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Interactive relationships in online learning communities can influence the process and quality of knowledge building. The aim of this study is to empirically investigate the relationships between network structures and social knowledge building in an asynchronous writing environment through discussion forums in a learning management system. The quality of the knowledge construction process is evaluated through content analysis, and the network structures are analyzed using a social network analysis of the response relations among participants during online discussions. Structural equation modeling is used to analyze relations between network structures and knowledge construction. Working on data extracted from a 6-week distance-learning experiment, we analyzed how 10 groups developed collaborative learning social networks when participants worked together on case resolution. The results show a positive correlation between cohesion and centralization, and the positive influence of the cohesion index and the centralization index on social presence and cognitive presence in knowledge building. However, this must be understood within the context of social networks in which messages sent to all group members occupy the center. This underlines the need for reinforcing participations that are directed to the group as a whole, and the importance of the fact the network contains both central and intermediate members. By contrast, we propose that the combination of analysis techniques used is a good option for this type of study while recognizing that it is necessary to continue validating the instruments in terms of their own theoretical suppositions.

**Keywords:** network cohesion; network centralization; social knowledge building; discussion forums; learning management system (LMS)

## 1. Introduction

Gone are the times when studies on collaborative learning were limited to identifying its effects on and relation to different methodological variants. Now the new generation of researchers seeks to identify the causes and mechanisms behind the positive results of collaborative learning, focusing attention on the processes of collaborative interaction among peers (Arvaja & Häkkinen, 2010; Kreijns,

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Kirschner, & Jochems, 2003; Kreijns, Kirschner, Jochems, & van Buuren, 2007; Neitzel & Neitzel, 2009).

Discussion forums that operate within an learning management system (LMS) produce high levels of student–student and student–teacher interaction; therefore, they can support teaching and learning models such as communities of inquiry that are highly interactive and consonant with the communicative ideals of university education. Higher education has consistently viewed community as essential to support the collaborative learning and discourse associated with higher levels of learning. Moreover, the asynchronous nature of online communication and the potential for disconnectedness has focused attention on the issue of community. This potential and the ubiquity of discussion forums in higher education prompted the authors of this article to develop communities of inquiry (Garrison, 2007; Garrison, Cleveland-Innes, & Fung, 2004; Rourke, Anderson, Garrison, & Archer, 2001; Shea & Bidjerano, 2009) among university students who develop practices in geographically separated centers.

Garrison, Anderson, and Archer (2000) developed a comprehensive framework as an online learning research tool. This is a tool for analyzing the content of discussion forum transcripts. The framework consisted of three elements – social, teaching, and cognitive presence – as well as categories and indicators to define each presence and to guide the coding of transcripts. This framework has provided significant insights and methodological solutions for studying online learning (Garrison & Archer, 2003; Garrison, Cleveland-Innes, Koole, & Kappelman, 2006). The structure of the community of inquiry framework has also been confirmed through factor analysis by Garrison, Cleveland-Innes, and Fung (2004) and Arbaugh and Hwang (2006).

Social network analysis (SNA) is also a useful tool for studying relations. It is a collection of graph analysis methods that researchers developed to analyze networks in social sciences, communication studies, economics, political science, computer networks, and others. Several authors have demonstrated the applicability of SNA to specific learning situations. In these studies, the collaborating persons (students, tutors, experts, etc.) are the actors. Links between a pair of actors represent the amount of communication between them.

While the qualitative analysis of content provides an understanding of micro-level interaction, incorporating a network analysis focused on the relations among participants may offer better understanding of the structural pattern of online interaction (Guerra, González, & García, 2010; Heo, Lim, & Kim, 2010; Lipponen, Rahikainen, Hakkarainen, & Palonen, 2002). The combination of content analysis and SNA has been used to study the effects of social network structures on knowledge construction. De Laat (2002) combined SNA with content analysis and demonstrated that the interaction patterns in the course analyzed were centralized and that the knowledge construction process focused on sharing and comparing information (i.e., concentrated in phase one). Likewise, Aviv, Erlich, Kavid, and Geva (2003) found high levels of cohesion and critical thought in structured groups in which the students were trained beforehand in the construction of knowledge through discussion forums. They note that cohesion could have both a beneficial or debilitating influence on discourse and reflection. Too cohesive a group could stifle criticism and, therefore, open discourse. Yang and Tang (2004) combine SNA with questionnaires when they analyzed the effect of group structure on performance in 25 groups and 125 students, finding that cohesion is positively related to the overall result. Zhu (2006) explores new methodologies for analyzing participation, interaction and learning in four discussion forums. This study uses SNA and a qualitative analysis instrument of content based on the model proposed by Henri (1992). The results of this study suggest that networks in which various members occupy central roles seem to facilitate collaboration and knowledge construction more than networks with a high level of centralization. This work confirms that interaction must be integrated in the course and promoted by the instructor and the students. Martinez et al. (2002) proposed a mixed evaluation method that studies participatory aspects of computer support for collaborative learning (CSCL) environments, by including SNA techniques, quantitative statistics, and computer data logs in an overall qualitative case study design. They identified as SNA indicators *network density*, *the degree of actor centrality*, and *network degree centralization*. Heo et al. (2010) investigate the patterns and the quality of online interaction in project-based learning on both micro- and macro-levels. To achieve this purpose, SNA and content analysis were employed to analyze online interaction during project work. However, the descriptive nature of this study and the lack of correlations between both types of analysis prevent us from drawing general conclusions from this article. In this sense, Wang (2010) utilize SNA, statistical analysis, and content analysis as research methods to investigate online learning communities at the Capital Normal University of Beijing. This research uses linear regression to identify the effects of centrality on knowledge construction in two learning communities of 44 and 18 members. The combination of these three analysis techniques produces results that can be applied more generally than those from content analysis and network analysis. The use of statistical analysis enables the structural characteristics of the groups to harmonize with knowledge construction via the establishment of relations or predictions. The research presented in our article sets out to test a methodology that combines SNA, content analysis, and structural equation modeling (SEM). The latter technique for statistical analysis enables us to identify and predict the effects and relations of several variables simultaneously, which provides results that can be applied generally. In terms of content, this investigation analyzes the influence of the global structural characteristics (cohesion and centralization) of 10 asynchronous learning networks (ALNs) via their LMS discussion forums on knowledge construction within the context of curricular practicals carried out at university level. This article is structured as follows: Section 2 provides background information regarding the two analytical schemes, content analysis, and SNA. Section 3 details research goals. Section 4 describes the experiment with 10 ALNs. Section 5 details the analysis method. Section 6 provides content analysis and SNA of the 10 ALNs; the structural equation analysis allows us to find the relationship between the structural factors of the social learning networks, such as cohesion and centralization, and the quality of the construction of the resulting knowledge (social presence and cognitive presence). Sections 6, 7, and 8 discuss the results, limitations of the analysis, and an outline of future research.

## 2. Theoretical background

### *2.1. Content analysis*

Asynchronous text-based discussions present several advantages as compared to synchronous discussions: students get more opportunities to interact with each other and students have more time to reflect, think, and search for extra information before contributing to the discussion (Pena-Shaff & Nicholls, 2004). The fact that all communication elements are made explicit in the written contributions to the discussions "makes the process of collaboration more transparent for the researcher, because a transcript of these conference messages can be used to judge both the group collaborative process and the contribution of the individual to that process [ . . . ]" (Macdonald, 2003, p. 378).

