Elsevier Editorial System(tm) for Computers in Human Behavior
Manuscript Draft

Manuscript Number:

Title: Applying learning analytics to students' interaction in business simulation games. What do students really learn?

Article Type: SI: Cognitive Computing

Section/Category: Full Length Article

Keywords: Student interaction; learning outcomes; online learning activities; business simulation games; learning analytics; data mining

Corresponding Author: Dr. Enric Serradell-Lopez, Ph.D.

Corresponding Author's Institution: UOC-Universitat Oberta de Catalunya

First Author: Ana B. Hernández-Lara, PhD

Order of Authors: Ana B. Hernández-Lara, PhD; Alexandre Perera-Lluna, PhD; Enric Serradell-Lopez, Ph.D.

Abstract: New teaching methods fostered by digital technologies, as well as information and communication technologies (ICT), offer new forms of learning, based on different ways of communication and interaction between the actors involved in the learning process. However, there are critical opinions that question the contribution of student interaction to real learning. This study explores the online discussion forums of 362 business students at the bachelor and master levels, who participated in business simulation games between 2011 and 2016. By applying learning analytics to 11,017 messages posted by students, which generated a text corpora of 997,158 words, this study aimed to explore the most frequent contents posted, and the influence, if any, of these contents on the students' learning results. Natural language processing revealed that the most frequent contents in the students' online discussion forums were related, firstly, to the parameters and features of the business simulation game, and, secondly, to elements that fostered the students' learning process, while small talk or regular conversation did not appear to be relevant. In addition, the contents with predictive power over learning results were related to uncertainty, time, interaction, communication and collaboration, although none of these elements influenced teacher assessment of student learning. These results provided evidence concerning the relevance of integrating advanced learning analytics and data mining in teaching strategies applied to online learning activities, directed towards better assessment and improvement of the student learning process.

Highlights

Relevance of integrating learning analytics and data mining in teaching strategies.

In business simulations games , teachers should pay special attention to the uncertainty involved in the game.

Teachers must be aware of the students' skills in terms of time management.

Collaboration, interaction, communication, among others improve the learning results.

***Title Page with Author details**

Applying learning analytics to students' interaction in business simulation games. What do students really learn?

Ana Beatriz Hernández-Lara [a], Alexandre Perera-Lluna [b], Enric Serradell-López [c*]

[a] Department of Business Management, Universitat Rovira i Virgili, Av. Universitat 1, 43204 Reus, Spain, anabeatriz.hernandez@urv.cat
[b] Automatic Control Department, Universitat Politècnica de Catalunya, C/Pau Gargallo 5, 08028 Barcelona, Spain, alexandre.perera@upc.edu
[c*] Economics and Business Department, Universitat Oberta de Catalunya, Av. Tibidabo 39-43, 08035 Barcelona, Spain, eserradell@uoc.edu, Tel: +34 932542112

Applying learning analytics to students' interaction in business simulation games. What do students really learn?

1. Introduction

New teaching methods fostered by digital technologies, as well as information and communication technologies (ICT), offer new forms of teaching, training and learning that have allowed students to reap the benefits for their educational and professional development (John & Wheeler, 2012). These methods frequently constitute online learning activities that foster different types of learning interactions, which promote the achievement of educational objectives (Noeth & Volkov, 2004).

In this new scenario, students are positioned as the main actors of their learning process, which shifts the focus from teachers to students (Cheng & Chau, 2014; Fitó-Bertrán *et al.*, 2015), with these latter being responsible for building their own knowledge and acquiring their own skills.

From a constructivist learning perspective, students learn both through their autonomous exposition to content that contributes to knowledge construction, and through richer interactivity that overcomes the communication style of the traditional classroom-based paradigm (Kent *et al.*, 2016). In the new learner-centred paradigm, the evaluating achievements have been transformed (Kent *et al.*, 2016), and the relevance of considering the opinions of students is emphasised in the design, monitoring and assessment of their learning process. Students' opinions have become a powerful source used for determining the success of online learning activities and how they promote the learning outcomes of students (Pando-Garcia *et al.*, 2015). These online learning activities offer more varied ways to interact by sharing ideas and experiences in online discussions, which could be used as richer and less biased sources of information in order to really understand the student learning experience and its outcomes (Lonn *et al.*, 2011).

Nevertheless, teachers are frequently unfamiliar with how students interact amongst themselves, because most of the time they do not take part in these interactions, and might not even be aware that they are occurring or under which circumstances they are carried out. Therefore, student interactivity is rarely evaluated or considered as a learning evaluation metric (Kent *et al.*, 2016; Reich, 2015), which explains the current doubts concerning whether or not teacher assessment of the students' learning outcomes reflects what the students really learn.

This study aimed to explore the online discussion forums of students participating in an online learning activity, more specifically a business simulation game. Therefore, the purpose was to respond to the following questions:

1. To explore the communication pattern of students in their online discussion forums in order to identify the most frequent contents that appeared in student interactions.
2. To determine, if any, the contents that better explained and predicted the students' learning results, seeking to identify the most frequent contents of the students who outperformed the simulation game and obtained better marks.

This study aspired to contribute to the open debate on the learning impacts of student interactivity, and to discover more about the learning process developed by students through the analysis of this interactivity. In addition, the study highlighted the usefulness of applying educational analytics and data mining techniques, such as natural language processing (NLP), in student forums. These techniques allow teachers and instructors to gain a more holistic view of student learning development, and to improve their decision-making for educational purposes.

2. Literature review

2.1. Conceptual framework of learners' interactivity

There are different definitions and classifications of interactivity based on different aspects, such as the agents involved, the frequency, or the participation mode (Agudo-Peregrina *et al*., 2014). Moore (1989) proposed a classic definition for interaction based on digital technology centred on the agents involved, which traditionally distinguished between content interaction (video classes, questions, tests, etc.) and social interaction (Northrup, 2001; Paiva *et al*., 2016), the latter including learner-teacher interactions and learner-learner interactions (Moore & Kearsley, 1996). With the advance of technology and increasing complexity in online education, additional categories were subsequently added, such as interactions with the interface or the environment itself (logging in the environment, completing profile information, reading help files, etc.) (Paiva *et al*., 2016), as well as self-interaction (Soo & Bonk, 1998) based on the reflexive thinking process and self-directed learning fostered by e-learning.

