Exploring a Community of Inquiry Supported by a Social Media-Based Learning Environment

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ABSTRACT: The Community of Inquiry (CoI) framework has been widely used in blended and online educational research, more recently being applied also to social media settings. This paper explores the learning community created in such a social media-based educational environment, using an extended version of CoI, which includes four components: cognitive presence, social presence, teaching presence and learning presence. The context of study is a project-based learning scenario implemented in an undergraduate Computer Science course. A quantitative content analysis method is employed, to examine a total of 1712 online contributions (blog posts and tweets), generated by 75 students. Results show that the social media tools provide complementary support to the community of inquiry: the blog is primarily a content space (as cognitive presence is dominant), while Twitter is mostly a discussion space (as social and learning presences are dominant). Teaching presence is barely exhibited by the students, being mainly the preserve of the instructor, while learning presence is quite strong, reflecting students' significant self- and co-regulation behavior.

Keywords: Community of Inquiry, Social media, Project-based learning, Computer-supported collaborative learning, Quantitative content analysis

1. Introduction

The *Community of Inquiry (CoI)* framework was proposed by Garrison et al. (2000) and has been used extensively over the past two decades for exploring the development of online learning communities. These can be characterized in terms of three interdependent components (see https://coi.athabascau.ca/coi-model):

- *Cognitive presence* (the extent to which learners can construct meaning through reflection and discourse)
- *Social presence* (the ability of learners to identify with the community and develop interpersonal relationships by projecting their personal characteristics into the community)
- *Teaching presence* (design, facilitation, and direction of cognitive and social processes to support learning).

The framework is still very popular for blended and online educational research, while underlying technologies and practices are continuously changing (Remesal & Friesen, 2014; Swan, 2019). Thus, CoI was initially introduced for computer conferencing, but subsequently extended to other asynchronous communication spaces between students. More recently, it was applied also to social media settings, such as blog (Angelaina & Jimoyiannis, 2012a; Jimoyiannis & Tsiotakis, 2017; Pifarré et al., 2014), wiki (Eteokleous et al., 2014), Twitter (Sinnappan & Zutshi, 2011), Facebook (Kazanidis et al., 2018; Öztürk, 2015) or SecondLife (Burgess et al., 2010). Indeed, these social media tools have been increasingly adopted in educational contexts, with positive effects on the learning process (Anderson, 2019; Ricoy & Feliz, 2016; Yeh et al., 2019). They can be used to foster communication and collaboration between learners and help create online learning networks, actively engaging students in their learning (Lumby et al., 2014; Kuo et al., 2017). Attributes of social, cognitive and teaching presence could be identified in these social learning spaces, thus proving the applicability of the CoI model (Remesal & Friesen, 2014). Nevertheless, the number of studies is limited, so further research is needed to fully investigate the development of online communities of inquiry supported by social media tools.

Furthermore, the CoI framework itself may also be revisited, adapted and enhanced (Swan & Ice, 2010; Remesal & Friesen, 2014). Thus, Shea and Bidjerano (2010) suggested the extension of the CoI model with an additional theoretical construct labeled "*learning presence*." This refers mainly to learner self-efficacy as well as self- and co-regulation, focusing on the active roles of students in terms of metacognitive, motivational, and behavioral traits. Indeed, various analyses identified learner utterances which could not be reliably coded within the original three CoI presences (e.g., attempts to manage time, divide tasks, set goals, or collaboratively try to understand teacher's instructions). This additional presence is aimed to "contribute to a more thorough account of knowledge construction in technology-mediated environments, expanding the descriptive and explanatory power of the Community of Inquiry framework" (Shea & Bidjerano, 2010, p. 1721).

According to Shea et al. (2012), learning presence is noticeably different from teaching presence; the former refers to forethought and planning, monitoring, and strategy use exhibited by students, while the latter refers to instructional design, facilitation of discourse, and direct instruction, which are mainly (though not exclusively) exhibited by teachers. Learning presence is also clearly distinct from the affective and cohesive dimensions of social presence, as well as from the phases of cognitive presence (i.e., triggering event, exploration, integration, and resolution) (Shea et al., 2014). Further studies showed that learning presence "moderates relationships of the other components within the CoI model" (Shea & Bidjerano, 2012, p. 316), is fostered when students are asked to collaborate more deeply and is the only construct significantly correlated with course grades (Shea et al., 2012). Shea et al. (2013) and Shea et al. (2014) provided additional evidence for the validity of the learning presence component, by combining quantitative content analysis and social network analysis (SNA). The construct was further considered in several studies, such as (Hayes, 2014; Hayes et al., 2015; Kreijns et al., 2014; Traver et al., 2014; Wertz, 2014). A coding scheme for learning presence was also proposed by Shea et al. (2012) and subsequently refined by Shea et al. (2014) and Hayes et al. (2015).