Henri calls CMC a "gold mine of information concerning the psycho-social dynamics at work among students, the learning strategies adopted, and the acquisition of knowledge and skills" (1992, p. 118). Other researchers use the transcripts of online discussion to investigate the process of the social construction of knowledge (Gunawardena, Carabajal, & Lowe, 2001; Gunawardena, Lowe, & Anderson, 1997) or critical thinking (Bullen, 1997). "In general, the aim of content analysis is to reveal information that is not situated at the surface of the transcripts. In-depth understanding of the online discussions is needed to be able to provide convincing evidence about the learning and the knowledge construction that is taking place" (De Wever, Schellens, Valcke, & Van Keer, 2006, p. 7).

This content analysis technique can be defined as "a research methodology that builds on procedures to make valid inferences from text".

However, the review by De Wever et al. (2006) of 15 of the most widely used content analysis tools in the field of investigation (Anderson et al., 2001; Bullen, 1997; Fahy, 2003; Fahy, Crawford, & Ally, 2002; Garrison et al., 2000; Garrison, Anderson, & Archer, 2001; Gunawardena et al., 1997; Henri, 1992; Järvelä & Häkkinen, 2002; Lockhorst, Admiraal, Pilot, & Veen, 2003; Newman et al., 1995; Pena-Shaff & Nicholls, 2004; Rourke et al., 2001; Veerman & Veldhuis-Diermanse, 2001; Veldhuis-Diermanse, 2002; Weinberger & Fischer, 2005; Zhu, 1996) reveals a number of limitations to consider: "The applied instruments reflect a wide variety of approaches and differ in their level of detail and the type of analysis categories used. Further differences are related to diversity in their theoretical base, the amount of information about validity and reliability, and the choice of the unit of analysis." This review highlights the need to improve the theoretical and empirical base of the existing instruments in order to promote the overall quality of CSCL research (De Wever et al., 2006).

Conscious of these limitations and their implications for the interpretation of the results of the research in this study, we used an adaptation of the instruments proposed by Garrison et al. (2000, 2001) and Rourke et al. (1999), because it has been applied in educational contexts similar to that of knowledge construction.

- The instrument of Rourke et al. (1999) is based on the analysis of social presence as one of the three elements of the community of inquiry as conceptualized by Rourke et al. (1999). The other two elements are cognitive presence and teaching presence. "Social presence supports cognitive objectives through its ability to instigate, sustain and support critical thinking in a community of learners" (Rourke et al., 1999, p. 54). Social messages, such as jokes, compliments, and greetings, do occur a lot in online asynchronous discussions (Rourke et al., 1999) and are considered to be important to motivate students. The social presence analysis model consists of three main categories: affective responses, interactive responses, and cohesive responses.
- The instrument of Garrison et al. (2001) is based on the analysis of cognitive presence as another element in the community of inquiry model. "Cognitive presence reflects higher-order knowledge acquisition and application, and is

closely associated with the literature and research related to critical thinking" (Garrison et al., 2001, p. 7). They operationalize cognitive presence through the practical inquiry process, which comprises four phases: (a) an initiation phase, which is considered a triggering event, (b) an exploration phase, characterized by brainstorming, questioning, and exchange of information, (c) an integration phase, typified by constructing meaning, and (d) a resolution phase, described by the resolution of the problem created by the triggering event (Garrison et al., 2001).

The asynchronous discussions analyzed in this research are identified with non-structured learning networks, in which teachers are not involved in the management of learning. Therefore, we will not analyze the presence of the teacher in the social construction of knowledge, but social presence and cognitive presence.



### 2.2. *Social network analysis*

It has been shown that active online participation is a key factor in the success of student learning (Hiltz & Turoff, 2000). Furthermore, we assume the hypothesis that cooperative learning is effective only within communicative groups. In distance learning based on collaborative production, we start with individuals that have to socialize in order to form a group which shares goals. The SNA focuses on the relationships between individuals instead of the individuals themselves. This kind of analysis also seems to be more appropriate than the long and detailed textual analysis of messages and the statistical distribution of participants' contributions (Reffay & Chanier, 2002). The SNA provides a new paradigm and methods for assessing knowledge building in online learning communities (Wang & Li, 2007).

As a result, SNA has been used as a tool to understand online classes and to extract useful information for teachers and teaching (De Laat, 2002; Martinez et al., 2002; Nurmela, Lehtinen, & Palonen, 1999; Reffay, 2003; Reffay & Chanier, 2002; Saltz, Hiltz, & Turoff, 2004).

The SNA analyzes the interactive relationships among participants by using algebra matrix and graph theory tools to describe the patterns of interaction and characteristics of networks with network measures. The markers used in the analysis of this experiment are the following:

- Size is one of the main structural determinants of the level of possible participation in a network. Group size is also important in the calculation of other parameters of network definition, such as density (Ridley & Avery, 1979). If certain students are not members of a particular network (because they opted for another communication network, for example), their absence must be noted in the size value (Fahy et al., 2002).
- Cohesion is an important factor that motivates participants to accomplish the requested task (Dewiyanti, Brand-Gruwel, Jochems, & Broers, 2007; Reffay, 2003; Wang & Li, 2007; Yang & Tang, 2004). "When it does not exist, the collaborative task may be considered by participants as a painful constraint and even an obstacle to learning" (Reffay & Chanier, 2002, p. 2). Cohesion can measure: (a) the number of exchanges between two individuals, (b) the

geodesic distance (or proximity) between two individuals, and the minimum number of cut-points necessary to disconnect two individuals, etc.

- Density gives an indication of the level of engagement in the network. Density calculations indicate how actively the participants are involved in the discourse (De Laat, 2002). Various methods have been proposed to calculate density (Ridley & Avery, 1979). We can take it to be the proportion between the number of links between group members and the number of total possible links among all colleagues. Density can be useful for determining the quality of interaction, but it needs to be treated with caution. Values for density could be high due to the efforts of a few "connectors" (subjects). If this occurs, we would be left with inflated density figures, while the mean number of connections for all network members remained low. That is, a relatively small number of participants would account for a large chunk of the interaction (Fahy et al., 2002). Another reservation is that network density is closely related to size, and density data from larger networks are predictably lower than in smaller networks. So, density value comparisons ought not to be made between groups of different sizes as a way of deducing network connection (Rytina, 1982).
- Centrality is generally associated to the relative centrality of the points on a graph and also occasionally refers to another completely different aspect, which is the network's degree of centralization as a whole. Scott (1991) proposes clarification by using centrality to refer only to the centrality of the points, and centralization as a reference to the problem of the internal cohesion of the graph taken as a whole, i.e., the centrality of the graph. Centrality studies those participants who are the most prominent, influential, and reputable. Markers deployed in the asymmetric networks provide specific information on these aspects, with outdegree and indegree markers indicating outgoing and incoming contact, respectively. The outdegree indicates each participant's social activity and the extent of access to other participants. Indegree reveals the most influential participants, the ones most referred to by the rest. In this sense, Wang (2010) concluded that actors in the "core" and "structural hole" (Burt, 1992; Freeman, 1979) positions have very different characteristics in terms of knowledge building. These actors, in particular, play important roles in online learning communities, impacting on the level of the constructed knowledge.
- Centralization. This index refers to the participant who acts as the center, connected to all the nodes which have to pass through this central node in order to connect to the others. A network's degree of centralization indicates how close it is to being a star network, in which a participant or an object acts as the center that controls or channels all activity in the network.



