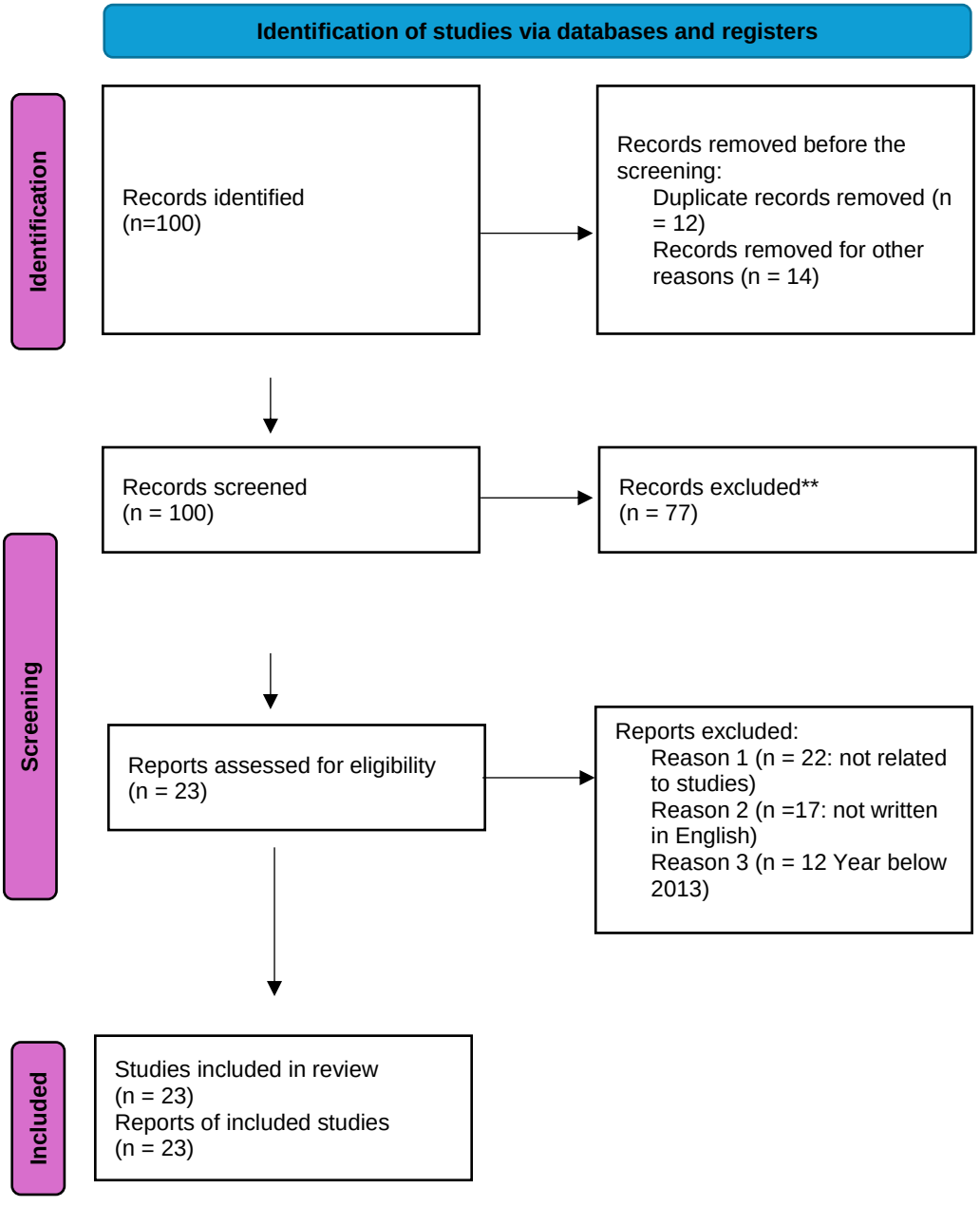

Figure 4: flow diagram for new systematic reviews, which included searches of databases and registers only

6. RESULTS AND DISCUSSION

Table 2: Clustering algorithm as applied in EDM.