The new construct has been applied so far only for analyzing online course discussions, as reported in the above mentioned studies; a blog platform was used in (Shea et al., 2013), but only as a basic means for hosting a single learning journal entry for each student. Hence, we believe it is worthwhile to use the *extended CoI model* also in the context of social media-based learning spaces. More specifically, in this paper we aim to investigate the community of inquiry created in a social learning environment called eMUSE (Popescu, 2014); the context is a project-based learning scenario implemented in an undergraduate Computer Science course. The novelty of our approach comes from using a blend of social media tools (blog and Twitter), rather than a single tool as in related studies (Angelaina & Jimoyiannis, 2012a; Jimoyiannis & Tsiotakis, 2017; Pifarre et al., 2014; Sinnappan & Zutshi, 2011); this offers the potential for comparative analyses and more in-depth investigations. A longitudinal analysis is also performed, to explore the evolution of the community of inquiry over the course of the semester. While many related works rely on post-hoc information collected through surveys (self-reported perceptions), our study has the advantage of being based on the examination of students' actual discourse (Remesal & Friesen, 2014). A quantitative content analysis method is employed, conducted with the help of an in-house tool, called CollAnnotator (Badea & Popescu, 2017). A total of 1712 utterances contributed by 75 students are analyzed (479 blog posts and 1233 tweets), which is a relatively large sample compared to similar studies.

Overall, our study aims to explore how social media tools (in particular blog and Twitter) can promote collaborative interaction between students in a higher education context. Understanding how blogs and Twitter can support collaborative learning and the creation of a community of inquiry is an important issue for both teachers and researchers (Pifarre et al., 2014). Investigating the cognitive, social, teaching and learning presences occurring during the group learning project may shed some light on the educational affordances of the social media-based learning environment. Indeed, many studies outline the importance of exploring CoI presences in various educational settings (Remesal & Friesen, 2014; Swan, 2019). CoI provides a useful framework for assessing students' learning activities and their involvement in the online community supported by social media tools (Angelaina & Jimoyiannis, 2012a). As these tools become more widely used in education, it appears more important to study their potential to foster the development of a community of students engaged in collaborative learning and social knowledge construction.

More specifically, our research aims to answer questions such as: To what extent do students experience social, cognitive, teaching and learning presence in a project-based learning activity supported by social media tools? What are the frequencies of occurrence of the four presences in the students' blog posts and tweets? What are the differences between blog and Twitter in terms of CoI support? How does the community of inquiry evolve over time? Thus, the main contributions of our paper are on two directions: (i) investigating the use of the *extended CoI model* in a social media-based learning environment (which, to the best of our knowledge, has not been attempted before); (ii) applying a quantitative content analysis on students' contributions on a blend of social media tools (blog and Twitter), enriched with comparative and longitudinal analyses.

The rest of the paper is structured as follows: the next section provides an overview of related work. The study settings and data collection process are described in section 3. The content analysis procedure is detailed in section 4, while the results are reported in section 5. A discussion of the findings and some concluding remarks are included in section 6.

2. Related work

In what follows, we present an overview of studies which explore the use of the CoI framework in social media settings, such as blog, microblog, wiki, social network or virtual world. According to the literature, there are two approaches for the investigation of the CoI presences, which we address in turn: (i) content analysis of students' online messages; (ii) questionnaires for gauging students' perception regarding their learning experience.

2.1. Studies based on quantitative content analysis

We start with several papers that explore the affordances of the blog for supporting a community of inquiry.

