

An Insight into Educational Data Mining

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Abstract- Education lays foundation for the development of the country. Enhancements in the educational technologies has improved educational process. Educational institutes are now capable to store large volumes of data related to student admissions, course attendance, examination results and so forth which need to be analysed for the progress of institutes. Data mining provides techniques to explore educational data. Educational Data Mining (EDM) is such an emerging multidisciplinary research field which deals with developing methods to explore the educational data to gain knowledge. The knowledge gained can be used to improve teaching- learning process and decision making process of higher educational institutes. It also helps in detecting student behaviour and their learning outcomes which can be used for their future betterment. This paper puts forth an effort to study EDM, its environment and components including tools and techniques used. It also gives an insight into the Education Data Mining process of knowledge discovery. The present study also puts forth challenges involved in EDM which represents opportunities for future research work to be carried out.

Keywords: Educational Data Mining (EDM), Data Mining (DM), Knowledge Discovery, EDM process, Student performance

I. INTRODUCTION

Education is one of the most essential element in the progress of a country as it lays the foundation for its future. Over the past decades, there is tremendous growth in the education sector both government and private. A large number of institutes are offering under graduate, post graduate and professional courses, which has increased the competition among the institutes to enrol students and hence even affected the quality of education. The advancement and digitalization in education industry has created huge volumes of academic data. The data coming from educational environment contains lots of hidden information which cannot be analysed manually. There is a requirement of analysing data using latest tools and techniques. DM is a technique which can be used in the field of education.

The International Educational Data Mining Society defines EDM as, “*Educational Data Mining* is an emerging discipline, concerned with developing methods for exploring the unique and increasingly large-scale data that come from educational settings and using those methods to better understand students, and the settings which they learn in”. Romero and Ventra defines EDM as “the application of data mining techniques to specific type of dataset that comes from educational environments to address important educational questions” [1].

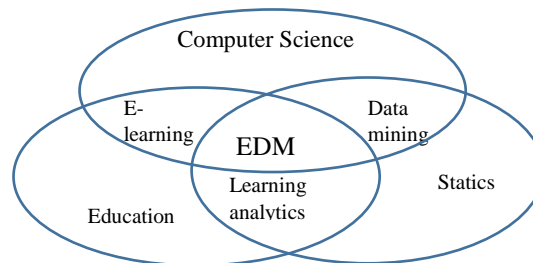


Figure 1: Areas in relation with EDM [1]

EDM is concerned with collecting, archiving and analysing data related to student’s assessments and learning [2]. This data can come from different sources like interactive learning environments, computer supported collaborative learning, data available with universities databases or administrative data. The large repositories of data generated from different sources should be analysed to fulfil the goals of education. The main focus of applying Data Mining to data coming for educational settings (educational data) is to analyse data contents, models, and to summarise and visualise the Knowledge obtained.

The main objectives of EDM based on perspectives of various researchers are [3, 4]-

1. To create student models that includes student behaviour, learning style, performance and environment in which they can develop their skills and solve their problems.

2. To create the design of methods, tools and techniques for the growth of particular branch/institution.
3. To develop the system for studying the effects of educational support. E.g. Pedagogical support
4. To build the computational models for learning and learners that consist of students, domain.
5. To study the effects of resources related to institutional infrastructure, human resource, and Industry-academic relationship in the organization.

The objective of this paper is to provide an insight on EDM and to put forth challenges involved in EDM. The paper is organised into following sections: Section I contains introduction to EDM, Section II gives a brief history, Section III describes various components of EDM, Section IV explains EDM process, Section V explores various EDM applications, Section VI highlights different Challenges and Section VII Conclusion.