NO	Reference	Problem/Objective	Attributes	Year	Algorithms
1.	[1]	Data Mining Resources for Educational Purposes	SPSS, KXEN, Microsoft Analysis Services, Weka	2022	Anomaly detection, regression, clustering, association rules, and summarization are among the algorithms used in data mining.
2.	[2]	Research on the Construction of College English Online Education	The partition-based clustering analysis algorithm, the K-means algorithm proposed the construction of University English Online education resources for the optimization algorithm.	2021	This paper applies the clustering analysis algorithm in data mining to the construction of network resources for college English teaching through K-means.
3	[3]	To cluster algorithms applied in educational data mining.	Clustering, LMS	2015	It is not applicable; it is a review paper.
4.	[4]	Systematic Review on Educational Data Mining	Not applicable	2017	N/A
5.	[5]	To predict a system for educational data mining.	Ensemble and filtering techniques, MCLUST method	2020	Based on the findings, the most commonly used algorithm is the e-learning style
6.	[6]	Analyzing the behavior of university students.	CFSFDP, SSE	2020	K-means and clustering by fast search and finding of density peaks is proposed.
7.	[7]	An automatic comparative approach.	BSCAN and k-medoids, OPTICS, TOPSIS, spectral clustering.	2020	Based on the findings, this work performs the same experiment on a normalized version of the datasets.
8.	[8]	To enhance engineering education	MSLS	2022	The proposed system measures learners' academic/skill data.
9.	[9]	To examine the parallels and discrepancies between educational data mining and learning analytics	Big Data and MOOCs.	2015	The initial parallels and contrasts between LA and EDM are discussed.
10.	[10]	To comprehend how basic education is evaluated.	Data Warehouse, Cluster Education, DEB	2015	After creating a data warehouse, some analyses of the indicators were carried out using clustering.
11.	[11]	To research college quality analysis	SAS Data Mining	2022	In 239 cases, 40% of the total results show good or exceptional English grades; 80% of the student's

					admission scores fall between 400 and 500.
12.	[12]	To analyze students' achievements through data mining.	Groups were made based on the CGPA.	2021	K-means.
13.	[13]	To evaluate graduate students' professional paths.	Enrollment, Curriculum, H School and H Grade, the date and the grade of the final examination, Final Date and Final Grade, as well as information about each exam.	2015	Based on the findings to examine, through analysis of the relevant database, the career behavior of graduate students at universities.
14.	[14]	A review on educational data mining.	EDM	2013	The meta-analysis.
15.	[15]	Different clustering approaches are studied.	Artificial benchmarks	2018	Clustering in Data sets.
16.	[16]	To monitor students' performance using predictive modeling and data clustering.	EDM AND VLE	2014	It specifies that the clustering will implement the K-means algorithm and that the prediction will be a regression methodology.
17.	[17]	In-depth analysis of student performance data	EDM AND VLE, extracting key fields	2022	Data cleansing, key field extraction, and integrated processing.
18.	[18]	Analysis of the academic performance of students.	GPA and Grades, Questionnaire	2020	Using Moodle course logs within the database system.
19.	[19]	Educational data analytics with a visual component	HP-based approach.	2018	The objective of this paper is to conduct a systematic literature review at the nexus of learning analytics and visual analytics based on the findings.
20.	[20]	A comprehensive survey of clustering algorithms.	Distance, taking into account indicators for resemblance measurement and assessment, the traditional ones and the modern ones are used.	2015	Partition and hierarchal algorithm.
21.	[21]	Analyzing the performance of students Using data mining techniques	(EDM) and learning analytics	2019	machine learning algorithms and statistical techniques
22.	[22]	Data Clustering Analysis and Implementation on Ideological and Political Education of College Students	Based on the clustering method of data mining, this paper studies its application to ideological and political education management.	2016	k-means algorithm
23.	[23]	Identifying Different Student Clusters			

	To identify four clusters of students: "Quick learning," "Hardworking," "Satisficing," and "Struggling" through cluster algorithms.	2023	K-means algorithm

