Using Learning Analytics to improve teamwork assessment

Ángel Fidalgo-Blanco [a,1], María Luisa Sein-Echaluce [b,*], Francisco J. García-Peñalvo [c,2], Miguel Ángel Conde [d,3]

[a] Laboratory of Information Technologies Innovation, LITI, Polytechnic University of Madrid, School of Mining and Energy Engineering, Ríos Rosas, 21, 28003 Madrid, Spain
[b] Department of Applied Mathematics, University of Zaragoza, School of Engineering and Architecture, María de Luna 3, 50018 Zaragoza, Spain
[c] Department of Computer Science, University of Salamanca, Faculty of Science, Plaza de los Caídos S/N, 37008 Salamanca, Spain
[d] Department of Mechanics, Computer Science and Aerospace Engineering, University of León, School of Industrial and Computer Science Engineering, Campus de Vegazana S/N, 24071 León, Spain

ABSTRACT

Acquiring the teamwork competency is fundamental nowadays, in order to guarantee a correct working performance for individuals. This means that a great deal of importance is being given to this activity in educational circles. Nevertheless, evaluating the development of teamwork individually is not simple, given that on many occasions there is no objective evidence to study. Information and Communication Technologies applied to educational contexts enable access to information that can help in this analysis. However, it is still complex due to the large amount of information that needs to be considered. This study proposes indicators based on the interaction between learning agents (student–student and active–passive). The exploration of these indicators contributes to the assessment of the individual development within the teamwork context. The analysis carried out in this study demonstrates that there is a direct relation between these interactions and final grading corresponding to individual assessment of teamwork activities by teachers. Additionally, a Learning Analytics system is introduced as support for the challenging task that teachers face in evaluating and monitoring individual progress within teamwork. The information provided by the Learning Analytics system and timely information extraction allow preventing problems, carrying out corrective measures and making decisions to improve the learning process of teamwork.

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1. Introduction

It is widely accepted that students should build their own knowledge in an active manner (Alexander, 2006). The cooperative model proposes that learning is produced more successfully when small groups of students share information and debate it together. Doing so in groups allows them to build mental models and, therefore, knowledge (Leidner & Jarvenpaa, 1995; Vogel, Davison, & Shroff, 2001). The teamwork competency (hereafter referred to as TWC) is highly valued by organizations that need cooperation between their members in order to achieve their objectives (Iglesias-Pradas, Ruiz-de-Azcárate, & Agudo-Peregrina, 2015). The

General Secretary of the United Nations includes the TWC amongst its Core Competencies that "... refer to the combination of skills, attributes and behaviour required of all staff, regardless of their level or function" (UN, 2014).

In educational circles, based on the implementation of the European Higher Education Area (EHEA), the large majority of universities include the TWC in its study programs and, therefore, should do the teamwork assessment to verify the extent to which such competency is acquired by means of evidence. Qualification Accreditation Programs like ABET (Accreditation Board for Engineering and Technology) (ABET, 2013) ask for this type of evidence within the internal evaluations of universities and, in particular, the Spanish quality agencies (national and regional) request it within their revision programs to verify qualifications (ANECA, 2014). Similarly, the Horizon report for Higher Education (Horizon, 2014) says that "Many educators are discovering that online platforms can be used in order to provide the solution to problems in groups, and to develop communication skills whilst the students' knowledge is increased". Helfand (2013) demonstrates how a progressive collaborative learning system in Higher

* Corresponding author. Tel.: +34 622158982.
  E-mail addresses: angel.fidalgo@upm.es (Á. Fidalgo-Blanco), mlsein@unizar.es (M.L. Sein-Echaluce), fgarcia@usal.es (F.J. García-Peñalvo), miguel.conde@unileon.es (M. Ángel Conde).
  [1] Tel.: +34 913367046.
  [2] Tel.: +34 923294400x1302.
  [3] Tel.: +34 987 29 34 18.

Education can produce graduates with communication skills, quantitative reasoning and teamwork. However, in order to carry out monitoring and a subsequent evaluation, evidence is needed. The development of teamwork leaves evidence of three types: individual (participation, cooperation, monitoring, leadership, efficiency, etc.), group (mission and objectives, standards, map of responsibilities, etc.) and results (Perez Martinez, Garcia Martin, & Sierra Alonso, 2014).

