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Educational Data Mining: A review of evaluation process in the e-learning

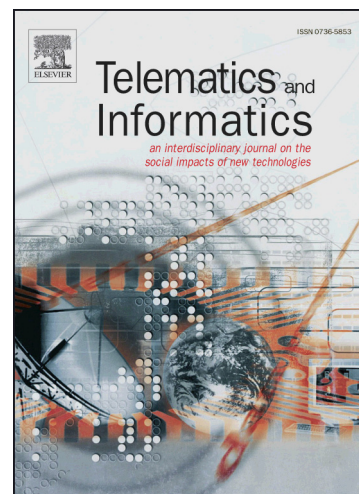
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Title:

**Educational Data Mining:
A review of evaluation process in e-learning**

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Educational Data Mining: A review of evaluation process in the e-learning

<< Blind submission >>

Abstract

Due to the growing interest in e-learning as an important process of teaching and learning, new mechanisms to evaluate its pedagogical effectiveness are necessary. This review describes the scenario of 20 years corresponding to data mining research where the context is the e-learning and the main subject is the evaluation aspect, which is considered a latent problem within this environment. Our goal is to provide an unexplored review of EDM research of the teaching and learning process considering the educational perspective. In order to obtain a more wide and complete review, the search of the bibliographic material was realized with the terms “data mining” and “education” which resulted in 525 articles. As exclusion criterion, articles that did not emphasize the improvement of the teaching and learning process were discarded, resulting in 72 articles. As result of our review, the analyzed papers show that the researches in EDM expanded into several areas and themes, for example, oriented studies on interactions between the educational actors, monitoring, and evaluation of teaching-learning process, administrators’ evaluation about the adopted pedagogical actions, learning risks, and recommendation and recovery of educational media. The review allowed to present perspectives, identify trends and observe potential research directions, such as behavioral research, collaboration, interaction and performance in the development of teaching-learning activities.

Keywords: Educational data mining. Education. e-Learning. Evaluation of teaching and learning process.

1 Introduction

Currently, the process of teaching-and-learning (TL) is strongly supported by educational technologies, which are used in educational environments both in traditional face-to-face classrooms and in online learning platforms (i.e. e-learning). In the last years, technological advancements have given assistance in providing relevant information for all educational actors (students, teachers, coordinators, and administrators) acting in different educational environments, and thereby promoting the quality and innovations in the educational context as highlighted by [Wang et al. \(2012\)](#); [Qiu and Lee \(2013\)](#); [Liu and Peng \(2013\)](#); [Yu and Jo \(2014\)](#).

In order to consolidate and achieve the better quality levels in the e-learning environment, it is necessary to continuously evaluate the teaching and learning process by observing its different aspects, such as the level of interaction of the actors involved, the effectiveness of pedagogical

actions from the student's own response and initiative, the use of multimedia resources, the administrative management responsible for institutional policies, and other aspects that influence the learning and development of better cognitive skills and collaborative work, as emphasized by Sankar and Clayton (2010).

Due to its relevance, the problem of evaluation of e-learning has attracted the attention of several authors, among them we can cite Liu (2005); Chen (2005); Mahlow et al. (2007); Calinger and Howard (2008). For example, in Liu (2005) the author emphasizes the need to evaluate the learning process in e-learning through factors such as achievement, motivation, and level of student anxiety during the learning process. In Chen (2005), the authors evaluate the student's learning through their experience, perception, and attitude during learning. The web-based instruction requires a broad and continuous process of evaluation of teaching and learning to ensure its effectiveness, as highlighted by Yubing and Jianping (2010).

Nowadays, it is possible to generate a great volume and wide variety of data from educational environments such as those related to academic records, monitoring and assessment, and the records of interactions by e-mails between students and educators/teachers, discussion forums and chats (Romero and Ventura, 2010; Zaiane and Luo, 2001; Adeva et al., 2006; Wang and Meinel, 2007; Sun and Zhao, 2009; Liu et al., 2010; Kechaou et al., 2011). The generated data by educational environments, specifically the data generated by the e-learning platforms, are important sources of information for decision support and improvement of the TL. The improvements can be reached from the students' data analysis through of their behavior, satisfaction, and performance. The objectives are always addressed to the expansion and advancement of the educational horizons, in order to contribute to the evolution of the educational process.

In the present scenario, data mining (DM) is an alternative to explore the data with the goal of extracting knowledge and useful information, making the TL more efficient. The data mining results can to guide students in the learning process and lead the educators and tutors to improve the educational practices and assist the management in the administrative process. In general, the generated information by the data mining practices has as objective the improvement of educational methods such as assessment, monitoring, and personalization of TL. For example, educators may monitor the students' learning level and re-adapt the educational basis periodically, with the purpose to modify their approach and the teaching application and students can use evaluating tools to evaluate their own knowledge (Anupama Kumar and Vijayalakshmi, 2012; Bunkar et al., 2012; Chen et al., 2012; Wang and Lin, 2012; Coelho, 2012; Gottardo et al., 2012b; Dejaeger et al., 2012; Sales et al., 2012; Harfield et al., 2013; Liu and Peng, 2013).

Currently, due to the growing interest in e-learning, as an important TL approach, new studies to evaluate its pedagogical effectiveness are necessary.

This paper discusses the researches in Educational Data Mining (EDM), considering as main research theme the evaluation of teaching and learning in *e-learning* environment, from a educational perspective. As the first question (*RQ1* on Section 3) to be answered, this review seeks to identify the perspectives and trends in EDM dealing the e-Learning domain from a educational evaluation view. After the review we observed the following aspects: a) evaluation of e-learning practices within the traditional classroom, observing the interactions among the educational actors, and monitoring the teaching and learning process; b) evaluation of the educational practices regarding the actions of educators, as well as the performed actions by the students; c) evaluation of the educational administrator's management regarding evaluating the educator's actions results, as well as to evaluate the learning risks; and d) evaluation of the use of multimedia resources, considering the recommendation and retrieval systems, as well as the use of these resources to evaluate

teaching and learning.

As a second question (RQ2 on Section 3) to be answered, it is also our objective to identify potential research topics that have received little attention from the EDM community regarding the evolution of teaching and learning. In response to this question, it was possible to identify potential topics such as: a) Discovery of behavior patterns expressed by educational actors' attitudes throughout the TL; b) Research to identify effective models of communication between student-educator and factors that favor this reciprocal and continuously interaction; and c) Research on student performance and factors influencing student's performance.

Our work is divided into 6 sections. In the next section, we summarize existing research on educational data mining by analyzing the main literature reviews on this subject, resulting in the difference of our proposal. Section 3 presents the research questions (RQ) of this review and the collection strategies of the bibliographic material. The analysis of evaluation process in the e-learning environment is performed in Section 4. In Section 5 we discuss the bibliographical material under the educational perspective presenting such as the main perspectives and future trends of research. Finally, we conclude the paper with a summary and outlook for further research in Section 6.

2 Related work

In order to trace an EDM research view, we have identified the literature review papers and highlighted their main contributions. The Table 1 shows these contributions (surveys) indicating the considered educational environments, the main goals of each review, the different techniques of data mining used by the contributions, the main observed tendencies, and the main educational concepts discussed in broad lines.

For example, in [Romero and Ventura \(2007\)](#), the authors aim to highlight the main DM techniques applied in the e-learning environment. In [Romero and Ventura \(2010\)](#), the authors lead a literature review focused on the different agents in the educational context as students, educators, researchers, institutions, and managers. They also describe a list of typical educational tasks that use the EDM techniques. In [Sachin and Vijay \(2012\)](#), the authors describe the main data mining techniques such as prediction, classification, clustering, and pattern recognition to provide subsidies for smart tutoring systems and interaction analysis in social networks. The review of [Mohamad and Tasir \(2013\)](#) provide a brief explanation of the DM techniques in order of relevance, tendencies, and limitations faced by each analyzed contribution.

[Baker and Yacef \(2009\)](#) perform a literature review where they discuss the trends and main changes in the EDM searches. The authors identify the most influential papers in the EDM community, highlighting the expansion of prediction models and the reduction of relationship mining models. Due to the limitations of the student's cognitive modeling, the authors encourage the use of artificial intelligence and of intelligent tutoring, considering the student's behavior, abilities and limitations in order to improve their level of interaction and Performance in educational activities. In [Huebner \(2013\)](#), the authors are focused on detecting the students' circumvention risks through predictive models and provide a custom recommendation to students by identifying their needs and learning disabilities.