II. HISTORY

EDM forms a bridge between the field of education and computing sciences. The usage of computers and computer science in field of education is not new, it date back to the 20th Century. Computer were then used as a tool in teaching/ learning process. Collecting, generating and analysing data was a tedious task. The revolution came with the development of World Wide Web in 1990's [5]. The technologies developed during this period provided a great boost to database and information repositories. Online teaching and learning came into existence [5]. The expansion in capability and computing power with the potential to record detailed/ fine-grained data about learners' use of computer-based learning environment, has motivated in developing techniques for interpreting and analysing the huge amount of data coming from educational institutes.

With time EDM has developed as an independent research area, beginning from research in 'Intelligent Tutoring Systems' (ITS), 'Artificial Intelligence in Education' (AIED), 'User Modelling' (UM), 'Technology-Enhanced Learning' (TEL), and 'Adaptive and Intelligent Educational Hypermedia' (AIEH)[1] [7]. The first workshop, introduced as 'Educational Data Mining', took place in 2005. In 2008 first Annual International Conference on 'Educational Data Mining' was organized by the 'International Working Group on Educational Data Mining' [1, 2].

Today, there are some international societies associated to EDM. The most significant is the 'International Educational Data Mining Society' (www.educationaldatamining.org). It was founded in 2011 that aims to support collaboration and scientific development in this discipline by organising conferences and to publish journal and to support sharing of data and techniques. The Society for Learning Analytics Research (SoLAR) (<http://www.solaresearch.org>) which was also created in 2011 with an aim to explore the role and

impact of Analytics on teaching, learning, training and development. It also deals with organizing Conferences and support open research ; and the IEEE 'Task Force of Educational Data Mining' (EDM-TF) was created in 2012 ([http:// datamining.it.uts.edu.au/edd](http://datamining.it.uts.edu.au/edd)).

III. COMPONENTS OF EDM

EDM can be seen as a working system which is made up of different components. The main components of EDM are Users/Stakeholders of Education, Educational data, Educational tasks and Outcomes, DM Methods-Tools and Techniques [1].

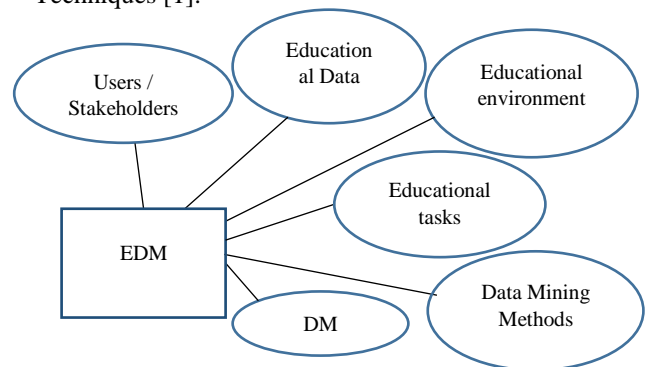


Figure: 2 EDM Components

A. Users and Stakeholders

EDM involves different users and stakeholders. These groups look at the information, provided from educational data analysis with different perspective according to their objectives. Although initially it looks like only two groups' learner and educator are involved but taking into consideration higher education there are many. These include Learners, Educator/ Teachers, Researcher and Administrators [1, 6, 7]:

- **Learners**– Learners are interested in methods to improve the learning experience and performance. To personalize online learning, to provide adaptive feedback and so on [6, 8].
- **Educators/ Teachers** –This group tries to understand the methods to improve teaching/ learning process. Educators can apply applications of EDM in organization and formulation of the curriculum. It can further help to identify various groups of learners like slow learners and to analyse students' behaviour and social aspects [8].
- **Researchers** – Researchers emphasize on the development and the assessment of data mining techniques for the growth of educational sector [6].
- **Administrators** – This group of people are responsible for allocating the resources available like humans and material for implementation and betterment of institutions [6, 8].

B. Educational Data

Educational systems generate large amount of heterogeneous data which is used for the purpose of decision-making and improving teaching learning process. These data sources can be diverse and distributed, structured and unstructured. The data generated from these numerous sources can be categorised as [6, 10]:

- **Offline Data:** Offline Data originate from interactive teaching and learning environment, classroom interaction (traditional and modern), learners information, educators information, student's attendance, various course information's so on [10].
- **Online Data:** This category of data originates from the geographically distinct stake holder of the education (distant and web based education), computer supported collaborative learning, online group forum and social networking site e.g. E-mails, Web logs [10].