Social interaction can be described as two-way communication between two or more people within a learning context (Gilbert & Moore, 1998). Learner-teacher interaction allows teachers to act as coachers, counsellors and supporters in the student learning process (Lonn *et al*., 2011), and provides teachers with useful information for the assessment of the students' learning achievements. Learner-learner interaction, or what we call learner or student interactivity, on the contrary, does not involve teachers or instructors at all. This type of interaction contemplates a social interactivity where teachers do not participate because the learners consider that they should not be included, with the result that these teachers are frequently unaware that such interaction occurs and what the consequences are in terms of student learning.

According to Kent *et al.* (2016) "social constructivism perceives knowledge as constructed between people by a social process of interacting". Therefore, a relationship is established between social interactivity and learning outcomes, although it depends on the nature of the interactivity, which involves not only communication but also other complex activities that develop collaborative skills, such as teamwork, coordination, problem-solving, conflict resolution and negotiation (Boticki *et al*., 2015). Social interactivity also implies putting into practice other complex activities that are not always related to collaborative skills, although they are also involved in the learning process, such as engaging, reflecting, questioning, answering, elaborating, constructing and analysing, among others (Liaw & Huang, 2000). As long as social interactivity allows students to engage in all these activities, it contributes to knowledge construction, and hence learning, through the interactive exchange of information and the development of relatedness between pieces of information (Kent *et al*., 2016).

2.2. Learners' interactivity and learning results

In the new educational era dominated by digital tools, computer technology and the Internet, more advanced ways of interaction have appeared that allow students to share ideas and experiences that contribute to their learning. In addition, these new technologies make more information available with regard to what the students really do while learning, making it easier to access the learners' opinions, which become a powerful source of information concerning the learning process and its outcomes (Pando-Garcia *et al*., 2015).

However, a literature review on the relationship between learners' interactivity and learning outcomes shows an unclear link and provides some inconclusive results that have enhanced the interest of researchers studying learner interactivity at an educational level.

The review reveals that most studies have looked for a correlation between participation in asynchronous discussions, and grades or classroom performance and achievements (Kent *et al.*, 2016). As Romero *et al*. (2013) stated: "there is increasing interest in the use of discussion forums as an indicator of student performance", although this research is not completely conclusive in its findings. For example, Wei *et al*. (2015) analysed the relationship between the students' self-reported perceptions, what they did online, and their performance in an online learning environment, and found that frequent accesses and interaction made the students learn more. In addition, Boticki *et al*. (2015) presented a mobile learning platform that relied on questions and promoted collaboration between students. Their results examined how the use of these tools, when focused on self-directedness (students manage their learning process on their own), quality of contributions, and answers to contextual questions, predicted the students' examination results. Their findings also suggested that badges or recognitions as an extrinsic motivational tool were related to an increase in the quantity and quality of the students' contributions (interactions) and with better results in exams, given an appropriate educational context.

However, not all the studies using this approach have achieved a clear consensus concerning whether or not this relationship actually exists (Kent *et al.*, 2016). For example, Swan (2002) pointed out the relevance of the quality of learners' interactions in online discussion, and found that discussion among students contributed to their success, although the study also stressed that not all contributions were the same, since it was possible to distinguish effective from ineffective contributions (Soller, 2001). Similar results were offered by Picciano (2002) who questioned the relationship between the nature and extent of interactivity and its effects on student performance. This author used multiple measurements of interaction and sense of presence in a course, and different measurements of performance beyond the typical data on grades or grades and withdrawal rates, including measurements specifically related to course objectives. The results concerning the effects exerted by actual postings on discussion boards and actual performance measurements related to the course objectives were not consistent, since they showed there were no differences when learner interaction was low, medium or high. This result contrasted with the strong relationship detected between students' perceptions of the quality and quantity of interaction and their perceived performance. Song & McNary (2011) also pointed out that this did not necessarily mean an improvement in the learning outcomes, although most of the previous research supported the relationship between interactivity and satisfaction or engagement in online learning. In their study conducted with 18 students participating in an online course delivered via discussion board posting, they found a considerable variability in the topic of postings across students and modules of the course, and more importantly, no correlation between the number of posts and student success measured as the global course mark. Their results showed that the theoretical foundation for determining what good quality interaction is and how it affects students' learning success was lacking.

These studies confirmed the problems of this approach. Firstly, the lack of consensus concerning whether or not the relationship between learners' interactivity and learning outcomes actually existed. Secondly, the most relevant problem of this approach, which may be related to the first problem, was the excessive focus on quantitative indicators when analysing interactivity, such as posting frequency, the number of logins, the number of messages read, their lengths, the connection duration, etc. Online learning environments record most learning behaviours and provide large volumes of educational data (Foley & Kobaissi, 2006; Romero & Ventura, 2007), which most of the time teachers themselves do not know how to process and analyse (Paiva *et al*., 2016). Therefore, this interaction is mostly neglected in the evaluation of the knowledge construction and learning of students, and is not taken into account for effects on instructional and pedagogical issues. This fact explains that learners' interactivity is rarely evaluated or considered as a learning evaluation metric (Kent *et al*., 2016). As Romero *et al.* (2013) stated: "with hundreds of contributions to review in an entire online forum, the instructor lacks a comprehensive view of the information embedded in the transcript […] and faced with the difficulty of interpreting and evaluating the learning and quality of the participation reflected in the students' contributions". Interactivity use, if any, has been restricted to reporting on student task completion or tracking students at risk of dropping out (Gašević *et al*., 2015), and it is not frequently used for assessing the learning process itself, the progress of the learners' understanding, their ability to relate to information and to build on existing knowledge (Reich, 2015). This knowledge gap makes it hard to discover more about the learning outcomes by considering learner interactivity (Song & McNary, 2011).

