Data Analytics and Visualization of Educational Data, Students' Academic Records as a Case Study

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Abstract

With the rapid increase of existing unused data records, the need of making use of this data became vital. Data mining (DM) is among the latest technologies that many researchers pay attention to currently. By applying data mining techniques, data can be analyzed, conclusions can be drawn, and future decisions quality can be improved. The goal of this study to perform a systematic literature review of educational data analytics and visualization. We review existing work in this field from four perspectives. Prior similar work must be taken into consideration to be reviewed and analyzed. Hence, a Systematic Literature Review (SLR) was carried out to review the research that has been done, which is relevant to the field of the study. In the first place, 180 papers were retrieved by a manual search in five databases and 27 primary studies were finally included. The findings deliverables determined the literature review on educational data mining and visualization. Moreover, commonly used data mining techniques are identified.

Keywords: *data mining, visualization, education, systematic literature review.*

1. Introduction

In this era, many educational institutions have a large set of data that have valuable hidden information (Pandey & Pal, 2011).As the most crucial goal of any educational institution is to offer high-quality education to its students (Baradwaj & Pal S, 2012), institutions tend to have a clear knowledge about students' performance and challenges.

Currently, big data and data mining techniques are used to analyse recorded datasets in order to be able to organize and analyse existing data, then draw conclusions based on the analytics results (Peña-Ayala, 2014). Data mining technique use to intensively discover hidden information in datasets. It is assured that by using data analytics techniques and tools, an organization improve its decision-making processes (Pérez-González, Colebrook, Roda-García, & Rosa-Remedios, 2019). Similarly, the educational institution may plan for a corrective plan for its academic performance based on its students' performance records.

Apparently, data analytics and visualization are being used in different scopes, and for different purposed. For example, data visualization was used to analyse trends on twitter to provide a real-time update for users (Murthy J, G.M. S, & K.G. S, 2019). Moreover, data mining analytics was used to improve course

content after analyzing students academic results (Damaševičius, 2009). Furthermore, Data analytics is reported to help in upgrading healthcare services (Ahmed & Liang, 2020).For instance, data analytics was used to improve healthcare quality in order to provide better care for cardiovascular patients (Rumsfeld, Joynt, & Maddox, 2016). As there isa vast algorithm of analytics in data mining, the researcher may select the most suitable algorithm for his/her case study. Some researchers preferred Decision Tree (DT) algorithm for data analytics as results can be extracted easily from its structure (Abellán, López, & de Oña, 2013) while researches proposed to use Apriori algorithm for students' profiling, as well as using K-means clustering to divide a set of observations into subsets of observations (Parack, Zahid, & Merchant, 2012).

Staff at organizations usually come with different backgrounds, so presenting visual reports provide them better understanding for issues and visualization technologies helps in improving accuracy of prediction future patterns , which leads to better decision making (Wei, L.aEmail Author, Roberts, D.W.b,c,d,e, Sanai, N.f, Liu, &J.T.C.a,g, 2019).

The aim of this paper is to conduct a systematic literature review (SLR) for data mining and machine learning analytics of educational data as well as visualization. There some systematic literature reviews that have been done in data analytics and visualization fields earlier, For example, visual learning analytics of educational data A systematic literature review and research agenda (Vieira et al., 2018). However, that review focused more on visualization tools for educational data and not on analytics.

The main objectives of the systematic literature review are to (1) to identify the usage of data mining for analyzing educational data, (2) to determine data mining analysis techniques in prediction educational type of data, (3) to determine tools that are used for data mining analytics, and (4) to analyze visualizing educational data previous work.

2. Methodology

To have a look at previous researchers on analyzing and visualizing educational, academic dataset, systematic literature review (SLR) approach was selected to be undertaken. SLR is an excellently-defined methodological step or procedure for analyzing related research with actual proof. SLR methodology implementation contains three primary phases which are: planning the study; conducting the study; and reporting the study. This approach contains a systematic five-step methodology outlined by Denyer and Tranfield (Briner and Denyer,2009). Figure1 shows the methodology used in this literature review.

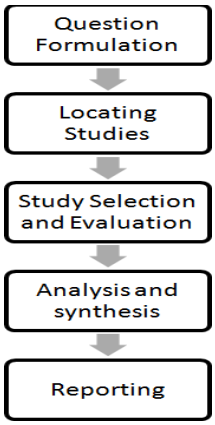

Figure1: SLR Methodology

These steps are briefly described as follows:

Question formulation – It is a crucial process where a study question is formulated. It is considered to be an important stage as it sets the direction for the study. The question needs to be precise and specific.

Locating studies – At this stage, resources and references are to be found and identified. Electronic literature databases will be used to get the genuine resources.