## 3. Study objectives

This study is based on the following assumptions: relationships of interaction in online learning communities can influence the quality of knowledge building in online learning communities (Wang, 2010; Wang & Li, 2007; Zhu, 2006).

Based on these suppositions, the aims of this study are:

- To describe the quality of the knowledge construction process based on the resolution of practical cases with regard to social presence and cognitive presence.

- To describe the structure of the social networks (cohesion and centralization) in the working groups organized to resolve cases in the context of university curricular practicals.
- To identify the influence of the centralization and cohesion of the working groups on knowledge construction via discussion forums in the context of university curricular practicals.

## 4. Description of the experiment

The students who took part in the experiment were third-year students of the social education graduate course at the University of Huelva. The experiment is based on the organization of groups of students who study two real cases at the centers where they carry out their curricular practicals. A total of 73 students were organized into 10 working groups.

Each working group is given the following resources:

- A protocol on how to resolve cases and problems in a cooperative form in virtual contexts, based on the Garrison et al. model (2000, 2001, 2004).
- On-site evaluation of practicals by a teacher–supervisor who will assess the student through the protocol on resolving cases and problems.
- This project's main instrument is the LMS (WebCT), which has three basic areas: content and material, communication, and work assessment. Each group also has a discussion forum where teamwork can be discussed and carried out, and an area for uploading and downloading files.

The task, which falls within the framework of techniques compiled by Barkley et al. (2007) for collaborative learning in the university context and which is applicable to the virtual environment, is a structured technique for problem solving. The students follow a structured protocol for solving problems that is used in the method procedure of cases in social work and is closely related to the dimensions of the instrument created by Garrison et al. (2000, 2001). That is: identify the problem situation (investigation), understand the situation, find out how this situation has arisen, why it persists (diagnosis), and propose an assistance plan (treatment) supported in available or viable institutional resources to solve the problem. In other words, the students have to work in the following way: (a) select a real problem or case for the team to resolve; (b) investigate the problem to understand its origin; (c) assess personal, relational, and environmental aspects that need to be treated in order to resolve the problem; and (d) propose valid and viable measures to be taken to resolve the case.

## 5. Method

In this article, we combined methods of SNA, content analysis (Aviv et al., 2003; Bravo, Redondo, Verdejo, & Ortega, 2008; Zhu, 2006), and statistical analysis (Wang, 2010). From this point of view, the dimensions considered for the analysis were the following:

- The quality of the resulting knowledge construction process: social presence and cognitive presence.
- The network structures: density, cohesion, and centralization of the ALN.

As an instrument for content analysis, we used the records of interventions in the forums created by each group on the LMS, taking as reference the instruments for measuring cognitive and social presence in the ALN (Table 1; Anderson et al., 2001; Garrison et al., 2000, 2001; Rourke et al., 1999).

To resolve the problem of system category reliability, triangulation was used when creating and analyzing the categories (Gros & Silva, 2006). In the codification process, we invited various researchers to analyze the same forum applying codes with regard to definitions of categories and subcategories. We then contrasted these codifications to get a redefinition of some categories and a definitive version of the systems of categories that would give us clear, unanimous criteria when applying the codes to the discourse.

For discourse description, the thematic unit (Aviv et al., 2003) was taken as the unit of analysis, as opposed to other units of analysis like the syntactic (proposition, work, phrase, or paragraph) or the message. The thematic unit, or meaning unit, is defined as a unit of meaning, thought, or idea (Rourke et al., 2001). Although the thematic unit is not objectively recognizable, like the message or the syntactic unit, it always adequately comprises the construct under investigation, even though it induces a subjective and inconsistent interpretation of the unit. In total, were analyzed 1440 thematic units.

We used the UCINET6.0 (Borgatti, Everett, & Freeman, 1999) for Windows in the application of SNA. Three social network markers were analyzed. Density was analyzed as a network property marker, enabling us to perceive the relations among group members.

We also examined global network cohesion markers through analysis of the geodesic distance of the network applied to asymmetric networks. These markers enabled us to study the network members' connections among themselves. These markers provide profiles that help reveal the degree of decentralization of communication in the forums.

Thirdly, we analyzed network centrality which, being asymmetric, involved measuring the outdegree and indegree, as well as social network centralization as a manifestation of the power of forums as a medium for collective communication.

The Netdraw program was used to draw graphs of the network structures. Graph distribution was nonrandom, taking into account the properties of the network, and its values of cohesion and centrality in terms of each subject (node) and the group (network).

Finally, SEM was used. The SEM combines factor analysis with multiple linear regression. According to this technique, each theory involves a set of correlations, and if the theory is valid then it must be possible to reproduce correlation patterns (suppositions) in empirical data. The aim of our investigation is to construct a model to corroborate the direct influence of cohesion and centralization on the quality of the knowledge construction process. The Amos 5.0.1 program was used for the modeling.

## 6. Results

The results are organized according to the three objectives proposed in this investigation. To achieve these objectives, analytical techniques were used that were closely related to these objectives. The SNA was used to discover the structural characteristics as a whole in each of the social networks created (working teams).

Table 1. System of categories for the register and analysis of activities.

| Category | Subcategories | Definition and indicators | Examples |
|---|---|---|---|
| Social presence (Rourke et al., 1999) | Affective | Expression of emotions: conventional expressions of emotion, or unconventional expressions of emotion. Use of humor: teasing, cajoling, irony, ... Self-disclosure: presents details of life outside of class or expresses vulnerability | *... Come on everyone! There isn't long to go! (let's not get stressed out, eh!) ...* (Message, 1310, B.P., Tuesday, 10 June 2009, 19:04). |
| | Interactive | Continuing a thread, quoting from others' messages or referring explicitly to others' messages. Asking questions | *... the child according to Ramón, where did we have to place him? In the School Absenteeism Plan?* (Message, 1136, A.M., Thursday, 5 June 2009, 17:10). |
| | Cohesive | Vocatives. Addressing or referring to participants by name. Addresses or refers to the group using inclusive pronouns. Phatics, greetings, communication that serves a purely social function; closures | *You're welcome, Inés. If anybody still can't see it, they can contact either of us and we will copy it here as a message ...* (Message, 900, S.C., Wednesday, 28 May 2009, 15:08). *... Sorry for the delay but I am only just getting used to this ...* (Message, 498, J.J., Wednesday, 14 May 2009, 17:03) |
| Cognitive presence (Garrison et al., 2001) | Triggering events | Recognizing the problem. Sense of puzzlement. Asking questions. Messages that take discussion in new direction | *... If you click on "students" you will see the names of all the students in the group ... (We are 10). Each of us presents a case and two are selected ...* (Message, 254, M.P., Thursday, 24 April 2009, 11:39). *... the child according to Ramón, where did we have to place him? In the School Absenteeism Plan?* (Message, 1136, A.M., Thursday, 5 June 2009, 17:10) |
| | Exploration | Information exchange. Personal narratives/descriptions/facts, not used as evidence to support a conclusion | *The steps we have to take are: plan, discuss the case demands, assess and share out roles, etc.* (Message, 309, N.P., 30 April 2009, 12:34) |

(*continued*)

Table 1. (*Continued*).

| Category | Subcategories | Definition and indicators | Examples |
|---|---|---|---|
| | | Brainstorming. Adds to established points but does not systematically defend/justify/develop addition | *With respect to institutional support, we have:* *- Ticket purchasing programme.* *- PAHI assistance.* *- Purchase of medication …* (Message, 338, J.M., Monday, 5 May 2009, 15:43) |
| | | Leaps to conclusions: offers unsupported opinions | *So far the contributions seem to be correct but apart from teachers' needs, teachers should also be trained.* (Message, 838, F.L., 26 May 2009, 20:43) |
| | Integration | Connecting ideas, synthesis, creating solutions | *What we could do is give the neighbourhood other alternatives, after-school activities that broaden their social circle.* (Message, 937, C.C., Thursday, 29 May 2009, 17:17) |



Content analysis was deployed to determine the quality of the knowledge construction processes. The SEM was applied in an attempt to verify the influence of cohesion and centralization on the social and cognitive presence in the processes of knowledge construction.

