


ADVANCED REVIEW

Text mining in education

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Abstract

The explosive growth of online education environments is generating a massive volume of data, specially in text format from forums, chats, social networks, assessments, essays, among others. It produces exciting challenges on how to mine text data in order to find useful knowledge for educational stakeholders. Despite the increasing number of educational applications of text mining published recently, we have not found any paper surveying them. In this line, this work presents a systematic overview of the current status of the Educational Text Mining field. Our final goal is to answer three main research questions: Which are the text mining techniques most used in educational environments? Which are the most used educational resources? And which are the main applications or educational goals? Finally, we outline the conclusions and the more interesting future trends.

This article is categorized under:

Application Areas > Education and Learning

Ensemble Methods > Text Mining

KEYWORDS

educational text mining, natural language processing in education, text analytics, writing analytics

1 | INTRODUCTION

Online education has become a new alternative to traditional education. In a broad sense, it adopts online learning platforms for creating new educational settings able to support instructors and students in the learning process. There is a wide range of online platforms to support online education, such as web-based Adaptive and Intelligent Educational Systems (AIES), web-based Intelligent Tutoring System (WITS), Learning Management System (LMS), Massive Open Online Courses (MOOCs), among others. All these Virtual Learning Systems (VLE) can engage hundreds or thousands of students that interact and generate a huge volume of structured and unstructured data requiring sophisticated methods of management and analysis. Specifically, the great amount of unstructured text data produced by different sources, and in different formats, such as discussion forum, chat, wiki, blogs, open questions, and essays, generally are not suitable to be processed and leading to problems related to using this information to aid students and instructors in the learning process (Valjataga, Põldoja, & Laanpere, 2011).

Recently, Educational Data Mining (EMD) and Learning Analytics (LA) techniques have been employed successfully for improving students' learning and aid instructors to improve the learning process (Romero & Ventura, 2017). Although good results were obtained, it does not fully explore all the educational resources available. For example, it is common to have learning activities involving open questions and essays exercises that could be used to evaluate the student and estimate the effectiveness of pedagogical strategies (Baker & Inventado, 2014). To address this issue, Text mining (TM) techniques could be adopted as it is done in other areas such as risk management, fraud detection, business intelligence, and social media

analysis. TM is the process to extract high-quality information from unstructured text (Berry & Castellanos, 2004). Hence, the new generation of online platforms could benefit from different text mining techniques such as natural language processing, text classification and clustering, information retrieval, and text summarization.

Text Mining (TM), also known as Intelligent Text Analysis (ITA), Text Data Mining (TDM) or Knowledge-Discovery in Text (KDT), generally refers to the process of extracting interesting and non-trivial information and knowledge from unstructured text. It is possible to find a variety of applications in diverse domains such as financial, business, clinical, biology, biomedical, among others (Luque, Luna, Luque, & Ventura, 2019). In the educational domain, TM has mainly focused on analyzing the contents of educational resources (Kovanovic, Joksimovic, Gasevic, Hatala, & Siemens, 2015), especially the research on Educational Text Mining (ETM) (Litman, 2016; Shum et al., 2016). The application of ETM techniques has achieved significant results, especially in online assignments and essays, forums and chats analysis, academic text production, social networks, and blogs. Despite the large number of educational applications of text mining have been published recently, it was not found a survey concerning these applications. Thus, this paper presents an overview of the Educational Text Mining (ETM) field, including the main techniques, resources, applications, and future trends. More specifically, this paper intends to answer the following research questions:

RQ1: Which are the main text mining methods and techniques adopted in the educational technology field?

RQ2: Which are the main educational resources used for doing ETM?

RQ3: Which are the main applications and educational goals enhanced by ETM?

This paper presents in Section 2 the methodology used to the systematic review. Then, Section 3 describes the text mining techniques and how they could be used to improve educational environments. Next, Section 4 presents educational resources and data sources which use TM to extract useful information. After that, Section 5 the primary educational goals and applications that benefit from TM methods. Finally, Section 6 presents the final remarks and future trends of text mining and education.

2 | METHODOLOGY

We performed a systematic review to collect all the papers published on the application of text mining in education. This section describes the details about the collection, selection, classification, and analysis of the papers.

2.1 | Data collection and selection criteria

The initial search was performed from January 2006 to July 2018 in the following databases: IEEE Xplore, Springer, ScienceDirect, ACM, and Google Scholar. The keywords used were: “Text Mining in Education,” “Natural Language Processing in Education” and “Writing Analytics” individually in order to retrieval the papers. After this initial search, we performed a reference analysis, which led to the inclusion of new papers in the initial selection.

All the retrieved papers were included in the first step of the analysis. The second step removed the papers that did not meet the following exclusion criteria:

1. Publications where the keywords defined did not appear in the title, abstract, conclusions, and keywords.
2. Publications about text mining without any educational goals or applications.

After that, we obtained 343 papers. Table 1 shows the number of papers retrieved from different sources. We can see that the three most important sources were: IEEE Xplore (20.40%), Springer (16.03%), and Association for Computational Linguistics (14.86%). Besides, Google Scholar is not shown because it does not have papers in its database, essentially Google Scholar indexes papers from other platforms.

2.2 | Data classification and analysis

In order to classify the retrieved papers, we used some additional information from each paper such as the number of citations, year of publication and type of publication (journal, conference, book, and workshop). First, Figure 1 presents the number of papers published over the selected years. Only seven works were found in the first year of the proposed search, although the average number of publications per year was more than 26. Moreover, the number of papers reached 56 only in the first 7 months of 2018 that it shows the current importance and growth of this research area.

TABLE 1 Summary of the search results regarding the academic databases

Database	Number of papers (%)
IEEEExplorer	70 (20.40%)
Springer	55 (16.03%)
Association for Computational Linguistics (ACL)	51 (14.86%)
Science Direct	38 (11.07%)
Association for Computing Machinery (ACM)	26 (7.58%)
Educational Data Mining Society (EDMS)	19 (5.53%)
IGI Global	11 (3.20%)
Others	73 (21.28%)

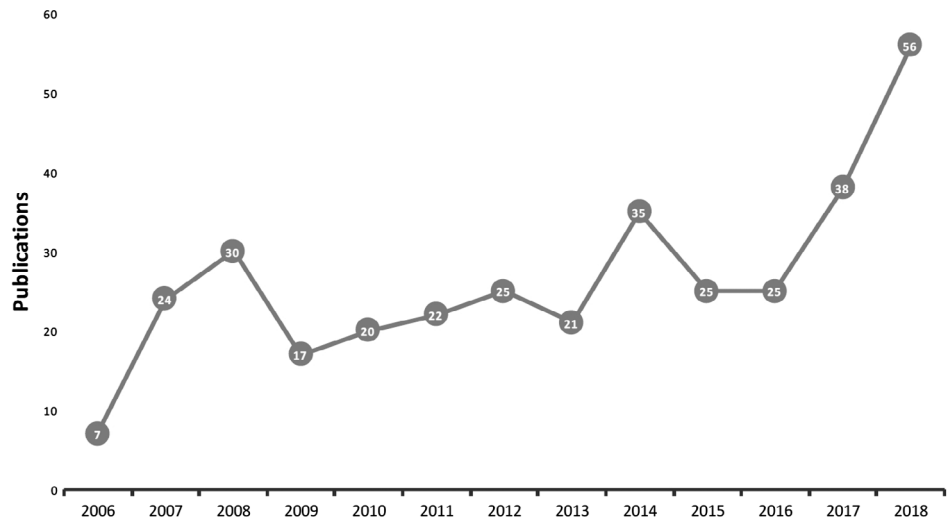


FIGURE 1 Number of papers by the year of publication

TABLE 2 List of top five most cited papers (in Google Scholar)

Paper	Number of cites
Content analysis schemes to analyze transcripts of online asynchronous discussion groups: A review (De Wever, Schellens, Valcke, & Van Keer, 2006).	1,073
Better to be frustrated than bored: The incidence, persistence, and impact of learners' cognitive-affective states during interactions with three different computer-based learning environments (Baker, D'Mello, Rodrigo, & Graesser, 2010)	483
Plagiarism-a survey (Maurer, Kappe, & Zaka, 2006)	374
Automatic recommendations for e-learning personalization based on web usage mining techniques and information retrieval (Khribi, Jemni, & Nasraoui, 2008).	342
An overview of automated scoring of essays (Dikli, 2006)	337

Then, we grouped the papers by the type of publication, most of them were published in conference proceedings (59%), followed by 25% of journal papers, 15% of workshop papers and 1% of others, which include books and Ph.D. thesis. We can also highlight some specific conferences and journals because of the high number of papers published about ETM field, such as Conferences on Intelligent Tutoring Systems, Learning Analytics and Knowledge, Advanced Learning Technologies, Artificial Intelligence in Education and Educational Data Mining; and Journals of Artificial Intelligence in Education, Computers & Education, Expert Systems with Applications and Computers in Human Behavior.

Finally, Table 2 shows the top-5 papers most cited according to Google Scholar. Three of them are reviews/surveys (De Wever et al., 2006) (Maurer et al., 2006) (Dikli, 2006) and the other two describe experiments and applications (Baker et al., 2010) (Khribi et al., 2008).

In the next sections, we will categorize all the papers (see Table A1) according to the three research questions: text mining methods, educational resources, and educational goals.

3 | TEXT MINING METHODS AND TECHNIQUES

This section presents the selected articles clustered by different text mining techniques and methods used, as presented in Table 3. The two main ones were text classification (32%) and natural language processing (31%), followed by information retrieval, text clustering, and text summarization. Besides, our search also recovered theoretical papers, which only present ideas about the possible applications of text mining to education. Finally, other less popular methods and techniques are information extraction, machine translate, text generation, among others.

3.1 | Text classification and clustering

Different machine learning algorithms have been used to extract information from texts. In general, these algorithms are divided into classification or supervised learning, and clustering or unsupervised learning. Classification categorizes items based on their features in a predefined set of categories, and clustering categorizes items based on the similarity among them. Machine learning could also be applied to different domains, including textual documents (Aggarwal & Zhai, 2012). The main difference between the processing of traditional data and text documents is the methods used to extract features from texts before the classification or clustering. Text classification has been used in Educational environments for different goals, some examples are: (a) the automatic classification of activities in common discourse tasks such as instructor lecturing, whole class discussion and student group work (Wang, Pan, Miller, & Cortina, 2014); and (b) the categorization of forums discussion in topics (Azevedo, Behar, & Reategui, 2011; Tobarra, Robles-Gómez, Ros, Hernández, & Caminero, 2014) and genres (Lin, Hsieh, & Chuang, 2009). Despite these applications the ones that stand out in this field are: Sentiment Analysis (Newman & Joyner, 2018), Question Classification (Ruseti et al., 2018) and Automatic Scoring (Yoo & Kim, 2014). Especially, Sentiment Analysis is a new technique extensively used in education in order to determine the attitude of a speaker, writer, or another subject concerning some topic or the overall contextual polarity or emotional reaction to a document, interaction, or event. Regarding text clustering, the educational applications found in the literature are related to group students and educational resources. Students clustering could be used to: improve text predictions (Trivedi, Pardos, & Heffernan, 2011), adapt the curriculum (Shi, Larson, & Jonker, 2015), measure engagement (Liu, Calvo, & Pardo, 2013), identify learning patterns (Cobo et al., 2010; Mansur & Yusof, 2013), among others. On the other hand, educational resources clustered to improve recommendation systems (Khribi et al., 2008; Mansur & Yusof, 2013). The SVM and K-means were the most used algorithms for text classification and clustering, respectively. Besides, techniques based on neural networks are also largely used.

3.2 | Natural language processing

Natural language processing (NLP) is a field in computer science used to manipulate natural language text or speech (Chowdhury, 2003). It can process and analyze large amounts of natural language data by using algorithms for semantic and syntactic analysis. Educational platforms had adopted NLP techniques over the years; however, the growing of big-data, mobile technologies, social media, and MOOCs resulted in the creation of many new research opportunities and challenges (Litman, 2016). The majority of applications of NLP to education are related to the automatic evaluation of essays and open questions. The literature proposes different methods to improve this kind of evaluation adopting text mining (Crossley, Allen,

Resource	Number of papers (%)
Text classification	109 (31.77%)
Natural language processing	105 (30.62%)
Theoretical	41 (11.95%)
Information retrieval	17 (4.96%)
Text clustering	17 (4.96%)
Text summarization	13 (3.79%)
Others	41 (11.95%)

TABLE 3 Number of publications according to text mining methods used

Snow, & McNamara, 2015). Regarding essays, NLP has been mainly used to analysis of text cohesion (Balyan, McCarthy, & McNamara, 2017; Dascalu, Trausan-Matu, Dessus, & McNamara, 2015) and written argumentation (Elouazizi et al., 2017; Persing & Ng, 2015). For open questions, the leading research line is to semantically evaluate student's answers (Cutrone & Chang, 2010) and generate new questions (Flor & Riordan, 2018). Besides, (Dzikovska, Steinhauser, Farrow, Moore, & Campbell, 2014) adopt different NLP techniques to provide feedback for intelligent tutoring based on student's interactions in basic electricity and electronics online courses. Following the idea of adopting NLP to enrich interactions, it was proposed papers to support collaborative work on chats (Trausan-Matu, Dascalu, & Rebedea, 2012), predict group project performance (Yoo & Kim, 2014), and predict interactions based on past discussions (Kim & Shaw, 2014).