Nevertheless, some studies have integrated indicators more centred on the contents and quality of learner interaction and their effects on learning results. This research line has given an idea of what the interaction should be in order to be relevant for effective learning. A good example was the study of Ransdell (2013) that considered both the number of student posts and the tracking of meaningful posts, which are more difficult to produce and are more related to knowledge construction. The findings showed that online learning was highly correlated to meaningful posts, while the total online interactivity of students did not predict learning outcomes.

This body of research, more centred on the quality of interactivity, has frequently recommended the use of educational data mining techniques for extracting information and conclusions. For example, Romero *et al*. (2013) proposed the use of different data mining techniques to predict whether students would pass their course or not, selecting instances and attributes and proposing different classification algorithms. They found that the students who passed a course were those that were more active in the forums not only in quantity but also in quality, measuring quality through the value given to their messages, their prestige and centrality. Their results also concluded the suitability of using a subset of attributes and messages for the contents of the course instead of using all messages. However, their research did not really develop an analysis of the content of the learners' interactivity.

Other studies have centred on qualitative information, mainly applying a content analysis approach, but excluding the use of educational data mining, in order to obtain a clearer model for the data in the discussion forums, which transformed them into an understandable structure for further use. Since the pioneer study of Henri (1992), who established several categories for analysing the cognitive dimensions of the learning process in computer conferencing environments, a wide variety of approaches has been used, which differ in their level of detail and the type of analysis categories used (De Wever *et al*., 2006). For example, Pena-Shaff & Nicholls (2004) used social constructivism learning theory to investigate the communication patterns and knowledge construction of students who used a computer bulletin board system. They analysed the content of the messages and the patterns of interactions and obtained a category system of indicators and descriptors, which included, among others: clarification, interpretation, conflict, assertion, consensus, judgement, reflection, questions, and support. Their results after revising 152 messages and 594 sentences, confirmed that student knowledge construction was mostly influenced by clarification, elaboration and reflection, although no correlation between these contents and learning outcomes was proved.

Another good example of the relevance of analysing content in learners' interactivity is offered by the taxonomy of conversation behaviours of Soller (2001), used to distinguish effective from ineffective contributions in collaborative learning. This author identified three levels of skills that contributed to effective peer interaction: creative conflict, active learning and conversation, each of which was further divided into sub-skills, such as mediation, discussion, motivation, information, requirements, acknowledge, maintenance and task. The study indicated that successful online learning was influenced by the acquisition of these skills, and it recommended strategies for improving the most relevant ones, although it was restricted by certain limitations that avoided its generalization. In addition, although the work was based on case studies, it did not prove the correlation between these skills and learning outcomes.

Therefore, previous studies have offered only a partial view of the relationship between learning results and learner interactivity. This approach should be complemented by the quality and quantity indicators of learners' interactions, centred on the content of student discussions, and supported by educational analytics, which allow teachers and instructors to really appreciate the learning construction favoured by peer-led discussion (Lonn *et al*., 2011). To fill this gap, the current study proposed two research questions, which pretended to identify the most relevant contents and determine their effects on learning results by using NLP in students' online forums. The response to these questions would allow us to understand more about:

- The most frequent contents in the online discussion forums of students while participating in a business simulation game,
- The game concepts in which the students were more interested,
- Whether these concepts and contents were related,
- The contents, if any, that better explained and predicted the learning results,
- Whether the contents that better explained and predicted the learning results were the same for different student performance indicators,
- The lessons teachers could extract from applying learning analytics to the online discussion forums of students while participating in a business simulation game.

3. Methodology

3.1. Business simulation games: Cesim Global Challenge

The purpose of this study related social interactivity and gamification as two elements that contribute to learning through communication and engagement. The game chosen to carry out this analysis was a business simulation game, *Cesim Global Challenge (www.cesim.com)*, which is a management and strategy game that allows decision-making to be practiced by integrating various management-related disciplines, such as financial, human resources, accounting, production, logistics, research and innovation, taxes, and marketing.

Cesim Global Challenge simulates a business context in which players organised into teams develop and execute strategies for an international mobile telecommunications company operating in the USA, Asia and Europe. The focus of the game is centred on strategic management, international business, global operations and business policy in a competitive and dynamic environment.

The game provided a participatory platform for students to contribute, share, and provide feedback by using online discussion forums that store this information for potential educational use. These forums were used to analyse the content of the students' interactions. Although the use of the forum was not mandatory, the teacher followed the suggestions of related research (Romero *et al*., 2013) and reminded students by email to participate in the online forum, which represented an extrinsic source of motivation required to obtain a good level of participation.

3.2. Data collection

Data was collected from students of the Open University of Catalonia studying at bachelor and master levels. All the students were taking part in a non-compulsory subject concerning "Business Simulation and Practice" that involved participation in the business simulation game (*Cesim Global Challenge*), which was always administered online by the same teacher/instructor. The subject had six European Credit Transfer System (ECTS) credits at the bachelor's degree level and three ECTS credits at the master's degree level. The difference in the number of credits for the courses was because the bachelor degree students played nine competitive rounds of the game over 15 weeks, while master degree students played seven competitive rounds over 8 weeks.

For the purpose of this study, data were analysed from all the students undertaking the subject and playing the game for nine consecutive academic semesters between 2011 and 2016. The population was composed of 442 students (60.2% at bachelor level and 39.8% at master level), who participated in the business simulation games by playing in teams. A total of 102 teams were considered that were all comprised of more than one student, distributed between 16 different competitions.

Despite the advice of the teacher to use the online discussion forums of the game, not all the teams used this means of communication, and finally the total number of forums was 84. The number of students who participated in these forums was 362, which represented an 81.9% sample of the population.