In organizational environments, group evidence and its identification are usually measured, and its knowledge and structure are used in the professional accreditation concerning the TWC (Baker, Day, & Salas, 2006; Salas, Bowers, & Edens, 2001; Salas, Tannenbaum, Cohen, & Latham, 2013). However, in higher education, the result is fundamentally evaluated (based on final work), because it provides a clear evidence that is suitable for comparisons and can be measured. Nevertheless, as Barkley, Cross, and Yhowellmajor (2007) indicate "…in collaborative learning two things need to be assessed: the students' command of the subject content and their participation in the group processes. The majority of teachers want to know to what extent the students have learnt the subject content related with the subject in question. Teachers that choose collaborative learning also believe that it is important to grade the team processes".

In this sense, the majority of students that start their studies at Spanish universities begin with a substantial lack of knowledge in terms of TWC development. According to the Fidalgo's study (Fidalgo, Leris, Sein-Echaluce, & García-Peñalvo, 2013) more than 65% of the students begin their higher education studies without (or hardly) having used teamwork tools and procedures. Fidalgo et al. (2013) demonstrate that 80% of university students that are starting out have never been evaluated in the TWC and, for the rest, only 20% have had the TWC assessed during the development of teamwork. All of this indicates that, in the context of the study, students reach university without having experience with the TWC, or without having had the development of their TWC monitored or evaluated. However, this lack of training concerning the phases of development in the acquisition of the TWC leads, on many occasions, to what some authors demonstrate in evidence: students work individually and only come together in order to compile the results obtained (Sancho-Thomas, Fuentes-Fernández, & Fernández-Manjón, 2009), reducing the interaction between peers to the greatest extent (Vik, 2001).

Furthermore, the effectiveness of the teamwork is not only measured by the results or group evidence, but also by the quality of the performance of the team members; in this way, Strom, Strom, and Moore (1999) state that "One of the most perplexing tasks for teachers is to identify the teamwork skills acquired by individuals" and that "Teachers know that group success depends on individual accountability".

Unfortunately, teamwork assessment methods, both for the results obtained and the group evidence, do not normally really measure the acquisition of the TWC by each individual. Most commonly, the monitoring and assessment of TWC development is carried out by student opinion surveys, in order to observe students' perceptions or peer evaluations to measure the individual evidence (Poblete & García Olalla, 2014). These methods highlight the relevance of mutual assessment among team members. Therefore, team members should be up-to-date with the tasks that each individual should undertake, as well as with group milestones and tasks. This translates into an improvement of the individual perception of the effectiveness of teamwork (Fransen, Kirschner, & Erkens, 2011).

On the other hand, this assessment should also take into consideration the behaviour of the leader, who has a great impact on the group performance and on the development of the teamwork (Huang, Kahai, & Jestice, 2010). Hambley, O'Neill, and Kline (2007) note the importance of the leaders when it comes to establishing the means of communication used for virtual groups in order to achieve a communication and collaboration that is more effective, in turn increasing their constructive interactions and cohesion, which in addition can ultimately affect the team performance.

Therefore, in order to evaluate TWC performance it is not enough to have evidence of aspects like cooperation or leadership, but it is also necessary to perform a total monitoring of the evidence collected about the performance of each and every one of the team members. Nevertheless, this is very difficult to achieve using traditional methods (Salas, Sims, & Burke, 2005). In order to carry out the monitoring and individual evaluation in a teamwork context, various tools have been developed: surveys that measure the perception of students (Battles & King, 2010; Perez Martinez et al., 2014), self-evaluation questionnaires and peer evaluation (Strom et al., 1999; De los Rios Carmenado, Figueroa Rodríguez, & Gómez Gajardo, 2012) and rubrics, closely related with peer evaluation. Those tools are used for the formative assessment (during the process) and for the summative assessment (at the end of the process), and thus allow monitoring of the competency so as to improve the learning process (Martínez-Figueira, Tellado-González, & Raposo-Rivas, 2013). With regard to the tools used to monitor the teamwork, recording the debates of each group stands when virtual debates are used (Gu, Shao, Guo, & Lim, 2015).