3.3 | Information retrieval

Information retrieval (IR) can be defined as the science of searching for documents within a large collection of texts (Manning, Raghavan, Schütze, et al., 2008). Also, it is used to organize document facilitating navigation among them. In the educational domain, different applications use IR to find relevant documents in libraries (Chinkina, Oswal, & Meurers, 2018; Zhang & Gu, 2011). The main goal of these applications is to aid the student to find relevant books (Chen, Wei, Chen, et al., 2008). It is also used to enhancing online discussion and collaboration in e-learning (Distante, Fernandez, Cerulo, & Visaggio, 2014; Nuutinen & Sutinen, 2009). As mentioned before, IR techniques improve navigation among different texts. For educational purpose, it is used to visualize different topics in students essays and writing assignments (O'Rourke, Calvo, & McNamara, 2011; Villalón & Calvo, 2011). Information retrieval could improve recommendation systems (Khribi et al., 2008; Mangina & Kilbride, 2008) and texts tagging systems (Vattam & Goel, 2011).

3.4 | Text summarization

Automatic text summarization (ATS) creates a short version of one or several documents containing the essential information. It is mostly used to deal with the overload of information in text datasets, such as a digital library, web news, scientific papers, among others. ATS techniques are classified as Extractive and Abstractive. Extractive systems select a set of the most significant sentences from a document, exactly as they appear, to form the summary. Abstractive systems attempt to improve the coherence among the sentences in the summary by eliminating redundancies and clarifying their context. ATS has been applied in Educational environments mainly to: (a) summarize contents (Mihalcea & Ceylan, 2007); (b) extract keyphrase (Sándor & Vorndran, 2009); (c) create visual models from student texts (Reategui, Klemann, & Finco, 2012); (d) improve different applications (Jorge-Botana, Luzón, Gómez-Veiga, & Martín-Cordero, 2015; Sung, Liao, Chang, Chen, & Chang, 2016). Besides the mentioned applications, ATS techniques are used to deal with traditional educational resources drawbacks, for example: (a) Automatic evaluation of forums posts (Azevedo et al., 2011); (b) Assist students to write academic texts (Whitelock, Twiner, Richardson, Field, & Pulman, 2015); Improve collaborative learning (Kang et al., 2008); (c) Evaluate student feedback (Nitin, Swapna, & Shankaraman, 2015).

4 | EDUCATIONAL SOURCES AND RESOURCES

All the selected papers in this survey can also be classified according to the educational resource in which the previous text mining methods were applied (see Table 4). The three most important are: forums (19%), online assignment (17%), and essays (16%), achieved more than 50% of the retrieved works. Besides, chats, documents, and social networks also reach a

TABLE 4 Number of publications according to the educational resources

Resource	Number of papers (%)
Forum	66 (19.25%)
Online assignment	61 (17.79%)
Essay	55 (16.04%)
Chat	29 (8.45%)
Document	29 (8.45%)
Social network	10 (2.91%)
Others	93 (27.11%)

representative number of published papers. Moreover, the articles classified as others include blogs, wiki, lecture notes, theoretical papers, among others¹.

4.1 | Forum

A forum, or online discussion, is a communication tool where multiple users interact asynchronously. In the educational context, the forum is the resource that allows greater interactivity between students and teachers (Caspi, Gorsky, & Chajut, 2003). Besides, it provides several possibilities for teachers to interact effectively with the class (De Wever et al., 2006).

Despite the advantages created by adopting the forum as a communication resource in educational environments, has also led to an overload of information problem (Wulf, Blohm, Leimeister, & Brenner, 2014). Therefore, it is important to use automatic methods for extracting relevant information from them. Different works are exploring text mining methods to provide user automatic feedback. Several papers propose the creation of conversational agents or chatter boots for educational forum (Shroff & Deneen, 2011). These systems benefit from ontologies (Eisman, López, Castro, & McPherson, 2008), natural language processing (da Costa Pinho, Epstein, Reategui, Correa, & Polonia, 2013), and machine learning (Dzikovska et al., 2014) to interact with students trying to answer questions and help to understand the subject. Besides, it is possible to use recommendation systems to provide user feedback. There are several works which suggest different resources for students. A first approach proposes the application of information retrieval techniques to structure the searching and navigating in forum content for different topics of discussion (Distant et al., 2014). The second uses different similarities measures to find related questions in order to recommend an answer to the students (Catherine, Singh, Gangadharaiyah, Raghu, & Visweswariah, 2012). The classification of posts, also called gender identification, is another topic widely researched in this field. Text classification could be used to assess students' online participation and contribution, investigation of an aspect of online learning instigated by a research project, evaluation, and monitoring of learning progress, among others (Lui, Li, & Choy, 2007). Another important application of text classification in this context is to avoid off-topic posts (Wu, 2017). Ravi and Kim (2007) propose the identification of student's interactions. Lin et al. (2009) propose a system to classify postgender using the frequency of the words as features and decision tree algorithm for classification. The papers (Cao, Yang, Lin, & Yu, 2011), and (Heiner & Zachary, 2009) use machine learning, graph representation, and similarity measure to better modeling the student questions. Nunes, Mera, Kawase, Fetahu, and Casanova (2014) and Wang et al. (2007) also intend to extract the context from forum. Also, to the postclassification, the extraction of indicators from forums aid teachers to follow up the discussion. McLaren et al. (2007) propose the use of Awareness Indicators to provide an interface that allows the teacher to oversee all of the e-discussions currently taking place in the classroom. Another relevant indicator is the cognitive presence, Joksimovic, Gasevic, Kovanovic, Adesope, and Hatala (2014) automatically extracted a series of linguistic features to measure the student presence in forums. In a different task, Cobo et al. (2010) propose an approach to generate a student forum activity model. In addition, other methods to incentive student participation in educational forum (Ghosh & Kleinberg, 2013) successfully adopted sentiment analysis. Finally, it is important to notice that, although the interaction on an educational forum could assist students, the overlap posts may generate problems for understanding the subject. Thus, the instructor and automatic systems need to identify the right moment to interact with the student (Mazzolini & Maddison, 2007).

4.2 | Online assignments

An online assignment is a resource used to evaluate students' progress as essays analysis. The two most popular type of assignments are: multiple-choice question (where there are some explicit answers to be selected) and open questions (where the student need to provide a free writing answer) (Wang et al., 2014). Text mining techniques can support both the creation and evaluation of questions. In order to automatically generate question and multiple-choice answers, Araki et al. (2016) proposed a method based on natural language processing and template-based algorithms. Mazidi and Tarau (2016) evaluated natural language understand and natural language generation methods to create a new question. Besides question creation, it is essential to analyze previously formulated questions. Text clustering and topic modeling techniques are applied to evaluate questions in a database qualitatively (Nagashree & Pujari, 2016). Besides, it is relevant to identify which question is relevant for each stage of learning (Sachan & Xing, 2016). Concerning question evaluation, there are different proposals to aid the instructor in the correction of open questions (Cutrone & Chang, 2010; Rahimi et al., 2014; Rus, Banjade, Lintean, Niraula, & Stefanescu, 2013). More recently, (Ruseti et al., 2018) introduced the adoption of deep learning methods to deal with the question of quality problem. Finally, other works also propose semi-automatic methods for grading answer. Thus, instructors

benefit from computational applications. However, they need to evaluate the analytics (Escudeiro, Escudeiro, & Cruz, 2011; Hsu, Chou, & Chang, 2011).

4.3 | Essays

The primary goal of TM applied to Essay is to evaluate the students. It evaluates the capacity of expression and critical insight from students. Many exams, such as university admission and idiom proficiency, include an essay exercise (Knight, Allen, Littleton, Rienties, & Tempelaar, 2016). However, the task of analyzing an essay is complex, and some exams produce a large number of essays. Thus, it is important to use automatic techniques in order to aid the appraiser (Latif, 2008).

Text mining has been largely used to evaluate different aspects of essays automatically (Dikli, 2006; Rahimi, Litman, Correnti, Wang, & Matsumura, 2017). Some researchers analyzed shallow features and error detection (Burstein, 2003). These errors in grammar, linguistic usage, and style were detected using statistical and natural language processing techniques (Crossley et al., 2015). Other applications of text mining for essay analysis also included: Recommendation Systems (Acosta, Behar, & Reategui, 2014), User Modeling (Allen & McNamara, 2015), Plagiarism detection (Oberreuter & Velásquez, 2013), and Essay visualization model (Villalón & Calvo, 2011). Another important task when assessing essays is the discourse analysis (Warschauer & Ware, 2006). It benefits from syntactic structures and automatic discourse analysis methods to deal with it.

Moreover, semantic features could be used to extract discourse information because for writing assessments these features are essential for measuring the text cohesion (Dascalu, 2014). Recent literature proposed the adoption of different cohesion index for essays scoring (Crossley, Varner, Roscoe, & McNamara, 2013). Besides, (Vajjala, 2018) analyzed different linguistic features applied to non-native learner essays. Besides the essay evaluation problem, text mining techniques could also be applied to help students to develop their writing skills. Thus, different approaches benefit from learning analytics and natural language processing for sending automatic feedback (Lewkow et al., 2016; McNamara, Crossley, & Roscoe, 2013; Woods, Adamson, Miel, & Mayfield, 2017). Another application is the automatic essay scoring that can use a classifier to combine the outputs of each feature mentioned above to present the final grade (Shermis, Burstein, Higgins, & Zechner, 2010). It is essential to mention that different style of essays could require different analysis (Varner, Roscoe, & McNamara, 2013). Finally, different works point out that interaction among students can improve the quality of text productions (Calvo, O'Rourke, Jones, Yacef, & Reimann, 2011). Southavilay et al. proposed different approaches based on text mining, maps, and probabilistic topic models to support collaborative learning (Southavilay, Yacef, & Callvo, 2010; Southavilay, Yacef, Reimann, & Calvo, 2013).

4.4 | Chats

Chat is a resource to provide synchronous communication. In educational environments, chats can be used to discuss a subject, perform group activity, ask questions, among others (Ferguson & Shum, 2011). Text mining has been applied to chats in order to (Leiyue & Jianying, 2012): summarizing conversation topic; understanding the user behavior, investigation of chat user attributes, understanding social and semantic interactions, monitoring chat room conversations, extracting relevant information, authorship attribution and so on.

There are several works to identify and evaluate collaboration on educational chats. Trausan-Matu et al. (2012) propose a method using graph among utterances and words to identify threads and user contribution based on Bakhtin's dialogism (Koschmann, 1999). The collaboration could be automatically assessed using discourse cohesion analysis (Dascalu, Trausan-Matu, et al., 2015). Another work that explores collaboration is (da Costa Pinho et al., 2013). It proposes a pedagogical agent capable of mediating synchronous online discussions. Scheuer and McLaren(2008) adopt text mining for helping teachers to find relevant information in chat data. (Reimann, Frerejean, & Thompson, 2009) also provide information to help the instructor by creating a model presenting the sequence of events discussed in chats. Trausan-Matu et al. (2012) propose the adoption of natural language processing techniques to find the crucial moments from the student's discussion. Besides, the papers (Rojas, Kirschenmann, & Wolpers, 2012) and (Coutinho, Moreira, Paillard, & de Lima, 2016) introduce the sentiment analysis applied to asynchronous discussion. Finally, many papers are working with the analysis of second language acquisition in a tutorial dialogue chat (Nayak & Rao, 2018; Sinclair, Lopez, Lucas, & Gasevic, 2018; Xu, Chen, & Qin, 2018).

