Social Network Analysis in eLearning environments: a study of learner's interactions from several perspectives

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Abstract

This research is based on the confluence of two research lines: eLearning and social network analysis (SNA). ELearning has already demonstrated its potential for profoundly affecting society, but its effectiveness depends on the appropriate use of technology. Technology should take on an important role during on-line training, but it should not itself become the goal. Instead, it should be a tool to empower educators to draw from different sources to create on-line educational activities that involve multiple applications promoting communication and interaction among participants as much as possible.

Ideally, eLearning courses should promote and be driven by social networks that emerge as a result of discussion or interaction between students as well as between students and tutors. This makes eLearning similar, in practice, to numerous other human activities that require extensive interaction and collaboration, including social support networks, groups of professional collaborators, and staff within organisations. Researchers in these other areas have used SNA to gain detailed insights into how individuals work and develop together. In contrast, SNA has yet to be applied extensively in eLearning. Therefore the present work sought to use it to analyse patterns of students' social behaviour under different conditions and from different theoretical perspectives.

First, the existing literature applying SNA to eLearning was systematically reviewed in order to take stock of what has already been investigated. On the basis of these findings, three SNA-based research studies were carried out: one focused on how learning styles may influence academic performance and participation, another focused on understanding how eLearners collaborate on joint projects, and a third examined the effectiveness of a "flipped class" format in a course. In the study on collaborative projects, the advantages of SNA for quantitative analysis of large amounts of interaction data were combined with the power of content analysis (CA) for qualitative analysis of the type and depth of interaction in order to provide more comprehensive social behaviour analysis.

The findings of the three experimental studies that were undertaken complement and extend the literature on learner networks in eLearning environments. They also offer preliminary insights to help teachers and instructional designers improve eLearning courses that include collaborative components or flipped class designs. These insights need to be verified in diverse eLearning settings involving larger numbers of students, so the present studies have provided research questions for several years to come. Indeed, the present studies establish the usefulness of SNA for analysing various aspects of eLearning in greater detail than traditional research tools allow, opening the door to potentially entirely new lines of investigation aimed at improving eLearning outcomes.

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1 Introduction

Technology has in recent decades catalysed several changes in education by providing new applications to help teachers design and improve lectures, facilitate communication between teachers and students and among students, and deploy learning materials in formats and platforms tailored to different users for different purposes (Safran, Helic, & Gütl, 2007). Within this broader context, eLearning has emerged as a new method that, whether used on its own for an entirely virtual experience or whether coupled with face-to-face learning, can bring several advantages over traditional classroom approaches. ELearning can accommodate a larger number of people, located potentially anywhere in the world, as reflected in the explosion of massive open on-line courses (MOOC). In addition, eLearning courses usually incorporate a greater range of content than traditional teaching, including multimedia animations and simulations (Mason & Rennie, 2006).

Despite these advantages, eLearning does present challenges. One is that because teaching and learning is largely (or entirely) shifted into a virtual domain, teachers exert less control over their students' progress. Students therefore must have the self-discipline and perseverance to organise their own time and activities to achieve course objectives. Not surprisingly, this means that eLearning courses often suffer dropout rates much higher than those of traditional courses (Frankola, 2001; O'Connor, Sceiford, Wang, Foucar-Szocki, & Griffin, 2003; Berge & Huang, 2004; Levy, 2007). This makes it even more important to investigate what factors about learners, teachers and course design in eLearning strongly influence student's willingness to complete the course.

Along these lines, researchers have begun to take advantage of user data stored in commonly used eLearning platforms, including Learning Management Systems (LMS), Content Management Systems (CMS), and Web 2.0 applications such as wikis and blogs in order to examine learner factors that may affect educational outcomes (Siemens, 2010). From the beginning, this work has highlighted how the "social network" aspect of eLearning -- interactions among learners and between learners and teachers -- can strongly influence outcomes. This has led some researchers to apply the tools of Social Network Analysis (SNA) to eLearning. SNA

uses graphical and mathematical methods to analyse the social structures of networks (Scott, 2000), and it has already proven useful in economic, political, social, professional, and medical contexts. In contrast to these other fields, eLearning has only recently begun to be addressed using SNA, so many fundamental educational questions remain to be addressed. SNA is well suited to these questions because it provides quantitative insights and can easily process the large amounts of data generated even by a relatively small eLearning class.

The present work therefore sought to explore the state of SNA-based research in eLearning, identify what we have already learned and what the most fruitful lines for future work are likely to be, and then undertake an array of studies to validate SNA for addressing these lines. This work is a natural extension of the author's previous research on the use of Web 2.0 applications and learner characteristics, which she carried out during her European Master's in Media Engineering for Education (Euromime).