However, monitoring methods, despite being widely used, present drawbacks in terms of their validity as assessment methods, because they are exclusively based on the perception of students (lacking in objectivity) or because they lead to difficult and cumbersome analysis procedures, like measuring the participation of each one of the team members (as in recording of debates).

Therefore, objective evidence about the participation of each member during the development of the teamwork needs to be collected. Nevertheless, teaching staff usually face great difficulties in order to follow the different phases of the development of the teamwork, due to the impossibility of carrying out direct individual monitoring and access to every objective evidence due to time limitations. This constraint prevents decision making throughout the process, which would enable timely solving of learning anomalies and improvement of learning. It is therefore necessary to have individual and group evidence that allow teaching staff to identify the skills related with teamwork of group members during its execution, and to give students feedback about their strengths and shortcomings, as well to detect problems, like delays and failure to assume individual responsibilities.

The CTMTC method (*Comprehensive Training Model of the Teamwork Competence*) (Leris, Fidalgo, & Sein-Echaluce, 2014), integrates tools that are present in the different Learning Management Systems (LMS) and facilitate registration of user interactions, as well as an easier access to teamwork evidence. This method works with the following kinds of evidence (Fidalgo et al., 2013):

- Final result of the work. In an online format (commonly on Wikis).
- Group evidence corresponding to the different phases of work (mission and objectives, time frame, map of responsibilities, organization of information). On Wikis and Dropbox.
- Individual evidence (active participation, responsibility, leadership, cooperation, etc.). On forums.

However, the CTMTC method and other similar ones, on their own, are not completely effective. The reason is that monitoring individual evidence in the teamwork and evaluating its performance requires a great deal of time for the teaching staff (the effort

should be multiplied by the number of students), because monitoring and assessment (formative and summative) of the individual evidences require a qualitative analysis of all of the interactions in the forum (what students say, how they say it, and when they say it).

LMS store quantitative data about forum interactions. These data act as a tool that helps in the prediction, intervention and decision making (Agudo-Peregrina, Iglesias-Pradas, Conde-González, & Hernández-García, 2015; Van Barneveld, Arnold, & Campbell, 2012). In general, an additional processing of information is required so that it may be useful for individual evaluation of the TWC.

Previous studies on the influence of different types of user interactions, in learning contexts based on IT (Agudo-Peregrina et al., 2014) show that the number of interactions is related with learning results. This means that the number of interactions throughout the teamwork processes should directly influence the result of the learning within the teamwork, and therefore interactions can be considered as indicators in order to evaluate the teamwork process.

As mentioned earlier, LMS provide data related to interactions; however, on many occasions the data gathered are underused (Phillips, Maor, Preston, & Cumming-Potvin, 2012), and in other cases they do not provide useful information, which means that it is necessary to further process the data with additional tools (Johnson, Adams, & Cummins, 2012). The application of *Learning Analytics* (hereafter referred to as LA), defined as "Learning Analytics is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs." (Long & Siemens, 2011), allows collecting, using and analysing the quantitative data about the interactions and evidence in the forums provided by the LMS, as well as handling the data with tools that offer different visualisations, and therefore can offer support in the assessment, training and development of the TWC.

Taking into account the foregoing, the objective of this study is the definition of mechanisms that allow accurate predictions based on measurable indicators, of individual grades in teamwork contexts (individual teamwork assessment), taking into account the impact derived from the use of LA tools. More specifically, this research shall consider the validation of data about interactions as predictors of the individual performance in a teamwork context, as well as the potential benefit deriving from the application of LA techniques to individual assessment in teamwork and decision making.

The next section explains the CTMTC method applied in this study to the training and development of the TWC, the indicators used to monitor the teamwork, the LA tool used in the study, as well as the analysis of the data obtained in the empirical study. Next, the results of the research are presented, followed by a discussion of the results, and the main conclusions from this study.