In [Jindal and Borah \(2013\)](#), the authors introduce a new perspective on the individualization and interaction between the educational actors. In [Peña-Ayala \(2014\)](#), the authors discussed the results of researches upon the behavior detection, personalization and student's performance

Table 1: Surveys and main contributions

Authors	Title	Contributions and themes covered
Romero and Ventura (2007)	Educational data mining: A survey from 1995 to 2005	<ul style="list-style-type: none"> - Environment: traditional classroom and e-Learning; - Objectives: organize the application of DM techniques in the teaching system between 1995 and 2005; - Techniques observed: clustering, classification, statistics, prediction, detection of outliers, association rules, sequential patterns; - Topics observed: web-mining, visualization, text-mining; - Concepts discussed: students, educators, tutors, interdisciplinarity, personalization, evaluation, interaction.
Baker and Yacef (2009)	The State of Educational Data Mining in 2009: A Review and Future Visions	<ul style="list-style-type: none"> - Environment: e-Learning; - Objectives: create and improve the teaching models which address the motivation, meta-cognition, student's activities and trends of EDM; - Techniques observed: clustering, classification, detection of outliers, association rules, sequential patterns, prediction; - Topics observed: educational artificial intelligence, intelligent tutorials systems, text-mining; - Concepts discussed: students, students' groups, interaction between actors, educational multimedia.
Romero and Ventura (2010)	Educational data-mining: A Review of the State of the Art	<ul style="list-style-type: none"> - Environment: traditional classroom and e-Learning; - Objectives: review of DM techniques applied to education, provide updated information about the institutional efficiency; - Techniques observed: forecast performance model, undesired behavior detection, monitoring support, recommendation, planning and scheduling, intelligent tutoring; - Topics observed: analysis and visualization of educational data, social network analysis, identification of behavior and students' performance; - Concepts discussed: students, educators, administrator, coordinator, didactic material, student groups.
Sachin and Vijay (2012)	A Survey and Future Vision of Data mining in Educational Field	<ul style="list-style-type: none"> - Environment: traditional classroom and e-Learning; - Objectives: describe the EDM techniques application both to traditional classroom and e-learning; - Techniques observed: prediction, classification, clustering, association rules, sequential patterns, correlation and outliers detection; - Topics observed: text-mining, social network analysis, intelligent tutoring systems, learning systems and e-learning; - Concepts discussed: students, educators, evaluation, personalization, cognition.
Huebner (2013)	A survey of educational data-mining research	<ul style="list-style-type: none"> - Environment: traditional classroom and e-Learning; - Objectives: presents a literature review of EDM focused on student's retention and evasion, recommendation systems and course administration; - Techniques observed: clustering, sorting, association rules, prediction; - Topics observed: academic analysis, learning, institutional effectiveness analysis; - Concepts discussed: student, educator, administrator, evaluation, personalization, recommendation.
Mohamad and Tasir (2013)	Educational data mining: A review	<ul style="list-style-type: none"> - Environment: e-Learning; - Objectives: student's behavior analysis, literature review of EDM and its trends; - Techniques observed: clustering, classification, pattern recognition, prediction, association rules; - Topics observed: EDM techniques applied in social networks, encourage collaborative learning between students; - Concepts discussed: students, educators, student's groups, evaluation, behavior, collaboration, personalization.
Jindal and Bohrah (2013)	A Survey on Educational Data Mining and Research Trends	<ul style="list-style-type: none"> - Environment: traditional classroom and e-Learning; - Objectives: highlights the trends and challenges of EDM in perspectives of educational actors; - Techniques observed: classification, statistics, clustering, prediction, neural network, association rule, web-mining; - Topics observed: environments and actors of education, educational data and tasks, methods and tools used; - Concepts discussed: students, educator, administrator, coordinator, teaching plan, interdisciplinarity.
Peña-Ayala (2014)	Educational data mining: A survey and a data-mining-based analysis of recent works	<ul style="list-style-type: none"> - Environment: traditional classroom and e-Learning; - Objectives: make a literature review of EDM to organize, analyze and discuss the EDM Tools and his application; - Techniques observed: prediction, decision trees, clustering, linear regression, classification, intelligent tutoring; - Topics observed: identify the behavior and student's performance, statistical analysis of student's group, descriptive and predictive models; - Concepts discussed: students, educators, evaluation, personalization.
Guleria and Sood (2014)	Data Mining in Education: A Review on the Knowledge Discovery Perspective	<ul style="list-style-type: none"> - Environment: traditional classroom and e-Learning; - Objectives: presents a literature review of EDM to discuss the EDM tools and educational application; - Techniques observed: classification, clustering, decision trees, association rules, prediction; - Topics observed: pattern recognition, fraud detection, text-mining and web-mining; - Concepts discussed: student, educator, teaching, multimedia, performance evaluation.

evaluation obtained by DM techniques such as clustering, classification, and regression. In Guleria and Sood (2014), the authors covered ubiquitous and pervasive data mining applied to education for fraud detection, and especially in the identification of students that require special attention.

As observed, the articles that realize literature review in EDM seek to highlight, mainly, the data mining techniques applied in the educational context, in order to use these techniques for discover useful knowledge in both environments, classroom, and e-learning.

The main objective of this review is to highlight and analyze the latent themes that relate to educational development. We seek to explore the educational evaluation process in the e-learning environment, in order to identify the main research trends at EDM from a educational perspective.

3 Methodology for review process

This literature review was developed by following the systematic literature review method proposed by Kitchenham et al. (2009). This method guides the selection and reading of scientific papers and defines the criteria for inclusion, exclusion, and filtering for the selection of the papers for the review process.

For the purpose of conducting this study, the following research questions were considered:

RQ1: What are the main perspectives and trends in EDM of scientific works that treat e-learning domain under a view of the educational evaluation?

RQ2: What are the potential research topics where there is a little attention in e-learning evaluation perspective?

The Figure 1 presents the development stages of this review. The process begins with the collection of bibliographic material in the main repositories, and then, filters are applied to reducing the research scope. The methodological process will be described from the next section.

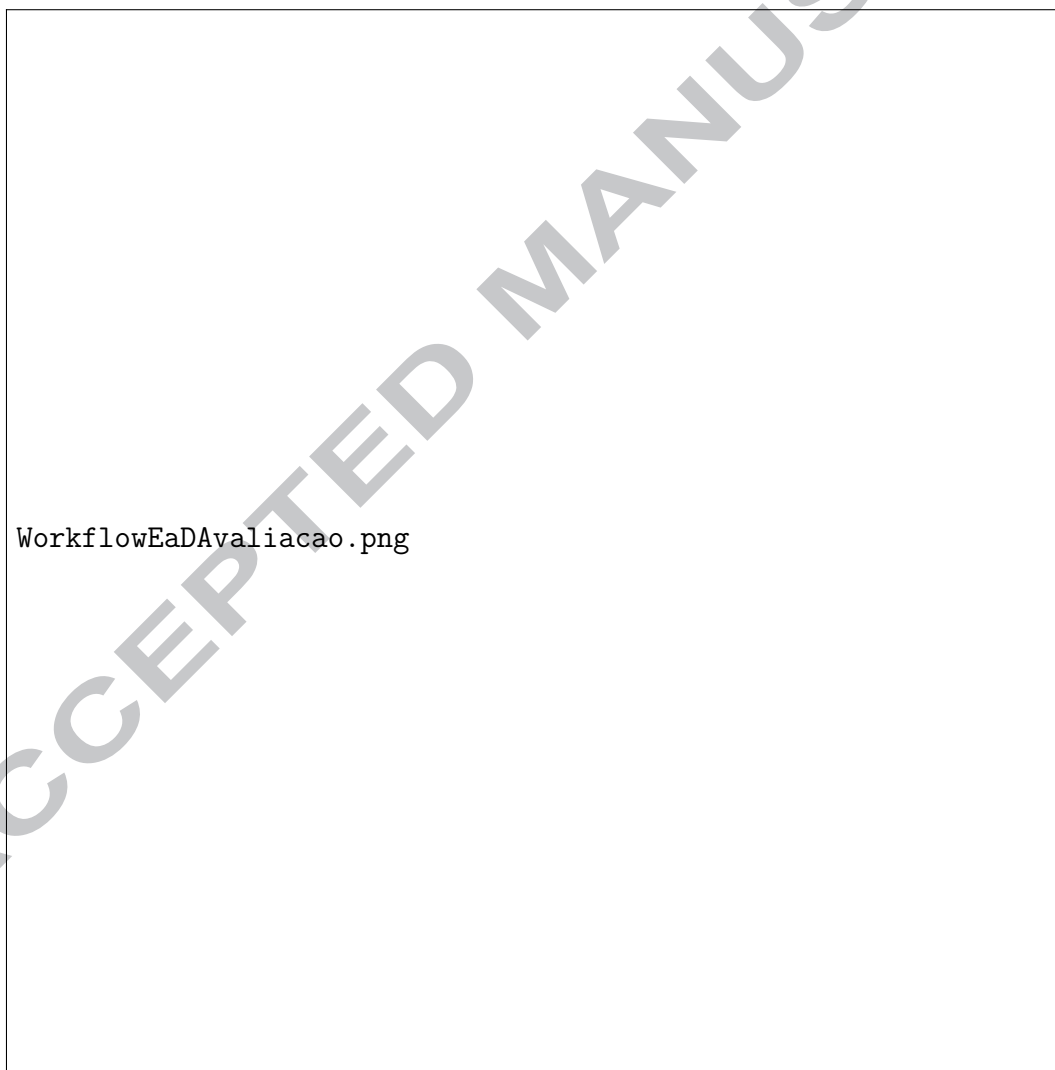


Figure 1: The flow of literature review process in the evaluation domain of e-learning