### *6.1. Interaction patterns from SNA*

Results of the analysis of participation and structural characteristics of the 10 ALNs are shown in Table 2 (see also Appendix 2). The number of message postings reflects the total number of messages posted within each team and differed among the 10 teams, ranging from the 39 in Team E to the 135 in Team B.

The SNA revealed the pattern of interaction within each team, as visualized in Figure 1. Each graph distribution takes into account the properties of the network and its values of cohesion and centrality in terms of each subject (node) and the team (network). The direction of the arrows reflects the direction of interaction between the two team members, and the thickness of the lines reflects the strength of the interaction. The size of each node indicates the degree of participation of each member of the network. Furthermore, the position of each node in the graph indicates the degree of centrality of each of its members.

Regarding network cohesion, as we see in the Tables 2 and Figure 1, a team with more links among the members presents more stable polygon. The more closed and stable networks are those with higher levels of cohesion and density. According to the results in Table 2, among the 10 teams, Team A and Team F showed the highest group cohesiveness in terms of the total interaction network (0.795). On the other hand, Team J showed the lowest group cohesiveness (0.667). The density and

Table 2. Structure of ALNs.

| | Size | Density | Number of postings (participation) | Distance-based cohesion ("compactness")* | Network centralization (outdegree) | Network centralization (indegree) |
|---|---|---|---|---|---|---|
| Team A | 7 | 33.92 | 94 | 0.795 | 96.003 | 3.486 |
| Team B | 10 | 22.52 | 135 | 0.695 | 98.489 | 1.489 |
| Team C | 9 | 21.11 | 69 | 0.678 | 98.107 | 1.811 |
| Team D | 9 | 22.22 | 91 | 0.700 | 98.029 | 0.996 |
| Team E | 5 | 33.33 | 39 | 0.767 | 94.621 | 2.759 |
| Team F | 7 | 33.92 | 11 | 0.795 | 97.019 | 1.638 |
| Team G | 6 | 33.33 | 53 | 0.774 | 95.251 | 1.792 |
| Team H | 6 | 28.57 | 134 | 0.774 | 94.274 | 5.427 |
| Team I | 6 | 30.95 | 63 | 0.762 | 96.429 | 1.190 |
| Team J | 8 | 20.83 | 49 | 0.667 | 98.086 | 1.055 |

Note: *Range 0–1; higher values indicate greater cohesiveness.

cohesion of each team seem to be related to the network size. In this sense, groups with more members (groups J, C, B, and D) have less cohesion and density than groups with fewer members (groups A, F, E, G, H, and I).

Regarding the centralization of networks, Table 1 shows the degree of centralization of each team. Outdegree shows the degree of centralization of the network, in terms of sending messages. Each message that comes to the forum simultaneously is received by all members of the network, ranging from 98.489 in Team B to 94.274 in Team H. This is the reason why centralization indices (outdegree) are very high. However, the network centralization indices (indegree) are very low, indicating that team members have received a similar number of messages, ranging from 0.996 in Team D to 5.427 in Team H. There is an inverse relationship between the indegree centralization index and the outdegree centralization index. In other words, the networks with a high level of centralization (outdegree) contain almost all the messages emerging from forum. Likewise, they also have a low level of centralization (indegree); that is, almost all members receive the same number of messages.

Table 2 and Figure 1 show those the highest centralized teams with their star-shaped graph. The networks with higher levels of centralization (teams B, C, D, and J) have nodes at the center, and the discussion forum is located in a central position.

By contrast, in networks with lower levels of centralization (teams E, F, G, and H), the central location of the nodes is not so obvious, even though the discussion forum also occupies a central place in the network. This shows the central role of discussion forums in teams' construction of knowledge. Therefore, the degree of centrality of the discussion forum determines the degree of centralization of the network. Later, we will try to show the influence of the degree of network centralization, identified as the central role of the forum, on the teams' work in the construction of knowledge.

### *6.2. Social construction of knowledge from content analysis*

Content analysis was employed to understand how learners interacted with others and constructed new knowledge during project work. Based on the coding scheme