2. Method

CTMTC allows the individual, group and result competencies of teamwork to be monitored and evaluated (Leris et al., 2014), based on evidence associated with the phases of the IPMA model: storming, norming, performing, delivery and documentation (AEIPRO-IPMA, 2009). CTMTC collects these evidences from three sources: forums (where the development of the work phases are presented), Dropbox (including management and sharing of documents on a hard drive online) and Wiki tools (where the results of the phases and the final results of the teamwork are stored). It involves a mixed learning context with the aim to promote the acquisition of teamwork skills and social skills, and to force the student to adopt a more active and cooperative role. This method promotes debates and discovery in collaboration, placing the focus on the process and not on the result (Duch, Grosh, & Allen, 2001).

CTMTC is also independent of the type of course; thus, it may be used in both initial courses, in which the contents are more general, and last year courses where more specialised education is given. In this study, CTMTC shall use virtual teamwork techniques (forums, wikis, etc.) in a b-learning context, with teams that can also have meetings in person. Virtual teamworks present more difficulties when the process begins because the students are used to debating in face-to-face meetings, as well as communicating over more immediate means (e.g. WhatsApp) that do not allow keeping a structured history of the interaction. Regardless, CTMTC with virtual teamwork adds other asynchronous communication possibilities to face-to-face communication, making it possible to capture evidence of the development of the work and to organise the knowledge created by the group.

In CTMTC, a LMS provides data about student–system interactions. The student–content interactions take place primarily in the wiki and the content management system, associated with the group and result evidence. The forum contains the interactions of the teamwork process (student–student, both active and passive) and it is the key tool for studying the individual evidence associated with the process. The analysis of forum interactions allows individual evaluation in the context of the teamwork, as well as detecting conflicts. Given its importance, this research focuses on forum indicators, as the fundamental element for teamwork assessment, as explained in the next section.

2.1. Proposal for monitoring indicators of the teamwork

In order to apply the CTMTC method, the members of each group use different threads in a private forum in order to organise and carry out the different work phases. By observing the interactions on each thread, it is possible to monitor and evaluate the actions of each member of the team for each one of the teamwork phases for, formative and summative assessments, respectively. Hammond (2000) states that the more structured the forum is, the more in depth the discussion is. This relation suggests that the discussion threads in an online forum should be easy to follow and review. It is particularly important, in online collaboration, that tasks are clearly defined (Tolmie & Boyle, 2000).

Welty (2013) says, with regard to formative assessment, that "data gathered in that evaluative effort can at the same time be made available to management, during the course of the training process, to allow decisions to be made about program improvement". The formative assessment allows students to know the extent of development of their competency, the corrective actions that should be taken and the level of development compared to that of their colleagues. It also helps the teaching staff to make decisions concerning the complementary actions and the necessary resources, so that the individual and group competencies of teamwork are developed.

The work of Agudo-Peregrina et al. (2014) provides important results regarding the influence that the student interactions in a LMS have in their learning process. That is why the interactions between members of a same team are chosen in this study as individual learning indicators in the teamwork context.

In the work mentioned (Agudo-Peregrina et al., 2014) there are three categories of interactions, based on *the agent* (student–student, student–teacher, student–contents) (Moore, 1989), *the frequency of use* (most used, moderately used and rarely used) and *the form of participation* (active or passive). In this last aspect, Pascual-Miguel, Chaparro-Peláez, Hernández-García, and Iglesias-Pradas (2011) define active interactions as "those contributions made by each student that could serve as a knowledge lever for

other students". Whilst on the other hand passive interactions are "those related to the access and reading of contributions from others".

In the CTMTC, the individual assessment is carried out in the forum, where the student–student interactions and active–passive interactions happen, and which correspond to the indicators chosen for monitoring and assessment of teamwork. The number of messages in the forum is the indicator use to measure active student–student interactions, whilst the passive student–student interactions are measured by the number of visits (message views).

Assessment of a member of the team, done in a manual way, requires the teaching staff to observe the reports that the LMS provides about student interactions in the forum, to measure the total number of interactions and to compare them with the interactions of the rest of the team members. This process is tedious and slow, and this is why an LA system has been developed to gather, organize and report that information. This system acts as fundamental help for the teaching staff in the continuous assessment, decision making and the assessment of the individual activity within the work team.