4.5 | Documents, social networks, blogs, and emails

Other resources that provide information about the users' interaction in educational environments are social networks, blogs, and emails. The text mining applications using these resources are usually related to text classification, mainly focusing on sentiment analysis. In this context, sentiment analysis has been applied in order to solve different problems, such as: to extract opinion about the educational environment (Kechaou, Ammar, & Alimi, 2011), to assist the instructor to improve the educational environment increasing the student engagement and create an adaptive educational environment (Ortigosa, Martín, & Carro, 2014), and to aid in teaching evaluation and provide feedback based on the user interaction on social network (Leong, Lee, & Mak, 2012). Different features can be applied in order to extract sentiment from online educational platforms by using traditional statistical features like TFIDF, Information Gain, Mutual Information and CHI statistics to natural language processing ones (Kechaou et al., 2011; Truong, 2016). It is also important to perform a preprocessing step before extract these features (Leong et al., 2012). In addition to sentiment analysis, text classification is used to extract students' behavior (Tobarra et al., 2014). It aids teachers to improve feedback and prevent student dropout. Mansur and Yusof (2013) proposed the adoption of a hybrid method based on a combination of logs from educational environments and social network analysis to extract user behavior. In the same direction, Tobarra et al. (2014) combines social network and forums interaction to generate students' models. Another example of text mining application is regarding emails analysis (Aghae, 2015). Finally, it is also possible to automatically predict the grade of each student based on his/her interaction with the course blogosphere (Gunnarsson & Alterman, 2012).

5 | EDUCATIONAL GOALS AND APPLICATIONS

The different educational goal or application can also group all the papers selected in this review (see Table 5). The three most popular applications of text mining in education are: evaluation (27%), student support (13%) and analytics ([13%]). They are followed by question/content generation, user feedback, and recommendation systems. Also, examples of different and less popular goals (Others category) were: automatic summarizing texts, visualization tools, and curriculum adaptation.¹

5.1 | Evaluation

TM has been largely used to evaluate student's performance in different contexts, especially to evaluate essays and online assignments (Dikli, 2006; Kadupitiya, Ranathunga, & Dias, 2017). Several works proposed the adoption of shallow features, as word counts, to assess essays (Dikli, 2006; Rudner, Garcia, & Welch, 2006). However, it is important to go beyond this analysis (Crossley et al., 2015; Ericsson & Haswell, 2006) and there are a great number of papers focused on adoption of semantic methods (Hughes, Hastings, Magliano, Goldman, & Lawless, 2012; Simsek et al., 2015), writing style (Oberreuter & Velásquez, 2013; Snow, Allen, Jacovina, Perret, & McNamara, 2015) and argumentation analysis Elouazizi et al. (2017). Following a similar direction, the evaluation of online assignments adopts lexical and semantic approaches (Cutrone & Chang, 2010; Prevost, Haudek, Urban-Lurain, & Merrill, 2012; Ramachandran & Gehringer, 2011). Nevertheless, in this case, the works tend to be more focus on solving specific problems as plagiarism (Adeva, Carroll, & Calvo, 2006), analyze short answer (Saha, Dhamecha, Marvaniya, Sindhgatta, & Sengupta, 2018), and classify the questions (Godea, Tulley-Patton, Barbee, & Nielsen, 2018). Finally, it also could be applied in formative evaluation to assist educators to establish a pedagogical basis for decisions in order to maintain the environment (Gibson et al., 2017; Lehman, Mills, D'Mello, & Graesser, 2012) and evaluate interactions on educational online discussions (Rubio & Villalon, 2016; Yoo & Kim, 2014).

Goal	Number of papers (%)
Evaluation	95 (27.69%)
Student support/motivation	48 (13.99%)
Analytics	45 (13.11%)
Question/content generation	22 (06.41%)
User feedback	18 (05.24%)
Recommendation systems	9 (02.62%)
Others	106 (30.90%)

TABLE 5 Number of publications according to the educational goal of the application

5.2 | Student support/motivation

Engaging the students in online platforms is essential. Especially in distance learning courses, collaboration among students is essential for pedagogical success. Thus, TM has been applied to provide support students (Liu, Pardo, & Liu, 2017; Murphy, 2004; Trausan-Matu et al., 2012). Once again, the writing activity has the majority of publications on this goal. Several works are focused on giving aid to students on the production of different text, such as traditional essays (Latif, 2008), academic documents (O'Rourke & Calvo, 2009), and e-books (Chen, Li, & Feng, 2007). In addition, the analysis of interactional resources like forums, chats, and blogs have been explored within this goal.

In this context, opinion analysis methods have been tried to extract the sentiment of the students (Kechaou et al., 2011; Ortigosa et al., 2014; Sinclair et al., 2018), and the adoption of methods to encourage collaboration (Li, Dong, & Huang, 2008; Trausan-Matu et al., 2012) have been used to keep the students motivated preventing dropout. Moreover, there are a few works that aid the instructor to monitor students within this tools (Perikos, Grivokostopoulou, & Hatzilygeroudis, 2017; Scheuer & McLaren, 2008).

5.3 | Analytics

It is vital to provide analytics to instructors for improving the educational environment and providing feedback to students continually (Dzиковska et al., 2014; Lyons, Aksayli, & Brewer, 2018). In this context, the ETM methods have been adopted to extract information from activities such as writing production (Clemens, Kumar, & Mitchnick, 2013) and forum/chat/e-mail interactions (Aghaee, 2015; Ferguson & Shum, 2011). The majority of the applications extract information that could potentially help the instructor to analyze the students' performance and behavior. In some cases, the student performance is extracted by using shallow features (Azevedo et al., 2011), topic modeling approach (Nunes et al., 2014), or sentiment analysis (Tucker, Pursel, & Divinsky, 2014). On the other hand, the different students' behavior and characteristics could be analyzed, such as Psychological characteristics, genres, and mental models (Joksimovic et al., 2014; Lin et al., 2009; Lintean, Rus, & Azevedo, 2012). These results have been used for online scaffolding discussion, create groups, and prevent dropout.

5.4 | Question/content generation

Automatic question generation (AQG) focus on generating a set of content-related questions based on a given text, and automatic content generation (ACG) could create content on any topics given. TM has been applied to automatic generated questions and content to aid instructors in educational environments Araki et al. (2016); Mazidi and Tarau (2016). The most traditional approach is to generate the question from a reference document like textbooks and educational resources (Araki et al., 2016; Mazidi & Tarau, 2016), but it is also possible to find useful knowledge from web (Ochi & Nakanishi, 2009). A different TM task was the use of scaffolding and the evaluation of questions according to the course context. For instance, Sachan and Xing (2016) proposed a case study to analyze if the students are more likely to continue the course when the instructor send more straightforward questions at first. In the same direction, (Becker, Palmer, van Vuuren, & Ward, 2012) and (Mazidi & Nielsen, 2014) propose an algorithm to automatically ranking questions in different context and evaluation of automatically generating questions, respectively.

5.5 | Student feedback

The goal of feedback is to provide students with insight that helps them to improve their performance. ETM has also been used to provide automatic feedback for students based on both their interactions and activities performed (Lewkow et al., 2016; Woods et al., 2017). In general, the literature deals with this goal using two different approaches. The first one focuses on sending feedback directly to the students, like a dashboard or recommendation, for example, based on an automatic method to analyze their behavior or performance (Lewkow et al., 2016). In this context, the range of applications goes from help students in a question-answering application (Alinaghi & Bahreininejad, 2011; Zhu, 2015) to support students in collaborative environments (Dascalu et al., 2015) and send feedback in real-time (Altrabsheh, Cocea, Fallahkhair, & Dhou, 2017). The second approach uses ETM to extract information to aid instructors in the elaboration of feedback from different resources (Goldin, Narciss, Foltz, & Bauer, 2017). Gibson et al. (2017), Akçapınar (2015) and Hwang, Cheng, Chu, Tseng, and Hwang (2007) presents different methods to help instructors to provide feedback based on writing activities. Also, several papers extract information to support formative feedback based on data from forums interactions and essays (Woods et al., 2017; Yang, Heinrich, & Kemp, 2011).

5.6 | Recommendation systems

Due to a large amount of resource available on the Internet and web-based educational environments, it is difficult to find the best contents for each specific course and student (Hsu, Hwang, & Chang, 2010; Mangina & Kilbride, 2008). So the adoption of recommendation systems aids the instructor and the students in the process of finding the most relevant information. The recommendations can be based on consolidated educational material as books (Garrido, Pera, & Ilarri, 2014; Nagata, Takeda, Suda, Kakegawa, & Morihiro, 2009), and on open environments like the web (Sommer, Bach, Richert, & Jeschke, 2014). Acosta et al. (2014) proposed a system that extracts relevant terms and keywords from the students' writings in order to search the web for related contents. In this case, the recommendation system filtered the most relevant content for different students. Following the same idea Khribi, Jemni, and Nasraoui (2007) proposed the adoption of information retrieval methods to recommend content to students. Finally, Figueira (2008b) applied text mining techniques to classify learning objects based on semantic categories in order to improve further recommendations.

6 | CONCLUSIONS AND FUTURE RESEARCH

This paper shows a systematic literature review of the application of text mining techniques in online education. The main contribution is to answer three research questions about which are the main text mining techniques, educational resources, and goals used till today:

RQ1: Which are the main text mining methods and techniques adopted in the educational technology field?

The current main text mining methods used in the educational domain are text classification and natural language processing. This result follows the same trend as the text mining techniques used in general applications (Hirschberg & Manning, 2015). However, the majority of educational text mining literature is more focused on the output than the process, which leads to systems with good accuracy, but with a lack of interpretation.

RQ2: Which are the main educational resources used for doing ETM?

The current main educational resources for doing TM are forums, online assignments, and essays. Additionally, there is an increasing interest in other sources such as the social networks with the creation of communities applications, and the documents, especially for the recommendation of documents within digital libraries.

RQ3: Which are the main applications and educational goals enhanced by ETM?

The current main educational goal of ETM application is the instructors' assistance in the evaluation of students' performance. However, the development of automatic methods to provide support to students and analytics for the instructors is also a fundamental educational goal.

Although there are much works published in ETM area, it also has some gaps to be improved, and there are some hot and new topics to develop. More specifically, after doing this review, we propose the next most interesting future researches lines in ETM:

- *Analyzing online discussion collaboration:* Although several papers have tried to address specific problems of online discussion (see Sections 4.1 and 4.4), only a few of them dealt with the participation and collaboration problems. The collaboration among students can be decisive for the completion of the course, especially in distance education (Brinton et al., 2014). So, it is necessary much more ETM research works about discussion collaboration in order to help achieve this objective.
- *Writing analytics:* In recent years, the Learning Analytics field has grown exponentially with applications to deal with different problems such as document understanding. The writing analytics objective is to provide a set of measurement, analysis, and reporting of data about students' writing in order to aid instructors and improve e-learning (Dawson, Gašević, Siemens, & Joksimovic, 2014). However, there are not much-published works until date about this. So, it is necessary to develop more writing analytics tools for providing instructor's feedback and improving the students' monitoring and evaluation (Gibson et al., 2017; Shum, Sándor, Goldsmith, Bass, & McWilliams, 2017).
- *Natural language generation:* Automatic generation of educational content is still an open challenge (Kempen, 2012). In the future, it could be widely applied to generate online questions, to automatically interact with students in forums and chats, to propose essays themes based on recent news, among others.

- *Text mining for different languages*: One of the current problems in text mining field is to deal with different languages (Gupta, Lehal, et al., 2009). As the methods for the education domain are adopted for courses with different educational environments and set-ups, they need to be adaptable for different languages.
- *Sentiment analysis*: Although nowadays there are a good number of works that use this technique (Coutinho et al., 2016; Kechaou et al., 2011; Newman & Joyner, 2018; Ortigosa et al., 2014; Rojas et al., 2012; Sinclair et al., 2018; Tucker et al., 2014; Wen, Yang, & Rose, 2014), it continues being a hot topic, and there is much work to do with it in the education field. For instance, it can be applied to all type of educational resources and not only forum, chats, social networks, blogs, and e-mails, but also essays and online assignments. Moreover, new algorithms for better detecting different type of students' emotions can be developed.

Finally, as future work we also want to highlight the next topics: (a) to develop and analyze specific educational resources for online discussion and essays; and (b) to use text mining methods like topic modeling to automatically extract information from the collected corpus, for instance, the trending topics.

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CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

ENDNOTE

¹ We have not included details about the others categories because there is not a general line of work, the paper presented very different application. However, the Appendix shows the complete references of the papers retrieved.