3.3. Measurement of variables

The dependent variables included in this research were related to the students' performance and their learning results. To measure the students' learning results, their marks or grades (Marks) were considered for the subject where the business simulation game was implemented (Boticki *et al*., 2015; Kent *et al*., 2016; Song & McNary, 2011). At both levels, bachelor and master, the students were graded by considering various aspects, which consisted of three reports and the competitive position of the team in the game. The reports asked the students about their strategic and operational objectives, their competitive position, their main decisions and the reasons why they made them, the main adjustments in their decision-making during the game, and the contribution of their decisions to their goals. Their performance and achievements in their grades while participating in the business simulation game were also considered. The success of players in the game was measured and compared by both operational and financial key performance indicators. These indicators included the following: the total cumulative shareholder return (TCSR), earnings per share (EPS), benefits at the end of the game (Profit), and the competitive position at the end of the game (Position), which provided the relative position of each team player in relation to the others (the lower the number, the better the position). The winners were decided in terms of the TCSR, which included the change in the value of shares, dividend paid out to shareholders by the company, and the interest that these dividends generated for the shareholders.

The 362 students participating in the sample contributed to 84 online discussion forums and posted a total of 11,017 messages. The complete text corpora contained 997,158 words in 100,758 lines of text, with an average of 11.2 lines per post (sd=9.48 lines) in an unstructured format.

With Catalonia being a bilingual region (Catalan and Spanish are *de facto* co-existing languages), forum content contained some messages in Catalan, some in Spanish and some mixing of both languages. All corpus was translated into Spanish, where necessary.

Natural language processing (NLP) consisted of pre-processing, creation of a data term matrix, and statistical analysis. Corpus was subject to a set of pre-processing steps, which were: white space stripping, conversion to lower case, removal of Spanish *stopwords*[1] (Rajaraman & Ullman, 2011) and removal of punctuation. Words in corpus were stemmed (suffix stripped; Porter, 1980) using the Spanish stemmer implemented in the *tm* R package (v. 0.6-2; Feinerer *et al*., 2008). The stemmed corpus was later used to construct a document term matrix (DTM) containing the frequency of terms per forum in a sparse matrix representation of the corpora. Sparse terms were removed from the DTM (80% sparsity threshold). The DTM was normalized to the number of occurrences per message per forum. All NLP was carried out using R, version 3.3.2 (R Core Team, 2016) and the *tm* R package (v. 0.6-2, Feinerer *et al*., 2008).

4. Data analysis

Two different types of analyses were conducted in order to achieve the goals of this study. The first concerned exploratory analyses for describing the communication patterns of students from the stemmed corpus, whereas the second analyses were more ambitious and had a greater explanatory and predictive nature that looked for the contents in the text corpora that were more related to the students' learning results.

4.1. Exploratory analyses

The distribution of the sample in terms of study type and gender showed that 65.47% of the sample were bachelor students, while 34.53% were master students. Likewise, 59.4% were men and 40.6% were women. As already mentioned, the students played the game organised in teams, and the average number of students in each team was 4.2. The average number of teams competing in each game was 6.375.

Table 1 displays the descriptive statistics for the dependent variables related to the students' learning results.

Table 1. Descriptive statistics of dependent variables

Variables	Min	Max	Mean	SD

[1] *stopwords* list accessed from http://snowball.tartarus.org/algorithms/spanish/stop.txt, on 31/01/2017

Marks	6.5	10	8.163	0.898
TCSR	-91.866	23.912	-1.247	18.992
EPS	-46.94	110.40	12.269	22.849
Profit	-199,562	4,415,874	363,982	846,336.8
Position	1.000	11.000	3.849	2.38

In terms of the online discussion forums, a description of the most frequent stems in the text corpora appears in Figure 1, which displays a word cloud that gives greater prominence to the most frequent word stems or roots in the corpus.

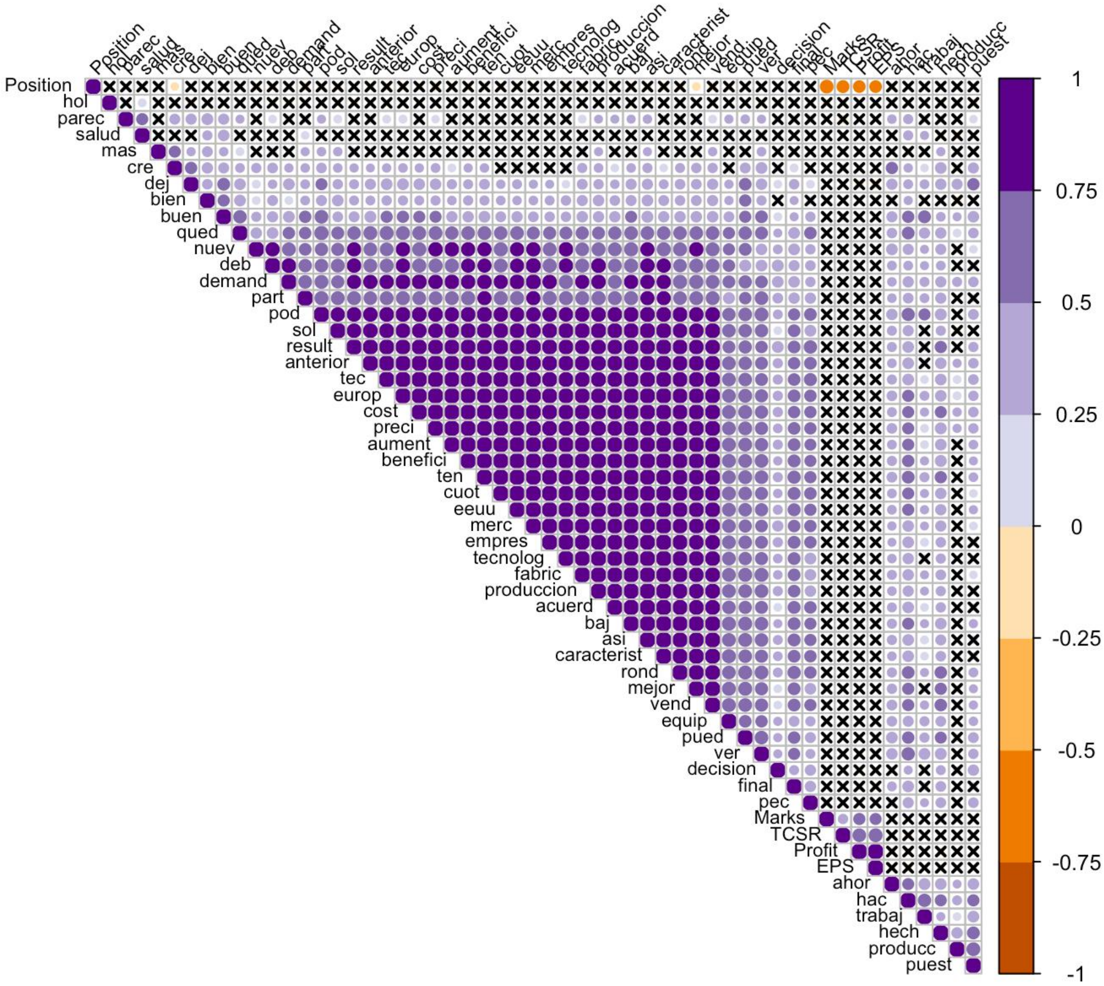
Figure 1. Word cloud of the most frequent word stems