2.2. Design and function of the LA system

For the analysis of the relations between the interactions in the forum and the individual evaluation in teamwork contexts in online education, the LA system allows compilation and aggregation of the different individual evidence about forum interactions, for each student. This section describes how the tool works, its technological support and empirical testing with data obtained for the summative assessment of 19 work teams, in order to analyse the most effective models for prediction of the individual academic result of each student and monitoring of the teamwork process.

2.2.1. How the LA system works

The LA system allows choosing a forum within the course and then display the data for the student–student interactions, with three different view modes: the whole forum, a team using that forum and an individual thread created by a specific team. *By selecting a forum* the system provides data about: the number of total messages in the forum, the number of people registered in the forum, (in other words, the total number of team members), the average number of messages of every member of all teams (average participation of each student), the list of teams and the total list of students with their respective of the number of messages (in percentage, compared to the total number of messages in the forum). *By selecting a participating team in the forum*, the data obtained comprises of the total number of team messages, total number of team views, number of members in the team, average number of messages of each member of the team, creation dates of the first and last thread, list of threads (with the date of creation for each thread, total views and total messages), and list of the team members (with number of messages and percentage in relation to team messages). *By selecting a thread for the specific team*, the system provides data about: number of messages of the thread, author of the first message and its date of creation, author of the last message and its date of creation, members of the team that have participated in the thread, number of messages of each member and the percentage of participation, in relation to the total number of messages in the thread, and the number of thread views. In addition, in this view rules of action can be defined based on thresholds set upon the number of messages.

2.2.2. Technological support

The system has been implemented as a web service in Moodle. A web service is a programming interface that describes a collection of operations accessible via internet, with messages based on XML (Conde, Gómez, et al., 2010; Conde, García-Peñalvo, et al., 2010). The use of web services ensures, amongst other things, that the solutions defined are independent of the underlying implementation (Gottschalk, Graham, Kreger, & Snell, 2002; W3C, 2004).

The implementation of this solution requires, on the one hand, the adaptation of the web services of the LMS to the desired goal: returning the information recorded on the learning platform (*Web services* in Fig. 1) and on the other hand, it defines a client capable of consuming that information (*Web Service Consumer* in Fig. 1) in order to provide a suitable view of the data.

After analysis of the web services provided by Moodle, and given that their output is not suited to the needs of the tool, ad-hoc services were defined using the extension mechanisms of the platform requires. Specifically, a service called "Group Competency" was created. That service includes functions for retrieval of information from the courses on the platform, the course forums, the course teams, the threads for a given team and a certain forum, particular information from the threads and the users of those threads, the number of messages per team, information from a post based on its id, information about users per team, number of views per discussion and views per discussion and user.

This information is consumed by a client that allows navigation by the structure of the information. To do so, the client lets users to select a course, forum and team from the learning platform and, depending on the selection, it shows particular information about the users' interactions in the forum and the thread. There would also be the possibility to retrieve specific information for a certain user. This information is valid for formative and summative assessment of the TWC. The next section presents examples of these types of assessment.

As mentioned above, the system allows defining a group of rules based on the number of interactions. For example, it may detect if a member of the team has less interactions than a certain number set by the teacher. That number is a percentage of the average number of team interactions. This functioning variant provides the tool with system alert capabilities and support in decision making.

2.3. Context of the research and analysis of data

In order to carry out the empirical analysis, 110 students from the Technical University of Madrid were selected and grouped into 19 work teams (with an average of 6 members in each team, a minimum of 5 members and a maximum of 7), among first year students of the Biotechnology degree (academic year 2013–2014).

The course design is as follows: upon beginning of the academic year a session of 2 h is carried out to explain the different phases of the teamwork (following the CTMTC model). Then, the work is carried out over the course during three months and the activities take place in the online tools: LMS-Moodle (forum), Dropbox and an external wiki.