The overall motivation for this work was to generate insights useful for improving the effectiveness of eLearning, thereby promoting it as part of a larger trend in inclusive education. On-line education can make learning available to people who otherwise could not attend for lack of time, money or suitable infrastructure.

2 Research Objectives

The overall objective of the present research was to assess and validate SNA as a method to measure interactions in eLearning environments from several perspectives, while in the process generating information useful for researchers, teachers and instructional designers.

This overall objective was operationalised into the following objectives:

O1. To identify what research questions about eLearning have been addressed using SNA and what SNA measures and network characteristics have been studied most often, and to identify gaps in the SNA literature on eLearning and suggest directions for future research.

O2. To use SNA to evaluate whether learning styles influence how learners interact in eLearning environments.

O3. To combine the quantitative approach of SNA with the qualitative approach of Content Analysis (CA) to examine whether assigning collaborative workgroups with desired topics or random topics affects how they collaborate.

O4. To use SNA to compare learner interactions in a flipped and traditional course design in an eLearning environment.

The objectives O2, O3 and O4 reflect the author's interest in addressing research topics not already adequately covered, based on the systematic review in O1.

The review identified three main topics in SNA-based studies of eLearning environments (Cela, Sicilia, & Sánchez, 2015) : (1) *Implementation of SNA software*, (2) *Analysis of interaction patterns*, and (3) *Improvement of learning designs*. Within topic (2), most studies focused on collaboration, and only one study used a mixed approach combining SNA and CA. Thus we incorporated O3 into the present research project, which used SNA and CA to analyze collaborative learning tasks.

The review failed to identify studies examining learning styles from the perspective of Felder and Silverman's model, which led us to incorporate O2 into the present research. The review also did not identify studies of flipped course designs, which is not surprising given the novelty of the flipped approach. Therefore we incorporated O4 into our research, which compared flipped and traditional course designs. This comparison is quite timely not only for eLearning but for education more generally because of the urgent need to understand the advantages and limitations of the flipped class (Bishop & Verleger, 2013).

3 Methodology

The research was planned and developed according to the following steps (Hernández, Fernández and Baptista, 2010): state the problem, review the literature, develop study objectives, develop study methodology, collect the data and analyse the data. First, the literature on SNA in eLearning was systematically reviewed, identifying 37 relevant studies. The results from this phase of the research were published in Cela et al. (2015).

Based on the results of the systematic review, three separate but strongly interrelated experiments were conducted. These experiments involved four eLearning and blended courses, designed specifically for the present research project. These courses were held eight times and involved a total of 601 participants: Web 2.0 for Citizenship (held once, n=34), Design of Learning Objects (three times; n=475), Scientific Writing (three times; n=92) and Technology-Enhanced Learning for Educators (once). Data were collected and analysed using a mixture of quantitative and qualitative approaches. Such mixed methods are useful for studying the breadth and depth of phenomena. Moreover, including qualitative analysis can provide a holistic view of phenomena (Hernández et al., 2010).

The results of these three experiments were disseminated in several forms, including conference presentations, journal articles, and book chapters. (See Publications, section 8).

4 Literature Review

In this section, the research literature is briefly reviewed in order to provide an empirical and theoretical background for the four studies carried out during this research project. The review focuses on (1) *SNA* and (2) *eLearning* in accordance with research objective *O1*, (3) *collaborative learning* in accordance with objective *O2*, (4) *learning styles* because of objective *O3* and (5) the flipped class because of objective *O4*.

4.1 Social Network Analysis

Social Network Analysis (SNA) describes and analyses the characteristics of social structures in a network (Scott & Carrington, 2010). It has been used in multiple disciplines, including education (Carolan, 2014), though it has not yet been used extensively to study eLearning. SNA is well suited to analysing education and specifically eLearning given that eLearning involves tools/applications that support individual student activities as well as inter-student communication and collaboration in a computer-based environment, where large amounts of data are easily retrieved, searched, and analysed. The databases of eLearning platforms contain, for example, digital records of student project completion, discussions in forums and chat rooms,

and collaboration on wikis. This universe comprises a multichannel network that can be probed in detail using the quantitative tools of SNA.

In early work, Haythornthwaite (1999) used SNA to analyse channels used by students to communicate during online collaboration, while Nurmela, Lehtinen and Palonen (1999) used SNA to analyse the functioning of collaborative training networks. More recent work has shown that SNA can aid in (1) understanding student interactions and participation in the network (Martínez, Dimitriadis, Rubia, Gómez, & de la Fuente, 2003; Lipponen, Rahikainen, Lallimo & Hakkarainen, 2003; Breuer, Klamma, Cao, & Vuorikari, 2009) ; (2) understanding relationships in the network, allowing measurement of tutor influence (Martínez et al., 2003) and identification of other influential actors (Cho, Gay, Davidson, & Ingraffea, 2007) and the most prominent groups (Daradoumis, Martínez-Monés, & Xhafa, 2004); (3) analysing student behaviour in the network (Fu-ren Lin & Chun-hung Chen, 2004); (4) analysing how students collaborate on group assignments (Dradilova, Martinovic, Slaninová, & Snásel, 2008); and (5) detecting interaction patterns in educational repositories (Sicilia, Sanchez-Alonso, Garcia-Barriocanal, & Rodriguez-Garcia, 2009).