RELATED WIREs ARTICLES

[Data mining in education](#)

[A survey on educational process mining](#)

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APPENDIX: A SUMMARY OF SELECTED PAPERS

TABLE A1 Summary of all papers retrieved in this review

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Heiner & Zachary, 2009)	Forum	Classification	Question/content generation	This paper analyzes questions from an introductory Java programming course by reducing the natural language of the questions to a vector space.
(Verdú, Verdú, Regueras, de Castro, & García, 2012)	Online assignments	Classification	Question/content generation	This paper discusses the validity of an expert system that automatically estimates the difficulty level of the questions posed in the QUESTOURnament competitive learning system.
(Sung, Lin, & Chen, 2007)	Online assignments	NLP	Question/content generation	The paper proposed an automatic quiz generation system to test learner comprehension of text content and English skills.
(Bhatnagar, Desmarais, Lasry, & Charles, 2016)	Online assignments	Classification	Question/content generation	This paper reports on early analysis of student rationales with multiple-choice questions using a text classification framework.
(Sachan & Xing, 2016)	Online assignments	Classification	Question/content generation	The paper proposed a number of heuristics, an ensemble, and several improvements for selecting the curriculum that improves upon self-paced learning.
(Araki et al., 2016)	Online assignments	NLP	Question/content generation	The paper proposed a question generation approach that engages learners through the use of specific inference steps over multiple sentences requiring more semantic understanding of text.
(Blanchard et al., 2016)	Online assignments	NLP	Question/content generation	The paper centers on a fully automated process for predicting instructor questions in a noisy real-world classroom environment.
(Wang et al., 2014)	Online assignments	Classification	Question/content generation	The paper report the development and validation of an automated system for recording and analyzing aspects of classroom discourse that can result in timely feedback.
(Becker et al., 2012)	Online assignments	Information retrieval	Question/content generation	This paper explores the use of supervised ranking models to rank candidate questions in the context of tutorial dialogues.
(Mazidi & Nielsen, 2014)	Online assignments	Classification	Question/content generation	The paper describe an automatic question generator that uses semantic-based templates and evaluates three automatic question generation systems.
(Jouault & Seta, 2014)	Online assignments	NLP	Question/content generation	The paper discuss the technical issues to overcome to generate content dependent questions to support learners in an open learning space.
(Mazidi & Tarau, 2016)	Online assignments	NLP	Question/content generation	The paper infuses natural language understanding (NLU) into the natural language generation (NLG) process by analyzing the central semantic content of each independent clause in each sentence.
(Ochi & Nakanishi, 2009)	Online assignments	NLP	Question/content generation	This paper presents a method to automatically generate questions for studying computer network management in Japanese.

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TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Borges & Barbosa, 2013)	Others	NLP	Question/content generation	This paper discuss the establishment and application of IMA tool—a web-based tool for the modeling and automatic generation of educational content.
(Larrañaga, Elorriaga, & Arnuarte, 2008)	Others	Information retrieval	Question/content generation	This paper describes an approach to semi-automatic generation of didactic resources from electronic documents using ontologies and natural language processing techniques.
(Khribi et al., 2008)	Recommendation systems	Information retrieval	Recommendation systems	This paper proposed a personalization approach taking into account both the web access history of learners as well as the content of the learning material.
(Nagata et al., 2009)	Recommendation systems	Information retrieval	Recommendation systems	This paper proposes a novel method for recommending books to pupils based on a framework called Edu-mining.
(Garrido et al., 2014)	Recommendation systems	NLP/information retrieval	Recommendation systems	The paper shows the SOLE-R, a topic map-based tool that yields book recommendations using lexical and semantic resources
(Acosta et al., 2014)	Recommendation systems	NLP	Recommendation systems	This paper presents the expansion of the SMILE project (Stanford Mobile inquiry based learning environment), whose goal is to allow students to create and share questions and answers using mobile devices.
(Hsu et al., 2010)	Recommendation systems	NLP	Recommendation systems	This study proposes a knowledge engineering approach for developing reading material recommendation systems by eliciting domain knowledge from multiple experts.
Figueira, 2008b	Recommendation systems	Information retrieval	Recommendation systems	The article proposes a repository of learning objects which is capable of automatic classification and categorization based on a semantic organization using text mining methods.
(Sommer, Bach, Richert, & Jeschke, 2016)	Recommendation systems	Information retrieval	Recommendation systems	The paper shows the development of a web-based recommendation system for related e-learning solutions to support instructors in the field of engineering education to find a matching e-learning system within minutes.
(Porcel, Moreno, & Herrera-Viedma, 2009)	Recommendation systems	Information retrieval	Recommendation systems	The paper presents a model of a fuzzy linguistic recommender system to help the university digital libraries users to access for their research resources.
(Khribi et al., 2007)	Recommendation systems	Information retrieval	Recommendation systems	This paper outlines the use of on-line automatic recommendations in e-learning systems based on learners' access history
(Nagata, Suda, Kakegawa, Morihito, & Showji, 2007)	Blog	Information retrieval	Student support	This paper describes an edu-mining technique for finding keywords to improve pupils' message production skills. It automatically finds keywords from blog items pupils create.
(Trausan-Matu et al., 2012)	Chat	NLP	Student support	This paper presents a system based on a discourse model following Bakhtin's polyphony ideas, very well suited for the analysis of instant messenger (chat) systems or forums.
(Reimann et al., 2009)	Chat	Classification	Student support	This paper introduces process modeling and mining as an approach to process analysis for CSCL

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TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Leyue & Jianying, 2012)	Chat	Topic Modeling	Student support	The paper uses text mining to find hot topics in chat groups, personal language behavior, personal motivation, and members of the emotions involved in the overall performance trends and the personal emotional expression trend.
(Wang & Lin, 2008)	Chat	NLP	Student support	This paper presents an English chat room system in which students can discuss course contents by interacting with instructors and students
(Weber & Brusilovsky, 2016)	Document	Classification	Student support	This paper provides a broader view on ELM-ART, one of the first web-based intelligent educational systems that offered a creative combination of two different paradigms—intelligent tutoring and adaptive hypermedia technologies.
(Mandin, 2014)	Document	Summarization	Student support	The aim of the paper is improve the summary activity and the understanding of texts. The authors design a TEL environment, Resum'Web, which they present to grade 10 students.
(Villiot-Leclercq, Mandin, Dessus, & Zampa, 2010)	Document	LSA	Student support	This article presents Pensum, an on-line document advisor, which aims at helping learners to improve their synthesis writing activity and at instrumenting tutors' assessment.
(Chen et al., 2007)	Document	Clustering	Student support	This paper applies a clustering approach before the mining process in other approach that automatically generate an e-textbook by mining the ranking lists of the search engine.
(Dascalu, 2014)	Essay	NLP	Student support	The approach based on advanced natural language processing techniques provides a qualitative estimation of the learning process and enhances understanding as a “mediator of learning” by providing automated feedback to both learners and instructors or tutors.
(Latif, 2008)	Essay	Survey	Student support	This article reviews literature of the real-time computer-aided study of the writing process
(O'Rourke & Calvo, 2009)	Essay	Information extraction	Student support	This article proposes that visualization can be used to mitigate many of the problems associated with the subjectivity of formative essay assessment.
(Calvo et al., 2011)	Essay	NLP/classification	Student support	This paper reports on an architecture for supporting collaborative writing that was designed with both pedagogical and software engineering principles in mind, and a first evaluation.
(Reimann, Calvo, & Yacef, 2010)	Essay	Information extraction	Student support	This paper has the goal to develop comprehensive software support tools for collaborative discipline-based writing, and to study how the team writing process is affected by the use of these tools.
(Villalón, Kearney, Calvo, & Reimann, 2008)	Essay	Others	Student support	This paper describes “glosser”, a system designed to provide support for the teaching and learning of academic writing in English.
(Song et al., 2016)	Essay	Text similarity	Student support	The authors propose a machine learning approach for automated sentence parallelism identification in student essays.

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TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Villalón & Calvo, 2011)	Essay	Information extraction/ summarization	Student support	The paper presents concept map miner (CMM), a tool that automatically generates concept maps from student' compositions, and discuss its design and implementation.
(McNamara et al., 2013)	Essay	NLP	Student support	This study assesses the potential for computational indices to predict human ratings of essay quality.
(Southavilay et al., 2010)	Essay	Classification	Student support	In this paper, process mining is used to analyze the process that groups of writers follow, and how the process correlates to the quality and semantic features of the final product.
(Knight, Martinez-Maldonado, Gibson, & Buckingham Shum, 2017)	Essay	Rhetorical structure	Student support	This paper discusses the extant literature on sequential and process analyses of writing, and proposes a number of approaches to both preprocess and analyze sequences in whole-texts.
(Simsek, Shum, De Liddo, Ferguson, & Sándor, 2014)	Essay	NLP	Student support	This paper describes a novel analytics dashboard which visualizes the key features of scholarly documents.
(O'Rourke et al., 2011)	Essay	Information extraction	Student support	This paper presents a novel document visualization technique and a measure of quality based on the average semantic distance between parts of a document.
(Liu, Calvo, Clancey, Papadourakis, & Panourgia, 2012)	Essay	Information extraction	Student support	The paper presents a novel approach to generate different forms of trigger questions (directive and facilitative) aimed at supporting deep learning.
(Miyazaki, Tanaka, & Koyama, 2014)	Essay	Classification	Student support	This paper discusses the development of a web application that supports non-native speakers of English in writing technical academic documents in English.
(Ando, Tsunashima, & Mizobuchi, 2007)	Essay	NLP	Student support	This paper proposes a writing support tool for learners of English as a second language by using search engines.
(Distante et al., 2014)	Forum	Information retrieval/topic Modeling	Student support	The paper proposes a strategy to assist a user writing a new post in choosing the most appropriate forum into which it should be added.
(Wang & Rosé, 2010)	Forum	NLP	Student support	This paper investigates how to identify initiation-response pairs in asynchronous, multithreaded, multiparty conversations.
(da Costa Pinho et al., 2013)	Forum	Classification/information retrieval	Student support	The paper discusses the use of text mining to support the design of a pedagogical agent that mediates synchronous online discussions of academic texts by undergraduate students of English as a foreign language.
(McLaren et al., 2007)	Forum	Classification	Student support	This paper discusses preliminary steps taken in using machine learning techniques to support the awareness indicators
(Li et al., 2008)	Forum	Information retrieval	Student support	This paper presents an enhanced discussion forum for both active knowledge-rich interactions and peer-to-peer collaboration.
(Scheuer & McLaren, 2008)	Forum	NLP	Student support	This paper provides an overview of the ARGUNAUT project and an in-depth treatment of the deep loop classification system.

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TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Yu, DiGangi, & Jannasch-Pennell, 2011)	Motivation	Theoretical	Student support	This paper illustrates how text mining of open-ended responses from a student survey could yield valuable information for improving student experience management (SEM).
(Liu et al., 2013)	Online assignments	Visualization	Student support	This paper describes tracer, a novel learning analytic system to visualize behavioral patterns of students while writing and measuring engagement.
(Hsu et al., 2011)	Online assignments	Information extraction	Student support	This study presents an approach to automatically conduct formative assessment and to visualize the results for instructors and learners.
(Petersen, 2007)	Online assignments	NLP	Student support	This study uses natural language processing technology to assess reading level and simplify text for bilingual education.
(Madnani, Burstein, Sabatini, Biggers, & Andreyev, 2016)	Online assignments	NLP	Student support	This paper presents a web-based tool that uses NLP algorithms to automatically generate customizable linguistic activities that are grounded in language learning research.
(Paiva & Nielsen, 2014)	Online assignments	Clustering	Student support	This paper discusses the comprehension SEEDING system and how it enhances the classroom discussion
(Hung, 2012)	Document	Survey	Theoretical	This study investigated the longitudinal trends of e-learning research using text mining techniques
(Nunes, Kawase, Siehndel, Casanova, & Dietze, 2013)	Essay	Text simplification	Theoretical	This paper presents a text simplification method that transforms complex sentences into simplified forms.
(Simon, Laura, Karen, Bart, & Dirk, 2016)	Essay	Theoretical	Theoretical	This paper focuses on the conceptual and empirical associations between those rubric-marks and textual features of the reports on a set of natural language processing (NLP) indicators.
(Yavuz et al., 2008)	Essay	Classification	Theoretical	The purpose of the current study is to investigate the extent of involvement of Turkish university students in academic dishonesty practices facilitated through internet and to question the conditions which lead to e-dishonesty.
(SHROFF and Shroff & Deneen, 2011)	Forum	Theoretical	Theoretical	This paper assesses textual feedback to support student intrinsic motivation using a collaborative text-based dialogue system.
(Dzikovska et al., 2014)	Forum	NLP	Theoretical	The paper describes a system that teaches conceptual knowledge about basic electronics and electricity through guided experimentation with a circuit simulator and reflective dialogue to encourage effective self-explanation.
(Mazzolini & Maddison, 2007)	Forum	Theoretical	Theoretical	This study investigated asynchronous forums that are used for tutorial-type teaching purposes and form part of the assessment mix in Swinburne astronomy online (SAO).
(Wen, Yang, & Rose, 2014)	Forum	Classification/ Theoretical	Theoretical	This paper explores mining collective sentiment from forum posts in a massive open online course (MOOC) in order to monitor students' trending opinions towards the course and major course tools, such as lecture and peer-assessment.