The final grading of the team is calculated from the different grades based on the individual evidence (forum), group evidence (wiki and Dropbox) and result evidence (wiki). The teacher assigns the final grade of the individual evidence in the forum at the end of the three months of completion of the work, and it is obtained by performing a semantic analysis of student–student interactions in the forum. In the subsequent analysis, the individual grades calculated by the teacher using a manual procedure (information about the individual performance in the forum, without the help of the LA system) are treated as the dependent variable and the number of written messages (active interactions) and number of views (passive interactions) are the independent variables.
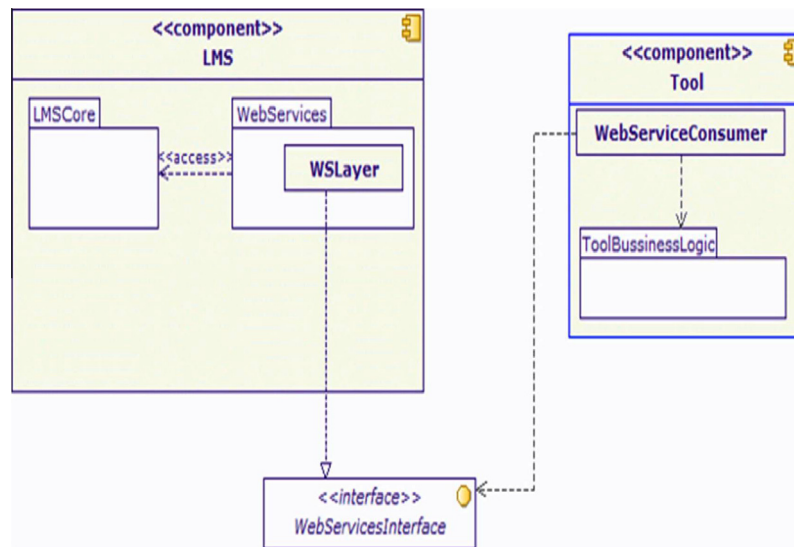
Fig. 1. Diagram connection of a client with the LMS web services.

The analysis aimes to test the validity of interaction data as predictors of the individual performance in a teamwork context. The analysis is based on the observation of correlations between the types of student–student interactions (both active and passive) and the individual academic performance from forum analysis (manual grades given by the teaching staff) (Agudo-Peregrina et al., 2014).

This research differs from previous studies focused on individual contexts (e.g. Macfadyen & Dawson, 2012) in that the relation between interactions and individual academic performance is analysed in a teamwork context.

3. Results

The 19 work teams created 5136 messages in the forum, with a total of 37,930 message views.

Table 1 shows the average and standard deviation of active interactions (messages in the forum) and passive interactions (views in the forum) per work team.

Table 2 shows the same data, but this time separating the leaders from the rest of the team members, in order to take into account their potential influence on the team performance (Hambley, O'Neill & Kline, 2007), due to the fact that the style of leadership can influence the participation of the rest of the team components.

The LA system provides information about the individual interactions of the team members. In order to explore the suitability of the indicators proposed as predictors of individual performance, the global correlation between the individual student–student interactions and the individual performances of the members of the whole class were calculated (Table 3).

Based on the correlations from Table 3, there is a significant and moderate relation between student–student interactions (both passive and active) and final grade. Nevertheless, the results of the previous analysis are global and do not provide enough information about the internal functioning of each team, and therefore a more detailed analysis (on a group basis) was considered necessary. The results of this analysis are presented in Table 4.

From Table 4, in all of the cases the correlations between written messages (active interactions between students) and individual final grade obtained in the teamwork are statistically significant, confirming that there is a strong relation between

them. However, in the case of the views of messages, the relation between message views and individual final grade is only significant in roughly more than half of the cases, meaning that it cannot be confirmed that the number of views of the forum is a valid predictor of the final performance of the student within a teamwork context.

It is interesting to observe a low and non-significant correlation in teams 1 and 15; the explanation for this result is that in those teams there are team members with a similar number of views as the leader (in fact, in team 1 there is one person who has more views than the leader, and another whose number of views is close to that of the leader, whilst in team 15 the difference is bigger, with a team member having a number of views that is notably higher than the leader, but also with a considerably lower grade). Future analysis should be used to detect if this type of behaviour is indicative of a poor individual performance in collaborative teamwork

Table 1
Means and standard deviation of the number of messages posted and message views per team.