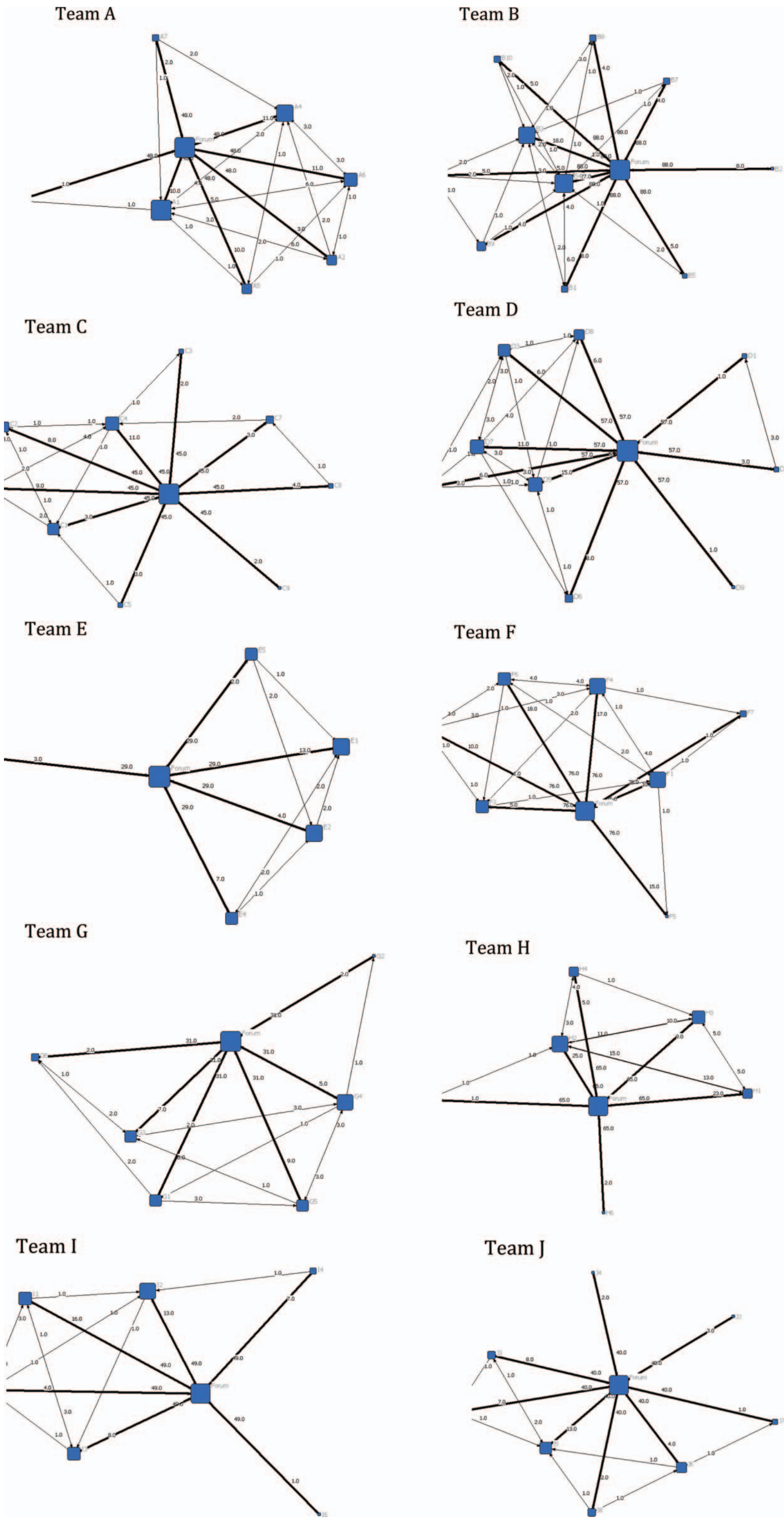


Figure 1. Interaction patterns visualized by SNA.

illustrated in Table 1 (see also Appendix 1), the level of social construction of knowledge presented by teams was analyzed.

In general, as Table 3 shows, all teams have higher rates of participation in social presence than in cognitive presence. In social presence, the average cohesion rates ($M = 30.29$; SD = 6.66) are slightly higher than those of interaction ($M = 29.70$; SD = 10.28), although the difference is not significant. The cohesion rates ranged from 39.47% in Team B to 18.71% in Team I. The interaction rates ranged from 41.24% in Team D to 13.68% in Team B.

In addition, the rate of emotional participations is lower ($M = 1.96$; SD = 1.35). Regarding cognitive presence, the participation rates are very similar in triggering event ($M = 15.49$; SD = 9.05) and exploration ($M = 14.24$; SD = 5.23). The participations in triggering event ranged from 37.07% in Team G to 4.47% in Team E. In the case of participations in exploration, the rates ranged from 22.09% in Team J to 6.21% in Team D.

The participations in integration are less frequent for cognitive activity in almost all teams ($M = 8.25$, SD = 4.83), ranging from 16.31% in Team B to 2.98% in Team E.

### 6.3. Structural equation model

The structural equation model was calculated to verify the effect of centralization and cohesion in the social construction of knowledge in non-structured ALNs. Although before generalizing, the results of this analysis should be studied with larger sample sizes.

The goodness-of-fit indices indicate that the model fitted well with the data ($\chi^2$/df = 1.96; $p > 0.001$; CFI = 0.93; IFI = 0.93; NNFI = 0.87; TLI = 0.87; RMSEA = 0.116; HOELTER = 61; Figure 2).

In social presence, the model explains the 71% variance in interactive participation and also explains the 86% in variance in cohesive participation. The



Table 3. Social construction of knowledge.

| | Social presence | | | | | | Cognitive presence | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Affective | | Interaction | | Cohesion | | Triggering event | | Exploration | | Integration | |
| | *f* | % | *f* | % | *f* | % | *f* | % | *f* | % | *f* | % |
| Team A | 7 | 4.6 | 33 | 22.14 | 50 | 33.55 | 33 | 22.14 | 20 | 13.42 | 6 | 4.02 |
| Team B | 0 | 0 | 26 | 13.68 | 75 | 39.47 | 26 | 13.68 | 32 | 16.84 | 31 | 16.31 |
| Team C | 4 | 2.94 | 43 | 31.61 | 45 | 33.08 | 14 | 10.29 | 16 | 11.76 | 14 | 10.29 |
| Team D | 2 | 1.12 | 73 | 41.24 | 52 | 29.37 | 26 | 14.68 | 11 | 6.21 | 13 | 7.34 |
| Team E | 2 | 2.98 | 22 | 32.83 | 25 | 37.31 | 3 | 4.47 | 13 | 19.40 | 2 | 2.98 |
| Team F | 4 | 2.08 | 60 | 31.25 | 69 | 35.93 | 14 | 7.29 | 35 | 18.22 | 10 | 5.20 |
| Team G | 2 | 2.24 | 11 | 12.35 | 22 | 24.71 | 33 | 37.07 | 7 | 7.86 | 14 | 15.73 |
| Team H | 1 | 0.45 | 89 | 40.45 | 58 | 26.36 | 35 | 15.90 | 22 | 10 | 15 | 6.81 |
| Team I | 2 | 2.08 | 34 | 35.41 | 18 | 18.71 | 16 | 16.66 | 16 | 16.66 | 10 | 10.41 |
| Team J | 1 | 1.16 | 31 | 36.04 | 21 | 24.41 | 11 | 12.79 | 19 | 22.09 | 3 | 3.48 |
| Mean | 2.5 | 1.96 | 42.2 | 29.70 | 43.50 | 30.29 | 21.10 | 15.49 | 19.10 | 14.24 | 11.80 | 8.25 |
| SD | 2.01 | 1.35 | 24.44 | 10.28 | 20.89 | 6.66 | 10.95 | 9.05 | 8.79 | 5.23 | 8.18 | 4.83 |

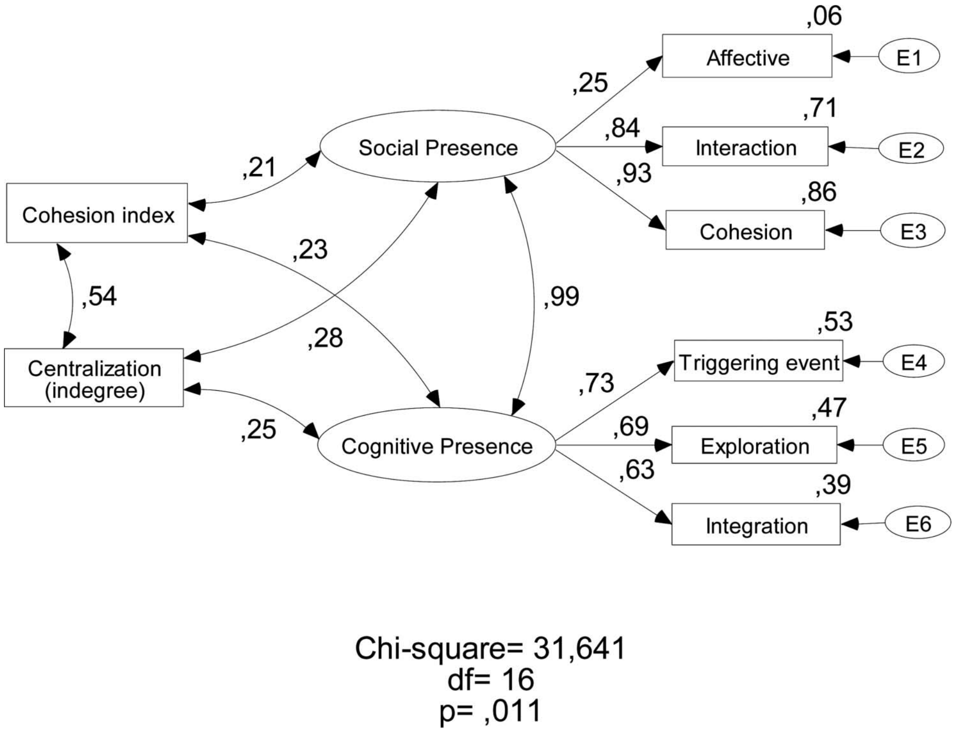


Figure 2. Effect of centralization (indegree) and cohesion on social construction of knowledge in discussion forum.

model only explains the 0.6 in variance in affective participation, because participation in this category is rare.