3.1 Strategies for collection of bibliographic material

The collected bibliographical material considers two type of publications: *articles* (academic paper or journal) and *inproceedings* (conference papers), in a period over than two decades (1994 until 2016).

In order to obtain a more comprehensive and complete review, the initial search for references was restricted to selected keywords in three languages: English, Portuguese and Spanish (see Table 2). The languages of Latin origin were included due significant contribution in EDM field has been observed.

The main keyword considered in our review is *educational data mining*. However, the preliminary reviews pointed to relevant contributions of *learning analytic* in EDM. This is why we decided to expand the search, by adding the keyword *learning analytic AND data mining*.

The considered leading sources (repositories) are presented in the first column of the Table 3.

Note that, the words that compose each term were concatenated by the logical operator *AND* thus, it is guaranteed that all found papers will be part of the bibliographic material of data mining in the educational context. From this initial search, 525 articles were identified (second column in Table 3).

In order to select the published works to this review and answer the questions *RQ1* and *RQ2* about the evaluation aspect in the e-learning domain, for each of collected papers, we first read the abstract and introduction sections, in order to identify and select only the papers dealing with evaluation in e-learning as subject in e-learning environment. In addition, as exclusion criteria, it is important to note that, the references that discuss only the “techniques of data mining” without considering the educational aspect, were removed from the bibliographical material. As mentioned, we consider the educational aspects of the emphasis given by the authors when they aim at the improvement of teaching and learning. In Table 3, the third column refers to papers that deal with the evaluation process in the e-learning environment, as selection criteria.

As shown in Table 3, the study scope was reduced to 72 articles, which will be analyzed in depth through of a more educational perspective.

4 Analysis of evaluation in the e-learning environment

In general, *e-Learning* environments seek technological solutions to reduce the impact of geographical distance between students and educators. Researches in EDM use the information generated by e-learning environments in order to understand primarily the interaction between educators and

¹IEEE: <https://www.ieee.org/index.html>

²Elsevier Science Direct: <https://www.elsevier.com/>

³International Educational Data-Mining Society: <http://www.educationaldatamining.org/>

⁴ACM Digital Library: <http://dl.acm.org/>

⁵CSBC - Congresso da Sociedade Brasileira de Computação: <http://sbc.org.br/eventos/csbc>

⁶SBIE - Simpósio Brasileiro de Informática na Educação: <http://www.sbie.com.br/>

⁷RENOTE - Revista Novas Tecnologias na Educação: <http://seer.ufrgs.br/renote/>

⁸ResearchGate: <https://www.researchgate.net/home>

⁹Springer: <http://link.springer.com/Springer>

¹⁰RBIE - Revista Brasileira de Informática na Educação: <http://www.br-ie.org/pub/index.php/rbie>

¹¹SEMINCO: <http://www.inf.furb.br/seminco/2004/>

¹²EBSCO: <https://www.ebscohost.com/>

¹³IJDJP: <http://airccse.org/journal/ijdkp/ijdkp.html>

¹⁴CLAIO: <http://www.sobrapo.org.br/>

¹⁵AIRCC: <http://airccse.org/>

Table 2: Terms for the references search

Language	Terms	References
English (62 references)	<ul style="list-style-type: none"> - educational data-mining - educational data mining - learning analytics data mining 	Shen et al. (2001); Zaiane and Luo (2001); Machado and Becker (2003); Kwan Lau and Fong (2003); Minaei-Bidgoli et al. (2004); Mylonas et al. (2004); Drigas and Vrettaros (2006); Chaczko et al. (2006); Manikandan et al. (2006); Nodenot et al. (2006); Hien and Haddawy (2007); Otsuka et al. (2007); Romero and Ventura (2007); Liu and Shih (2007); Chen et al. (2007); Song et al. (2007); Hongxia and Yao (2008); Santos and Boticario (2008); Gong (2008); Caballe et al. (2008); Qingxian et al. (2009); Dongsheng and Wenjing (2009); Chen and Chen (2009); Fernández-Luna et al. (2009); Deng et al. (2010); Wang et al. (2010); Romero and Ventura (2010); Lajis and Aziz (2010); Yu and Sun (2010); Yubing and Jianping (2010); Da et al. (2010); Tovar and Soto (2010); Pascual-Cid et al. (2010); Kechaou et al. (2011); Liu and Xia (2011); Rosales et al. (2011); Wang et al. (2011); Sachin and Vijay (2012); Zeng (2012); Wang and Lin (2012); Anupamā Kumar and Vijayalakshmi (2012); Tang et al. (2012); Ivancevic et al. (2012); Liu and Peng (2013); Huebner (2013); Jindal and Borah (2013); Mohamad and Tasir (2013); Eagle and Barnes (2013); Robles and Gonzalez-Barahona (2013); Guleria and Sood (2014); Peña-Ayala (2014); Akerkar et al. (2014); Shahiri et al. (2015); London et al. (2015); Kaur et al. (2015); Pedro et al. (2015); Wang et al. (2015); Xing et al. (2015); Nižnan et al. (2015); Gobert et al. (2015); Marbouti et al. (2016); Howard et al. (2016)
Portuguese-BR (10 references)	<ul style="list-style-type: none"> - mineração dados educacionais - mineração de dados educacionais 	Sales et al. (2001); Lopes and Schiel (2004); Longhi et al. (2010); Sales et al. (2011); Ricarte and Junior (2011); Coelho (2012); Gottardo et al. (2012a); Jaques et al. (2012); Sales et al. (2012); Gottardo et al. (2012b)

Table 3: Repositories of bibliographical references

Publication sources	Publications in EDM domain		E-learning evaluation domain	
	Amount	(%)	Amount	(%)
IEEE Xplore Digital Library ¹	327	62.29%	43	59.72%
Elsevier Science Direct ²	19	3.62%	9	12.50%
International Educational Data-Mining Society ³	90	17.14%	4	5.56%
ACM Digital Library ⁴	40	7.62%	2	2.78%
CSBC ⁵	2	0.38%	2	2.78%
SBIE - Simpósio Brasileiro de Informática na Educação ⁶	4	0.76%	2	2.78%
RENTE ⁷	4	0.76%	2	2.78%
ResearchGate ⁸ , Springer ⁹ , RBIE ¹⁰ , SEMINCO ¹¹				
EBSCOhost ¹² , IJDKP ¹³ , CLAIO ¹⁴ , AIRCCSE ¹⁵	35	6.67%	8	11.11%
articles	76	14.48%	19	26.39%
inproceedings	449	85.52%	53	73.61%
Total	525	100%	72	100%

students. According to the searched papers, the authors seek to investigate how teaching media and communication channels can affect the TL, and how to evaluate the students' learning performance through their participation and interest in the educational activities (Chen et al., 2007; Liu and Shih, 2007). In synthesis, the papers seek to address research themes such as: a) to decrease the distance between educator and student by improving the level of communication between them (Romero and Ventura, 2007; Jindal and Borah, 2013); b) establish more appropriate channels of interactions as chat rooms, discussion forums, and virtual rooms (Kechaou et al., 2011; Gottardo et al., 2012a); c) explore the needs of the student in order to enhance the educational content for educational media (Rosales et al., 2011; Hongxia and Yao, 2008); and finally, d) monitoring the students' activities and establishing strategies for the personalization of students' learning (Sachin and Vijay, 2012; Guleria and Sood, 2014). It is important to note that these research issues will be also addressed in the follow sub-sections.