This analysis showed that some of the most frequent stems were related. For example, it can be seen that stems related to technology and R&D development were quite relevant. This result was coherent with the core business of the simulated company in the game with stems such as *"tec"* (with appeared 10,230 times) and *"caracterist"* (1,922 times) representing the features added to each technology through R&D investments, and *"tecnolog"* (1,509 times). There were also frequent stems related to functional areas simulated in the game, such as *"demand"* (which appeared 2,980 times), *"produccion"*, which is the Spanish word for production (1,769 times), and word roots related to marketing and sales, such as *"vend"* (1,549 times), which is the root of the Spanish word for sales or to sell. Terms relative to position or that implied comparison also emerged in several topics in the corpus, as can be observed for the stems *"mejor"* (1,871 times), the Spanish word for better or best, and *"puest"* (1,539 times) related to position. In addition, there were frequent stems that involved decision-making, both the action of deciding itself as well as the object of the decisions. For example, the stem *"decision"* appeared 3,863 times, which could be expected since the game simulated the decision-making process at the top of a company, *"acuerd"* that refers to agreement or agree (1,163 times), *"merc"* referring to market (4,153 times) and *"preci"* referring to price (4,881 times), as well as *"EEUU"* referring to the USA (2,868 times) and *"Europ"* (2,608 times) as two of the markets where the simulated company worked. Some frequent stems also appeared that referred to the results and performance of the simulated companies as a consequence of their decision-making. This was the case for stems such as *"result"* (2,071 times), *"cost"* (2,061 times), or *"cuot"* referring to the market share (1,865 times). Finally, there were frequent stems regarding teamwork, such as *"equip"* referring to the teams (1,982 times); time, such as "*rond"* that is the Spanish stem for round or period of time in which the game was split; or stems associated with generic actions, such as *"pued"* linked to the verb to be able, *"parec"* linked to the verb to seem, *"hac"* referring to the verb to do, or *"ver"* linked to the verb to see.

It is also interesting to describe the bivariate correlation between the most frequent terms per posts, and the correlation of these contents with the learning results. This analysis is depicted in Figure 2, which shows the correlogram between these variables (Feinerer *et al*., 2008).

Figure 2 shows that most of the measurements for the learning outcomes, marks and key performance indicators of the game were highly and positively correlated, with the exception of Position, whose correlation was negative. This is coherent with the reverse measurement of this indicator, since the lowest value indicated the best position. However, in general, key performance indicators and marks did not seem to be correlated with the most frequent stems in the corpus. On the other hand, by considering the bivariate correlations between these stems, it could be concluded in general that these correlations existed (except for small exceptions), were positive, and were quite strong between some of the stems. This result indicated that the most frequent contents appeared together, were not mutually exclusive, and formed a whole idea expressed by students concerning game development. The strongest correlations were observed between stems such as *"demand"*, *"pod"*, *"sol"*, *"result"*, *"anterior"*, *"tec"*, *"Europ"*, *"cost"*, *"preci"*, *"aument"*, *"benefici"*, *"ten"*, *"cuot"*, *"EEUU"*, *"merc"*, *"empres"*, *"tecnolog"*, *"fabric"*, *"produccion"*, *"acuerd"*, *"baj"*, *"asi"*, *"caracterist"*, *"rond"*, and *"major"*. This list of stems again highlighted the relationship in the students' interactions between concepts such as technology, decision-making and seeking agreements, as well as functional areas such as production, demand and sales, outcomes such as results or costs, relative positions such as to enhance or to fall, and concepts related to time, such as round or past.

Figure 2. Correlogram plot depicting mutual correlation between the top terms and the learning results metric. Crossed positions mark non-significant correlations ($p<0.05$).



4.2. Predictive analyses

The second analyses aimed to predict the effects, if any, that the most frequent contents in the students' online forums exerted on their learning results.

To achieve this, two different analyses were conducted. The first one, which was less ambitious, conducted univariate models in order to detect the most frequent stems with significant effects on some of the five indicators related to the learning results (considering $p<0.05$). A total of 23 stems were found that individually influenced some of the students' learning results metrics. These stems are shown in Table 2.