One of the first studies belongs to Angelaina and Jimoyiannis (2012a), where the instructional scenario consists in using an educational blog for a project-based learning approach. The study participants are 21 high-school students (15 years old), from two different classes in a Greek school, together with their teacher; they used the blog for 9 weeks, in the context of an informatics curriculum. They published a total of 39 posts and 92 comments, which were extracted from the blog and analyzed by the researchers using CoI model; the unit of analysis was the entire post or comment. Results showed the following distribution of blog entries:

- 95 belong to the *Cognitive presence* (*Triggering event* - 14, *Exploration* - 56, *Integration* - 25)
- 22 belong to the *Social presence* (*Open communication* - 15, *Emotional expression* - 3, *Group cohesion* - 4)
- 14 belong to the *Teaching presence* (*Design and organization* - 1, *Facilitating discourse* - 7, *Direct instruction* - 6), most of them originating from the teacher.

The authors conclude that "project-based blogs can support online learning groups where students are able to share content and ideas, and construct knowledge within a supportive CoI" (Angelaina & Jimoyiannis, 2012a, p. 180).

In a subsequent paper, Angelaina and Jimoyiannis (2012b) extended the analysis by using a combined framework: CoI model in conjunction with the representation of learning mapping (e.g., chain, spoke or network structure). Blogging patterns and students' engagement in blogging activities are investigated. Results suggest that "properly designed blog activities can help students to achieve higher cognitive levels through enhancing their collaboration skills and critical thinking" (Angelaina & Jimoyiannis, 2012b, p. 183).

Pifarre et al. (2014) also investigated the use of blogs for supporting a community of inquiry in secondary education. 15 students from seventh and eighth grades in a Spanish school worked on a science blogging project for four months, discussing topics related to astronomy and space sciences. Each student had to create 6 blog posts solving specific learning activities and also add comments on their own and peers' blogs. A total number of 87 comments were posted by the students and their two instructors, whose content was subsequently analyzed by two coders. First, posts were divided into "meaningful units" (480), which were then coded using CoI scheme. The first 20% of the units were coded by both raters and a good inter-rater reliability measure was obtained; hence, the rest of the units were analyzed by one coder. Results showed the following distribution:

- 130 units belong to the *Cognitive presence*
- 230 units belong to the *Social presence*
- 120 units belong to the *Teaching presence.*

No detailed classification is reported in the paper (i.e., at category level). Authors conclude that "the blog environment afforded the construction of a Community of Inquiry and therefore the creation of an effective online collaborative learning community" (Pifarre et al., 2014, p. 72).

Another study was performed by Jimoyiannis and Tsiotakis (2017), who investigated an educational blogging community created in an undergraduate course entitled "Internet Services and Applications." The course took place at a Greek university and included 48 students split in 10 groups of 4-5 members; each group had to create a blog with valuable content on the topic of "internet safety." A total of 1,214 entries were published on the blogs (200 articles, 15 group pages and 999 comments). Their content was coded by two researchers based on CoI model, using each post as unit of analysis. However, the overall frequency counts for each presence and category were not reported in the paper. Instead, only three representative student groups were analyzed; *cognitive* and *social presences* played a significant role for these groups, while *teaching presence* was less well represented. In addition, the authors applied topic analysis (learning mapping representation of blog topics) and SNA (cohesion analysis, power analysis, role analysis) in order to further explore the learning community.

Twitter's affordances for supporting a community of inquiry have been less explored so far. The study performed by Sinnappan and Zutshi (2011) is a notable exception. Two student cohorts were involved in the study, one from an Australian university and one from an American university. They were enrolled in two similar undergraduate courses on eBusiness. Students were encouraged to use Twitter for exchanging thoughts, ideas and questions on topics like privacy, ethics and censorship, for a period of four weeks. The two instructors collaborated in order to foster interaction between students across universities. A total of 47 learners participated in the study, posting 324 curriculum-related tweets. Their content was analyzed by two coders, using CoI scheme. Up to two categories could be assigned to each tweet (unit of analysis): a primary one (mandatory) and a secondary one (optional); 186 tweets had 2 assigned categories. The following distribution of tweets was obtained (taking into account only the first category / both categories):

- 279 / 284 belong to the *Cognitive presence* (*Triggering event* - 82 / 84, *Exploration* - 194 / 197, *Integration* - 3 / 3)
- 13 / 194 belong to the *Social presence* (*Open communication* - 1 / 4, *Affective* - 4 / 8, *Group cohesion* - 8 / 182)
- 32 / 32 belong to the *Teaching presence* (*Design and organization* - 8 / 8, *Facilitating discourse* - 22 / 22, *Direct instruction* - 2 / 2), most of them originating from the teacher.