In the next sub-section, the first research question (*RQ1*) will be answered, seeking to identify

perspectives and trends.

For better understanding and reduction of the analysis efforts of the bibliographical material, the published papers of *e-Learning* and *Evaluation* domain were grouped into four sub-domains identified during the review process (see Figure 2). For the formation of these sub-domains, was realized a careful reading to identify the main purposes and objectives and, thus, clustering the collected papers.



Figure 2: Main topics addressed by bibliographical material

The domain of this work is formed by the educational concepts *e-learning* and *evaluation*. Since this domain has many papers, we have identified the following educational aspects, which we considered as educational sub-domains (Table 4): papers dealing with the *traditional classroom*, papers dealing with the *pedagogical* actions of *educators*, papers dealing with the *management educational administrator*, and papers dealing with the use of *multimedia resources*.

It is important to note that after the reading of the bibliographic material, it was possible to

Table 4: Summary of evaluation in e-learning educational environment

Sub-domain	Purposes and objectives	References
Evaluation of e-learning in traditional classroom (29 papers)	Improve/evaluation interaction between the TL actors	Pang et al. (2002); Kwan Lau and Fong (2003); Liu and Shih (2007); Chen et al. (2007); Romero and Ventura (2007, 2010); Kechaou et al. (2011); Longhi et al. (2010); Sachin and Vijay (2012); Sales et al. (2012); Peña-Ayala (2014); Kaur et al. (2015); Marbouti et al. (2016)
	Monitoring/evaluation of teaching	Romero and Ventura (2007); Hongxia and Yao (2008); Caballe et al. (2008); Fernández-Luna et al. (2009); Romero and Ventura (2010); Kechaou et al. (2011); Sales et al. (2011); Liu and Peng (2013); Guleria and Sood (2014); Shahiri et al. (2015)
	Monitoring/evaluation of learning	Lopes and Schiel (2004); Chen et al. (2007); Liu and Shih (2007); Romero and Ventura (2007, 2010); Kechaou et al. (2011); Ricarte and Junior (2011); Ivancevic et al. (2012); Sales et al. (2012); Huebner (2013); Kaur et al. (2015); Pedro et al. (2015); Xing et al. (2015); Howard et al. (2016)
Evaluation of pedagogical actions (34 papers)	Analysis of educator's actions	Romero and Ventura (2007); Fernández-Luna et al. (2009); Liu and Xia (2011); Deng et al. (2010); Liu and Peng (2013); Sales et al. (2011); Sachin and Vijay (2012); Liu and Peng (2013); Huebner (2013); Jindal and Borah (2013); Guleria and Sood (2014); Peña-Ayala (2014); London et al. (2015); Howard et al. (2016)
	Analysis of student's actions	Zaiane and Luo (2001); Sales et al. (2001); Mylonas et al. (2004); Minaei-Bidgoli et al. (2004); Lopes and Schiel (2004); Chen et al. (2007); Romero and Ventura (2007); Chen and Chen (2009); Pascual-Cid et al. (2010); Tovar and Soto (2010); Rosales et al. (2011); Sales et al. (2011); Ricarte and Junior (2011); Sachin and Vijay (2012); Tang et al. (2012); Wang and Lin (2012); Zeng (2012); Gottardo et al. (2012a,b); Sales et al. (2012); Huebner (2013); Jindal and Borah (2013); Mohamad and Tasir (2013); Guleria and Sood (2014); Peña-Ayala (2014); Kaur et al. (2015); London et al. (2015); Shahiri et al. (2015); Xing et al. (2015); Howard et al. (2016)
Evaluation of Administrative management (14 papers)	Management evaluation of the educators' pedagogical actions	Otsuka et al. (2007); Romero and Ventura (2007); Hongxia and Yao (2008); Dongsheng and Wenjing (2009); Deng et al. (2010); Liu and Peng (2013); Huebner (2013); Jindal and Borah (2013); London et al. (2015)
	Management evaluation of the educators' pedagogical actions	Hien and Haddawy (2007); Romero and Ventura (2007); Rosales et al. (2011); Tang et al. (2012); Wang and Lin (2012); Sales et al. (2012); Huebner (2013); Jindal and Borah (2013); London et al. (2015)
Evaluation of Multimedia resources (26 papers)	Evaluation in the media recommendation and recovery systems	Drigas and Vrettaros (2006); Otsuka et al. (2007); Liu and Shih (2007); Santos and Boticario (2008); Romero and Ventura (2010); Sachin and Vijay (2012); Akerkar et al. (2014); Guleria and Sood (2014)
	The use of multimedia resources to evaluate the learning process	Machado and Becker (2003); Nodenot et al. (2006); Drigas and Vrettaros (2006); Chen et al. (2007); Caballe et al. (2008); Wang et al. (2010); Pascual-Cid et al. (2010); Romero and Ventura (2010); Rosales et al. (2011); Wang et al. (2011); Ricarte and Junior (2011); Sachin and Vijay (2012); Wang and Lin (2012); Sales et al. (2012); Robles and Gonzalez-Barahona (2013)
	The use of multimedia resources to evaluate the teaching process	Mylonas et al. (2004); Song et al. (2007); Gong (2008); Hongxia and Yao (2008); Kechaou et al. (2011); Sachin and Vijay (2012); Wang and Lin (2012); Liu and Peng (2013)

identify the sub-domains (Table 4) and separate these papers according to their main objectives, in fact, each article may belong to one or more sub-domains. Thus, our discussion considered the papers more representative and directly linked the identified theme. The other articles, although they are part of the identified sub-domains, deal with considered studies very specific.

From the papers which comprise the sub-domain evaluation of e-learning in traditional classroom (Sub-section 4.1), the following purposes and/or objectives were observed: a) papers which seek to improve the interaction between student-educator, educator-tutor, educator-coordinator, and coordinator-administrator; b) papers which seek to establish the monitoring strategies to properly evaluate the teaching practices; and c) papers which aimed at establishing the monitoring strategies to evaluate the student's learning.

According to the reading of papers from sub-domain evaluation of pedagogical actions from educator on e-learning environment (Sub-section 4.2), two approaches have been identified: a) papers which aim to analyze the educator's pedagogical strategies in relation to the multimedia content and teaching plan, encouraging the creation of a participative and collaborative environ-

ment of TL; and b) papers that seek to analyze the student's learning through behavioral patterns, identifying his interests, participation and enjoyment in carrying out of educational activities.

The analysis of the bibliographical material related to the sub-domain evaluation of administrative management on e-learning environment (Sub-section 4.3), has identified two distinct aspects of analysis: a) papers that seek to evaluate the knowledge and pedagogical skills of educators, as a way of assessing the quality of teaching, and to encourage continuous improvement of educator; and b) papers that seek to identify and evaluate the circumvention or deprecation risks of students, and thus, compromising their performance throughout their learning.

The papers of the sub-domain evaluation of the use of multimedia resources on e-learning environment (Sub-section 4.4) address four distinct aspects to multimedia approach: a) papers that develop or evaluate recommendation systems on educational multimedia or resources of custom format; and papers that seek to solve problems related to the organization and retrieval of wide amount of educational multimedia; b) papers that seek to evaluate the student's learning through the identification of behavior patterns during his access and navigation on the multimedia content; and c) papers that seek to evaluate the teaching process through of use of the teaching materials estimating their quality, according developed and organized by the educator.

4.1 Evaluation of e-learning in traditional classroom

The papers in this sub-domain compare the educational environments (traditional classroom and e-learning) and, emphasize the relevance of the use on *e-learning* environment in the *traditional classroom* environment. Some papers do not differentiate these environments, considering thus a hybrid educational environments (Kwan Lau and Fong, 2003; Kechaou et al., 2011; Sachin and Vijay, 2012). Another observed approach corresponds to interaction between the actors of the TL in the hybrid environments, and monitoring and evaluation of teaching and learning in these environments (Caballe et al., 2008; Pedro et al., 2015).

- ***Improve and evaluation of interaction between the TL actors:***

The interaction between students and educators mediated through technological artifacts is observed to establish the best teaching practices and to improve the learning process in the traditional classroom (Liu and Shih, 2007; Chen et al., 2007; Kechaou et al., 2011; Sachin and Vijay, 2012).

Kwan Lau and Fong (2003) investigate how technology, educational media and especially the interaction mode in web-based learning can influence the student's learning process. This paper uses the quantitative assessment of data generated by the student's interaction with the web-learning environment (Sales et al., 2012). The goal of the authors is to establish the most appropriate approach to the teaching process to best meet the needs of student's learning.