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TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Azevedo, Behar, & Reategui, 2010)	Forum	Classification/ clustering	Theoretical	This paper proposes a qualitative analysis of discussion forums using a particular text mining technique which uses a graph formalism to represent relevant terms found in a text, as well as their relationships.
(Shum et al., 2016)	Motivation	Theoretical	Theoretical	The aim of this paper is discuss analytics that can help to better understand both the writing process as well as the final product, as well as their interactions with task demands, such as essay genre and voice
(Comer, 2016)	Motivation	Theoretical	Theoretical	This paper uses the frame of writing transfer to explore how researchers can transfer strategies, approaches, and knowledge about writing gained from big-data writing analytics to other writing pedagogy contexts.
(Dowell, Brooks, Kovanović, Joksimović, & Gašević, 2017)	Motivation	Theoretical	Theoretical	This study explores the temporal changes in MOOC learners' language and discourse characteristics.
(Sethi & Singla, 2016)	Motivation	Theoretical	Theoretical	The paper aims to address the process of natural language learning and its implication in the educational settings
(Knight, Allen, Gibson, McNamara, & Shum, 2017)	Motivation	Theoretical	Theoretical	This study aims to build capacity in the learning analytics community and developing an approach to resourcing for building "writing analytics literacy".
(Litman, 2016)	Motivation	Theoretical	Theoretical	This paper organizes and gives an overview of natural language processing to address the needs of instructors and students, focusing on opportunities as well as challenges.
(Alhawiti, 2014)	Motivation	Theoretical	Theoretical	The paper aims to address the process of natural language learning and its implication in the educational settings.
(Wen, Yang, & Rosé, 2014)	Motivation	Theoretical	Theoretical	This paper proposes to gauge a student's engagement using linguistic analysis applied to the student's forum posts within the MOOC course.
(Lee, Cheng, & Zeleke, 2014)	Motivation	Theoretical	Theoretical	In this study, the authors attempt to apply text mining method to analyze students' written reasons of a question related to the concept of variation.
(Baker et al., 2010)	Motivation	Theoretical	Theoretical	The authors study the incidence, persistence, and impact of students' cognitive-affective states during their use of three different computer-based learning environments.
(Nagashree & Pujari, 2016)	Online assignments	Classification	Theoretical	This paper describes a tutor assisting e-framework (TAeF) that enables the tutors to analyze the quality of a question bank.
(Holcomb & Buell, 2018)	Online assignments	Theoretical	Theoretical	The authors of this study have prototyped software to study revision of students' writing processes in a large corpus of student papers.
(Ward & Litman, 2008)	Others	Theoretical	Theoretical	This study measures cohesion by counting semantic similarity (the repetition of meaning) as well as lexical reiteration (the repetition of words) cohesive ties in a corpora of tutoring dialogues.

(Continues)

TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Brinton et al., 2014)	Social network	Theoretical	Theoretical	The authors study user behavior in the courses offered by a major massive online open course (MOOC) provider during the summer of 2013.
(Bhaduri & Roy, 2017)	Forum	NLP	Analytics	The purpose of this paper is to understand the key similarities and differences between the choice of words used in the mission statements of the two groups: public colleges and private colleges of engineering.
(Ferreira, Kovanović, Gašević, & Rolim, 2018)	Forum	Others	Analytics	This paper presents a novel method for the evaluation of students' use of asynchronous discussions in online learning environments.
(Lyons et al., 2018)	Forum	Theoretical	Analytics	This study aims to add to the existing literature by researching language use in a wide range of mental distress categories by using communication in online peer-to-peer support networks.
(Knight, Buckingham Shum, Ryan, Sándor, & Wang, 2018)	Others	Classification	Analytics	This paper describes the design of a natural language processing (NLP) tool to provide formative feedback.
(Atapattu, Falkner, & Falkner, 2017)	Others	Classification	Analytics	This study investigates the effectiveness of automated approaches in extracting concept maps from lecture slides and the suitability of auto-generated concept maps as a pedagogical tool.
(Amigud, Arnedo-Moreno, Daradoumis, & Guerrero-Roldan, 2017)	Others	IR	Analytics	This paper proposes a novel approach to visualization of textual data that depicts information on a continuum (temporal or spatial) allowing inferences to be made about thematic organization of a document and its structure.
(Hirokawa & Flanagan, 2018)	Chat	Classification	Evaluation	In this article, the authors approach the problem of identifying characteristic differences and the classification of native languages from the perspective of 15 automatically predicted writing errors by online language learners.
(Mirza, Joy, & Cosma, 2017)	Document	NLP	Evaluation	This paper focuses to identify whether a data set consisting of student programming assignments is rich enough to apply coding style metrics to detect similarities between code sequences.
(Neto, Cavalcanti, Costa, Ferreira, & Dionísio, 2017)	Essay	Classification	Evaluation	This article proposes the analysis of different algorithms for identification of prejudiced phrases in essays.
(Rahimi et al., 2017)	Essay	NLP	Evaluation	This paper presents an investigation of score prediction based on natural language processing for two targeted constructs within analytic text-based writing.
(Balyan et al., 2017)	Essay	NLP	Evaluation	This study examined how machine learning and natural language processing (NLP) techniques can be leveraged to assess the interpretive behavior that is required for successful literary text comprehension.
(Kong, Li, & Song, 2018)	Essay	Others	Evaluation	This study evaluated a bilingual text-mining system for understanding learner-generated text in the learning management systems through automatic identification and counting of matching key words.
(Vajjala, 2018)	Essay	Theoretical	Evaluation	This article addresses that by exploring the role of various linguistic features in automatic essay scoring using two publicly available datasets of non-native English essays written in test taking scenarios.

(Continues)

TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Cavalcanti et al., 2017)	Forum	NLP	Evaluation	This paper aims to propose a new measure of similarity between sentences in Portuguese for detection of internal plagiarism in educational forums.
(Newman & Joyner, 2018)	Others	Classification	Evaluation	The authors used a sentiment analysis tool, VADER (valence aware dictionary and sEntiment Reasoner), to analyze student evaluations of teaching (SET) of a single course.
(Nguyen, Xiong, & Litman, 2017)	Others	Classification	Evaluation	A peer-review system that automatically evaluates and provides formative feedback on free-text feedback comments of students was iteratively designed and evaluated in college and high-school classrooms.
(Wiley et al., 2017)	Others	NLP	Evaluation	This article describes several approaches to assessing student understanding using written explanations that students generate as part of a multiple-document inquiry activity on a scientific topic (global warming).
(Godea et al., 2018)	Question	Classification	Evaluation	This paper presents a system that classifies questions asked in an educational context based on the expected characteristics of answers, with a future goal to facilitate the analysis of student responses.
(Ruseti et al., 2018)	Question	Classification	Evaluation	This study assesses the extent to which machine learning techniques can be used to predict question quality.
(Saha et al., 2018)	Question	Classification	Evaluation	This study proposes a novel feature encoding based on partial similarities of tokens, its extension to part-of-speech tags and question type information.
(Passonneau et al., 2018)	Question	Classification	Evaluation	This study presents two methods that automate the content assessment
(Erabadda, Ranathunga, & Dias, 2017)	Question	Classification	Evaluation	This paper presents a system that automatically identifies errors made by students in answering algebra questions that require multiple steps.
(Ramachandran, Gehringer, & Yadav, 2017)	Question	NLP	Evaluation	The authors developed an automated meta review software that provides rapid feedback to reviewers on their assessment of authors' submissions.
(Kadupitiya et al., 2017)	Question	NLP	Evaluation	The authors introduce a system that can be easily used to assess answers to both numerical and algebraic type word problems and automatically identifies the exact errors made by students by using a marking rubric.
(Wijesinghe, Kadupitiya, Ranathunga, & Dias, 2017)	Question	Others	Evaluation	This paper presents a system capable of automatically assessing student answers consisting of Venn and Euler diagrams
(Altrabshesh et al., 2017)	Essay	Others	Feedback	The authors developed the SA-E system for analyzing students' real-time feedback provided via social media, and presented the evaluation of this system in real settings with lecturers and students.
(Woods et al., 2017)	Essay	Others	Feedback	This paper first establishes a new ordinal essay scoring model and its state of the art performance compared to recent results in the automated essay scoring field.
(Goldin et al., 2017)	Others	Theoretical	Feedback	This paper focuses on the role of formative feedback through a lens of how technologies both support student learning and enhance our understanding of the mechanisms of feedback.

(Continues)

TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Nam, Frishkoff, & Collins-Thompson, 2017)	Others	NLP	Generation	This paper explores the use of multidimensional semantic word representations for modeling and predicting short- and long-term learning outcomes in a vocabulary tutoring system.
(Pirovani, Spalenza, & Oliveira, 2017)	Question	NLP	Generation	This work presents a strategy that aims at automatic question generation from named entities identified in teaching texts.
(Sinclair et al., 2018)	Chat	NLP	Others	This paper measures the influence of ability on lexical priming to understand how learner ability interacts with alignment.
(Chen et al., 2017)	Document	Classification	Others	This paper presents a system called WeiboFinder to suggest topic-based words and documents related to a target word for Chinese learners.
(Jiang, Feng, Cong, Miao, & Li, 2017)	Document	NLP	Others	This paper proposes a novel cascade model, which can capture both the latent semantics and latent similarity by modeling MOOC data.
(Wu, 2017)	Forum	Others	Others	This study tries to design a mechanism that reduces off-topic discussion by means of filtration prompting strategy and self-reflection strategy.
(Liu, Sun, Zhang, Cheng, & Liu, 2018)	Forum	Theoretical	Others	This article adopts the content analysis method to summarize students' engagement patterns within a course forum in a small private online course (SPOC) system.
(Liu, Zhang, Wang, & Chen, 2017)	Others	Classification	Others	This paper aims to mine and analyze topic information hidden in the unstructured reviews data in MOOC.
(Chau, Barria-Pineda, & Brusilovsky, 2018)	Others	Clustering	Others	This paper presents a course-adaptive recommender system that assists instructors of programming courses in selecting the most relevant learning materials.
(Ferreira & Fernandes, 2017)	Others	Clustering	Others	This work deals with the evaluation of texts written by students, who can, for example, be captured in chats and forums in an AVA, to detect personality traits.
(Thanasuan, Chaisangmongkon, & Wongviriyawong, 2017)	Others	NLP	Others	This study combined one symbolic technique for an unsupervised machine learning with clustering algorithm to discover emerging patterns among texts written in Thai that could reflect student's learning attitudes.
(Gutu, Dascalu, Ruseci, Rebedea, & Trausan-Matu, 2017)	Others	Others	Others	This paper presents a research on using Word2Vec for determining implicit links in multiparticipant computer-supported collaborative learning chat conversations.
(Dias, Barbosa, Barrère, & de Souza, 2017)	Others	Others	Others	This paper proposes an approach to identify similar resources in instructional resources repositories through the use of DBpedia categorizations.
(Aguar & Cury, 2017)	Others	Others	Others	This article presents a new technological approach for the automatic construction of conceptual maps from scientific texts, in Portuguese language.
(Li, Gobert, Dickler, & Morad, 2018)	Others	Theoretical	Others	This study examined the use of academic language in students' scientific explanations in the form of written claim, written evidence, and written reasoning (CER) statements during science inquiry within an intelligent tutoring system.