The study shows Twitter's potential for pedagogical use, being able to enhance and complement all CoI presences (Sinnappan & Zutshi, 2011).

An alternative approach to the manual content analysis performed in the above studies is the use of machine learning and text mining techniques for classifying students' posts (Wu et al., 2020; Xing & Gao, 2018). In recent years, these have started to be used also in the context of the CoI framework, providing automatic labeling of learner messages according to the categories of CoI presences. Such studies have been performed based on the coding scheme for the *cognitive presence* (Farrow et al., 2019; Neto et al., 2018) or the *social presence* (Ferreira et al., 2020). To the best of our knowledge, no automatic methods have been devised so far for classifying messages with respect to *teaching presence* or to the whole CoI model. While this is a promising research direction, it is outside the scope of this paper, which focuses on manual content analysis; furthermore, manual coding can provide a higher accuracy than currently existing automatic approaches.

2.2. Studies based on students' perceptions

CoI model has also been applied to other social media tools, such as wiki, Facebook and Second Life; however, no content analysis has been performed in these cases; instead, researchers relied on the *Community of Inquiry Survey* (Arbaugh et al., 2008) in order to extract students' subjective perceptions regarding the three presences.

Thus, Öztürk (2015) investigated the suitability of a social networking site for supporting a community of inquiry. Facebook was used in a blended course on Philosophy of Education in a Cypriot university. 198 students were involved in the study (from two different cohorts); one large group (77 students) and 5 smaller groups (around 24 students) were formed, who participated in various discussion activities around short videos and articles. Data was collected through CoI Survey and a Motivation Scale, which were filled in by 158 students. Results showed that *teaching presence* perception was highest, followed by *cognitive presence* and then *social presence*; a high correlation among the three presences was determined. Furthermore, all presence perceptions were higher for students in the small groups compared to the large group. The study also found that students with a higher cognitive presence perception have higher academic success, while students with higher teaching presence and cognitive presence perceptions have higher motivation. The authors conclude that Facebook can be effectively used for educational purposes, facilitating the creation of communities of inquiry.

The same social networking site was used by Kazanidis et al. (2018), in an attempt to compare students' learning experience with Moodle and Facebook in a course on Instructional and Learning Theories at a Greek university. 97 students participated in the study, being split into two groups based on the learning and communication platform adopted: 47 learners used Moodle (control group) and 50 learners used Facebook (experimental group). Students worked in teams of 4-5 people over the course of six weeks in order to create various educational resources and reports. At the end of the study, students filled in a revised version of the CoI Survey. Results indicate that students who used Facebook had a higher *social presence* perception compared with students who used Moodle, while *teaching* and *cognitive presence* perceptions were similar for both groups. Furthermore, female students in the experimental group had higher teaching and cognitive presence perceptions compared with their male peers. Overall, the study outlines Facebook's potential to support teaching and learning processes, increasing students' engagement and learning satisfaction.

Eteokleous et al. (2014) evaluated the integration of wiki as educational tool in an elementary school in Cyprus. 20 fifth-grade students were enrolled in a Language and Linguistics class and used a wiki for the course of five lessons, under the guidance of their teacher. Data was collected through several methods: the CoI Survey, reflective journal for the teacher, based on the Dynamic Model of Educational Effectiveness (Creemers & Kyriakides, 2010), observations performed by an external coder, and interviews with students. Results of CoI survey suggest that *teaching presence* was perceived as strongest, highlighting the important role of the teacher, especially in terms of *direct instruction* and *facilitation*. *Cognitive presence* was less strong, but *integration* and *resolution* phases of learning were well supported, while *triggering event* had a satisfactory appearance. *Social presence* was perceived as relatively weak, indicating that students did not have enough opportunities for *open communication* and fostering *group cohesion*; instead, they interacted more offline than through the wiki. Overall, the use of wiki promoted the development of a CoI to a satisfactory degree, contributing to the achievement of educational goals.