C. Educational environments

Educational environments are the environments in which different users/ stakeholders learn. These can be classified into three categories [1, 6, 10]:

- **Traditional Class Room / Formal Environment:** It involves direct interaction with primary users where lectures are given, e.g. face to face classroom interactions in schools and colleges [9].
- **Online / Informal Environment:** It involves indirect interaction where learner learns with help of Internet e.g. web based education or e-learning.
- **Hybrid / Computer Based Learning:** It means using computers in education for providing instructions or directions to the students. It is combination of both formal and informal environment where user can work offline or online.

D. Educational Task

Educational tasks are continuous processes helping students to address their issues. It also helps in the formation of vision of an institute and to achieve administrative as well as academic objectives. This task can divide into two types [7]:

- **Decision Based Tasks:** these are related to administrative and academic decision making which require active participation of the authorities to fulfil administration oriented objectives.
- **Learner Based Tasks:** It involves active participation of primary stakeholders to improve learning process and to introduce new methods and techniques for teaching learning process to fulfil academic objectives.

E. Methods

There is wide variety of methods popular within EDM [3]. The methodologies used in EDM have come from number of sources like data mining, analytics, statics and so on. Romero and Ventra (2007) and later Baker summarized and

defined a new topology according to which the EDM methods were divided into Prediction (Regression, Density estimation, and Classification), Clustering, Outlier Detection, Relationship mining (Association rule mining, Sequential pattern mining, Correlation mining, and Causal data mining), Discovery with model and Distillation of data for human judgment[4,11, 12, 13].

• Prediction

The aim of prediction is to build a model which infer one attribute of the data known as predicted variable purely on the basis of combination of some other attributes called predictor variables [14]. Methods of Prediction are predominantly divided into Classification, Regression, and Density estimation [10]. In EDM, prediction is being used for predicting student performance and for discovering student behaviours [1].

• Clustering

It is unsupervised learning. The objective of clustering is to group instances that are similar in some aspect. These groups are known as clusters. Once the new clusters are formed, new instances can be grouped into clusters by finding the nearest cluster [15].

• Outlier Detection

The main aim of outlier detection is to find objects/ instances that don't comply with rest of data [1, 15].

• Relationship Mining

The aim of relationship mining is to determine association between attributes of a data set and put them in codes/ rules which can be used in future [1, 14]. Association rule, Sequential pattern mining, Correlation mining, and Causal data mining [3, 13] are some popular techniques of Relationship mining.

• Discovery with Model

In discovering with model, a model is created using methods like prediction, clustering, and so forth. The developed model is further used as a component in development of another model or in analysis such as relationship mining [3, 14].

• Distillation of Data for Human Judgment

The aim intends to present data using intelligent techniques such as visualization, summarization, and interactive interfaces to support decision-making as well as to highlight useful information [13, 14].

F. EDM tools

In EDM, data mining provides tools and techniques to extract the knowledge. This knowledge helps to predict future trends and to take knowledge driven decisions [16]. In recent years, many data mining tools have been developed by both commercial and academic sector [13]. These tools are available as free/open source under General Public Licence and commercially. The reason for this large development is the widespread use. Publicly available tools such as Rapid miner, WEKA, R, SNAPP and KEEL include algorithms that implement methods like classification,

clustering, regression, discovery by model etc [13]. A comparison is done for free/open source tools as these tools are widely used by researchers due to their availability and support provided. Further some of these tools allow the user to add their own libraries which further enhance their capabilities [7, 16, 17, 18, 19].

Table 1: Describe Platform, language and tool type of 6 free/open source tools of data mining [16].