Studies applying SNA to eLearning have also shown that the method can be combined with other approaches to increase analytical power. De Laat (2002) combined SNA with Content Analysis to describe networks of interactions quantitatively and qualitatively. This mixed-methods approach proved key to one of the studies conducted by the author of this thesis.

This literature on SNA in eLearning suggests that by extracting information about social structures among learners and between learners and teachers, it is possible to gain insights into teaching and learning that may help improve eLearning design and interaction among learners, identify and track isolated learners, analyse the characteristics of star students, reduce learner dropout, and improve learner outcomes. The article by Cela et al. (2015) (see Appendix A1) provides a complete overview of how SNA has already contributed to eLearning.

4.2 ELearning

The term eLearning has several definitions. According to Keegan (2002), eLearning includes web-based virtual universities and classes, digital collaboration and training based on distance learning technology. Nichols (2003) describes eLearning as the application of various technological tools for educational purposes. Romiszowski, (2004) argues that eLearning refers to an individual or group process in which meetings are conducted synchronously or asynchronously.

For learners, eLearning offers several advantages over traditional classroom learning (Almenara, 2006): (1) content is constantly available, (2) it is usually easy to incorporate a rich array of multimedia content, (3) students have greater autonomy to select learning materials and work at their own pace, and (4) costs of participation are generally much lower, making it more inclusive than traditional education.

For teachers and researchers, eLearning facilitates course development and improvement because nearly all participant activity can be recorded in a digital, easily archivable and transferable format, allowing detailed analysis. Indeed, this can also benefit the learner when it is used to provide feedback on his or her contributions to the network. Additionally, eLearning offers multimedia web resources for providing information and for supporting collaboration, which can significantly enrich the learner experience (Cacheiro, 2011).

At the same time, eLearning presents several potential disadvantages to the learner and teacher: (1) course design is complex and requires a multidisciplinary team, (2) both teacher and student must have basic operating knowledge of the technology involved, and (3) the teacher usually needs to invest more time outside of class than with a traditional classroom course. Despite these disadvantages, eLearning has already had, and continues to have, a significant impact in education, especially where teachers design courses using a student-centred and collaborative approach (Laal, Laal, & Kermanshahi, 2012).

ELearning and SNA make an excellent partnership because the abundant data generated in eLearning courses can be analysed to explore social structures promoting

or inhibiting learning. SNA can be used to analyse discussion in forums, emails, and chats, as well as collaboration on joint projects (Haythornthwaite, 1996).

4.3 Collaborative Learning

Modern education aims to prepare citizens able to live in a diverse, multicultural and connected world (Lehtinen, Hakkarainen, Lipponen, Rahikainen, & Muukkonen, 1999). The constant interaction of persons and technology has made collaboration a core competency (Laal & Ghodsi, 2012), leading to a prominent role for collaborative learning in current educational trends. Collaborative learning is defined as an educational approach that involves groups of learners working together in order to accomplish a task or activity (Bruffee, 1995). Collaborative learning is based on the idea that learning is a social act and occurs as a result of learner interactions (Bandura, 1977).

Collaboration networks arise based on common interests and may have nothing to do with whether the collaborators live geographically close to each other. Some eLearning platforms have already heavily integrated collaborative tools (Capuano, Laria, Mazzoni, Pierri, & Mangione, 2011). Applications based on collaborative work include forums, blogs, wikis, and document sharing. These channels offer students the opportunity to discuss, argue, exchange ideas and contrast opinions. Thus, these types of applications reflect a social approach to learning (Alexander, 2006).

Studies of SNA in collaborative eLearning are sparse, with available research suggesting that SNA can indeed help elucidate how learners work together. Andi et al. (2011) found that students collaborated as they spent time, while Lipponen, Rahikainen, Lallimo, and Hakkarainen (2003) found that learners differed in their level of collaboration. De Laat, Lally, Lipponen and Simons (2007) combined SNA and CA to examine how learners constructed knowledge during collaborative activities. Haythornthwaite (1999) identified which communication channels learners preferred to use, and Chen and Watanabe (2007) found that members of the same social position tended to collaborate better than members in different positions.