(Continues)

TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Barrón-Estrada, Zatarain-Cabada, Oramas-Bustillos, & González-Hernández, 2017)	Chat	Classification	Support	This paper presents an implementation of sentiment analysis module that works in an affective intelligent tutoring system.
(Perikos et al., 2017)	Chat	NLP	Support	This paper presents an assistance and feedback mechanism in an intelligent tutoring system for teaching conversion of natural language into logic.
(Liu, Pardo, & Liu, 2017)	Essay	Others	Support	This article describes a learning analytic system that analyzes writing behaviors, and creates visualizations to support student engagement.
(Azevedo, Ferreira, Mendonca, & Miranda, 2017)	Forum	Classification	Support	This work proposes a technique of sentiment analysis that helps the instructor in the detection of student motivation from postings of educational forums, predicting a possible case of evasion.
(Dionísio, Ferreira, Cavalcanti, Carvalho, & Neto, 2017)	Forum	Classification	Support	This paper presents an approach that uses text mining to automatically identify collaboration in educational forums.
(Rolim, Ferreira, & Costa, 2017)	Forum	Others	Support	This study aims to develop an approach to manage educational forums posts using machine learning techniques
(Botelho, Baker, & Heffernan, 2017)	Others	Classification	Support	This study aims to construct a new “deep” sensor-free affect detectors and report significant improvements over previously reported models.
(Howard, Jordan, Di Eugenio, & Katz, 2017)	Others	NLP	Support	In this paper the authors describes a unique peer dialogue agent that they created to test the effects of tracking and reacting to initiative shifts.
(Dun, Wang, Wang, & Hao, 2017)	Question	Classification	Support	This paper proposes an approach based on question topic mining for revealing learners' concerned topics in real community question-answering systems.
(Taek, François, Desmet, & Fairon, 2018)	Chat	NLP	Others	This paper introduces NT2Lex, a novel lexical resource for Dutch as a foreign language (NT2).
(Ramanarayanan & LaMar, 2018)	Chat	NLP	Evaluation	This paper formulates a Markov decision process based measurement model, and applies it to text chat data collected from crowd sourced native and non-native English language speakers interacting with an automated dialogue agent.
(Klerke, Martínez-Alonso, & Plank, 2018)	Chat	NLP	Others	This paper presents the submission to the 2018 Duolingo shared task on second language acquisition Modeling (SLAM).
(Nayak & Rao, 2018)	Chat	NLP	Others	This paper uses a logistic regression model to predict the likelihood of a student making a mistake while answering an exercise on Duolingo in all three language tracks.
(Osika, Nilsson, Sydoruchuk, Sahin, & Huss, 2018)	Chat	NLP	Others	This paper proposes a novel ensemble model to predict student knowledge gaps.
(Rich, Osborn Popp, Halpern, Rothe, & Gureckis, 2018)	Chat	NLP	Others	This study used a well-known class of algorithms (gradient boosted decision trees), with features partially informed by theories from the psychological literature for the SLAM shared task.

(Continues)

TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Xu et al., 2018)	Chat	NLP	Others	This paper proposes a neural network based system to utilize rich contextual, linguistic and user information for second language acquisition Modeling.
(Chinkina et al., 2018)	Document	IR	Support	In the online study described in the paper, the authors collected 240 responses from English instructors in order to investigate whether they preferred automatic input enrichment over web search when selecting reading material for class.
(Gao, Davies, & Passonneau, 2018)	Document	NLP	Analytics	This paper reports on a project to examine how and why automated content analysis could be used to assess precis writing by university students.
(Bingel, Barrett, & Klerke, 2018)	Document	Others	Evaluation	This paper presents the first work on predicting reading mistakes in children with reading difficulties based on eye-tracking data from real-world reading teaching.
(Bryant & Briscoe, 2018)	Essay	NLP	Evaluation	This paper re-examines language models (LMs) in grammatical error correction (GEC) and show that it is entirely possible to build a simple system.
(Zhang & Litman, 2018)	Essay	Others	Evaluation	This paper presents an investigation of using a coattention based neural network for source-dependent essay scoring.
(Horbach, Stenmanns, & Zesch, 2018)	Essay	Others	Evaluation	This study investigates the feasibility of cross-lingual content scoring, a scenario where training and test data in an automatic scoring task are from two different languages.
(Nadeem & Ostendorf, 2018)	Essays	NLP	Evaluation	This paper proposes a neural approach, training on science and other informational texts for estimating linguistic complexity.
(Holz, Weiss, Brehm, & Meurers, 2018)	Essays	NLP	Others	This paper presents COAST, a web-based application to easily and automatically enhance syllable structure, word stress, and spacing in texts, that was designed in close collaboration with learning therapists to ensure its practical relevance.
(Wani, Mathias, Gajjam, & Bhattacharyya, 2018)	Others	Classification	Evaluation	This paper presents an effective system using voting ensemble classifiers to detect contextually complex words for non-native English speakers.
(Vajjala & Rama, 2018)	Others	Classification	Others	This study explores universal CEFR classification using domain-specific and domain-agnostic, theory-guided as well as data-driven features.
(Aroyehun, Angel, Pérez Alvarez, & Gelbukh, 2018)	Others	Classification	Others	This paper describes the systems of NLP-CIC team that participated in the complex word identification (CWI) 2018 shared task using two approaches: feature engineering and a deep neural network.
(De Hertog & Tack, 2018)	Others	Classification	Others	This paper describes a system for the CWI-task that includes information on five aspects of the (complex) lexical item, namely distributional information of the item itself, morphological structure, psychological measures, corpus-counts and topical information.
(Vajjala & Lucic, 2018)	Others	NLP	Evaluation	This paper describes the collection and compilation of the OneStopEnglish corpus of texts written at three reading levels, and demonstrates its usefulness for through two applications—automatic readability assessment and automatic text simplification.

(Continues)

TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Zhang, Chen, Cummins, Andersen, & Briscoe, 2018)	Others	NLP	Evaluation	The authors of this paper suggest that it could be useful to include the other texts written by this learner in the same exam as extra references in an ATS system.
(Alfter & Volodina, 2018)	Others	NLP	Others	This paper present work-in-progress where we investigate the usefulness of previously created word lists to the task of single-word lexical complexity analysis and prediction of the complexity level for learners of Swedish as a second language.
(Bingel & Bjerva, 2018)	Others	NLP	Others	The authors approach the 2018 shared task on complex word identification by leveraging a cross-lingual multitask learning approach.
(Butnaru & Ionescu, 2018)	Others	NLP	Others	This paper presents a kernel-based learning approach for the 2018 complex word identification (CWI) shared task.
(Kajiwara & Komachi, 2018)	Others	NLP	Others	This paper presents the TMU systems that use random forest classifiers and regressors whose features are the number of characters, the number of words, and the frequency of target words in various corpora.
(Tomoschuk & Lovelett, 2018)	Others	NLP	Others	This study explores a variety of linguistic and cognitive features to better understand second language acquisition in early users of the language learning app Duolingo.
(Tomoschuk & Lovelett, 2018)	Others	NLP	Others	This paper introduces a corpus of between-draft revisions of student argumentative essays, annotated as to whether each revision improves essay quality.
(Lugini, Litman, Godley, & Olshefski, 2018)	Others	NLP	Support	The authors introduce an annotation scheme, then show that the scheme can be used to produce reliable annotations and that the annotations are predictive of discussion quality.
(Settles, Brust, Gustafson, Hagiwara, & Madnani, 2018)	Others	Others	Others	This paper presents the task of second language acquisition (SLA) modeling
(King & Dickinson, 2018)	Others	Others	Analytics	This paper aims to investigate issues of variability and acceptability in written text, for both non-native speakers (NNSs) and native speakers (NSs).
(del Río Gayo, Zampieri, & Malmasi, 2018)	Others	Others	Others	This paper presents the NLI-PT, the first Portuguese dataset compiled for native language identification (NLI), the task of identifying an author's first language based on their second language writing.
(Loukina, Zechner, Bruno, & Beigman Klebanov, 2018)	Question	Classification	Evaluation	This paper compares the performance of an automated speech scoring engine using two corpora.
(Rudzewitz et al., 2018)	Question	Classification	Feedback	This paper presents a novel approach leveraging task information to generate the expected range of well-formed and ill-formed variability in learner answers along with the required diagnosis and feedback.
(Kulkarni & Boyer, 2018)	Question	Classification	Generation	This paper explores the possibility of building a tutorial question answering system for Java programming from data sampled from a community-based question answering forum.

(Continues)

TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Ha & Yaneva, 2018)	Question	NLP	Evaluation	This paper proposes a fully automatic method for generating distractor suggestions for multiple-choice questions used in high-stakes medical exams.
(Jin, King, Hussein, White, & Danforth, 2018)	Question	NLP	Generation	This paper investigates the use of paraphrasing for data augmentation and neural memory-based classification, finding that the two methods work best in combination.
(Flor & Riordan, 2018)	Question	NLP	Generation	This paper presents a novel rule-based system for automatic generation of factual questions from sentences, using semantic role labeling (SRL) as the main form of text analysis.
(Liang et al., 2018)	Question	Others	Evaluation	This study investigates how machine learning models, specifically ranking models, can be used to select useful distractors for multiple choice questions.
(Kechaou et al., 2011)	Blog	Sentiment analysis/classification	Analytics/student information	This study applying three traditional feature selection methods (IG, MI and CHI) to the sentiment classification of e-learning blogs and forums.
(Ferguson & Shum, 2011)	Chat	None	Analytics/student information	This study investigates the use of sociocultural discourse analysis to analyze synchronous text chat during an online conference.
(Rus, Lintean, & Azevedo, 2009)	Chat	Information extraction	Analytics/student information	This paper presents several methods to automatically detecting students' mental models in MetaTutor.
(Lintean et al., 2012)	Chat	NLP	Analytics/student information	This article describes the problem of detecting the student mental models, that is, students' knowledge states, during the self-regulatory activity of prior knowledge activation in MetaTutor.
(Chalfoun, De Menezes, & Frasson, 2007)	Chat	Classification	Analytics/student information	This paper presented an agent-based system to assist in effectively learning the vocabulary of a foreign language, namely Portuguese.
(Simko & Bieleková, 2009)	Course information	Information retrieval	Analytics/student information	This paper presented a method of automatic concept relationship discovery for an adaptive e-course.
(Kolog, Montero, & Sutinen, 2016)	Document	Sentiment analysis	Analytics/student information	This study investiga the influence of counselors' state of emotions on their emotion perception through annotation agreement of emotions in text.
(Roy, Sarkar, & Ghose, 2008)	Document	Information extraction	Analytics/student information	This article presented automatic annotation tool for annotating documents with metadata such as concepts, type of concepts, topic and the learning resource type.
(Aghaee, 2015)	Email	Classification	Analytics/student information	To help students who are in the final stages of the project, this study uses a content analysis tool to analyze emails sent to a support group (ThesisSupport).
(Whitelock et al., 2015)	Essay	NLP	Analytics/student information	This article presents the OpenEssayist tool focused on real-time learning analysis that combines a language analysis mechanism and a web application that uses the output of the language analysis engine to generate feedback.
(Clemens et al., 2013)	Essay	Classification	Analytics/student information	(workshop)

(Continues)

TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Nitin et al., 2015)	Forum	Clustering	Analytics/student information	This paper evaluated aspect or topic based sentiment mining techniques to build a solution to analyze topics and their sentiments from student generated feedback in universities.
(Nunes et al., 2014)	Forum	Topic Modeling	Analytics/student information	This paper propose a topic extraction process that combines semantic technologies and a statistical method to find, expose and recommend relevant topics to be discussed in online discussion forums.
(Azevedo et al., 2011)	Forum	Information extraction	Analytics/student information	This paper presents a study aimed at investigating on whether the text mining technique using graphs can be used to analyze the relevance of the messages in online forums.
(Murray, Xu, & Woolf, 2013)	Forum	Classification	Analytics/student information	This article proposes to use text processing methods (LJWC and CohnMetrix) and machine learning to classify social deliberative ability.
(Lin et al., 2009)	Forum	Classification	Analytics/student information	This study uses text mining techniques to classify postings of discussion forums in the following classes: Announcement, a question, clarification, interpretation, conflict, assertion, etc.
(Wang et al., 2007)	Forum	Classification	Analytics/student information	Text
(Tucker et al., 2014)	Forum	Classification/sentiment analysis	Analytics/student information	This research is to mine student-generated textual data to quantify their impact on student performance and learning outcomes.
(Cobo et al., 2011)	Forum	Clustering	Analytics/student information	This paper the use of time series and an agglomerative hierarchical clustering algorithm is proposed with the aim of determining what different behavior patterns are adopted by students in online discussion forums.
(Joksimovic et al., 2014)	Forum	NLP	Analytics/student information	This study analyzed postings of online discussions according to the levels of cognitive presence of CoL using the LJWC framework.
(Kim & Shaw, 2014)	Forum	Information retrieval	Analytics/student information	This article presented the PedaBot tool that is designed to aid student knowledge acquisition, promote reflection about course topics and encourage student participation in discussions.
(Kim et al., 2008)	Forum	Information retrieval	Analytics/student information	This paper describes the system and presents a comparative analysis of the information retrieval techniques used to respond to free-form student discussions.
(Chiru & Trausan-Matu, 2012)	Forum	Classification	Analytics/student information	This paper presented an application for the identification and classification of important moments from the students' collaborative chats.
(Tagawa, Yasutake, Yamakawa, Inoue, & Sumiya, 2007)	Forum	Information extraction	Analytics/student information	This paper is to investigate the structural characteristics of networks formed by co-occurrence of keywords in each message in discussion on bulletin board system used in e-learning courses.