Regarding cognitive presence, the model explains the 53% in variance in triggering event participation, the 47% in variance in exploration participation, and the 39% in variance in integration participation.

The social presence endogenous variable scores high in the regression coefficient for interactive participation ($\beta = 0.84$, $p < 0.05$) and in cohesive participation ($\beta = 0.93$, $p < 0.05$). It scores low in the coefficient for affective participation ($\beta = 0.25$).

The cognitive presence endogenous variable has a high score in the regression coefficient for the triggering event ($\beta = 0.73$), in exploration ($\beta = 0.69$; $p < 0.001$), and in integration ($\beta = 0.63$; $p < 0.001$).

The cohesion and centralization indices (indegree) of the networks have been positively correlated ($r = 0.54$). The results of the correlation between the cohesion and centrality indices and endogenous variables were:

- The index of cohesion of the networks is positively correlated with both endogenous variables: social presence ($r = 0.21$) and cognitive presence ($r = 0.23$).
- The index of centralization of the networks is positively correlated with both endogenous variables: social presence ($r = 0.28$) and cognitive presence ($r = 0.25$).

## 7. Conclusion

This article demonstrates the potential of the combination of content analysis techniques, SNA and SEM as a method for a more complete understanding of knowledge construction in groups of students working in an asynchronic communication context. The use of SEM alongside instruments that are usually applied together provides a more global perspective of the phenomenon than other statistical tools such as correlation or regression analyses. The indices of network cohesion and centralization have correlated positively, which means that if the centralization index increases there will be a similar rise in the cohesion index in the network. Nevertheless, this has to be understood within the context of the network in which the discussion forum (messages sent to all, messages received by all) plays a central role. The high scores in the centralization indices (outdegree) are due to the pivotal role of the forum. The majority of messages were sent to all members of the group. In other words, the majority of messages were sent from the forum. So, the discussion forum is understood to be a collective entity that gives the group its identity; it is a medium but also the main agent for sending messages. In this sense, the increasing centralization of the group correlates to the rise in group cohesion.

The positive effects of centralization on social presence and cognitive presence, as revealed by SEM, would suggest the need to increase the messages sent to all students during the knowledge construction process.

The low scores for the centralization indices (indegree) are also due to the prominent role of the forum. That is, high scores in the centralization indices mean a lesser role for the forum as a collective communicative space. For example, the extreme case of the centralization index (indegree) registering 0% would mean that all participation was directed to all team members. And if the centralization index (indegree) was 100%, it would mean that each participation of each member of the group would be directed toward one single member. In this case, the forum, meaning a collective communicative space, would have been inoperative. In all the groups analyzed, the majority of messages were send to the discussion forum. As a consequence, the differences in the reception of messages between team members are not significant. Both circumstances explain the low values recorded in the centralization indices (indegree) for all the teams, which means that the forum, as a collective communicative space, has an important role in the social construction of knowledge.

However, the positive correlation of centralization (indegree) and cohesion could be explained by the presence of those members who occupy central and intermediate locations. The rise in centralization (indegree) would mean an increase in group cohesion. This fact, taken within the context of low levels of centralization (indegree), could be due to the prominence of members at the center, which is in line with the results from the study by Wang (2010).

In addition, the positive influence of centralization (indegree) on knowledge construction, as SEM demonstrates, would appear to reveal the importance of the fact that there are members who occupy central or intermediate locations in the group during the process, without their positions of power reaching the degree of centrality of the discussion forum. It should not be forgotten that high levels of centralization will necessarily have negative effects on cohesion and, consequently, on the social construction of knowledge.

## 8. Limitations

Regarding content analysis as a technique used to analyze transcripts of asynchronous, computer-mediated discussion groups in formal educational settings, De Wever et al. (2006) present an overview of different content analysis instruments, building on a sample of models commonly used in the CSCL literature. They argued that although this research technique is often used, standards are not yet established. The instruments applied reflect a wide variety of approaches and differ in their level of detail and type of analysis categories used. Further differences are related to diversity in their theoretical base, the amount of information about validity and reliability, and the choice for the unit of analysis. The authors put forward the need to improve the theoretical and empirical base of the existing instruments in order to promote the overall quality of CSCL research (Wever et al., 2006). In this sense, we agree with Zhu (2006), who considers that qualitative data from student and instructor interviews will be necessary to enrich our understanding of multiple factors and their effects on knowledge building, as well as the use of other instruments that measure the quality of the results and allow them to be applied to the processes.

Rourke and Anderson (2004) argue for a quantitative content analysis technique and question the rigor of the research in this area. Their point is that much of the online transcript analysis is descriptive and, at some point, there needs to be a transition to inference and "a richer definition of test validity." In this sense, SEM is a good technique that can lead to advances in instrument validation.

We recognize the need for validation of the coding schemes and their relation to theoretical framework. As Garrison (2007, p. 69) argued, the community of inquiry framework offers a more comprehensive perspective capable of identifying interaction effects among social, cognitive, and teaching presence dynamics, but a key question is whether the three elements capture the core dynamics of a community of inquiry? On the other hand, regarding the coding schemes, "the issue is whether the elements have been well-defined and the categories are valid (representative of the element). Do the categories fully describe the elements (i.e., presences) of the community of inquiry? Are the indicators of sufficient detail and range to be useful in coding?". These are questions and issues that are challenges for the refinement of the community of inquiry framework and the categories and indicators of its elements/constructs (Garrison, 2007).

The results of this study are limited to a small, specific group of participants as well as to the context of a virtual discussion environment where online interactions may reflect partial group performance only.

Future research should consider the questions of validity discussed here and the analysis of experiences that include the presence of the tutor/professor, who can act as a facilitator of the social construction of knowledge.

Finally, the immediate attention of our research group turns to preparing a team of professors/tutors to manage communities of inquiry in various educational propositions. This will open lines of investigation into the role of the tutor in these contexts. Another open research theme is the rigorous validation of instruments that analyze interactions that lead to a greater understanding of the processes of the construction of knowledge in asynchronic communication contexts, and to the need to advise students and teachers in the efficient management of the collective creation of knowledge.