This limited literature established the usefulness of SNA for examining collaborative networks in eLearning, but it has only scratched the surface. Given the increasing

importance of both collaborative learning and eLearning, much more comprehensive SNA-based analyses are needed. This was, in fact, one of the motivations for the study based on collaboration in eLearning environments.

4.4 Learning Styles

Learning style, which reflects a learner's characteristics and preferences during the learning process (Felder, 1996), is a major concern in many educational settings (Alonso, Gallego, & Honey, 1994; Galotti, Clinchy, Ainsworth, Lavin, & Mansfield, 1999; Muir, 2001; Paredes & Rodriguez, 2004; Liu, 2007; Melare, 2011). Many believe that understanding learning style can help both student and teacher: the student, because he or she will be aware of which learning tasks or activities are more effective for him or her (Felder & Silverman, 1988; Wang, Hinn, & Kanfer, 2001); and the teacher, because he or she can tailor the course design and content to best match the actual learning styles of the students, rather than attempt to cater to all possible styles (Hong & Kinshuk, 2004; Tseng, Chu, Hwang, & Tsai, 2008).

Felder and Soloman (2004) developed a scale based on Felder and Silverman's (1988) model of learning styles involving eight styles across four dimensions: processing (active/reflective), perception (sensing/intuitive), input (visual/verbal) and understanding (sequential/global). This scale served as the basis for the present study because it has been widely tested in educational and engineering contexts.

In this scale, *Active* learners do not learn through passive activities; they prefer group work and feel more comfortable with activities involving experimentation, discussion and testing. *Reflective* learners learn better by themselves; they tend to be theoreticians. *Sensing* learners prefer observing, gathering data and experimenting, whereas *intuitive* learners prefer imagination and speculation and dislike repetition. *Visual* learners are comfortable with charts, graphs, demonstrations and visual representations, whereas *verbal* learners prefer lectures, reading and discussions. *Sequential* learners prefer linear or sequential thought processes, while *global* learners can make intuitive leaps.

The systematic review by Cela et al. (2015) suggests that more eLearning studies are needed that use an SNA-based approach to analyse learning styles. The only study

identified in that review that analysed learning styles used the model of connected and unconnected knowers of Galotti et al. (1999) to show that ego density correlated negatively (-0.195) with knower connectedness in a modern Greek course of 104 students at a nonprofit organisation (Laghos & Laghos, 2008).

The present project sought to extend the sparse research on learning styles in eLearning by exploiting the potential of SNA to examine whether learning style affects how learners interact. The results should be helpful to learners, teachers and instructional designers alike.

4.5 The Flipped Classroom

The flipped class, a term coined by Bergman and Sams (2008), refers to a new pedagogical model in which lectures are prepared as videos of at most 5-7 minutes that the student can view at home, while classtime is reserved for discussion and practicing.

The term "flipped" refers to the fact that this structure is the opposite of the traditional one in which students encounter topics during class and are asked to process and practice them at home. The flipped classroom design has taken hold in several teaching disciplines, including chemistry (Bersgmann & Sams, 2008; Teo, Tan, Yan, Teo, & Yeo, 2014), calculus (McGivney-Burelle & Xue, 2013), and nursing (Bristol, 2014).

The systematic review of Cela et al. (2015) uncovered a lack of studies examining the flipped class format in eLearning environments, as well as a lack of studies applying SNA to flipped class process and outcomes. The limited research available suggests that the flipped class offers several advantages: students have more time to discuss problems and questions with their teacher as they practice the material in class; the format may allow more content to be covered than in a traditional class; and the flipped class can be useful for absentee learners, who can watch video lectures as needed (Bristol, 2014).

At the same time, the flipped design has the disadvantages that as students first encounter the material, they cannot ask teachers for clarification in real time (Bagby,

2013); and that preparing lectures for a flipped class may require more time than for a traditional one (Davies, Dean, & Ball, 2013).

The scarcity of studies on the flipped class in eLearning environments and on the use of SNA to analyse flipped class process and outcomes inspired the present work. This also provided an occasion to assess new educational approaches for adult learners.

5 Results

This section summarises the main results from the four studies carried out during this research. The research objectives and the corresponding results are depicted in Table 1.

Table 1: Summary of research objectives and characteristics of studies.

Obj.	Description	Theoretical Background	Duration of study[1] (months)	Number of participants	Results
O1	To identify what research questions about eLearning have been addressed using SNA and what SNA measures and network characteristics have been studied most often, and to identify gaps in the SNA literature on eLearning and suggest directions for future research.	**SNA** and eLearning	Eight	N/A	**R1**
O2	To use SNA to evaluate whether learning styles influence how learners interact in eLearning environments.	Learning styles and **SNA**	Three	213	**R2**
O3	To combine the quantitative approach of SNA with the qualitative approach of Content Analysis (CA) to examine whether assigning collaborative workgroups with desired topics or random topics affects how they collaborate.	Content Analysis, **SNA**, Collaborative learning	Three	103	**R3**
O4	To use SNA to compare learner interactions in a flipped and traditional course design in an eLearning environment.	**SNA** and the flipped classroom	One	68	**R4**

The objectives and results are discussed below in more detail.