(Continues)

TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Knight & Littleton, 2015)	Motivation	Theoretical	Analytics/student information	This paper maps the terrain of discourse-centric learning analytics (DCLA), outlining the distinctive contribution of DCLA and outlining a definition for the field moving forwards.
(Urban-Lurain et al., 2009)	Online assignments	NLP	Analytics/student information	This article exploring the use of computerized lexical analysis of students' writing in large enrollment undergraduate biology and geology courses.
(Cheng & Chau, 2015)	Others	Classification	Analytics/student information	This paper reports and discusses on a project about designing a digital tool to support Chinese undergraduate students in reflecting on their English language (L2) learning experience.
(Ramos-Soto, Lama, Vázquez-Barreiros, Bugarín, & Mucientes, 2015)	Others	Information extraction	Analytics/student information	This paper presented the soft learn activity reporter (SLAR) service which automatically generates textual short-term reports about learners' behavior in virtual learning environments.
(Omheni, Kalboussi, Mazhoud, & Hadjkacem, 2015)	Others	Classification	Analytics/student information	This paper proposed modeling learner's personality by referring to their annotations. The experiments show the significant role of annotation activity to reflect certain learner' personality traits.
(Colace, Casaburi, De Santo, & Greco, 2015)	Social network	Classification	Analytics/student information	This study investigated the adoption of a probabilistic approach based on the latent Dirichlet allocation (LDA) as sentiment grabber. The proposed method has been tested in different context including a collaborative learning scenario.
(Tobarra et al., 2014)	Social network	Topic Modeling	Analytics/student information	This article analyzed the students' behavior patterns in the forums of a distance subject, and characterize the relevant topics and subtopics from the forums' messages belonging to two academic years.
(Altrabshah, Gaber, & Cocea, 2013)	Social network	Classification	Analytics/student information	This paper proposed a sentiment analysis system for education (SA-E).
(Leong et al., 2012)	Social network	Classification	Analytics/student information	This paper explores the potential application of sentiment mining for analyzing short message service (SMS) texts in teaching evaluation.
(Ortigosa et al., 2014)	Social network	Classification	Analytics/student information	This paper presents a new method for sentiment analysis in Facebook. According to the authors, this information can be used by adaptive e-learning systems to support personalized learning.
(Di Capua, Di Nardo, & Petrosino, 2015)	Social network	Classification	Analytics/student information	This paper reports the activities of the group in sentiment analysis to be engaged in an e-learning system.
(Song, Lin, & Yang, 2007)	User feedback	Classification	Analytics/student information	This paper utilized a method of opinion mining to help e-learning systems to know the users' opinions on the course-wares.
(Altrabshah, Cocea, & Fallahkhair, 2014)	User feedback	Classification	Analytics/student information	This study evaluated machine learning algorithms in the task of analyzing feedback feelings of students.
(Gunmarsson & Alterman, 2012)	Blog	None	Evaluation	This paper presents a method for monitoring student progress based on their participation in blogging.

(Continues)

TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Dascalu, Trausan-Matu, et al., 2015)	Chat	NLP	Evaluation	This paper validated ReaderBench, a system capable of evaluating collaboration in discourse based on a social knowledge-building perspective.
(Lehman et al., 2012)	Chat	Classification	Evaluation	This article proposed and evaluated a model to classify answers as correct or incorrect in intelligent tutors systems based on dialogues.
(Cavalcanti, Pires, Cavalcanti, & Pires, 2012)	Document	Classification	Evaluation	This paper utilized text mining methodology for academic dishonesty (cheating) detection and evaluation on open-ended college exams.
(Dessus, 2009)	Document	NLP	Evaluation	This study presented an overview of LSA-based systems that have been used in instructional settings.
(Sung et al., 2016)	Document	Summarization	Evaluation	This study developed an automatic summary assessment and feedback system based on latent semantic analysis (LSA) to provide score, concept and semantic feedback.
(Dikli, 2006)	Essay	Survey	Evaluation	This article provide an overview of current approaches to automated scoring of essays.
(Rudner et al., 2006)	Essay	Classification	Evaluation	This report provides a two-part evaluation of the IntelliMetric automated essay scoring system.
(Farrus & Costa-jussa, 2013)	Essay	NLP/LSA	Evaluation	This paper analyzes and discusses some of the most advanced assessment systems in education. Including an automatic assessment tool that allows the student to evaluate themselves at any time and receive instant feedback.
(Shermis et al., 2010)	Essay	Survey	Evaluation	Text
(Warschauer & Ware, 2006)	Essay	Theoretical	Evaluation	This article analyzed recent developments in automated writing evaluation (AWE) and propose a multifaceted process/product research program on the instructional use of AWE.
(Varner et al., 2013)	Essay	Survey	Evaluation	This study utilized automated textual analyses to examine potential misalignments between students' and instructors' evaluation criteria for writing quality.
(Simsek et al., 2015)	Essay	NLP	Evaluation	This paper describes an evaluation study of a particular language analysis tool, the Xerox incremental parser (XIP), on undergraduate social science student essays.
(Ericsson & Haswell, 2006)	Essay	Theoretical	Evaluation	Text
(Kakkonen & Mozgovoy, 2010)	Essay	Survey	Evaluation	This study provides an empirical evaluation of eight plagiarism detection systems for student essays.
(Crossley et al., 2015)	Essay	Classification/NLP	Evaluation	This study investigates a new approach to automatically assessing essay quality that combines traditional approaches based on assessing textual features with new approaches that measure student attributes.
(Lárusson & White, 2012)	Essay	NLP	Evaluation	This paper describes a new method for the objective evaluation of student work through the identification of original content in writing assignments.

(Continues)

TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Allen, Crossley, & McNamara, 2015)	Essay	NLP	Evaluation	This paper investigated linguistic factors that relate to misalignment between students' and instructors' ratings of essay quality.
(Oberreuter & Velásquez, 2013)	Essay	Classification	Evaluation	This study explore the problem of text plagiarism and the possibility of its detection by the use of computer algorithms.
(Jiang & Xu, 2008)	Essay	Text similarity	Evaluation	This paper a novel feature for semantic scoring is presented to assess English proficiency.
(Crossley et al., 2013)	Essay	NLP	Evaluation	This study present an evaluation of the writing pal (W-pal) intelligent tutoring system (ITS) and the W-pal automated writing evaluation (AWE) system through.
(Stappenbelt & Rowles, 2009)	Essay	Theoretical	Evaluation	In this study an online plagiarism detection software was adopted as a learning tool for students instead.
(Snow et al., 2015)	Essay	NLP	Evaluation	This study investigates how students vary in their use of linguistic features across 16 prompt-based essays.
(Elouazizi et al., 2017)	Essay	NLP	Evaluation	This paper report on a model that uses a mathematically and cognitively augmented LSA method to automatically assess aspects of written argumentation.
(Jackson, Boonthum-Denecke, & McNamara, 2015)	Essay	NLP	Evaluation	This article describes the incorporation of NLP in the system called interactive strategy training for active Reading and thinking (iSTART).
(McNAMARA et al., 2009)	Essay	NLP	Evaluation	This study describes a new iSTART module recently developed and tested, called interactive paraphrasing (IP), in which students are interactively and adaptively taught how to paraphrase sentences.
(Mozgovoy, Kakkonen, & Cosma, 2010)	Essay	Theoretical	Evaluation	This article an classification of types of plagiarism is presented, and an analysis is provided of the most promising technologies that have the potential of dealing with the limitations of current state-of-the-art systems.
(Hughes et al., 2012)	Essay	Classification	Evaluation	This study investigated the efficacy of three different algorithms at classifying student essays according to an expert model of the essay topic.
(Lui et al., 2007)	Forum	Classification	Evaluation	This paper evaluates text categorization and examines whether the attainable accuracy can satisfy the requirements of common content analysis tasks.
(Wellner & Pustejovsky, 2007)	Forum	NLP	Evaluation	This study presented a fully automated system capable of identifying the arguments of discourse connectives.
(Rubio & Villalon, 2016)	Forum	NLP/LSA	Evaluation	This work presents an automatic method to evaluate and quantificate participation in order to score messages using text mining algorithm.
(He, 2013)	Forum	Clustering	Evaluation	The study applied data mining and text mining techniques to analyze two different datasets and then conducted an in-depth correlation analysis for two educational courses with the most online questions and chat messages respectively.

(Continues)

TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Lopez, Luna, Romero, & Ventura, 2012)	Forum	Classification/ clustering	Evaluation	This paper proposes a classification via clustering approach to predict the final marks in a university course on the basis of forum data.
(Yoo & Kim, 2014)	Forum	Theoretical	Evaluation	This study used emotional features covered by LIWC (linguistic inquiry and word count), cohesiveness of the dialogue, the coherence captured by Coh-Metrix, and temporal patterns of participation for part of supporting instructional assessment of online discussions.
(Sorour, Mine, Goda, & Hirokawa, 2014)	Forum	Classification/ sentiment analysis	Evaluation	This paper employ latent semantic analysis technique (LSA) to extract semantic information and artificial neural network model to the analyze comments and predicting students' performance.
(Feeney & Heilman, 2008)	Forum	NLP	Evaluation	This paper describe an algorithm for generating automatically reading comprehension questions.
(Weng, Chang, Yen, Shih, & Hsu, 2014)	Forum	Classification	Evaluation	This article employs the rule-space model and the student-problem chart for learning performance evaluation.
(Bishop & Verleger, 2011)	Motivation	Theoretical	Evaluation	This work analyzes sketches generated by students during model identification activities (MEAs).
(Batane, 2010)	Motivation	Theoretical	Evaluation	This paper reports on a pilot project of the Turnitin plagiarism detection software.
(Maurer et al., 2006)	Motivation	Theoretical	Evaluation	This study report on some results of textual plagiarism detection software.
(Adeva et al., 2006)	Online assignments	Classification	Evaluation	This paper describe a novel plagiarism detection system and its integration with an e-portfolio used in first year engineering teaching.
(Cutrone & Chang, 2010)	Online assignments	NLP/information retrieval	Evaluation	This study used natural language processing for evaluated of student responses to open questions based on the semantic meaning of those responses.
(Leeman-Munk, Wiebe, & Lester, 2014)	Online assignments	Classification	Evaluation	This paper presented, WriteEval, a hybrid text analytics method for analyzing student-composed text written in response to constructed response questions.
(Wang & Seneff, 2007)	Online assignments	Machine translate	Evaluation	This paper have presented an algorithm for automatically assessing spoken translations produced by language learners.
(Trivedi et al., 2011)	Online assignments	Clustering	Evaluation	This work introduce a more sophisticated method by which we can ensemble together multiple models based upon clustering students.
(Ramachandran & Gehring, 2011)	Online assignments	LSA	Evaluation	This work use machine-learning techniques such as latent semantic analysis (LSA) and cosine similarity to classify comments based on their quality and tone.
(Escudeiro et al., 2011)	Online assignments	Classification	Evaluation	This study evaluated models of grouping of student responses.
(Pascual-Nieto, Pérez-Marín, O'Donnell, & Rodríguez, 2008)	Online assignments	Classification	Evaluation	This study presented web-based application which automatically and adaptively assesses students' free-text answers written in Spanish and English.

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TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Rus et al., 2013)	Online assignments	NLP	Evaluation	This paper report efficacy of using SEMILAR to investigate and tune assessment algorithms for evaluating students' natural language input based on data from the DeepTutor computer tutor.
(Winters, Shelton, & Payne, 2007)	Online assignments	Clustering	Evaluation	This paper use educational data mining techniques to analyze score matrices from university-level computer science courses.
(Scherbinin & Butakov, 2008)	Online assignments	Theoretical	Evaluation	This study concentrate on implementation of well-known anti-plagiarism algorithm for local and global search for the original source of plagiarized assignment.
(Prevost et al., 2012)	Online assignments	NLP	Evaluation	This study investigate the use of lexical analysis software for examining students' constructed responses using a group of three questions related to reaction thermodynamics.
(Lee, Choi, & Kim, 2011)	Online assignments	NLP	Evaluation	This paper presents an automated scoring system which grades students' English writing tests.
(Rahimi et al., 2014)	Online assignments	Classification	Evaluation	This study presented an automated for evaluate approach for response to text assessment (RTA).
(Koh, Wang, Huang, & Lee, 2015)	Online assignments	Summarization	Evaluation	This study proposed a system to automatically grade the summarization questions on English narrative article without correct answer given by instructors.
(Nomura, Ohwaki, Kouno, Saito, & Takahashi, 2011)	Online assignments	Classification	Evaluation	This study show the new algorithm for test generating by using the human expert knowledge.
(Spellmann & Dixon, 2009)	Online assignments	NLP	Evaluation	Text
(Kaser et al., 2013)	Others	Clustering	Evaluation	This paper introduces a method to predict and analyze students' mathematical performance by detecting distinguishable subgroups of children who share similar learning patterns.
(Hanakawa & Obana, 2012)	Others	Classification	Evaluation	This article presented a plagiarism detection system for report examinations in university education.
(Mangina & Kilbride, 2008)	Recommendation systems	Information extraction	Evaluation	This article show a textual document recommendation system.
(Balahadia & Comendador, 2016)	User feedback	Classification	Evaluation	This paper promotes adoption of opinion mining in the faculty performance evaluation system by the students using naive Bayes algorithm.
(Whitelock & Watt, 2007)	Chat	Classification	Feedback	This paper describe the open Mentor that reads and opens assignments written in Microsoft word to extract the tutor comments.
(Dascalu, Stavarache, et al., 2015)	Document	NLP	Feedback	This study presented the ReaderBench framework which automatically assesses textual contributions from students.
(Lewkow et al., 2016)	Essay	NLP	Feedback	This paper describe a scalable platform for learning analytics called OpenACRE (analytics collaborative research environment).