7. PARAMETERS

For a Thorough survey of clustering algorithms, algorithms used Distance, considering similarity measurement and estimate indicators, artificial benchmarks, and both predictable and contemporary methods are applied in clustering learning style. For Visual learning, analytics of educational data HP-based approaches are used. Data mining tools in EDM SPSS, KXEN, Microsoft Analysis Services, and Weka are used [1]. Educational data mining for predicting student performance and systematic review algorithms are used Firstly, preprocessing algorithms EDM and some specific data mining, meta-analysis, hybrid algorithm methods Clustering in EDM AND VLE [4]. To predict a system for educational data mining the algorithms are filtering and ensemble methods, MCLUST method [5]. Analyzing the students' achievements through data mining algorithms are used clustering, decision trees, and regression analysis, using Moodle program logs within the database system. Evaluating the behavior of university students, estimating graduate students' careers at universities, and approaching in prediction of educational problems we have the algorithms K-means, CFSFDP, SSE, EDM, LA, LM, sequential patterns techniques [6]. For automatic comparative approaches, the algorithms are BSCAN and k-medoids, OPTICS, TOPSIS, and spectral clustering [7]. To enhance engineering education and Enhancement of educational data mining and the algorithms are MSLS, Knowledge acquisition, data visualization, and pattern recognition [8]. Reviewing the parallels and dissimilarities of educational data mining and Learning Analytics Big Data and MOOCs following algorithms are used [9]. To comprehend how basic education is assessed the following algorithms are used Data Warehouse, Cluster Education, DEB. Perform thorough data mining on student performance data cleaning, key field extraction, and embedded processing of the data methods are used [10].

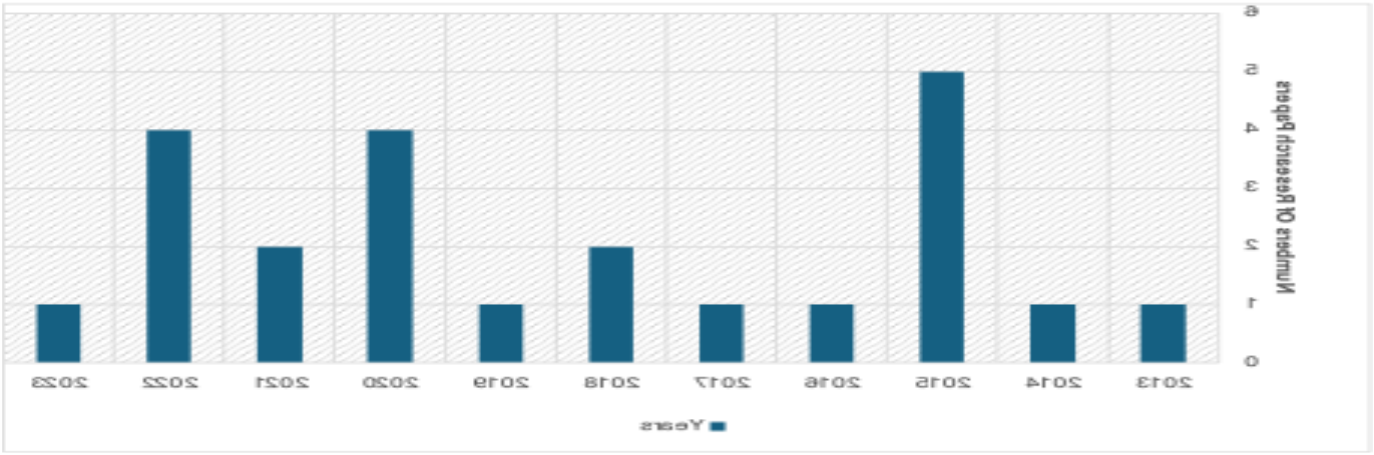

Figure 5: This graph shows the number of research papers per year.

8. CONCLUSION

By mining and analyzing the data that is being gathered as technology advances, educational data mining aims to improve learning outcomes. Educational researchers believe that this kind of research has the potential to significantly improve learning, just like in the scientific and business fields of study. The clustering set of rules and their relevance and functionality in the context of EDM has been the subject of a systematic review that spans more than ten years in this paper. Data mining includes cluster analysis, which is among the most crucial. Data collection is a popular way to find categories of unknown data in a database. These records' foundation is "data collection". According to the current literature studied in this research, various future insights on academic data clustering have also been discussed. In conclusion, the key advantage of using the clustering algorithm for records analysis is that it provides an incredibly clear schema of getting to know the fashion of college students given several variables like time spent on finishing studying obligations, getting to know in behavior, learner conduct in magnificence, classroom decoration and scholar motivation closer to mastering. Further, to use different algorithms to know more about educational data mining. In the research, the fundamentals of the K-means grouping algorithm were presented.

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