[1] This includes the time needed to design and implement the eLearning courses performed as part of Research Objectives O2-O4.

R1: SNA and eLearning

> **O1:** To identify what research questions about eLearning have been addressed using SNA and what SNA measures and network characteristics have been studied most often, and to identify gaps in the SNA literature on eLearning and suggest directions for future research.

A systematic review of the research literature was undertaken to fulfill objective O1. The review uncovered 37 studies directly analysing SNA in eLearning. The review showed that this field is fairly new and that the number of published studies is increasing (Cela et al., 2015).

Studies were found to address three main research topics: (1) *Evaluation and/or implementation of SNA tools,* (2) *Analysis of interaction patterns* and (3) *Improvement of learning design*. Studies covering the first topic developed or applied software programs for extracting data and analysing them using SNA. These data came primarily from LMS and CMS. Studies covering the second topic focused on identifying and analysing patterns of learner interactions in various eLearning contexts, including on collaborative tasks, in forum discussions, and in communications during knowledge construction. Studies covering the third topic analysed social aspects of learning, design of discussions, roles of students and teachers, factors that motivate learners to contribute to the network, and learning performance.

Of these three research topics, the second one about *pattern identification* occurred most often, appearing in 51% of the studies identified. This reflects the SNA approach of regarding interactions as the drivers of learning. Many studies (32%) combined SNA with Content Analysis to gain a more comprehensive understanding of interaction quantity and quality in learning networks.

The studies examined diverse networks comprising from 5 to 839 nodes, with 37% of studies involving networks of 5-50 nodes. Most studies (89%) analysed interaction networks, based on the taxonomy of Borgatti, Mehra, Brass, and Labianca (2009); in these cases, density and centrality were the main characteristics examined.

The systematic review helps define the state of the art for using SNA to understand eLearning environments and identifies research gaps that should be addressed to move the field forward.

The complete results of the systematic review are shown in Appendix A1.

R2: SNA and Learning Styles

> **O2:** To use SNA to evaluate whether learning styles influence how learners interact in eLearning environments.

To fulfill this objective, an on-line course lasting eight weeks and involving 214 participants was studied. Learner interactions via forum discussions were analysed using the Felder and Soloman (2004) scale and SNA measures of centrality and density.

Centrality was found to weakly and positively correlate with active learning style and negatively with reflective style. The results suggest that learners in this course interacted differently in the network according to their learning style. One implication is that teachers should employ specific strategies to boost virtual discussion among reflective learners.

To our knowledge, this study is the first published work to apply Felder and Soloman's scale of learning styles to SNA-based analysis of eLearning. Previous work (Laghos and Laghos, 2008) used the Attitudes Towards Learning Scale (ATTLS) to assess learning style and social measures, and those authors found that ego density values correlated negatively with knower connectedness. Our study is an important addition to the literature because it is based on a widely used and validated learning styles scale, and it has provided some clear proposals for tailoring eLearning environments to students with certain learning types.

At the same time, it is important to keep learning styles in perspective: previous work in non-eLearning environments suggests that these styles account for a relatively small proportion of variation in learning outcomes, highlighting the need to address other learner and teacher factors as well. In addition, learning styles are only one of several personality aspects likely to affect learning (Furnham, Monsen, & Ahmetoglu, 2009). These other personality factors, together with communication and motivation factors, should be studied for a more comprehensive understanding of how to improve eLearning outcomes.

Detailed results are shown in Appendix A2.

R3: SNA and Collaborative Learning

> **O3:** To combine the quantitative approach of SNA with the qualitative approach of Content Analysis (CA) to examine whether assigning collaborative workgroups with desired topics or random topics affects how they collaborate.

To achieve this objective, we examined an eLearning course in which participants were assigned to small groups to carry out a collaborative project, which involved creating a wiki. The course was carried out in two sections. In the first section, learners (n = 53) were assigned randomly to groups without regard for the topic; in the second section, learners (n = 50) were assigned to groups according to their interest in the topic assigned to that group. The two groups were compared in terms of the quantity and quality of learner interactions and learner performance.

Data on interactions were collected in the form of forum discussions during the collaborative work. For quantitative analysis, we focused on several SNA parameters, including centrality degree and density. To complement this quantitative analysis, we also used CA (De Laat, 2002; Erlin, Yusof, & Rahman, 2008).