Burgess et al. (2010) explored the use of a Multi-User Virtual Environment (MUVE), Second Life, for supporting a community of inquiry. Ten graduate students from a US university (pre-service or in-service educators) were enrolled in an online instructional technology course; the instructor used Second Life for two class meetings. Two instruments were used for gathering data: CoI Survey for students' perceptual data and the Multi-User Virtual Environment Education Evaluation Tool (McKerlich & Anderson, 2008) for observational data, recorded by two coders. High perception levels were reported by the students for all three presences; also, a medium number of observations were recorded by the coders for each presence. Hence, a community of inquiry may be developed inside a MUVE, and the main elements of the CoI model apply to immersive environments, as previously suggested by McKerlich and Anderson (2008).

Finally, the Community of Inquiry Survey was also used in the context of a blogging activity, as reported by Yang et al. (2016). The study included 26 graduate students at a Taiwanese university, who took a Digital Learning course; learners had to write at least two posts per lecture and could also comment and rate their peers' posts. At the end of the semester, students were asked to fill in a questionnaire for identifying their perceptions of CoI presences, as well as their subjective learning outcomes. Regression analysis was applied and results showed that all three presences have a significant role in predicting learning performance: *cognitive presence* played the most important role, followed by *social presence* and to a lesser extent by *teaching presence*.

The works presented above vary in terms of context of study, social media tool, discipline, participants, analysis methods and results. The scale of the studies is relatively small: most of them involve 10 to 50 participants, with the exception of (Öztürk, 2015), which includes almost 200 students. The set of disciplines being taught in the studies is varied, ranging from informatics to education and instructional technology, and from eBusiness to language and linguistics, showing that communities of inquiry may be developed around any topic. While the blog is the most popular medium in existing studies, research has been performed also on the affordances of other social media tools for supporting a community of inquiry, e.g., microblog (Sinnappan & Zutshi, 2011), wiki (Eteokleous et al., 2014), social network (Kazanidis et al., 2018; Öztürk, 2015) or virtual world (Burgess et al., 2010). As far as the analysis method is concerned, most existing studies rely on students' perceptions, gauged by means of the CoI survey, but there are also a few which perform content analysis (Angelaina & Jimoyiannis, 2012a; Jimoyiannis & Tsiotakis, 2017; Pifarre et al., 2014; Sinnappan & Zutshi, 2011). While presence distribution varies from study to study, all surveyed works confirm the suitability of the respective social media tool to support a community of inquiry, to various extents. However, none of them uses the extended CoI model; to the best of our knowledge, the current study is the first one to employ this extended model in social media-based learning settings. Furthermore, all the papers reviewed in this section investigate a single social media tool, while the current study explores and compares a conjunction of tools, as described in subsequent sections.

3. Study settings and data collection

Our study took place in the context of a semester-long (i.e., 14 weeks) course on Web Applications Design (WAD), taught to 4th year undergraduate students in Computer Science from the University of Craiova, Romania. Students followed a collaborative project-based learning (PBL) scenario, in which they had to design and implement a relatively complex web application of their choice (e.g., a virtual store, an online travel agency, an auction website, an educational social network, an online library). A total of 75 students were involved in the study, 18 female and 57 male (average age 22). They were grouped in 20 teams of 3-4 peers, formed according to students' preferences. Each team member took various roles throughout the semester: system analyst, database specialist, interface designer, application architect, programmer, tester, project manager etc. At this stage,

students had already taken several programming courses, as well as a Database Design, a Software Engineering and a Project Management course; therefore they had enough knowledge and experience to undertake a team-based development of a real-life software product. At the end of the semester, students had to make a presentation of their product in front of the whole class; in addition, they were asked to give four intermediary presentations, in order to show the progress of the project. The evaluation was based both on the final product and the collaborative work carried throughout the semester.

A blended learning approach was implemented: every week students participated in face-to-face classes with the instructor and used a mix of social media tools for online communication and collaboration. As PBL has a strong social component, being rooted in constructivist principles (Savery & Duffy, 1995), the social media tools can and have been used to support communication and collaboration in the PBL framework (Ardaiz-Villanueva et al., 2011; Kim et al., 2011). More specifically, each team had a dedicated wiki space for collaborative writing tasks, for gathering and organizing educational resources and for documenting each stage of the project. They also had a team blog, for reporting the progress of the project (i.e., learning diary), reflecting on their learning experience, publishing thoughts, ideas, and resources, describing problems encountered and asking for help, providing feedback and solutions. In addition, each student had an individual Twitter account, for staying connected with peers and posting short news, announcements, questions, status updates regarding the project. All these social media tools were integrated in a social learning environment called eMUSE (Popescu, 2014). The platform provided various functionalities, both for students and instructors: easy access to the tools and latest activity notifications, learner tracking and data visualizations, peer review module, grading support. More details regarding the platform can be found in (Popescu, 2014; Popescu & Petrosanu, 2016).