	algœ	algun	aspect	ayer	chic	coherent	concret	contest	empez	empiez	emple	envi	gris	hab	mail	mañan	plan	podriam	recuerd	respuest	tiemp	
Marks	0.15	-0.01	-0.04	0.01	-0.03	0.02	-0.01	-0.01	-0.05	-0.03	0.02	-0.01	0.05	-0.01	-0.05	-0.17	-0.01	0.10	-0.10	-0.02	0.01	
	(0.729)	(0.998)	(0.998)	(0.998)	(0.999)	(0.999)	(0.998)	(0.998)	(0.999)	(0.998)	(0.998)	(0.998)	(0.998)	(0.998)	(0.998)	(0.998)	(0.998)	(0.764)	(0.998)	(0.998)	(0.998)	(0
TCSR	0.16	**-0.48**	0.20	0.12	**-0.42**	**-0.40**	0.22	0.19	**-0.45**	**-0.51**	**-0.38**	0.10	**-0.44**	0.17	0.16	**-0.45**	**-0.44**	0.21	0.13	0.12	**-0.48**	**-**
	(0.992)	**(0.001)**	(0.992)	(0.992)	**(0.007)**	**(0.016)**	(0.992)	(0.992)	**(0.003)**	**(0.000)**	**(0.038)**	(0.992)	**(0.003)**	(0.992)	(0.992)	**(0.003)**	**(0.003)**	(0.992)	(0.992)	(0.992)	**(0.001)**	**(0**
Profit	**0.38**	-0.11	**0.42**	**0.38**	-0.20	-0.18	**0.42**	**0.45**	-0.12	-0.10	-0.25	**0.39**	-0.11	**0.51**	**0.39**	-0.20	-0.10	**0.49**	**0.45**	**0.38**	-0.09	-
	(0.032)	(0.999)	**(0.013)**	**(0.032)**	(0.999)	(0.999)	**(0.013)**	**(0.004)**	(0.999)	(0.999)	(0.663)	**(0.032)**	(0.999)	**(0.000)**	**(0.028)**	(0.999)	(0.999)	**(0.000)**	**(0.004)**	**(0.037)**	(0.999)	(0
EPS	0.35	-0.12	**0.39**	0.33	-0.18	-0.21	**0.42**	**0.41**	-0.12	-0.11	-0.30	0.33	-0.12	**0.46**	**0.40**	-0.21	-0.11	**0.46**	**0.40**	0.33	-0.13	-
	(0.146)	(0.998)	**(0.030)**	(0.193)	(0.998)	(0.998)	**(0.021)**	**(0.021)**	(0.998)	(0.998)	(0.327)	(0.193)	(0.998)	**(0.006)**	**(0.030)**	(0.998)	(0.998)	**(0.006)**	**(0.027)**	(0.193)	(0.998)	(0
Position	-0.14	0.01	-0.11	-0.11	0.09	0.04	-0.14	-0.16	0.03	0.04	0.14	-0.08	0.03	-0.14	0.03	0.11	0.10	-0.23	-0.10	-0.08	-0.02	
	(0.756)	(0.989)	(0.756)	(0.756)	(0.773)	(0.879)	(0.756)	(0.756)	(0.916)	(0.909)	(0.756)	(0.780)	(0.943)	(0.756)	(0.943)	(0.756)	(0.756)	(0.756)	(0.756)	(0.779)	(0.945)	(0

Table 2. Regression analysis between stems and learning results (univariate models)

β and p values (in parentheses). Significant values in bold

Table 2 shows that the words that influenced some learning outcome metrics, when they could be clearly identified by their stems, were the following: *"something"*, *"any"*, *"aspect"*, *"yesterday"*, *"coherent"*, *"precise"*, *"answer"*, *"begin"*, *"employ"*, *"mail"*, *"tomorrow"*, *"plan"*, *"could"*, *"remember"*, *"time"*, and *"whatsapp"*. Some of these stems referred to similar concepts that pointed to uncertainty (*"something"*, *"any"*, *"plan"*, *"could"*), time (*"yesterday"*, *"tomorrow"*), interaction and collaboration (*"could"*, because the Spanish stem used implied a group of people), and communication media (*"mail"*, *"whatsapp"*).

The effect of all these stems on learning results was statistically significant and positive for Profit and EPS, which meant that, in these univariate models, a greater presence of these stems in the corpus indicated a better learning result in terms of Profit and EPS. When TCSR was considered as the indicator of the learning result the findings showed the opposite, meaning that the higher the appearance of these stems, the lower the TCSR. These results were obtained especially for some stems related to actions such as *"to begin"*, *"to employ"*, *"to see"* and *"to plan"*. No significant effect was observed for the rest of the relevant concepts, such as time, interaction, collaboration, and communication.

A second, more restrictive, analysis tested to which extent the variance of the learning results could be explained by linear multivariate models of the stem vectors. The models could explain approximately 25% of the variance of the learning results with two stems having significant influence on more than one metric of the learning results. These stems were *"podriam"* (*"could"* in English) and *"propong"* (*"propose"* in English). Both of them had a positive influence on learning results. The first one, *"podriam"*, had a positive effect on EPS and a negative effect for Position (β=274.69, $p<0.05$ for EPS and β=-9.58, $p<0.05$ for Position). The second one, *"propong"*, had a positive influence on Profit and EPS (β=3018927.07, $p<0.05$ for Profit and β=52.38, $p<0.01$ for EPS). These stems were related to uncertainty, collaboration, decision-making or establishing alternatives, which are concepts from the very essence of the simulation business game used.

5. Discussion

The main aim of this study was to contribute to the open debate on the learning impacts of student interactivity. Therefore, advanced learning analytics were applied following the suggestions of previous research (Romero *et al*., 2013) and, more specifically, NLP was used for student online forums while participating in business simulation games.

Two research questions were proposed. The first one aimed to explore the communication pattern of students in order to identify the most frequent contents that appeared in their interactions. The application of NLP allowed us to stem words in the corpus and build a DTM containing the frequency of terms per forum in a matrix that represented the text corpora. The analysis of the most frequent contents that appeared in the online discussion forums of students also allowed us to determine the main interests of students while playing, which were centred on the game itself, according to their learning process or social aspects motivated by their interactions.

The most frequent stems in the DTM allowed us to clarify this point, and it was concluded that they were related to relevant concepts of the business simulation game and, to a lesser extent, to the learning process itself. The most frequent stems referred to technology and R&D investments, decision-making and seeking agreements, time, the functional areas recreated in the game (production, demand, sales), or the relevance of obtaining a position and the importance of relativeness because the decisions in the game would be good or bad depending on what the other players also decided. In addition, other frequent stems referred to certain relevant game parameters, such as plants, prices, markets, business or enterprises, etc., or they referred to measurements of performance in the game, such as the results or costs of the simulated companies. Finally, there were also frequent stems that referred to generic actions, such as to do or to make, to observe or to see, to propose, to seem or to be able. Some of these actions implied uncertainty and collaboration, as far as they were not developed individually, and they were also relevant parameters in the design of the game. Therefore, it was concluded by analysing all these frequent stems that the students' interactions were concerned with specific features and parameters of the game, more than simple conversation or small talk. Another interesting conclusion was that students' interactions involved more of these specific characteristics of the game than terms related to the learning process itself, which implied, for example, clarification, interpretation, discussion, conflict, assertion, motivation, acknowledge, consensus, judgement, reflection, questions, and support, among others (Pena-Shaff & Nicholls, 2004; Soller, 2001). In the text corpora, stems more related to the learning process were those referring to seeking agreement, uncertainty and collaboration.