Mean of messages created (st. dev.)	Mean of message views (st. dev.)
270.31 (110.57)	1996.31 (722.86)

Table 2
Means and standard deviation of the number of messages posted and message views by the leader and the rest of team.

Mean of messages created: leader (st. dev.)	Mean of message views: leader (st. dev.)	Mean of messages created: rest of members (st. dev.)	Mean of message views : rest of members (st. dev.)
85 (43.59)	584 (262.77)	38 (13.63)	293 (103.26)

Table 3
Pearson's correlation between individual grades and views and messages of each student ($n = 110$).

Views – individual grade	Messages – individual grade
0.46[*]	0.57[*]

[*] $p < 0.01$.

Table 4
Pearson's correlations between individual views and messages and final individual grades for each one of the teams (average number of components in each team: $n = 6$).

TEAM	Individual views/ individual grade	Individual messages/ individual grade
Team 1	0.30	0.97[*]
Team 2	0.98[*]	0.97[*]
Team 3	0.88[**]	0.89[*]
Team 4	0.91[*]	0.85[**]
Team 5	0.56	0.90[*]
Team 6	0.83[**]	0.80[*]
Team 7	0.71	0.90[*]
Team 8	0.81[**]	0.96[*]
Team 9	0.71	0.90[*]
Team 10	0.65	0.97[*]
Team 11	0.57	0.86[**]
Team 12	0.72	0.77[**]
Team 13	0.64	0.87[*]
Team 14	0.87[**]	0.88[*]
Team 15	0.28	0.92[*]
Team 16	0.87	0.96[*]
Team 17	0.64	0.87[*]
Team 18	0.77[**]	0.86[**]
Team 19	0.78[**]	0.88[*]

Without asterisk: non-significant correlations.
[*] $p < 0.01$.
[**] $p < 0.05$.

contexts. In that case, a fundamental advantage of the LA system is that it would allow a more direct observation of these patterns of anomalous behaviour, and therefore it may offer relevant information which may lead to corrective interventions by the instructor in order to improve the learning process in the teamwork context.

4. Discussion

Previous studies have confirmed the existing relation between the number of interactions and the learning results. Like Agudo-Peregrina et al. (2014), this study confirms this relation, but applied to a more specific situation: teamwork. The results of the analysis of the relation between individual final grades and the number of individual messages/views have confirmed the relation of active and passive interactions in the team and their academic performance. The use of LA systems to monitor the interactions also helps individual assessment in teamwork contexts.

The teamwork development process itself reflects the injustice of grading all of the members based on the results of the final work, which means that the monitoring of the individual work of each member is necessary.

In the analysis, the members are considered individually, consistent with prior studies which confirm that the quality of the individual performance of their members is a fundamental factor for the success of the team (Storm, 1999). This study confirms these findings and also shows that the scope of the analysis should be the work team (note that in Table 4, in comparison with Table 3, the correlation is significantly lower when the analysis includes all the course members).

Similarly, from Tables 3 and 4, active student–student interactions have a greater relation with the individual performance in teamwork contexts than passive student–student interactions, and therefore the former can be considered better predictors of final grade.

On the other hand, the information in Table 2 reflects that the leaders show a greater number of active and passive interactions than the rest of the team members (almost double). In the same way, the results in Table 3 showed how two teams had much lower correlation coefficients than the rest of teams, but a closer examination of individual data of both teams revealed that in one of those teams there was a member who had more views than the leader and another member had a similar number of views as the leader, with both having grades that are close to those of the leader. However, in the second team, there was a member with a greater number of views than the leader, but considerably lower grade.

Apart form the indicators used in this study, individual work assessment in a team, on a LMS context, could benefit from using additional indicators of activity, like correspondence between the name of a thread (and a certain stage of the teamwork process), the distribution of threads along time, sequencing within the thread, message semantics, etc.), all of which involves complex work that requires a great deal of effort.

It has been demonstrated in the analysis that certain indicators are strongly related to final grades. Therefore, LA systems may facilitate grading by automating data acquisition. The LA tool developed for this research may become a fundamental support for teachers to monitor the activity of individual students in the forum. By using tools such as the one presented in this study, the teaching staff may pass from having to dedicate a minimum of 10 min per team member and having to manually count the number of active–passive interactions in order to relate them with the rest of the members, to carrying out these tasks almost instantly. Notice that completion of formative or summative assessment, without the help of the LA system, requires an average allocated time of 1 h per team, which considerably limits the number of formative assessments to be completed.