According to the authors Longhi et al. (2010), the e-learning environment must be able to identify effective characteristics of the student and of the educator during their interaction. Effective systems must capture the physiological and behavioral aspects, gestural and modulations. The authors use the analysis of subjectivity technique (Pang et al., 2002) by means of emotional content in discussion forums and chats. The developed system makes the recognition of words with emotional overtones, also known as opinion-mining, sentiment analysis, subjectivity analysis and judgment analysis. According to the classification of words with

emotional connotations, the student's emotional state is determined, being able to predict a certain future behavior of the student (Sachin and Vijay, 2012; Peña-Ayala, 2014; Kaur et al., 2015; Marbouti et al., 2016).

- **Monitoring and evaluation of teaching:**

The papers which discuss the monitoring and evaluation of teaching in the e-learning, consider the student as an active actor of the TL and, the educator and tutor as responsible to provide a favorable interaction. In Caballe et al. (2008), the authors seek to monitor and evaluate the educators and tutors to improve the educational process through self-assessment and, peer assessment (Shahiri et al., 2015).

Fernández-Luna et al. (2009) address the technical and pedagogical aspects for the design of information retrieval systems. The extracted information is used to elaborate didactic-pedagogical methods that help in the design and organization of courses, improves the teaching process of students and helps to improve education adopting the best pedagogical practices based on experience (Hongxia and Yao, 2008; Guleria and Sood, 2014).

Kechaou et al. (2011) seek to analyze the textual opinions of students' postings on Web sites, blogs, and discussion forums, so as to assess the positive or negative aspect of the TL according to the student's feeling.

- **Monitoring and evaluation of learning:**

The authors Kechaou et al. (2011); Howard et al. (2016) assert that monitoring the student's learning in the e-learning environment is a matter that requires attention due to the absence of the perception of the educator in front of the student's difficulties. Lopes and Schiel (2004) propose a student's monitoring strategy based on the analysis of their educational profile as a means to improve the learning performance and the interaction with the educator through chats and discussion forums. Techniques of grouping and association rules on student's profile and interaction in the e-learning environment are used to identify their interest level and participation in the activities. The purpose of the authors is to evaluate the student's performance and provide feedback to the educator, in order to improve the learning process by identifying useful patterns on student's tracks (Ivancevic et al., 2012; Kaur et al., 2015; Pedro et al., 2015).

4.2 Evaluation of pedagogical actions on e-learning environment

The papers of this sub-domain address the actions applied from *educator* aiming at the improvement of the teaching. The works recognize that the teaching methods are effective only when the student and educator are in accordance. Among these activities and actions include: to detect the behavior and interaction between *educator* and *student*; verify how the *educator's* pedagogical experience can positively or negatively influence *student's* performance; and lead strategies to improve the *teaching plan*. Educational actions planned by the educator have goals that directly impact on the student's actions (Chen et al., 2007; Jindal and Borah, 2013; Howard et al., 2016).

- **Evaluation of educator's actions:**

Evaluating the teaching process adopted by the educator is one way to raise the educational quality level and, consequently, to adjust the teaching strategies which best influence the student's learning (Deng et al., 2010; Liu and Xia, 2011).

Liu and Xia (2011) aim to assess the education quality and identify the strengths and weaknesses on pedagogical actions from the educator. Firstly, the authors use the Fuzzy theory to determine the indicator scores of efficiency. Then, the association rules technique is used to identify redundant indicators. The authors show that the evaluation of teaching becomes more consistent by indicators, as well as the education quality evaluation becomes even more useful and efficient Shahiri et al. (2015).

Deng et al. (2010) propose a model for evaluation of educator based on decision trees technique. The model use data obtained from the evaluation of the educator and from the activities and curriculum data. The goal is to identify the factors that can interfere with the teaching and learning quality (Chen et al., 2007).

Liu and Peng (2013) aim to strengthen education managements; to improve the higher education quality; to improve the educational material quality; to evaluate the student's performance; and to assess the degree of educator's efficiency. For this, the authors used the association rules (Apriori) technique to evaluate the educator's practices in order to improve higher education. For such purpose, the authors seek to improve the extraction model of teaching resources, such as teaching multimedia to better understand the impact of these resources on the student's learning quality.

- ***Evaluation of student's actions:***

In e-learning, to evaluate the proposed activities and understand the behavior patterns of the students for the educators, are important and complex issues. The following papers seek to find solutions to these questions (Mohamad and Tasir, 2013).

Zaiane and Luo (2001) seek to assess the students' activities in an attempt to identify atypical behavior patterns from access logs and activities realized by the students. The authors seek to extract useful patterns through statistical analysis and application of summarizing technique from web-logs in order to find trends in these patterns. The goal is to assist the educator in the learning evaluation and to interpret the students' needs in order to improve their performance (Chen and Chen, 2009).

On the other hand, Sales et al. (2001) aim to reduce the workload of educator and tutor by the generation of the score from participants (students) in the discussion forums. The authors use the learning indicators *Learning Vectors* (LV) (Kohonen, 1995) as a tool for evaluation. In addition to reducing isolation sense from the student in an e-learning course, the authors also aim to reduce the dropout rate of the student, using the monitoring techniques and constant adjustment of student's teaching during the learning Sales et al. (2011).

Minaei-Bidgoli et al. (2004) use the generated data by educational web systems to identify important patterns in the relationship between student's profile and the solving problems, in order to establish the best strategies of resolution which can be recommended for different student profiles. The authors use association rules for the discovery of these patterns Minaei-Bidgoli et al. (2004). The goal is to provide suggestions to educators' for didactic-pedagogical interventions that aim at improving the students' performance during the TL based on solving problems (Pascual-Cid et al., 2010; Xing et al., 2015).

Lopes and Schiel (2004) propose an accompaniment strategy of student based on his history analysis and interactions with the educator through chats and discussion forums. The authors use the clustering and association rules techniques on the historic data and students'

interactions and it aims at identifying the student's interest level and his participation in the activities.

Chen et al. (2007) seek to assess the performance of students' learning using information from interaction and access to educational media. The goal is to provide better insight to educators regarding the main factors that influence students' learning performance. To achieve these goals, the Grey's relational analysis (Chen et al., 2000), clustering technique, Fuzzy association rules and Fuzzy inference algorithms are applied. The extracted information by these algorithms assist the educator in best pedagogical strategies plans and production/organization of educational media.

As there are no definitive mechanisms to evaluate the performance of *e-Learning* process, (normally, the final result is given by a summative evaluation), Mylonas et al. (2004); Chen and Chen (2009) present a web system to realize the formative assessment¹ using statistical correlation analysis, Fuzzy clustering, among other techniques (Pascual-Cid et al., 2010; Peña-Ayala, 2014; London et al., 2015). The aim is identifying the main formative assessment rules according to the student's profile aiming personalization in the educational media used. This system allows educators and tutors to understand the factors that influence on student's learning and it ensures better teaching material production and the best teaching practices (Chen et al., 2007; Mylonas et al., 2004).

Tovar and Soto (2010) developed a predictive model of student's performance that, based on the performance achieved in prior skills tests, is capable to predict the student's performance during the teaching process. Thus, the prediction model detects the learning shortcomings periodically, allowing the educator track student's performance and, eventually, make the appropriate interventions in order to prevent the avoidance or student's failure (Chen et al., 2007; Tovar and Soto, 2010).

Making a prediction of student's behavior allows you to understand the aspects that influence positively the learning. The authors Da et al. (2010) seek to get personal information and information about the student's behavior and his performance during learning. The authors propose a self-tuning model capable of identifying habits, needs, and preferences. For this, the Naive Bayes algorithm is used to student's classification. The results show a good level of accuracy in prediction of student's performance (Romero and Ventura, 2007).

On the other hand, Tang et al. (2012) claim that monitoring students' learning means understanding their behavior, needs and deficiencies and, to establish strategies to guide educator in decision-making in student's aid. The authors propose to apply association rules on data for the educators' evaluation application via *Predictive-Apriori* algorithm (Scheffer, 2001; Sachin and Vijay, 2012). These strategies provide more reliable parameters to assist the educator in better decisions to according to the student's interests.