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TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Eisman et al., 2008)	Forum	NLP	Feedback	This paper present a natural language virtual tutoring system that has been developed to assist students during the learning process.
(Zhu, 2015)	Forum	Classification	Feedback	This paper present an advanced cloud-based student response system that can be used in lieu of clickers.
(Yang et al., 2011)	Forum	Classification/NLP	Feedback	This study provides a new approach to addressing the assessment of online discussions, by automating the collection of discussion data and by generating input into the assignment module of the LMS.
(Huang et al., 2007)	Online assignments	Information retrieval	Feedback	This paper, the authors proposed a mobile video QA (question answering) system for online annotation and ubiquitous multimedia learning.
(Akcapinar, 2015)	Online assignments	Sentence similarity	Feedback	This study is intended to decrease learners' plagiaristic behavior in online assignments by providing automated feedback based on text mining analysis.
(Blitsas & Grigoriadou, 2008)	Online assignments	NLP	Feedback	This article presented an methodology that can support automated reasoning from a technical text, and, subsequently, to automated normalized answers assessment.
(Nielsen, Ward, & Martin, 2008)	Online assignments	NLP	Feedback	This paper presents a process for automatically extracting a fine-grained semantic representation of a learner's response to a tutor's question.
(Hwang et al., 2007)	Online assignments	Classification	Feedback	This paper proposed an intelligent English tense learning and diagnostic system which is able to identify student learning problems on English verb tenses.
(Alinaghi & Bahreinejad, 2011)	Online assignments	NLP	Feedback	This paper presents a multiagent system for building a question-answering system in learning management systems and collaborative learning environments.
(Gibson et al., 2017)	User feedback	NLP	Feedback	This paper reports progress on the design, implementation, and validation of a reflective writing analytics platform to provide actionable feedback within a tertiary authentic assessment context.
(Lee & Lim, 2016)	User feedback	Classification	Feedback	This research analyze the feedback from all the students in a university to highlight their key concerns through the key terms in their feedback using text mining method.
(Hsu & Chang, 2012)	Blog	Theoretical	Others	This paper used the text mining technology to analyze the diary of the preservice instructors attending the service learning activities.
(Sándor & Vorndran, 2009)	Chat	Summarization	Others	This article presented an exploratory NLP system in the field of education sciences that highlights the key phrases that should reflect the most important topics of an article.
(Rus, Lintean, Graesser, & McNamara, 2009)	Chat	Sentence similarity	Others	This paper presented an approach to assessing student paraphrases in the intelligent tutoring system iSTART.
(Barnes & Stamper, 2008)	Chat	Classification	Others	This paper proposed a novel application of Markov decision processes (MDPs), a reinforcement learning technique, to automatically generate hints for an intelligent tutor that learns.

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TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Boyer et al., 2010)	Chat	Classification	Others	This work applied hidden Markov modeling to a corpus of annotated task-oriented tutorial dialogue to learn one model for each of two effective human tutors.
(Zhang, 2012)	Chat	Classification	Others	This paper applied topic theme detection using latent semantic analysis to identify discussion themes and potential target audiences.
(Selent & Hefferman, 2014)	Chat	Classification	Others	The goal of this research is to improve existing forms of help in tutoring systems by using “buggy” messages.
(Bayer, Čuhel, Géryk, Obšivác, & Popelínský, 2010)	Course information	Classification	Others	(I do not find).
(Ananiadou et al., 2010)	Course information	Classification/topic clustering	Others	This article evaluated text mining tools and methods to facilitate improved search, navigation, and viewing of educational documents.
(Shi et al., 2015)	Course information	Clustering/topic Modeling	Others	Text
(Šimko & Bieliková, 2009)	Course information	NLP	Others	This paper present a method for automated metadata generation addressing the educational knowledge discovery problem.
(Chen et al., 2008)	Document	Relation extraction	Others	This paper is to construct e-learning domain concept maps from academic articles.
(Mihalcea & Ceylan, 2007)	Document	Summarization	Others	This paper explore the problem of book summarization.
(Zipitria, Arruarte, & Elorriaga, 2008)	Document	Summarization	Others	This paper presents LEA a web application for summarization exercise development.
(Yang, Sutinen, Wen, et al., 2012)	Document	Summarization	Others	This paper presented an content summarizer to help mobile learners to retrieve and process information more quickly.
(Sun, Li, & Zhang, 2013)	Document	Topic Modeling	Others	This paper introduce a tool to analyze various evolution patterns that emerge from multiple texts based on combination of topic modeling and visualization techniques
(Zhang & Gu, 2011)	Document	Information extraction	Others	This paper proposed a scheme organizing customer knowledge in academic libraries by using text mining technology.
(Reategui et al., 2012)	Document	Summarization	Others	This paper presents a mining tool that is able to extract graphs from texts, and proposes their use in helping students to write summaries.
(Yang et al., 2013)	Document	Summarization	Others	This study focuses on a methodology for investigating the effectiveness of automatic text summarization used in mobile learning context.
(Vrablecová & Šimko, 2016)	Document	NLP/information retrieval	Others	This article propose a method for the automated acquisition of hierarchical relationships between relevant domain terms from educational content.
(Vattam & Goel, 2011)	Document	Information retrieval	Others	This paper present Biologue, a social citation cataloging system that uses model-based tagging to address these challenges.

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TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Šimko & Bieliková, 2012)	Document	Information extraction	Others	This paper present a method for automated discovery of is-a relationship, the method leverages specifics of educational content.
(Urban-Lurain et al., 2013)	Essay	NLP	Others	This paper used automated analysis to create feedback for instructors.
(Allen & McNamara, 2015)	Essay	NLP	Others	This study investigates the degree to which the lexical properties of students' essays can inform stealth assessments of their vocabulary knowledge.
(Stuker, Fay, & Berkling, 2011)	Essay	NLP	Others	This article propose a novel, context-sensitive spelling correction algorithm that uses phonetic similarities.
(Ullmann, 2017)	Essay	Classification	Others	This study presented an automated analysis of reflection in texts.
(Gibson & Kitto, 2015)	Essay	Classification/NLP	Others	This work propose a process for capturing subjective and affective analytics based on the identification and recontextualisation of anomalous features within reflective text.
(Huang, Zhou, & Yang, 2007)	Forum	Classification	Others	This paper presents a novel approach for extracting high-quality pairs as chat knowledge from online discussion forums.
(De Wever et al., 2006)	Forum	Survey	Others	This article presents an overview of different content analysis instruments, building on a sample of models commonly used in the CSCL-literature.
(Kardan, Sadeghi, Ghidary, & Sani, 2013)	Forum	Classification	Others	Text
(Ghosh & Kleinberg, 2013)	Forum	Theoretical	Others	This paper introduced a game-theoretic model for online forums for education, and investigated how an instructor can influence student participation and utility in these forums.
(Nuutinen & Sutinen, 2009)	Forum	Information retrieval	Others	This paper analyze six different algorithms for seeking similar sections of text in context of a social mind tool called the woven stories.
(Ravi & Kim, 2007)	Forum	Classification	Others	This paper presents an approach for automatically profiling student interactions in on-line discussions using N-gram features and linear SVM.
(Lau, Chung, Song, & Huang, 2007)	Forum	Information retrieval	Others	This paper presented an mechanism can automatically construct a concept map based on the messages posted to an online discussion board.
(Miksato & McLaren, 2008)	Forum	Clustering	Others	This study designed an algorithm that takes an example cluster as input and uses inexact graph matching, text analysis, and machine learning classifiers to search for similar patterns in a given corpus.
(Tsurugi, Maejima, & Tamura, 2008)	Forum	NLP	Others	This paper proposes a method to automatically generate a structure of statements in CSCL activity.
(Atapattu, Falkner, & Falkner, 2014)	Lecture notes	NLP	Others	This paper proposed a novel set of features to automatically extract entity-relation triple from lecture notes.

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TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Wilson & Oberlander, 2014)	Motivation	Theoretical	Others	This study examine properties of deixis to communicative artifacts using a collection of learning texts.
(Jung, Makoshi, & Akama, 2008)	Motivation	Theoretical	Others	This study propose a new web-based associative language learning system, called ALL.
(Luo, Liu, & Litman, 2018)	Online assignments	Summarization	Others	This work explore a new methodology that effectively extracts summary phrases from the student responses.
(Jorge-Botana et al., 2015)	Online assignments	Summarization	Others	This study applied a latent semantic analysis-based automated summary assessment in a distance education context.
(Goncher, Boles, & Jayalath, 2014)	Online assignments	Classification	Others	This paper aimed to employ textual analysis software to efficiently and, arguably, sustainably evaluate students' performance and deduce causes of conceptual misunderstanding.
(De Medio, Gasparetti, Limongelli, Sciarone, & Temperini, 2016)	Online assignments	Classification/NLP	Others	This study propose a general-purpose content-based approach for identifying the prerequisite relationships among learning objects.
(Leng, Liao, & Huang, 2007)	Online assignments	Classification	Others	This paper describes a system that analyzes discussion content by combining word frequency counts with a key word in context analysis.
(Lau, Song, Li, Cheung, & Hao, 2009)	Others	Information retrieval	Others	This paper proposed a mechanism can automatically construct concept maps based on the messages posted to online discussion forums.
(Tam, Lam, & Fung, 2012)	Others	Information retrieval	Others	This paper proposed a complete system framework that can perform an explicit semantic analysis on the course materials.
(Günel & Aslıyan, 2010)	Others	NLP	Others	This paper a system, which automatically detects the concepts to be learned by students, has been designed.
(Zouaq & Nkambou, 2008)	Others	Classification	Others	This paper presents a semi-automatic framework that aims to produce domain concept maps for the e-learning and AIED.
(Kulkarni, Heilman, Eskenazi, & Callan, 2008)	Others	Clustering	Others	This work study the effects of such lexical ambiguities on second language vocabulary learning.
Figureira, 2008a	Others	Classification	Others	This paper describe a repository of learning objects which automatically organizes the content in clusters of semantic proximity by the use of text mining.
(Sathiyamurthy & Geetha, 2012)	Others	Classification	Others	This paper proposes to extract information from documents using NLP and organizing the content into appropriate presentation slides for learning purposes using domain ontology and learning oriented pedagogy ontology.
(Hendricks, Curtis, & Zeng-Treitler, 2010)	Others	Sentence simplification	Others	This paper deals with the simplification of sentences.
(Osawa, Yatsuka, & Higashibara, 2010)	Others	NLP	Others	This paper analyzes the description of student instructors' teaching portfolios in accordance with INTASC standards.

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TABLE A1 (Continued)

Reference	Educational resource	Text mining method	Educational goal	Study overview
(Hoff, Gatz, & Rothkugel, 2007)	Others	NLP	Others	This paper introduces context-sensitive predictions for learning materials reflecting the context of the user for a better learning experience.
(Kumar, Geetha, & Kumar, 2014)	Social network	Classification	Others	This paper aims to analyze the role of online social networks (OSNs) in education institutions data analysis.
(Mansur & Yusof, 2013)	Social network	Clustering	Others	This research is to find the most efficient way to classify the behavior of students from their log activities in Moodle e-learning system.
(Wang, Al-Rubaie, Al Dhanhani, & Ng, 2015)	Social network	Classification	Others	This paper introduces the partial-supervised learning for hierarchical Dirichlet process (HDP) for text classification with inherent hierarchical structure in education.
(Toyota & Sun, 2014)	Wiki	Classification	Others	This paper is to provide a solution of extracting appropriate keywords to identify meaningful learning-contents on the web.
(Liu, Calvo, & Rus, 2010)	Essay	Text generation	Question/content generation	This paper presents a novel automatic question generation (AQG) approach that generates trigger questions as a form of support for students' learning through writing.
(Hastings, Hughes, Magliano, Goldman, & Lawless, 2011)	Essay	Classification	Question/content generation	This paper explore techniques for analyzing student essays to give feedback to instructors on how well their students deal with multiple texts.