Content Analysis based on Gunawardena´s (1997) model of knowledge construction showed that under both group allocation conditions, learners showed a low level of knowledge construction. Most forum discussion (88%) was assigned to phase I, which

consists of *comparing and sharing information*. Previous studies in other countries and with other course types and sizes detected similarly low levels, suggesting that CA is a valid approach (De Laat, 2002; Gunawardena, Lowe, & Anderson, 1997; Jiangtao Qiu, Zhangxi Lin, Changjie Tang, & Shaojie Qiao, 2009).

While the groups under the two allocation conditions did not differ significantly in centrality or learner performance, the groups that worked on preferred topics showed significantly higher density. This suggests that a greater proportion of learners participated in the collaborative discussions when they worked on topics they preferred. These findings imply that forming groups in on-line courses based on learner topic preferences may increase the number of learners engaged in the collaborative task, although it may not necessarily improve performance or level of knowledge construction.

The complete results can be found in Appendix A3.

R4: SNA and the Flipped Class

> **O4:** To use SNA to compare learner interactions in a flipped and traditional course design in an eLearning environment.

This objective was addressed by studying a one-week course (n=68) divided into two sections: the first one (n = 34) followed a traditional class format, while the second one (n = 34) used a flipped class format. Using SNA, we compared the level of interaction, learner satisfaction and learner performance between the two sections. Data were gathered in the form of virtual discussion among learners during the course.

Density was similar for the two groups, while centralisation was slightly closer to being a star for the flipped class than for the traditional class. The traditional class showed more cliques (n = 4) than the flipped one (n = 2). Ego analysis showed the traditional class to have higher degrees of centrality and closeness than the flipped class. Taken together, these results suggest that learners were more central in the

traditional class, while the flipped class was closer to being a star network. Furthermore, the traditional class was slightly denser than the flipped class.

We were surprised by these results because we expected to see significant differences between the sections, especially since one of the hallmarks of the flipped class is that learners can interact and discuss in class in order to resolve questions. In fact, we observed a similar level of discussion in both groups. These results are intriguing because they suggest that a flipped eLearning format may not, by itself, improve learner interactions. The flipped design may work in concert with other factors to boost learner interactions, or the flipped design may not influence learner interactions at all. The present study will hopefully catalyse future work to address this question.

As with the level of interaction, both learner satisfaction and learner performance were similar between the two groups. Learner satisfaction was measured on a Likert scale (5 levels), and learner performance was measured using grades on a final exam covering the entire course. Our results on satisfaction contrast with results reported by Strayer (2012) and Missildine, Fountain, Summers, & Gosselin (2013), who measured lower satisfaction among learners in the flipped class than among learners in the traditional one. Our results on performance are consistent with those reported by Davies et al. (2013), who found no significant differences between flipped and traditional designs. In contrast, Missildine et al. (2013) measured better performance in the flipped class.

Combining the results of our study with previous work suggests that the effectiveness of the flipped class is far from clear, at least in eLearning environments. While the flipped design may slightly increase learner interaction over a traditional design, it does not necessarily improve learner performance or satisfaction. The small sample size in our work, combined with the heterogeneity of course types and students in the literature, highlights the need to verify and extend these findings in larger studies.

Our complete results can be found in Appendix A4.

6 Conclusions

Conclusions are presented according to the research objectives.

6.1 SNA in eLearning Environments

The main goal of this research was to assess SNA as a method to measure and explore interactions in eLearning environments from several theoretical perspectives, using a variety of comparative experimental conditions. A systematic review of the literature on SNA in eLearning showed us the breadth of existing research as well as several gaps, which motivated the three subsequent experimental studies.

The systematic review identified 37 studies, suggesting that SNA is an emerging approach in eLearning, though the rate of publications per year suggests the field is growing. The 37 studies covered three main topics: (1) implementation of SNA software tools, (2) analysis of interaction patterns and (3) improvement of eLearning design. Nearly half the networks in the identified studies involved 5-50 nodes, suggesting that larger studies are needed to verify and extend the literature.

While SNA is usually used to analyse interactions among learners and between teachers and learners throughout a course, some studies also used the approach to examine interactions specifically during collaborative tasks within the course. Such network analyses are facilitated by the data already collected by widely used LMS and CMS.

The systematic review also revealed the power of combining SNA with CA in order to obtain both quantitative and qualitative insights. This mixed-method approach proved essential in the experimental phases of the present research.

6.2 SNA and Learning Styles

The study related to learning styles and SNA provided preliminary support for the idea that active learners may be more dynamic in their virtual interactions. This correlation was weak and so should be verified and extended in future work in analyses that also take into account other variables that may influence learner interactions in eLearning environments. If verified, these results suggest that teachers should pay more attention to learning styles in order to improve learner outcomes

using adequate learning technology. We also examined learner interactions over the duration of the course and were able to detect differences in their interaction. This suggests the usefulness of SNA to detect time-dependent changes in network interactions.