Another interesting topic for discussion in the exploration of the communication patterns of the students was the relationship, if any, between the most frequent stems. The analysis confirmed that there were strong positive correlations between many of the most frequent stems, which meant that these stems together confirmed the ideas behind the students' interactions. The strongest correlations highlighted the relationship between concepts such as technology, decision-making, seeking agreements, production, demand, sales, cost, results, relativeness and time.

The second research question sought to determine the content that better predicted and explained the students' learning results. Univariate and multivariate tests were conducted to respond to this question, and the findings showed that there were stems with a certain type of significant influence on the learning results metrics. These stems pointed to relevant concepts directly related to learning results, which were uncertainty, decision-making, establishing alternatives, time, interaction, collaboration and communication. This latter was especially interesting because students with better learning results frequently included references to other communication media in their conversations, such as mail or whatsapp, which indicated that the online discussion forums were unable to capture all the students' interactivity.

It was also interesting to note that the influence of these concepts was not the same for all the learning results metrics considered in the study. For example, Profit, EPS and Position received a positive influence from communication, uncertainty, collaboration, decision-making or time, while TCSR was basically negatively related to actions involved in the development of the game, such as employ, see, begin or plan. Therefore, it was concluded that general actions involved in the students' conversation did not really exert a positive influence on learning results but that, on the contrary, stems highlighting ideas around communication, uncertainty, decision, collaboration and time frequently emerged in the conversation of students who outperformed in the business simulation game. Another relevant result was that no stem exerted a significant influence on Marks, which was the learning metric directly proposed by the teacher. This result was in line with previous research stating that teachers evaluated and assessed the learning process of students but neglected their interactions (Kent *et al*., 2016) because they often did not know how to process and analyse these huge quantities of data (Paiva *et al*., 2016). This finally meant that they assessed students and took educational and pedagogical decisions without looking into the learning process that students developed through collaboration and interaction when they used online methodologies (Reich, 2015).

6. Conclusions

This study highlighted that advanced educational analytics and data mining techniques were useful tools for teachers and instructors because they allowed them to discover more about the learning process of their students, especially when they were not in a face-to-face situation, but rather involved in online educational activities.

In the specific case of business simulation games, this study established that to improve the learning results of students, teachers should pay special attention to the uncertainty involved in the game. They should do this by being aware of the concerns of students related to risk and insecure situations derived from managerial decision-making, asking the students to express these concerns and looking for solutions that would make the students more comfortable at dealing with uncertainty and risk. For example, specific discussion groups could be formed, where these doubts could be shared with the teacher or the rest of the classmates. Teachers should also motivate collaborative work among students, not just by forming groups but also work teams, looking for the best team composition in order to foster this collaboration. They should also promote more fluent communication within the teams, which may include different media, and encourage active roles in the students by proposing different alternatives and solutions to apply in the decision-making process. Finally, teachers must be aware of the students' skills in terms of time management, investigate which teams have problems with this ability and propose activities that develop such skills.

According to the results, the promotion of these aspects centred on uncertainty, collaboration, interaction, communication, decision-making and time management will improve the learning results of students. In fact, to be fair, all the student advances and improvements in these topics should be included in the teachers' assessments and be considered in the students' final marks, which would force the redesign of the evaluation parameters applied by teachers.

Nevertheless, this study also had limitations, such as the inability to capture all the communications developed by students while playing because, despite the teachers' advice, some of them neglected to participate in the online discussion forums. However, this does not mean that this communication did not exist because it was developed by using other media, to which the teachers did not have access. In addition, the focus of the analyses could be expanded and include not only contents but also the learning profiles and roles of students, looking for relationships between these profiles, contents and learning results.

The inclusion of more varied variables, as well as different advanced learning analytics, including non-linear analyses, could improve the knowledge related to the learning process derived from students' online discussion forums.

References

Agudo-Peregrina, A. F., Iglesias-Pradas, S., Conde-González, M. A., & Hernández-García, A. (2014). Can we predict success from log data in VLEs? Classification of interactions for learning analytics and their relation with performance in VLE-suported F2F and online learning. *Computers in Human Behavior*, *31*, 542-550. http://dx.doi.org/10.1016/j.chb.2013.05.031

Boticki, I., Baksa, J., Seow, P., & Looi, C. K. (2015). Usage of a mobile social learning platform with virtual badges in a primary school. *Computers & Education*, *86*, 120-136. http://dx.doi.org/10.1016/j.compedu.2015.02.015

Cheng, G., & Chau, J. (2014). Exploring the relationship between learning styles, online participation, learning achievement and course satisfaction: An empirical study of a blended learning course. *British Journal of Educational Technology*, *47*, 257–278. http://dx.doi.org/10.1111/bjet.12243

De Wever, B., Schellens, T., Valcke, M., & Van Keer, H. (2006). Content analysis schemes to analyze transcripts of online asynchronous discussion groups: A review. *Computers & Education*, *46* (1), 6-28. http://dx.doi.org/10.1016/j.compedu.2005.04.005

Feinerer,I., Hornik, K., & Meyer, D. (2008). Text Mining Infrastructure in R. *Journal of*

Statistical Software, *25*, 1-54.
https://www.jstatsoft.org/article/view/v025i05
(doi: 10.18637/jss.v025.i05)

Fitó-Bertrán, A., Hernández-Lara, A. B., & Serradell-López, E. (2015). The effect of competences on learning results: An educational experience with a business simulator. *Computers in Human Behavior*, *51*, 910-914.
http://dx.doi.org/10.1016/j.chb.2014.11.003

Foley, B.J., & Kobaissi, A. (2006). Using virtual chat to study in informal learning in online environments. In: American Educational Research Association: Annual Meeting, San Francisco, CA.