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## Appendix 1

This appendix shows how participations were measured for SNA. Each member of each team directs his participations to other individual members or to the discussion forum (i.e., to all members of the team). The discussion forum is deemed to be a collectivity (communication between all), and the messages are sent to all its members. The messages received by members are not personal messages but messages that are sent to the group as a whole. This is why the research team decided to designate one row and one column to the discussion forum to differentiate it as an entity.

| | Forum | A1 | A2 | A3 | A4 | A5 | A6 | A7 |
|---|---|---|---|---|---|---|---|---|
| Forum | × | 48 | 48 | 48 | 48 | 48 | 48 | 48 |
| A1 | 10 | × | 3 | 1 | 4 | 1 | 5 | 0 |
| A2 | 3 | 6 | × | 0 | 2 | 0 | 1 | 0 |
| A3 | 1 | 0 | 0 | × | 0 | 0 | 0 | 0 |
| A4 | 11 | 2 | 0 | 0 | × | 1 | 3 | 0 |
| A5 | 10 | 1 | 0 | 0 | 2 | × | 1 | 0 |
| A6 | 11 | 6 | 1 | 0 | 3 | 0 | × | 0 |
| A7 | 2 | 1 | 0 | 0 | 2 | 0 | 0 | × |

| | Forum | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | B10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Forum | × | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 |
| B1 | 8 | × | 0 | 2 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| B2 | 8 | 0 | × | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| B3 | 18 | 3 | 0 | × | 2 | 0 | 0 | 0 | 1 | 0 | 0 |
| B4 | 27 | 4 | 0 | 5 | × | 1 | 0 | 1 | 1 | 0 | 1 |
| B5 | 5 | 0 | 0 | 0 | 2 | × | 0 | 0 | 0 | 0 | 0 |
| B6 | 5 | 0 | 0 | 2 | 2 | 0 | × | 0 | 0 | 1 | 0 |
| B7 | 4 | 0 | 0 | 1 | 1 | 0 | 0 | × | 0 | 0 | 0 |
| B8 | 4 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | × | 0 | 0 |
| B9 | 4 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | × | 0 |
| B10 | 5 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | × |

| | Forum | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 |
|---|---|---|---|---|---|---|---|---|---|---|
| Forum | × | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| C1 | 3 | × | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| C2 | 8 | 1 | × | 0 | 1 | 0 | 3 | 0 | 0 | 0 |
| C3 | 2 | 0 | 0 | × | 0 | 0 | 0 | 0 | 0 | 0 |
| C4 | 11 | 1 | 1 | 1 | × | 0 | 4 | 0 | 0 | 0 |
| C5 | 3 | 1 | 0 | 0 | 0 | × | 0 | 0 | 0 | 0 |
| C6 | 9 | 0 | 3 | 0 | 2 | 0 | × | 0 | 0 | 0 |
| C7 | 3 | 0 | 0 | 0 | 2 | 0 | 0 | × | 0 | 0 |
| C8 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | × | 0 |
| C9 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | × |

| | Forum | D1 | D2 | D3 | D4 | D5 | D6 | D7 | D8 | D9 |
|---|---|---|---|---|---|---|---|---|---|---|
| Forum | × | 57 | 57 | 57 | 57 | 57 | 57 | 57 | 57 | 57 |
| D1 | 1 | × | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D2 | 3 | 3 | × | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D3 | 6 | 0 | 0 | × | 2 | 1 | 0 | 3 | 1 | 0 |
| D4 | 6 | 0 | 0 | 1 | × | 3 | 0 | 0 | 0 | 0 |
| D5 | 15 | 0 | 0 | 0 | 1 | × | 1 | 3 | 1 | 0 |
| D6 | 8 | 0 | 0 | 0 | 0 | 1 | × | 0 | 0 | 0 |
| D7 | 11 | 0 | 0 | 3 | 1 | 3 | 1 | × | 4 | 0 |
| D8 | 6 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | × | 0 |
| D9 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | × |

| | Forum | E1 | E2 | E3 | E4 | E5 |
|---|---|---|---|---|---|---|
| Forum | × | 29 | 29 | 29 | 29 | 29 |
| E1 | 13 | × | 0 | 0 | 2 | 0 |
| E2 | 4 | 2 | × | 0 | 0 | 0 |
| E3 | 3 | 0 | 0 | × | 0 | 0 |
| E4 | 7 | 2 | 1 | 0 | × | 0 |
| E5 | 2 | 1 | 2 | 0 | 0 | × |

| | Forum | F1 | F2 | F3 | F4 | F5 | F6 | F7 |
|---|---|---|---|---|---|---|---|---|
| Forum | × | 76 | 76 | 76 | 76 | 76 | 76 | 76 |
| F1 | 10 | × | 0 | 0 | 4 | 1 | 2 | 1 |
| F2 | 10 | 0 | × | 1 | 3 | 0 | 1 | 0 |
| F3 | 5 | 1 | 1 | × | 1 | 0 | 0 | 0 |
| F4 | 17 | 1 | 3 | 2 | × | 0 | 4 | 1 |
| F5 | 15 | 0 | 0 | 0 | 0 | × | 0 | 0 |
| F6 | 18 | 1 | 2 | 1 | 4 | 0 | × | 0 |
| F7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | × |

| | Forum | G1 | G2 | G3 | G4 | G5 | G6 |
|---|---|---|---|---|---|---|---|
| Forum | × | 31 | 31 | 31 | 31 | 31 | 31 |
| G1 | 6 | × | 0 | 0 | 0 | 3 | 2 |
| G2 | 2 | 0 | × | 0 | 0 | 0 | 0 |
| G3 | 7 | 0 | 0 | × | 2 | 0 | 2 |
| G4 | 5 | 1 | 1 | 3 | × | 3 | 0 |
| G5 | 9 | 0 | 0 | 1 | 3 | × | 0 |
| G6 | 2 | 0 | 0 | 1 | 0 | 0 | × |

| | Forum | H1 | H2 | H3 | H4 | H5 | H6 |
|---|---|---|---|---|---|---|---|
| Forum | × | 65 | 65 | 65 | 65 | 65 | 65 |
| H1 | 23 | × | 13 | 5 | 0 | 0 | 0 |
| H2 | 25 | 15 | × | 11 | 3 | 1 | 0 |
| H3 | 9 | 5 | 10 | × | 0 | 0 | 0 |
| H4 | 5 | 0 | 4 | 1 | × | 0 | 0 |
| H5 | 1 | 0 | 1 | 0 | 0 | × | 0 |
| H6 | 2 | 0 | 0 | 0 | 0 | 0 | × |

| | Forum | I1 | I2 | I3 | I4 | I5 | I6 |
|---|---|---|---|---|---|---|---|
| Forum | × | 49 | 49 | 49 | 49 | 49 | 49 |
| I1 | 16 | × | 1 | 1 | 0 | 3 | 0 |
| I2 | 13 | 0 | × | 1 | 0 | 1 | 0 |
| I3 | 8 | 3 | 0 | × | 0 | 1 | 0 |
| I4 | 7 | 0 | 1 | 0 | × | 0 | 0 |
| I5 | 4 | 1 | 1 | 0 | 0 | × | 0 |
| I6 | 1 | 0 | 0 | 0 | 0 | 0 | × |

| | Forum | J1 | J2 | J3 | J4 | J5 | J6 | J7 | J8 |
|---|---|---|---|---|---|---|---|---|---|
| Forum | × | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| J1 | 7 | × | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| J2 | 3 | 0 | × | 0 | 0 | 0 | 0 | 0 | 0 |
| J3 | 8 | 1 | 0 | × | 0 | 1 | 0 | 0 | 0 |
| J4 | 2 | 0 | 0 | 0 | × | 0 | 0 | 0 | 0 |
| J5 | 13 | 0 | 0 | 2 | 0 | × | 0 | 0 | 0 |
| J6 | 4 | 0 | 0 | 0 | 0 | 1 | × | 1 | 0 |
| J7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | × | 0 |
| J8 | 2 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | × |

**Appendix 2.** This appendix is a codified record of the participations of each subject, according to the category system used.