Wang and Lin (2012) claim the importance to evaluate the learning system in order to provide a dynamic and appropriate orientation to the student as activities implementation and to provide feedback to the educator about the behavior and performance of the student during the teaching process. This paper develops *Practice Score* processes and *Interactive Learning* to analyze the activities carried out by the students. For this, the authors utilize the Fuzzy

¹The formative evaluation is provided while the course is ongoing so as to permit improvements in the student performance. In contrast, the summative evaluation is performed towards the end of a course.

Analytic Hierarchical Process (FAHP) (Buckley, 1985) and the association rules techniques to evaluate the procedures applied by educators.

Zeng (2012) developed a learning evaluation system based on digital games, seeking information about the importance and the quality of teaching practice. To analyze the generated data during the teaching practice were used the Frequent Itemsets (CLOSET) (Pei et al., 2000) and association rules (Apriori) algorithms. The improved CLOSET technique proved to be more suitable than the traditional Apriori algorithm because the improved CLOSET found rules without redundancies and without breaking the completeness in extracting patterns. The results showed efficiency in assessing the quality of education through the useful information about the profile of the educator and, obtained important rules to guide the educator and the educational management regarding the student's performance Sachin and Vijay (2012); Zeng (2012); Tang et al. (2012).

Finally, according to Gottardo et al. (2012a) to find out important information about student's performance, it is necessary to analyze data as e.g.: access to the record system (logs); student-educator interactions; and semantic data from discussion forums and chats. The paper seeks to achieve inferences in relation to student's performance using Multilayer Perceptron classification and Random Forest techniques (Kaur et al., 2015). The results emphasize the importance of perform inferences in the student's individual performance and, to assist in the pedagogical strategies proposed to reduce students' evasion and failure (Chen et al., 2007; Chen and Chen, 2009; Deng et al., 2010).

4.3 Evaluation of administrative management on e-learning environment

The educational Administrator represents the actor responsible for the management of all stages of the TL. For this role are required specific skills and knowledge in educational management, the experience obtained by the educational *administrator* should assist in the evolution and improvement of the educational environment (Romero and Ventura, 2007; Hongxia and Yao, 2008). The most papers recommend that the educational *administrator* must possess technical skills, human behavior skills (culture, beliefs, attitudes, and opinions), and finally, must have an overview of the institution in relation to his structure and goals. The administrator should be aware of issues such as the structure of the learning environment, quality, and availability of teaching materials and, provide suitable access to the educator and student in the educational environment (Dongsheng and Wenjing, 2009; Wang and Lin, 2012; Rosales et al., 2011). Two aspects of managerial evaluation observed in the review process are analyzed below.

- ***Management evaluation of educators' pedagogical actions:***

The educator's pedagogical actions correspond to all necessary activities for the teaching practice results in student's learning. From the administrator's view, these educator's actions are summarized as e.g.: curriculum development; creating and updating of educational media; and monitoring of students' learning (Rosales et al., 2011). In evaluating these actions the administrator wants to establish the most appropriate strategies based on the student's satisfaction and evaluation of the educator's actions to improve the education quality (Hongxia and Yao, 2008; Dongsheng and Wenjing, 2009; Deng et al., 2010).

- ***Management evaluation of risks of the learning:***

An alternative to properly evaluate the student's learning, from the administrator's point of view, is to monitor their interactions with the teacher, in order to better understand the student's behavior in the teaching environment, in order to identify its needs and the possible risks of disapproval and evasion (Romero and Ventura, 2007; Rosales et al., 2011).

The data obtained through the student's profile and access records in the e-learning environment, may be insufficient to detect students' complex actions. Thus, the paper of Rosales et al. (2011) propose a monitoring system of student and educators for the administrators. For this, approaches based on ontologies and Fuzzy logic are used to interpret the data. The objectives of this system are: decrease the learning deficiencies; improve the interaction level between student and educator; identify possible risks of circumvention; and create custom measures to improve student's performance (Romero and Ventura, 2010).

Tang et al. (2012) cite the difficulty in monitoring the student's learning. The authors propose the use of association rules for evaluation of educators. The goal is to provide reliable indicators to the administrator to take the better decisions in support of educator according to the students' interests (Rosales et al., 2011; Liu and Peng, 2013; Huebner, 2013).

The paper of Sales et al. (2012) seek to establish a learning indicator to support the quantitative and qualitative evaluation of learning (Hongxia and Yao, 2008; Dongsheng and Wenjing, 2009; Deng et al., 2010). This indicator is updated through of communication between students, educators/tutors and administrators and, it is capable to provide information about student's performance for all educational actors in the TL. According to the authors to quantify performance, effort, collaboration and interaction can provide better results to administrators management (Hien and Haddawy, 2007).

4.4 Evaluation of the use of multimedia resources on e-learning environment

The *multimedia* in the e-learning environment has the main objective of improving the student-educator interactivity through the systematization of relations among the main actors of the TL. Therefore, the multimedia evaluation on e-learning environment seeks to support the didactic material organization and improve the recommendation system in order to make the teaching process more efficient Drigas and Vrettaros (2006); Liu and Shih (2007); Liu and Peng (2013); Akerkar et al. (2014).

- *Evaluation in the media recommendation and recovery systems:*

The development of a recommendation system based on access to educational multimedia has the main goal to raise the level of students' satisfaction and, consequently, improve their performance during the learning process (Liu and Shih, 2007; Santos and Boticario, 2008; Rosales et al., 2011).

Otsuka et al. (2007) developed a recommendation system based on collaborative pedagogical actions between the educators and students. The pedagogical model of assessment proposed uses text-mining to monitor continuously the student's participation in chats and discussion forums. The model explores the interactions between students and the multimedia resources available in order to review and organize the educational material (multimedia resources) (Drigas and Vrettaros, 2006; Wang and Lin, 2012). In order to improve performance and the satisfaction level of the student, Liu and Shih (2007) propose a content recommendation system for multimedia resources. The recommendation system uses association rules on

the activities records (logs) and keywords, associated with the multimedia resources, that classifies the educational multimedia, aiming to identify the student's behavior for the recommendation system. This paper explores the collaborative filtering (rules, content, and activities) to improve the accuracy of keywords search of the didactic content [Gong \(2008\)](#); [Sales et al. \(2012\)](#); [Wang and Lin \(2012\)](#).

In an attempt to help educators with educational media adequacy the paper of [Santos and Boticario \(2008\)](#) seek to develop effective strategies in support of learning through a personalized recommendation system using machine learning techniques to identify the students' needs and preferences. The goal is to evaluate and increase the student's satisfaction during the learning process by means of interaction and collaboration dynamic between student and educator.

The need to organize and retrieve the teaching media led the authors [Drigas and Vrettaros \(2006\)](#) to develop an intelligent system based on SOM (Self-Organized Map) ([Kohonen, 1982](#)) algorithm for search and organization of didactic content. The proposed search system is able to adjust and re-size the didactic material queries via keywords and terms associated with the education media library. The goal is to improve efficiency in the organization and performance in the recovery of educational media, making adjustable the intelligent search system to any TL environment.

- ***Learning evaluation in use of media:***

[Wang et al. \(2010\)](#) developed an evaluation system for student's learning through the factors analysis that influences their behavior during the media usage. To evaluate the level of student's learning, the decision tree technique (J4.8) was used. The goal is to improve the evaluation method in order to improve the students' behavior in relation to use of the learning media ([Wang et al., 2010](#)).

The search for students' behavioral patterns while accessing and browsing educational resources is the goal of the paper of [Machado and Becker \(2003\)](#). The authors extract behavioral patterns related to the student's interaction with the educational media. For this, the authors use the association rules and sequence detection in the student's access records to the educational material. The result highlights the student's perception and identifies the trends regarding the use of educational media for learning [Gong \(2008\)](#).

The e-learning environments generate data such as e.g.: access logs; usability of teaching medias; notes of activities; and students-educators interactions. [Pascual-Cid et al. \(2010\)](#) developed a system to explore and visualize the generated data in these environments, and seek to analyze these data using web-mining and statistical techniques to extract behavior patterns of the student. The data are presented in an interactive way, thus providing important data to educator's assessments in order to establish the best teaching practices ([Chen et al., 2007](#); [Liu and Peng, 2013](#); [Sachin and Vijay, 2012](#)).

[Wang et al. \(2011\)](#) claim that, currently, the computer games have attracted the educators' attention presenting additional feature to the learning process. This study compares other evaluation methods as Delphi method ([Alhajj, 2007](#)), AHP (Analytic Hierarchical Process) ([Saaty, 1980](#); [Bhushan and Rai, 2004](#)) and the Fuzzy evaluation method ([Li, 1999](#)). The authors propose a machine learning method based on the artificial neural networks as an alternative to the assessment model using the educational games. The evaluation model uses

training samples to reduce the subjective factors influence and provide accurate indicators for automatic evaluation of educational media.