The LA system also facilitates organization, structuring and filtering of data from the LMS, contributing to different perspectives about the information collected. In addition to providing data about the interactions, by teams, members and by threads, alerts may be defined in the LA system by setting different thresholds. These alarms may be triggered when certain conditions are met (e.g. a relative low level of participation of the team, or of an individual in a team). Future research should explore the possibility of including the study of the relation of these variables with the individual performance in the teamwork context and its potential to detect anomalies, so that the members are aware of their status, with respect to the rest of team members.

As a result, the LA system could be used to detect conflicts in each phase of the development: team delays (e.g. not meeting deadlines), lack of leadership, shared leadership, detecting members who are not participating, etc. Additionally, the application of the LA system at specific points in time in the teamwork, allows timely retrieval of information about student interactions in each phase of the team work, which can in turn help in the individual assessment in a specific phase of the teamwork. This capacity capability for real-time analysis positions the LA system as an adequate tool for formative assessment (and the subsequent decisions and actions derived from it). Furthermore, we suggest to explore the use of other indicators in combination with the ones used in this study (such as sequencing of the interactions, the semantics of the messages, the transient nature, etc.) in order to evaluate their adequateness for inclusion in future versions of the tool.

5. Conclusions

In educational contexts, teamwork activities have become highly relevant, fundamentally due to the need for the development of the TWC, and particularly in order to guarantee the future team work performance of the student. It has been observed, nevertheless, that the assessment of the TWC cannot be based on the result of the group activities, but rather that it is necessary to evaluate the activity of each member in an objective manner. The assessment methods used until now, like measuring the perception

of students about their work throughout the development of the teamwork, or peer-assessment, are not sufficient. It is necessary to assess real evidence of the work of each team member in the group activities. One way of doing so is the study and analysis of the interactions between students, upon which it is possible to infer the individual performance of the teamwork context.

The present study has confirmed the relation of certain types of interaction (student–student active and passive interactions) with individual performance within the team. Those interactions are stored in the VLE. However, individual assessment of the team work is not an easy task, particularly when the number of teams involved in the assessment is very large. As this study shows, LA systems offer support for individual monitoring and assessment (both formative and summative) of the teamwork.

The LA system presented in this study collects information about student–student active and passive interactions from the VLE forums. This information can be grouped by teams, individuals and stages of the teamwork development (the different stages correspond to the different threads in the forum). The analysis confirms that there is a direct relation between the active and passive interactions and the final grade from individual evaluation by the teachers. Using this data, the LA system can be used to perform formative assessments and initiate a subsequent process of decision making based on the results of that assessment. The LA system enables real-time detection of anomalies, and therefore it may allow teachers to make decisions oriented toward helping with the acquisition of the individual competency, working with members that try not to assume their responsibilities, correcting the development of a malfunctioning group activity, motivating the individuals involved in the development of the group activity and increasing their interaction, identifying the progress of the teamwork, comparing the results between the different teams in order to analyse the efficiency of the educational plan, knowing what can be improved in future approaches to similar group activities, etc. Likewise, the LA system facilitate final assessment, gas it allows identifying individuals that have worked less than average when compared to their colleagues.

In terms of the possible lines of future studies, it would be interesting to analyse the semantics of active interactions, as well as their transient nature and the distribution of threads. Future research should be also consider other possible indicators about interaction, which have not been contemplated until now, as well as the inclusion of other types of interactions beyond those that are collected from forum activity. For example, some types of interaction in work contexts may fall outside the control of the institution, like personal learning contexts (mainly on social networks). Furthermore, the LA system presented here could be improved to include techniques for the visualisation of information that would allow simultaneous comparison of the work and progress of different teams. It would also be interesting to define different types of roles for the LA system, in such a way that the leader of a team would have the chance to access some of the information provided by the LA system and to observe how the members of their team are working and supervise that all of the members of their team are successfully participating in the teamwork process.

Acknowledgements

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