Study selection and evaluation - At this step, selection criteria are to be used in order to include or exclude studies based on the relevance of those resources to the study. The most frequent used inclusion criteria currently include timeframe, or publication date year period, language used or main focus of the paper. Selected studies might be more refined in order to get the highest quality assessment of our research.

Analysis and synthesis – After the initial screening, the relevant studies will be identified. The aim of the analysis is to break down individual studies into each constituent parts and describe how each relates to one another. On the other hand, the aim of synthesis is to make associations between the parts identified in individual studies.

After the beforehand screening, the studies that are related to our study will be configured out. The purpose of the analysis is to break down previous studies units and to describe how those studies related to each other. Next will be studies synthesis to generate connections between the areas that were defined in published studies.

Reporting : The results of the previous studies review will be acknowledged.

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3. Result and Discussion

At this point the outcome of implementing SLR will be discussed.

a. Question formulation

The core question that this study was conducted to answer is ‘What is the most accurate data mining algorithms for students’ records analytics?’. The literature search process was performed in electronic databases with “data mining algorithms AND academic records ” AND “visualization” as the search key. A

vast net enables us to evaluate whether the data mining algorithms for educational, academic records will be the same as others.

b. Locating studies

SLR focuses on searching on the most famous scientific online databases rather than other information resources. This research was done using five electronic databases, and they are ScienceDirect, SpringerLink, IEEEXplore Digital Library, Google Scholar and, and Scopus.

- Science Direct – Elsevier (http://www.elsevier.com).
- Springer Link (http://www.springerlink.com).
- IEEE Xplore Digital Library(http://www.ieee.org/web/publications/xplore/).
- Google Scholar (www.scholar.google.com).
- Scopus (https://www.scopus.com/home.uri)

c. Study selection and evaluation

At this stage, the process of selecting the possible relevant resources took place. After the resources were retrieved, they were reviewed and related resources were determined. The selection criteria used were: (a) the resource was written in the English language, and (b) the article was published in a peer-reviewed journal or conference proceedings. Since the literature review is done for the purpose of analyzing an educational dataset, resources that were not related to the educational field were excluded. The reviews include resources that were published between January 2010 and 2019. The screening process has been done by skimming all retrieved article according to the following sequence: title and abstract, then the main body of resource.

In the early stages, the search process returned 180 related articles for possible inclusion based on skimming the titles and abstracts. After excluding the irrelevant and duplicated papers, 38 articles were finally included for a more comprehensive review. Eventually, 27 were proved to meet the criteria of selection. Hence, they were included for more detailed review in this study. Figure 2 shows the taken process for articles' selection process in the study.

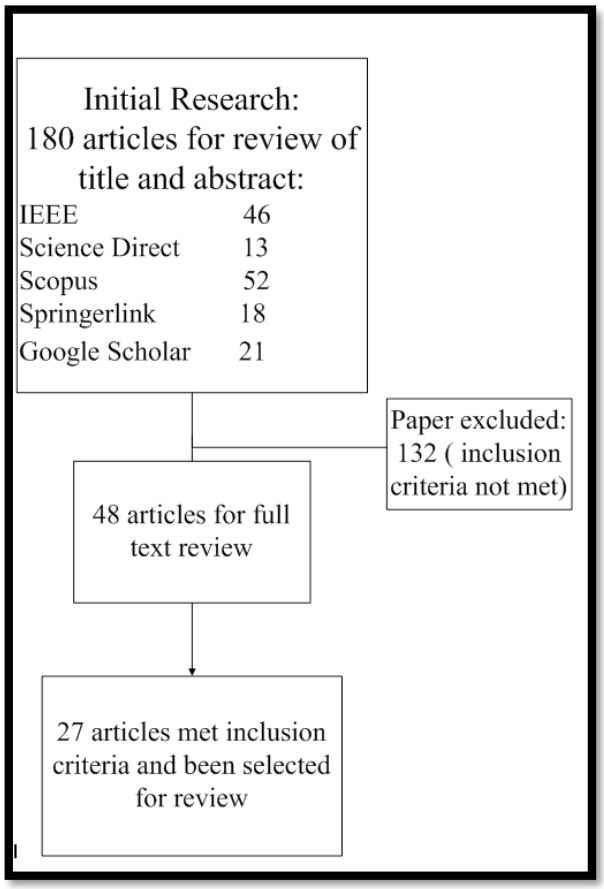

Figure 2: The Selection Process For Including Articles In Review

After finding the relevant papers, they were filtered, and only a few were selected. Table 1 shows the number of articles found based on the keywords search in six selected databases.

Table 1: Number of related articles and their source.