6.3 SNA and Collaborative Activities

The second study evaluated whether collaboration among members of the group differs if the group is assigned a topic at random or a topic that all members prefer. Our results suggest that taking into account learner preferences when assigning group topics may increase the collaborative engagement of individual learners, but this may not translate into better learner performance or into a higher number or quality of interactions.

By supplementing the quantitative approach of SNA with the qualitative depth of CA, we were able to determine that most interactions focused on *comparing and sharing information,* indicating a low level of knowledge construction. This result is similar to other studies. Taken together, our results and previous work suggest that discussion in eLearning environments tends to be superficial, highlighting the need for research into how to improve discussion quality.

6.4 SNA and the Flipped Class

The final experimental study in this research used SNA to compare flipped and traditional class designs. At the global level, our results did not reveal significant differences, including in learner performance and satisfaction, though the traditional class featured more cliques. At the ego level, the traditional class showed higher centrality and closeness. These findings not only validate the usefulness of SNA for distinguishing factors that do or do not influence eLearning outcomes, but they also highlight the need for further research to clarify the effectiveness of flipped courses in the context of eLearning.

6.5 Overall Conclusions

The results from this research have theoretical, practical and methodological implications for researchers, teachers and instructional designers specialising in eLearning. The three studies provide valuable examples of how to apply SNA to eLearning in order to study collaborative learning, flipped course design and learning styles.

The study on collaboration shows that SNA is useful for quantifying collaboration among learners, and that it can be complemented with other methodologies such as Content Analysis in order to provide a more complete overview of learner interactions. The superficial knowledge construction observed in this study highlights the need for more extensive research into methodology and technology that may improve the quality of learner interactions in eLearning environments.

The study on the flipped class suggests that a flipped design, by itself, does not necessarily lead to better outcomes than a traditional design. The small study sample in this work highlights the need for larger, more extensive work on this question, especially since the flipped class has been the subject of relatively few studies. In particular, we are unaware of other studies of flipped classes in eLearning environments. The present study therefore may lay valuable groundwork for future work in this unexplored area.

The study on learning styles has practical implications in showing that students with different styles interact in different ways, particularly those who are active or reflective. Nevertheless, we should be aware that numerous other factors influence on-line interactions, which should be taken into account in future work expanding on the present study.

In addition to the three specific contexts in which we apply SNA in this research, the project as a whole provides valuable methodological support for using SNA to explore social structures in various contexts. This analysis of social structures helps elucidate the on-line behaviour of individual learners. Longitudinal studies, such as some of the work in this project, can even provide insights into how these behaviours change over time. Such work may begin to reveal patterns of learner interactions.

Finally, these three experimental studies suggest that SNA can be adapted to different eLearning contexts, which is consistent with what we found in our systematic review. In particular, they show that SNA can be used to compare different collaborative learning formats, compare different course designs for different learning styles using the scale of Felder and Soloman (2004), and assess new educational approaches not yet optimised for eLearning environments, such as the flipped class. These three studies have already provided several results that are useful starting points for future work examining larger courses with an even broader range of learners.

7 Future Work

Future work may include an update to our systematic review, which should be considered preliminary given the early stage of the field and the small number of studies identified. Such a systematic reassessment of SNA in eLearning may help ensure that the field remains focused on the most relevant questions and methodologies.

Future work to verify and extend our findings on learning styles and eLearning should employ other scales of learning style. In addition, they should include other variables that may affect learner behaviour in on-line environments, including communication style, personality style, and motivation. Studies of learning style that neglect these other variables may run up "against a wall" because learning style by itself may explain a relatively small proportion of variation in learning outcomes.

Future work should focus on what technologies and pedagogical methodologies can increase the level of knowledge construction in eLearning discussions. Larger studies are needed to verify and extend our somewhat surprising findings about the flipped class format in an eLearning environment.

8 Publications

8.1 Research Articles

Cela, **K**., Sicilia, M., and Sánchez, S. (2015). Social Network Analysis in E-Learning Environments: A Preliminary Systematic Review. *Educational Psychology Review*, *27*(1), 219–246. http://doi.org/10.1007/s10648-014-9276-0

If:1.394 (Q1).

Cela, K. L., Sicilia, M. Á., and Sánchez, S. (2014). Social Network Analysis in E-Learning Environments: A Preliminary Systematic Review. *Educational Psychology Review*, 1-28. *If: 2.846 (Q1)*.

Sie, R. L., Ullmann, T. D., Rajagopal, K., **Cela**, K., Bitter–Rijpkema, M., and Sloep, P. B. (2012). Social network analysis for technology–enhanced learning: review and future directions. *International Journal of Technology Enhanced Learning*, *4*(3), 172-190.