S.no	Name of tool	Operating System	Language	Tool type
1.	RAPID MINER	Cross Platform	Language Independent	Machine learning, Data mining, Statistical analysis, and Predictive analysis.
2	ORANGE	Cross Platform	Python, C++, C	Data mining, Machine learning, Data visualization
3	KNIME	Linux, OS X, Windows	Java	Business Intelligence, Financial data analysis, Data mining
4	WEKA	Cross Platform	Java	Machine Learning.
5	KEEL	Cross Platform	Java	Machine Learning
6	R	Cross Platform	C, Fortran and R	Statistical Computing

		algorithms, -attribute/subset evaluators, search algorithms for feature selection. -algorithms association rules -3 graphical user interfaces : “The Explorer”, “The Experimenter”, “The Knowledge Flow” -poor documentation - Strongly suited for machine learning
5	KEEL	-collection of libraries for both pre and post processing. -Classification, Clustering, Regression, Association Discovery, Data Visualization. - A user-friendly graphical interface, -Evolutionary learning
6	R	-Used by statisticians -used for data analysis -supports Graphics - Data and error handling, requires array language, poor mining, -Command line driven

Table 1 and 2 describes the basic features and functionalities of free/open source tools available based upon theoretical analysis performed. All these tools have their own strengths and weakness, but each tool offers a standard platform, and generic data mining tasks. Rapid miner is a tool which has capabilities to perform predictive and statistical analysis. It can read and write different databases, moreover it incorporate maximum algorithms which are available in WEKA also. A more detailed analysis of available tools will help to identify a suitable tools for future research work.

IV. EDM PROCESS

Educational data mining is a process of applying techniques of data mining in educational system. This process form an interactive cycle of hypothesis formation, testing, and refinement [2, 4, 25]. The discovered knowledge is further used to improve the education system [4, 20, 25].

Table 2: Features and functionality of 6 free/open source tools of data mining [16].

S.no	Name of tool	Tool features
1.	RAPID MINER	-stand alone , client/server model -support all stages of data mining process -More than 20 functions for data handling (including aggregation functions) and analysis. - Macro viewer to display macros and their values during process execution - Intuitive GUI
2	ORANGE	-Visual Programming front end, - support Data analytics and Visualization - support modelling and model evaluation -support data pre-processing and feature scoring -GUI - Large toolbox, Scripting interface - Extendable Documentation
3	KNIME	- support data analytics, data pre-processing as well as cleaning -Scalable, interactive user interface -Well-defined API for plugin extensions -Sophisticated data handling, intelligent automatic caching of data, -Data visualization
4	WEKA	-stand alone, client/server - support data pre-processing -tools for data visualization - classification, regression, clustering

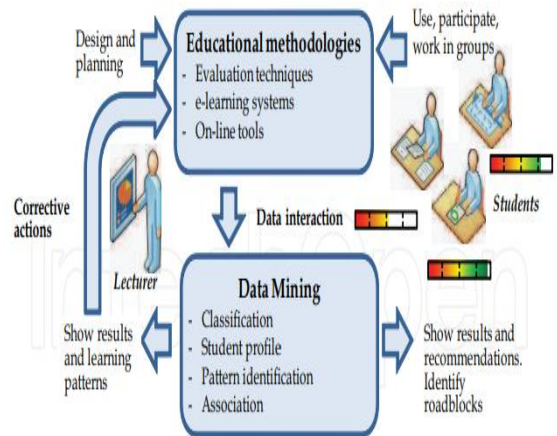


Figure 3: Data mining for determining student' results and learning pattern [4, 20]

Figure 3 show a generalized process of educational data mining where educators are responsible for designing and planning various methodologies, activities and technique related to education. The student uses and take part in various activities, the data thus obtained is processed for classifying, identifying patterns or association and so on [20].

Data mining is one of the main activity in a knowledge discovery process (KDP). The KDP extracts and pre-process the data taken from educational environments. The updated data can be stored in the DW and analysed using different data mining techniques [21].