Source	Papers found	After exclusion	Selected
IEEE	46	11	2
Science Direct	13	5	4
Scopus	52	10	0
Springerlink	18	3	3
Google Scholar	21	20	18
Total	180	48	27

d. Analysis and synthesis

Out of the retrieved 180 references, 27 were selected for analysis and synthesis. The analysis can be segregated into four main sections, which are: supporting the usage of data mining in the educational sector, using data mining analysis techniques in prediction educational type of target, tools that are used for data mining analytics, and lastly visualizing educational data. Table 2 shows the number of papers that support each section.

Table 2: Identified previous work from reviewed papers

Section	Number of Articles
usage of data mining in educational	13
using data mining analysis techniques in prediction educational type of target	7
tools that are used for data mining analytics	2
visualizing educational data	5

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-Usage of data mining in educational

Data mining was said to be a new technique that is used extensively to discover hidden patterns and discover buried knowledge. Using this advantage, the results of data mining techniques have given teachers a new horizon of improving academic performance, and provide proactive feedback to learners (Looi et al.,2005). Data mining is a powerful tool to be used in academic involvement. The concept of using data mining in an educational environment is called Educational data mining. And that implies the usage of data mining classifiers to predict future educational students' academic performance (Singh and Kumar, 2013). Using data mining and predictive analytics for the purpose and analyzing and learning hidden knowledge is an active field nowadays . In the case of numerous loads of data, big data is being used to transform education. Exploratory data analysis, data mining, predictive analytics, machine learning, and visualization techniques are being applied to educational data to predict future trends, in order to improve learning based on existing student's records. Tools might vary, for example, Spark or Python. However, the aim is the same (Agnihotri et al., 2016).

The usage of data mining in education was discussed in numerous previous researches. As Hussain mentioned, the process of analyzinga scenario of the educational data in the higher education institutes by using data mining tools and techniques for academic improvement of the student performance and to prevent drop out (Hussain et al., 2018). Weka is a practical tool for data mining, at which random forest outperforms the other classifiers based on accuracy and classifier errors for academic performance dataset. Secondly, educational institutions were identified to have a huge load of data, and that made it challenging to make use of that enormous data in order to improve the quality of education, and the performance of students (Kumar and Chadha, 2012). Hence, the use of that data became a need by analyzing it using data mining techniques. According to (Agarwal et al., 2013), decision tree classification is considered to be an effective way of generating classification rule. Moreover, the

WEKA classifiers were compared in terms of accuracy to classify educational data, and the results showed the classifier's working principles. In addition, LIBSVM was said to outperform other classifiers in education.

Next, a framework called "Student Advisory Framework" was proposed for using data mining for educational data. The framework utilizes classification and clustering to build intelligent (Nagy et al., 2013). Moreover, data mining techniques are used to study the performance of undergraduate students in order to predict their future performance. Thus some earlier studies, two aspects have been focused. Firstly, predicting students' academic performance for the whole four-year study program. Secondly, identifying progressions of students, as well as combining them with academic performance prediction results (Asif et al., 2017). Furthermore, institutions are concerned with the quality of education in order to meet the expectations of all parties in the education system. As a result, one study proposed a new data mining model that helps in making decision making in the strategic levels of higher institutions to be the disciplines of students' admission (Al-Twijri et al., 2015).

In addition, data mining was used for several case studies that analyze educational data. Educational data mining are used to generate predictive models for future student's dropout of the engineering program. As data mining techniques use records of incoming students, as a case study, the predictive model tends to provide an accurate prediction of student dropout list for engineering program (Pal, 2012).

As Goyal and Vohra stated, one of the most important benefits of applying data mining in higher education learning students' academic performance, student behavior. And that will lead to carefully design course curriculum and materials in order to motivate students academic performance (Goyal and Vohra, 2012). In addition, Data mining is considered as a vital approach to analyze educational data. A case study

from Gaza is proposed to support the idea of determining students clusters based on their e-Learning behavior records (El-Halees, 2009).

Talking about challenges, one of the most challenging issues faced by educational institutions is predicting students academic performance paths. To be able to overcome this issue is by using data mining techniques in prediction students performance based on existing academic records (Bhullar , 2012).

- *Using data mining analysis techniques in prediction educational type of target*

Few studies discussed the usage of data mining in predicting educational data. A framework for predicting students' academic performance of first-year bachelor students in Computer Science course is proposed. Moreover, the comparative analysis of three classification techniques are; DT, NB, and RB using WEKA tool. In addition, the results showed that RB has the best classification performance, based on the accuracy compared to NB and DT (Ahmad et al., 2015). Another study presented a comparative study for classification techniques in mining academic performance in order to predict future performance. The used classifiers were Naive Bayes, Decision tree, and Multilayer Perception. Naive Bayes was proved to outperform the two classifiers (Mueen et al., 2016). In addition, one of the most influencing factors in predicting academic performance is the ranking of the course that the students are taking. Moreover, the classifiers are mostly used with educational data are Naive Bayes, AODE, and RBF Network as they achieved the highest accuracy (Affendey et al., 2010). Currently, the prediction of students outcomes is performed using data mining techniques. a framework for prediction was proposed to organize, analyze and classify students details using K-mean Clustering algorithm which is based on academic records. The produced clusters are Low-performance Student, Average Student, and Smart Student (Sumitha et al., 2016). Furthermore, a new student's performance prediction model was proposed by using data mining techniques with new data features or student's behavioral features. These features are connected to the learner's interactivity with the e-learning management system (Amrieh et al., 2016).