Cela, K., Fuentes, W., Alonso, C., and Sánchez, F. (2010). Evaluación de herramientas web 2.0, estilos de aprendizaje y su aplicación en el ámbito educativo. *Journal of Learning Styles*, 3(5).

Gallego G., D. J. G., **Cela**, K. L. C., and Raza, C. M. H. (2011). Una mirada hacia el Ecuador frente a las tecnologías de la información y la comunicación en el ámbito educativo. Educación y Futuro: *Revista de investigación aplicada y experiencias educativas*, (25), 115-132.

Cela, K. L., Sicilia, M. Á., and Sánchez, S. (in press). Comparison of collaboration and performance in groups of learners assembled randomly or based on learners\topic preferences. *Journal of Educational Technology and Society*. if: 0.8 (Q2)

8.2 Conference Papers

Cela, K. (2013). Social interaction in on line learning. In Proceedings of the XVIII International Congress of Technologies for Education and the Knowledge and Digital Slate V: Intercultural, Strategies and Technologies InterESTRATIC. Universidad Nacional de educación a distancia. Madrid, Spain.

Cela, K. (2015). Analysis of social interaction of separate and connected knowers in on line environments. In Proceedings of the international conference on digital exclusion in the information and knowledge society, SEMIME, Lisboa, Portugal.

8.3 Book Chapters

Hinojosa, C., **Cela,** K. (2013). Web 2.0 e interacciones sociales. D. Gallego & M. Álvarez. (Eds.), *Capacitación y gestión del conocimiento a través de la Web 2.0*. (pp 97-113) Madrid, Spain: Dykinson.

Cela, K., Hinojosa, C. (2013). Web 2.0 y educación. D. Gallego & M. Álvarez. (Eds.), *Capacitación y gestión del conocimiento a través de la Web 2.0*. (pp 141-154) Madrid, Spain: Dykinson.

Cela, K, Sicilia, M.Á., Hinojosa, C. (In press). Interacciones sociales en entornos eLearning. In Press. Gallego, Alvarez, Rosanigo & Cela. (Eds.), *TIC y formación Web 2.0 para la inclusión social y el desarrollo sostenible*. Madrid, Spain: Dykinson.

Cacheiro, M, **Cela,** K., Pindado, M.J. (In press). Web 2.0 perspectiva tecno social. Gallego, Álvarez, Rosanigo & Cela. (Eds.), *TIC y formación Web 2.0 para la inclusión social y el desarrollo sostenible*. Madrid, Spain: Dykinson.

Hinojosa, C., **Cela,** K., Sánchez, L. (In press). Tecnologías para la inclusión social. Gallego, Álvarez, Rosanigo & Cela. (Eds.), *TIC y formación Web 2.0 para la inclusión social y el desarrollo sostenible*. Madrid, Spain: Dykinson.

8.4 Projects

Formación virtual en tecnologías de la información para la educación, 2014-2015, Universidad de las Fuerzas Armadas ESPE, código PCC-P1-2014. [03 2014-03 2015].

TIC y formación web 2.0 para la inclusión social y el desarrollo sostenible código AECID AP/048416/11, [01/12/2011 - 13/03/2013].

Capacitación y gestión del conocimiento con herramientas web 2.0 para la docencia universitaria, gestión administrativa y educativa y desarrollo profesional continuo. AECID Código A/024521/09, [01/01/2010 - 15/06/2011].

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Cela, K., Sicilia, M., & Sánchez, S. (2015). Social Network Analysis in E-Learning Environments: A Preliminary Systematic Review. *Educational Psychology Review*, *27*(1), 219–246. http://doi.org/10.1007/s10648-014-9276-0

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10 Appendix

Appendix 1: **Cela**, **K.**, Sicilia, M., & Sánchez, S. (2015). Social Network Analysis in E-Learning Environments: A Preliminary Systematic Review. Educational Psychology Review, *27*(1), 219–246. http://doi.org/10.1007/s10648-014-9276-0. *Impact factor: 2.846 (Q1)*

Appendix 2: **Cela, K.,** Sicilia, M.-Á. and Sánchez-Alonso, S. (2015). Influence of learning styles on social structures in online learning environments. *British Journal of Educational Technology*. doi: 10.1111/bjet.12267. Impact factor:1.394 (Q1).

Appendix 3: **Cela, K.**, Sicilia, M. Á., & Sánchez, S. (accepted - in press). Comparison of collaboration and performance in groups of learners assembled randomly or based on learners\' topic preferences. *Journal of educational technology and society*. Impact factor: 0.8 (Q2)

Appendix 4: **Cela, K.,** Sicilia, M. Á., & Sánchez, S. (under review). Comparative analysis of learner interactions in flipped and traditional classes using social network analysis.