The EDM process is not much different from data mining process applied in other applications like genetics, medicine etc. As in conventional mining process, almost same steps are performed in EDM process. These steps are summarized in three broad steps [22]:

- **Data Pre-processing:** it allows to transform the data coming from educational environment into suitable format to be used in mining algorithms. Data pre-processing involves different steps like[9, 22]:
 - a. Data cleaning is one of the important task to delete irrelevant data from item sets that are not required for mining [9].
 - b. Data transformation consist of deriving new attributes from already existing attributes, converting data types like changing numerical values to nominal etc.
 - c. Data integration is concerned with integrating and synchronizing data from various sources which can be heterogeneous in nature [9].
 - d. Data reduction is concerned with reducing the dimensions of data [9].
 - e. Attribute selection allows to select the attributes which are relevant and required.
- **Data Mining:** is the principal step which designates name to entire process [22]. Suitable data mining techniques like classification, regression, clustering, association rule mining, and sequential pattern mining etc. can be applied on the pre-processed data. These techniques are applied with the help of various tools available for data mining.
- **Post – Processing:** it’s the final step where the model is tested and results are interpreted which can be used for decision making and improving teaching learning process in educational environment

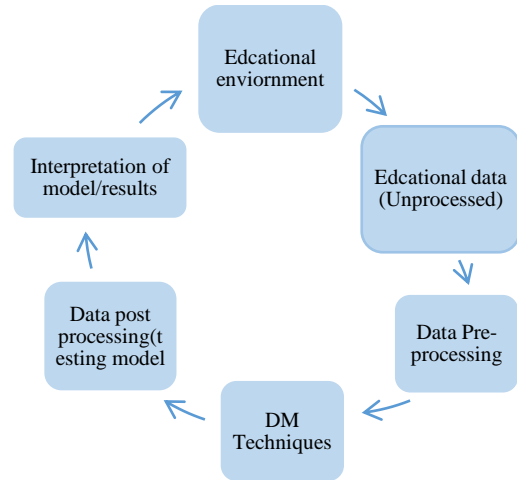


Figure 4: Educational Data Mining process for Knowledge discovery [6, 21, 22]

V. EDM APPLICATIONS

Educational data mining methods are used for various applications. Based upon previous survey and research studies [1, 4, 23] applications of EDM can be categorised into groups like student modelling, decision support systems, Adaptive systems, Evaluation etc. In one of the recent surveys on EDM, four categories of applications namely decision support system, student behaviour, course management systems and student retention were included. The concept map of various applications based on educational data mining [23] and Romero[1] is given below

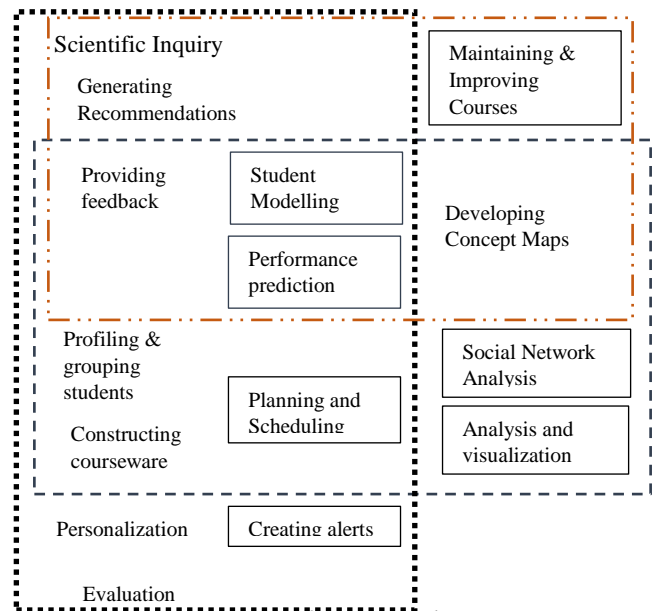


Figure 5: Concept map of various applications in EDM [5]