Next, the large scale of data is said to be such a powerful asset in order to help the process of predicting the future course outcomes. It is used currently to help students to express their expectations and future learning outcomes, to be able to avoid future failure (Schulte et al., 2017). A review has been done on the prediction to determine the most important features for students' academic records. By using educational data mining techniques, some benefits will be gained by students, as well as educators and academic institutions (Shahiri et al., 2015).

- *Tools that are used for data mining analytics*

In this era, according to (Slater et al., 2017), a various range of tools are introduced for purposes of applying educational data mining (EDM) and/or learning analytics (LA) research. By highlighting the most

widely used, most accessible and powerful tools available for EDM/LA research. Researchers could use is as a guide when using EDM/ LA. The tools can be concluded in:

i. The tools used for manipulation, cleaning, and formatting of data, which are: Microsoft Excel, Google Sheets, and the EDM Workbench.

ii. The tools that are used for data analytics, which are: RapidMiner, Waikato Environment for Knowledge Analysis (WEKA), KEEL, KoNstanz Information MinEr (KNIME), Orange, and SPSS.

iii. The tools that used for visualization, which are: Tableau, D3.js, and InfoVis.

iv. The tools that are used for integrating data collection, construction, analysis, and visualization, which is: DataShop.

As data mining techniques have been used widely nowadays, various tools were developed for data mining analytics. A study has been done to compare the technical attributes of three open-source data mining tools, which are: RapidMiner, Knime and Weka. Based on the results, it can be concluded that Weka provides the largest number of implemented algorithms, followed by RapidMiner and finally, Knime (Fernandez and Lujan-Mora, 2017).

- *Visualizing educational data*

With the rapid usage of information and communication technologies in educational data scope exploration, the issue of unexpected drop-out percentage has increased. Hence, educational institutions decided to use new analytics and visualization techniques. These techniques support the analysis of students' data to guide teachers' future decision-making (Paiva et al., 2018).

Educational data visual analytics field motives researchers to explore this active area more. It was noticed that few studies took into consideration visual learning analytics tools. Moreover, fewer studies analyze students' records. Hence, more effort is needed to conduct a literature review for visualization and education (Vieira et al., 2018).

The combination of both data mining analytics and visualization is a practiced trend in order to simplify the result of data mining predictions. Thus, data mining based detection and visualization was used successfully to analyze academic discussion forum records. Moreover, the results would help teachers to identify the possibility that their students can meet learning outcomes (Wong et al., 2016).

Some students used to drop-out their engineering course in the first year. Educational institutions felt the necessity of avoiding that by predicting students risk of failing their studies. Visualization dashboards were used to show a summary statistic, study progression graph, as well as credit completion graph (Vaclavek et al., 2018).Various educational institutions realize the importance of data analytics in order to explore the existing datasets. Moreover, the institutions made use of visualization in the form of graphs of the result rule repository. In addition , This system was online that integrates

with visual analytics that enables a better exploration of the educational system (Sukhija et al., 2018).

e. *Reporting using the results*

Based on the analysis and synthesis, in the 27 reviewed articles, we can conclude that the data mining analytics is being used intensively for the purpose of exploring data, as well as predicting future variables that help in future decision making. Moreover, various tools are implemented for data analysis. However, based on the analytics results, Weka outperforms other data mining tools. In addition, data visualization was proved to provide a more understood presentation of data, that people from any background might refer to make right decisions. Furthermore, Tableau and Power Bi are two easy yet powerful tool for visualization. Finally, data mining classifiers are various, and according to experiments, it is not possible to generalize the best one for all educational data, but it can be said that each particular set of data has a different nature. However, some of them have been used in the educational field such as Naive Bayes, Multilayer Perception, and LIBSVM. As a result, a specific classifier might perform better compared to other classifiers. And that can be tested and compared for other datasets.

4. Conclusions

Based on the conducted SLR, the review has identified the basics of analytics and visualization of educational students' academic records. Based on the retrieved and reviewed articles, we can conclude that educational data can be classified and visualized using Weka and Power Bi tools for patterns discovery. Moreover, for Weka classifiers, Naive Bayes, Multilayer Perception, and LIBSVM were the models that have been used by some researchers. However, different datasets can be used to generalize the best classifier for educational datasets.

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