| | Social presence | | | Cognitive presence | | | |
|---|---|---|---|---|---|---|---|
| | Affective | Interaction | Cohesion | Triggering events | Exploration | Integration | Total |
| A1 | 2 | 9 | 15 | 9 | 2 | 2 | 39 |
| A2 | 0 | 4 | 6 | 4 | 4 | 0 | 18 |
| A3 | 1 | 0 | 1 | 0 | 0 | 0 | 2 |
| A4 | 0 | 8 | 9 | 8 | 4 | 1 | 30 |
| A5 | 2 | 4 | 8 | 4 | 4 | 1 | 23 |
| A6 | 1 | 7 | 9 | 7 | 5 | 2 | 31 |
| A7 | 1 | 1 | 2 | 1 | 1 | 0 | 6 |
| *Total* | *7* | *71* | *50* | *33* | *20* | *6* | *187* |
| B1 | 0 | 6 | 7 | 6 | 2 | 2 | 23 |
| B2 | 0 | 1 | 6 | 1 | 1 | 2 | 11 |
| B3 | 0 | 3 | 11 | 3 | 11 | 3 | 31 |
| B4 | 0 | 8 | 24 | 8 | 17 | 7 | 64 |
| B5 | 0 | 0 | 7 | 0 | 0 | 4 | 11 |
| B6 | 0 | 2 | 7 | 2 | 0 | 2 | 13 |
| B7 | 0 | 0 | 2 | 0 | 0 | 3 | 5 |
| B8 | 0 | 4 | 2 | 4 | 1 | 3 | 14 |
| B9 | 0 | 1 | 3 | 1 | 0 | 2 | 7 |
| B10 | 0 | 1 | 6 | 1 | 0 | 3 | 11 |
| *Total* | *0* | *26* | *75* | *26* | *32* | *31* | *190* |
| C1 | 0 | 3 | 2 | 2 | 0 | 2 | 9 |
| C2 | 0 | 5 | 5 | 2 | 4 | 3 | 19 |
| C3 | 0 | 1 | 3 | 0 | 1 | 1 | 6 |
| C4 | 1 | 15 | 18 | 4 | 4 | 1 | 43 |
| C5 | 1 | 1 | 3 | 0 | 0 | 2 | 7 |
| C6 | 0 | 11 | 9 | 4 | 5 | 1 | 30 |
| C7 | 0 | 3 | 3 | 0 | 0 | 2 | 8 |
| C8 | 0 | 2 | 2 | 0 | 1 | 2 | 7 |
| C9 | 2 | 2 | 0 | 2 | 1 | 0 | 7 |
| *Total* | *4* | *43* | *45* | *14* | *16* | *14* | *136* |
| D1 | 1 | 1 | 2 | 0 | 0 | 1 | 5 |
| D2 | 0 | 3 | 3 | 0 | 0 | 1 | 7 |
| D3 | 0 | 9 | 4 | 7 | 1 | 2 | 23 |
| D4 | 0 | 9 | 8 | 1 | 0 | 1 | 19 |
| D5 | 0 | 21 | 13 | 8 | 3 | 3 | 48 |
| D6 | 0 | 7 | 7 | 1 | 0 | 2 | 17 |
| D7 | 0 | 15 | 12 | 4 | 5 | 1 | 37 |
| D8 | 1 | 7 | 3 | 4 | 1 | 2 | 18 |
| D9 | 0 | 1 | 0 | 1 | 1 | 0 | 3 |
| *Total* | ***2*** | ***73*** | ***52*** | ***26*** | ***11*** | ***13*** | ***177*** |
| E1 | 0 | 8 | 8 | 1 | 7 | 0 | 24 |
| E2 | 1 | 2 | 4 | 0 | 2 | 1 | 10 |
| E3 | 0 | 1 | 3 | 0 | 0 | 0 | 4 |
| E4 | 0 | 7 | 7 | 1 | 3 | 1 | 19 |
| E5 | 1 | 4 | 3 | 1 | 1 | 0 | 10 |
| *Total* | *2* | *22* | *25* | *3* | *13* | *2* | *67* |
| F1 | 0 | 12 | 14 | 3 | 4 | 3 | 36 |
| F2 | 0 | 6 | 7 | 1 | 3 | 1 | 18 |
| F3 | 0 | 5 | 6 | 1 | 2 | 0 | 14 |

(*continued*)

Appendix 2. (*Continued*).

| | Social presence | | | Cognitive presence | | | |
|---|---|---|---|---|---|---|---|
| | Affective | Interaction | Cohesion | Triggering events | Exploration | Integration | Total |
| F4 | 3 | 21 | 21 | 3 | 9 | 4 | 61 |
| F5 | 0 | 4 | 5 | 2 | 9 | 0 | 20 |
| F6 | 1 | 12 | 16 | 4 | 7 | 2 | 42 |
| F7 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| *Total* | *4* | *60* | *69* | *14* | *35* | *10* | *192* |
| G1 | 0 | 1 | 4 | 5 | 2 | 4 | 16 |
| G2 | 0 | 1 | 1 | 2 | 0 | 2 | 6 |
| G3 | 1 | 1 | 6 | 7 | 1 | 3 | 19 |
| G4 | 0 | 3 | 8 | 11 | 0 | 3 | 25 |
| G5 | 1 | 4 | 2 | 6 | 2 | 2 | 17 |
| G6 | 0 | 1 | 1 | 2 | 2 | 0 | 6 |
| *Total* | *2* | *11* | *22* | *33* | *7* | *14* | *89* |
| H1 | 0 | 26 | 16 | 12 | 10 | 3 | 67 |
| H2 | 1 | 37 | 23 | 14 | 8 | 7 | 90 |
| H3 | 0 | 17 | 10 | 7 | 2 | 1 | 37 |
| H4 | 0 | 7 | 7 | 1 | 0 | 4 | 19 |
| H5 | 0 | 1 | 2 | 0 | 0 | 0 | 3 |
| H6 | 0 | 1 | 0 | 1 | 2 | 0 | 4 |
| *Total* | *1* | *89* | *58* | *35* | *22* | *15* | *220* |
| I1 | 1 | 12 | 5 | 7 | 3 | 4 | 32 |
| I2 | 0 | 6 | 2 | 4 | 8 | 2 | 22 |
| I3 | 0 | 7 | 6 | 1 | 1 | 2 | 17 |
| I4 | 0 | 6 | 4 | 2 | 2 | 1 | 15 |
| I5 | 0 | 3 | 1 | 2 | 2 | 1 | 9 |
| I6 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Total* | *2* | *34* | *18* | *16* | *16* | *10* | *96* |
| J1 | 0 | 4 | 3 | 1 | 3 | 1 | 12 |
| J2 | 0 | 3 | 1 | 2 | 1 | 1 | 8 |
| J3 | 0 | 7 | 5 | 2 | 2 | 0 | 16 |
| J4 | 0 | 2 | 2 | 0 | 0 | 0 | 4 |
| J5 | 1 | 10 | 6 | 4 | 8 | 1 | 30 |
| J6 | 0 | 3 | 3 | 1 | 1 | 0 | 8 |
| J7 | 0 | 1 | 1 | 0 | 0 | 0 | 2 |
| J8 | 0 | 1 | 0 | 1 | 4 | 0 | 6 |
| *Total* | *1* | *31* | *21* | *11* | *19* | *3* | *86* |

Note: The number of message postings reflects the individual number of messages posted for each subject in each category.