Table 3: Few examples of EDM Applications/ Tasks [2]

Application/ Task	Description
Student performance	To predict the unknown value of student's

prediction	performance, final grades, and other learning outcomes.
Analysis and Interpretation of Student Data	The objective of this is to analysis and interpret the student data with help of visualisation to highlight hidden yet important information and to support the decision making task.
Providing feedback to support instructors	The aim is to provide feedback to teachers and decision makers. This will help them to take decision for improving teaching/learning process, improve learning outcomes of students and help them in taking proactive remedial action.
Personalizing student learning	Its objective is to automate learning, content navigation and presentation to each student according to his/her learning style and requirement.
Generating recommendations	To give recommendations to students with respect to contents, tasks, problems or courses which are most appropriate.
Student behaviour analysis	The aim of detecting undesirable student behaviour is to find those students who face some type of problem like low self-esteem, motivation, cheating, failure, dropping out, etc. this helps in providing these students appropriate help within time.
User (Student) modeling	The motive is to develop student model taking into consideration user characteristics and their learning behaviour.
Domain modeling	It is concerned with describing the domain of instruction with respect to skills, concepts, learning items and their interrelationships
Classifying students into groups	To classify students into groups based on their learning patterns, data, personal features, characteristics and so forth
Construction of courseware	The objective is to help course developers and educators in the process of designing and developing courseware and learning contents
Planning and scheduling	It deals with planning of resource allocation, future courses, counselling and admission processes, developing curriculum, student course scheduling and so forth

VI. CHALLENGES IN EDM

EDM is a field related to several areas including ITS, e-learning, web –mining, data mining. But EDM needs to take into account various pedagogical aspects of the learner as well as the system [9]. In an educational system, different users interpret the results and data differently according to their objectives. This has led to some challenges in the field of EDM. Some of these challenges are being resolved but still more work is needed to be done in this area. Some of these challenges are:

- In EDM there is lack of tools which are specifically designed for EDM research.
- There is need to develop EDM tools which are more easy to use and user friendly for both educators and non-expert

users. The tools should be powerful yet flexible and having intuitive and easy to use interface with good visualization facilities [8, 9].

- Current tools of DM are useful to developers, but there is need of tools and techniques that are applicable on data coming from educational environment. Therefore there is a need of standardization of data as well as pre-processing and post-processing stages [8, 9].
- DM algorithms need to be modified for educational data. Educational specific techniques can considerably upgrade pedagogical decisions and instructional design [8, 9].
- Building tools for enhancing open education resources as well as developing generalized tools which can be used by both expert and non-expert users [6].
- Need of developing tools for protecting the privacy of individual person [6].
- Incremental nature of educational data leads to difficulty in maintaining the data and to monitor the operational source data. Optimum utilization of human as well as computing resources is also a challenge [7].
- Possibility of uncertainty arise due to existence of certain unseen errors, there is no model that can predict 100 percent accurate results in terms of modelling and planning [7].

Currently large amount of work is being carried out but there is scope of further improvement. EDM needs to be applied and used not only by researchers for research but also by educators and educational institutes also. It should not be theoretical but implemented practically. EDM tools should be integrated into computer based educational systems so that educator should be able to select DM algorithms/methods and apply it by selecting suitable parameters [1]. DM tools should be able to facilitate all the EDM process to the educators. Further the results obtained from EDM research are specific to a particular research project. It is required to obtain generalised results and carry out studies to test the results on broader areas.

VII. CONCLUSION

In recent years, EDM has emerged as multidisciplinary research area. It is one of the most demanding research areas with innovative concepts for mining new knowledge from the existing datasets originating from educational environment. EDM is providing its users different methods, tools and techniques which give them a better learning and research environment. The present paper is an attempt to review all the EDM modules which are required to achieve the objectives of EDM research. Lastly, it presents various challenges related to EDM research. EDM has lot of scope it requires strong collaboration across researchers, ICT specialists, educationists and the learners.

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