Gašević, D., Dawson, S., & Siemens, G. (2015). Let's not forget: Learning analytics are about learning. *TechTrends*, *59*, 64-71.
http://dx.doi.org/10.1007/s11528-014-0822-x

Gilbert, L., & Moore, D. R. (1998). Building interactivity into web courses: Tools for social and instructional interaction. *Educational Technology*, *38*, 29-35.
ISSN: ISSN-0013-1962

Henri, F. (1992). *Online education: Perspectives on a new environment*. NY: Praeger.

John, P., & Wheeler, S. (2012). *The digital classroom: Harnessing technology for the future of learning and teaching*. New York, NY: Routledge.
ISBN: 9781843124450

Kent, C., Laslo, E., & Rafaeli, S. (2016). Interactivity in online discussions and learning outcomes. *Computers & Education*, *97*, 116-128.
http://dx.doi.org/10.1016/j.compedu.2016.03.002

Liaw, S., & Huang, H. (2000). Enhancing interactivity in web-based instruction: A review of the literature. *Educational Technology*, *40*, 41-45.
https://eric.ed.gov/?id=EJ606830

Lonn, S., Teasley, S. D., & Krum, A. E. (2011). Who needs to do what where? Using learning management systems on residential vs. Commuter campuses. *Computers & Education*, *53*, 686-694. http://dx.doi.org/10.1016/j.compedu.2010.10.006

Moore, M. G. (1989). Three types of interaction. *The American Journal of Distance Education*, *3*, 1-6. http://aris.teluq.uquebec.ca/portals/598/t3_moore1989.pdf

Moore, M. G., & Kearsley, G. (1996). *Distance education: A systems view*. Belmont, CA: Wadsworth Publishing Company.

Noeth, R. J., & Volkov, B. B. (2004). *Evaluating the effectiveness of technology in our schools. ACT policy report*. Washington, DC: ACT.

Northrup, P. (2001). A framework for designing interactivity into web-based instruction. *Educational Technology*, *41*, 31-39. https://eric.ed.gov/?id=EJ625228

Paiva, R., Bittencourt, I. I., Tenório, T., Jaques, P., & Isotani, S. (2016). What do students do on-line? Modelling students' interactions to improve their learning experience. *Computers in Human Behavior*, *64*, 769-781. http://dx.doi.org/10.1016/j.chb.2016.07.048

Pando-Garcia, J., Periañez-Cañadillas, I., & Charterina, J. (2015). Business simulation games with and without supervision: An analysis based on the TAM model. *Journal of Business Research*, *69*, 1731-1736. http://www.sciencedirect.com/science/article/pii/S0148296315004695 (doi: 10.1016/j.jbusres.2015.10.046).

Pena-Shaff, J. B., & Nicholls, C. (2004). Analyzing student interactions and meaning construction in computer bulletin board discussion. *Computers & Education*, *42*, 243-265.

http://dx.doi.org/10.1016/j.compedu.2003.08.003

Picciano, A. G. (2002). Beyond student perceptions: Issues of interaction, presence, and performance in an online course. *Journal of Asynchronous Learning Network, 6*, 21-40. http://www.anitacrawley.net/Articles/Picciano2002.pdf

Porter, M. F. (1980). An algorithm for suffix stripping. *Program*, *14.3*, 130-137. http://www.cs.toronto.edu/~frank/csc2501/Readings/R2_Porter/Porter-1980.pdf

Rajaraman, A., & Ullman, J.D. (2011) *Mining of Massive Datasets*. Cambridge University Press.

R Core Team (2016). R: A language & environment for statistical computing. Vienna: R Foundation for Statistical Computing.

Ransdell, S. (2013). Meaningful posts and online learning in Blackboard across four cohorts of adult learners. *Computers in Human Behavior*, *29*, 2730-2732. http://dx.doi.org/10.1016/j.chb.2013.07.021

Reich, B. J. (2015). Rebooting MOOC Research. *Science*, *347*, 34-35. http://science.sciencemag.org/content/347/6217/34 (doi: 10.1126/science.1261627).

Romero, C., & Ventura, S. (2007). Educational data mining: A survey from 1995 to 2005. *Expert Systems with Applications*, *33*, 135-146. http://dx.doi.org/10.1016/j.eswa.2006.04.005

Romero, C., López, M. I., Luna, J. M., & Ventura, S. (2013). Predicting students' final performance from participation in on-line discussion forums. *Computers & Education*, *68*, 458-472. http://dx.doi.org/10.1016/j.compedu.2013.06.009

Soller, A. L. (2001). Supporting social interaction in an intelligent collaborative learning system. *International Journal of Artificial Intelligence in Education*, *12*, 40-62. https://telearn.archives-ouvertes.fr/hal-00197321/document

Song, N., & McNary, S. W. (2011). Understanding students' online interaction: Analysis of Discussion Board Posting. *Journal of Interactive Online Learning*, *10*, 1-14. http://www.ncolr.org/jiol/issues/pdf/10.1.1.pdf

Soo, K. S., & Bonk, C. J. (1998). Interaction: What does it mean in online distance education? In: *Proceedings of the World Conference on Educational Multimedia and Hypermedia & World Conference on Educational Telecommunications*. *ED-MEDIA/ED-TELECOM 98*, Freiburg, Germany.

Swan, K. (2002). Building learning communities in online courses: The importance of interaction. *Education, Communication & Information*, *2*, 23-49. http://dx.doi.org/10.1080/1463631022000005016

Wei, H.-C., Peng, H., & Chou, C. (2015). Can more interactivity improve learning achievement in an on-line course? Effects of college students' perception and actual use of a course-management system on their learning achievement. *Computers & Education*, *83*, 10-21. http://dx.doi.org/10.1016/j.compedu.2014.12.013

AP acknowledges the support of TEC2014-60337-R grants from the Ministerio de Economía y Competitividad (MINECO). AP is part of the 2014SGR-1063 consolidated research group of the Generalitat de Catalunya, Spain. CIBER of Bioengineering, Biomaterials and Nanomedicine is an initiative of ISCIII.