Ricarte and Junior (2011) seek to provide useful information to evaluate the interest level of students on the educational media, using its access data to instructional materials (medias). The access data are grouped and analyzed in order to recognize behavior patterns, for example, identify whether the instructions were inadequate or insufficient, or to identify visibility problems in the content posted, in order to review and organize the educational content. For such, the cluster techniques were used (K-Means and SOM: Self-Organizing Maps) in order to find groups with specific behaviors and detecting individuals with atypical behavior (Liu and Shih, 2007; Romero and Ventura, 2010). The author suggests that it might be interesting to correlate the default behavior with the evaluation results of the students.

- ***Teaching evaluation in use of media:***

The teaching media also have an important role in the evaluation of the teaching process. Thus, as the student's grades can indicate their level of learned and how often the student uses the teaching media can help understand the student's behavior, and thus making the pedagogical practice less challenging (Machado and Becker, 2003; Liu and Shih, 2007; Wang et al., 2010).

Mylonas et al. (2004) provide different procedures for educators to extract related data to the student's preferences from their profiles. This information is extracted by statistical methods applied in the student's profile and used in a custom system to aid the educator in the didactic-pedagogical practices (Nodenot et al., 2006), in order to broaden their knowledge about the student and improving the TL.

Song et al. (2007) use the textual analysis as, phrases, negative words, and adverbs of intensity, considered very important in identifying feelings. This paper applies opinion-mining in discussion forums and educational medias evaluation. Thus, the goal of opinion-mining is to evaluate the educational process, being able to determine if the sentimental analysis of educators is positive or negative, and how strong it represents its satisfaction during the pedagogical practice (Kechaou et al., 2011).

Gong (2008) proposes the development of a smart algorithm capable of identifying the student's personality. This algorithm is composed of association rule techniques and collaborative filtering (Resnick et al., 1994). The proposal of these intelligent algorithms is to make possible meet differences of age, gender, social, culture, experience and interest from the student, in order to provide custom resources in the teaching process. The goal is to support and improve the teaching practices through custom distance learning.

The students' opinions in textual blogs and discussion forums are analyzed by Kechaou et al. (2011) that seek to identify whether the student's feeling is positive or negative. In this paper, the classification of feelings and opinions is realized by using the Markov's Model (HMM: Hidden Markov's Models) and the SVM (Support Vector Machine) method. This approach provides parameters for the best decision-making, thus allowing to improving the e-learning quality (Song et al., 2007; Kechaou et al., 2011).

Finally, Liu and Peng (2013) aim to strengthen education management, to improve the educational media, and assess the efficiency of the educator's actions. For this, the authors use clustering, association rules and decision tree techniques to extract and combine rules

relating to educational media and teaching plans, aiming at assisting the educational management of administrator and to improve the TL (Liu and Shih, 2007; Chen et al., 2007; Ricarte and Junior, 2011; Sachin and Vijay, 2012).

4.5 Mutual improvement between e-learning and classroom environments

On the other hand, there are papers that contribute to the improvement of pedagogical practice in both environments e-learning and the traditional classroom. For e-learning, the established practices in the traditional classroom as e.g.: monitoring of learning, interaction and collaboration between student-educator are taken into account, for the traditional classroom. The established practices in e-learning as e.g.: registration of access to educational media and extraction of behavior patterns and students' group are considered.

5 Discussions

This literature review sought to highlight the main perspectives of evaluation in e-learning environment from EDM. According to the questions raised in Section 2, about which are the main perspectives and trends of published works (RQ1), and which are the potential research topics on the evaluation of e-learning environment (RQ2). Summarily, the analyzed papers are oriented to:

- a) Evaluation of e-learning practices within the traditional classroom, observing the interactions among the educational actors, and monitoring the teaching and learning process. As future research, provide a web-based learning that allows influence, positively, the interaction between educator-student, monitoring this interaction more closely;
- b) Evaluation of the educational practices regarding the actions of educators, as well as the performed actions by the students. It is proposed to identify the needs in the student's learning, and also the deficiencies in the educator's teaching in order to improve the teaching and learning;
- c) Evaluation of the educational administrator's management regarding evaluating the educator's actions results, as well as to evaluate the learning risks. The propose is to establish administrative strategies identifying the educational actions that impair the teaching and the risks that can impair the learning, helping the decisions of the educational administrator;
- d) Evaluation of the use of multimedia resources, considering the recommendation and retrieval systems, as well as the use of these resources to evaluate teaching and learning. It is proposed to improve the systems of recommendation and recovery of multimedia resources through the evaluation and use of the multimedia resources by the educational actors searching for quality indicators;
- e) Propose strategies in order to incentive the collaborative practices in the TL environments, instead of focusing on individual learning. It is proposed to organize knowledge through of semantic association of the content obtained from the forums and chats, in order to provide accurate personal information improving the learning and the knowledge network;
- f) Evaluate activities and identify behaviors in the use of technological resources such as educational material recommendation systems, geolocation devices, multimedia whiteboards and smart tutoring systems. The proposal is the development of new media recommendation systems for educational activities, providing more suitable didactic-pedagogical support to students and more assistance to educators. Also, it is proposed the information extrac-

tion from the collective intelligence² according to goals established for the TL in traditional classroom environments;

- g) Identification of profile of students' groups with anomalous behavior, and proposal of educational strategies to achieve customized learning. It is proposed the development of smart tutoring systems to identify student's groups with similar learning characteristics, or anomalous students behavior, such as difficulty in assimilating content, motivation absence, evasion risks, low performance and social ineptitude;
- h) Evaluation and identification of efficient channels of communication to improve and strengthen student-educator bonds, even if the success of communication and interaction relies less on technology and more on the cognitive capabilities of those involved. As future research, it is proposed new methods to shorten the distance between the educators and the students, so increasing the interactivity of the TL actors;
- i) Development of hybrid and collaborative learning models. These models are built from data mining techniques. It is proposed to development of mobile technology to allow the create, interact and share teaching medias as hybrid learning model (a mixture of traditional classroom and e-learning), in order to enable decentralized mobile laboratories;

Through the analysis of the bibliographical material, we were able to recognize potential new research themes in EDM.

- a) Research in Behavior: The *behavior* concept describes a factor that, more often, is crucial to the evaluation of student's performance, be it partially (in each assignment), or at the end of a course, or even to evaluate educators' actions when preparing educational material or their educational practices during the teaching process. Even though this concept can be understood as two probable situations, positive or negative, the *behavior* concept is vested in values and attitudes identifiable through the entire TL. In the *e-Learning* educational environment, the *behavior* concept should try to answer questions such as: What factors favor interaction? How can collaboration mechanisms increase the degree of interest among participants? How the *behavior* can influence the performance? The answer to these questions can provide relevant information to educators and students when attempting to evaluate teaching or learning;
- b) Research in Collaboration: According to our analysis, *collaboration* should be guided by the following themes: continuous and reciprocal student-educator interaction; cooperation towards knowledge construction; knowledge and experience exchange to reach common goals; intellectual/affective relations defined by mutual commitment. The *collaboration* concept has a very broad meaning which directly depends on the problem domain. For example, the *collaboration* concept is crucial when it comes to concepts like interdisciplinary or multidisciplinary, requiring multiple approaches to solving complex problem;
- c) Research in Interaction: From our analysis, the *interaction* concept can initially be understood as direct communication between educator and student; on second thought, as technological advances and communication which serve as a bridge to interactivity. Teaching media are responsible for the increase of student-educator interactions, communication, and independence. So, considering the possibilities of communication and interaction between student-educator, it is possible to identify six communication models for interaction, which can be explored in EDM:
 - a) diffuse model where there is no interaction, because communication is established exclusively by educators;
 - b) tutoring model where the interaction established between the educator and the student originates, predominantly, from the educational activities;
 - c) moderate communication

²Use of knowledge generated and disseminated in social networks, forums, websites and knowledge base repositories.

model which preaches balanced communication; d) oriented model where the interaction is predominantly initiated by students; e) collaborative model where the interaction is stimulated by either students or educators, according to a purpose; and f) cooperative communication model where the interaction is continuous, balanced and committed, with no distinction between educator and student's roles. Hence, it is important to characterize each type of model in order to achieve the goals in the TL;

- d) Research in Performance: From the point of view of the analyzed papers, the *performance* concept concerns results obtained by completing a certain task, assignment or test. Therefore, to evaluate performance either from educators or students, it is important to demonstrate an aptitude to fulfill minimum requirements to attain a certain goal. Many factors can influence the *performance* concept: the quality of educators' educational practices; students' academic profile; consistency and availability of teaching media; the level of interaction between students and educators; customized strategies used according to student's behavior; and the organization and management of the TL itself. The *performance* concept is directly related to the options offered to students and their choices, or the lack thereof. So, more than giving numbers to students' performance, the concept must reveal how much students actually learned. Research topics in this direction should seek to optimize the various factors involved in the TL.

6 Conclusion

This literature review was developed with the goal to describe the two decades scenario of the EDM in relation to the main contributions that aim at the improvement of teaching and learning. Initially, in order to make our review more comprehensive and complete the search terms of the bibliographic material were restricted only in "Data Mining" and "Education", which resulted in the collection of 525 articles. In this way, it was possible to avoid articles relevant to the purpose of this review being discarded. However, since our objective is to review the articles that seek to contribute to the improvement of teaching and learning through evaluation processes in the e-learning environment from a careful re-reading, this review was limited to 72 articles.

During the process of collecting bibliographical material, it was possible to identify other literature review works in EDM which focused on providing a technical perspective of the application of data mining algorithms in the educational scenario. Through this perspective, the articles have mainly emphasized the application of data mining techniques in both environments, both in traditional classrooms and in the e-learning environment, aiming to identify the performance of student learning and the effectiveness of teaching in relation to the educational actions of the teacher. Also as an indirect contribution of this work, we show a synoptic picture describing the contribution of these previous revisions.

In relation to our review, it was possible to identify latent themes faced by the educational environment that can stimulate data mining research. Among these themes, we can highlight: a) works that aim to improve the interaction between the educational actors; b) works that allow the monitoring and temporal evaluation of teaching and learning; c) works that allow evaluating the educational actions of the teacher and the student's behavior patterns; d) works that aim to identify and manage the risks of evasion and disapproval during the learning process; and e) works that allow evaluating temporarily the improvement of the learning process in relation to the use of the teaching media.

From the analysis of the bibliographic material, it was possible to observe trends of research

that we can highlight: a) works that aim to reduce the distance between the educational actors, mainly between teacher-student; b) works that seek to recommend teaching media more didactic and effective; c) works that aim to identify similar characteristics of learning as well as unusual behavioral actions of the student; and d) work to improve the process of personalized learning through information obtained from social networks and forums that deal with knowledge.

Finally, as a result of our literature review, it was possible to recognize potential research, such as e.g.: a) research aimed at identifying patterns of student behavior during the learning process; b) research oriented to cooperation and collaboration between teacher-student during the accomplishment of the educational activities; c) research that seeks to identify the main factors that influence the student according to the use of educational media; and, finally, d) research aimed at improving student performance by highlighting their skills or identifying their deficiencies during the learning process.

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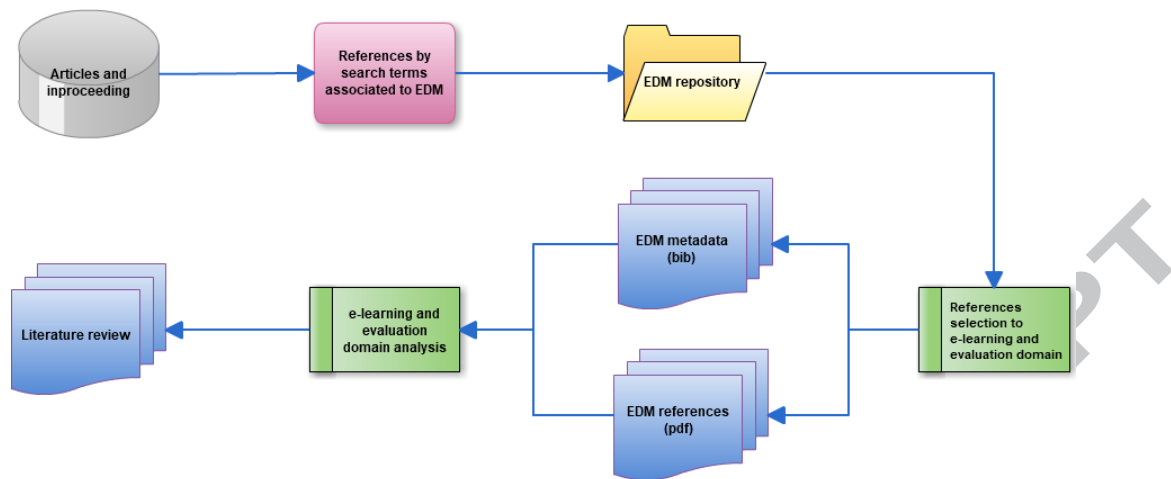


Figure 1: The flow of literature review process in the evaluation domain of e-learning

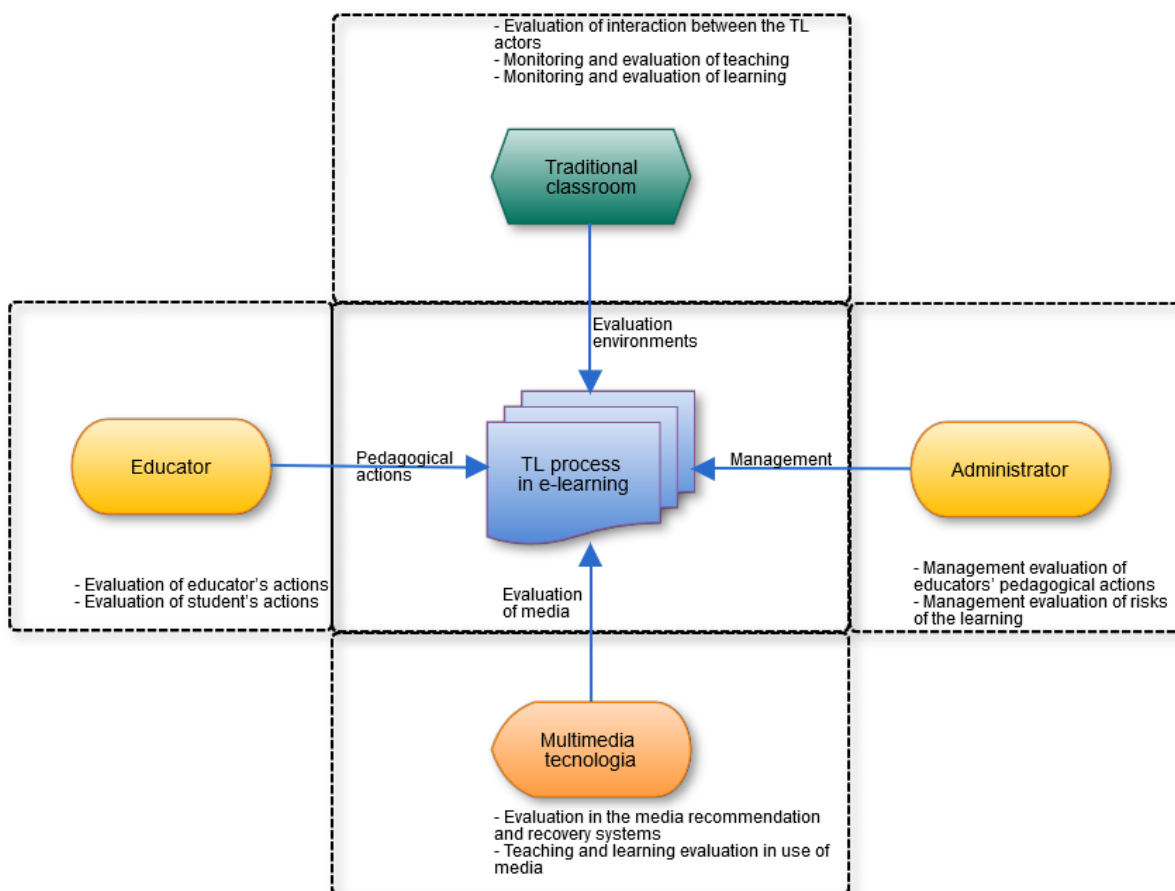


Figure 2: Main topics addressed by bibliographical material

RESEARCH HIGHLIGHTS

- We present 20 years of data mining research on e-learning and evaluation aspects.
- We analyzed 525 papers and 72 of them focused on teaching-learning evaluation.
- We identified and classified challenges to improve student's performances.
- We presented four new research themes in EDM focusing on the pedagogical perspective.

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