Students had no prior experience with eMUSE platform; however, most of them had used the social media tools before, in out-of-school contexts. The use of the tools was mandatory, as students' contributions were part of their final grade; this was a way of assessing students' collaborative work throughout the semester. More specifically, the intermediary presentations and continuous collaborative work counted for 70% of the grade, while the final project counted for 30%. The instructor provided brief guidelines regarding the use and expected role of each tool at the beginning of the study (as mentioned above); continuous feedback and clarifications were provided throughout the semester. However, no specific scaffolds or prompts were included, so students had a high degree of freedom and flexibility. Thus, every week there was a two hours face-to-face class with the instructor, in which students received hands-on tutorials and help with their projects; subsequently, students used the social media tools in eMUSE for online communication and collaboration when developing their projects at home (every week, after class). The specific amount of activity performed on each tool varied from one week to the other, as detailed in section 5.3.

The aim of our study was to investigate the community of inquiry created around the WAD project and the affordances of the social media tools to support it. More specifically, we were interested to apply the extended CoI model to the communication space created through blog and Twitter. The wiki was not included in this analysis, as it was used especially for writing the project documentation and students did not use the associated discussion pages for further communication. Hence, blog posts, comments and tweets supported all message exchanges between students and they were automatically collected and stored by eMUSE, as mentioned above. Thus, a total of 399 blog posts, 80 blog comments and 1,233 tweets were recorded throughout the semester. Their content was subsequently analyzed, according to the procedure described in the following section.

4. Content analysis procedure

4.1. CollAnnotator tool

We used quantitative content analysis based on the extended CoI model, as presented in the Introduction. This is a popular approach in technology enhanced communication and learning for generating categorizations and frequency counts based on various coding schemes (Hayes et al., 2015).

Indeed, transcript / content analysis can offer significant insights to understand students' interaction patterns and discourse quality in online communities of inquiry (Garrison et al., 2006). However, content analysis is generally a laborious task, therefore an analysis support tool could facilitate the coding and negotiation process (Garrison et al., 2010). A potential solution would be to use generic commercial software for content analysis (e.g., ATLAS.ti (see http://atlasti.com), NVivo (see http://www.qsrinternational.com/nvivo-product), Dedoose (see http://www.dedoose.com) etc.). However, this is costly, more difficult to learn and use, not accommodating CoI specificities, it requires input data in a particular format and does not always offer support for multiple coders.

Hence, a dedicated tool for supporting content annotation based on CoI would prove useful to the researchers. In particular, based on literature reports (Garrison et al., 2006; Garrison et al., 2010; Sinnappan & Zutshi, 2011), we extracted the following set of essential functionalities which need to be provided by such a tool:

- Intuitive and easy to use interface, which requires virtually no learning curve for the coders (i.e., persons who annotate and assign codes / categories to content)
- Rich annotation support, which can be done both at message level (i.e., unit of analysis) but also at higher levels of granularity (e.g., word, phrase, sentence)
- Possibility to attach more than one code to a message (e.g., include a primary and a secondary category)
- Support for multiple coders and suggestive comparisons between them, which may increase the rigor and reliability of the coding process
- Support for the negotiation phase, in which researchers discuss their individual codes and aim to bring them into alignment with each other, pursuing a shared identification of meaning; visualizing the other coders' notes, comments and highlights can substantially aid this process
- Detailed statistics and reports of the coding results, including graphical visualizations.
- Starting from these requirements, we developed a dedicated content analysis tool called *CollAnnotator*. The platform was briefly introduced in (Badea & Popescu, 2017) and a preliminary analysis was reported in (Popescu & Badea, 2017).

In what follows, we provide a concise description of CollAnnotator platform and its functionalities. The tool is adapted to our goal of using CoI for investigating the online community formed in our social media-based learning environment, eMUSE; it directly retrieves student content (blog posts and tweets) from eMUSE database and generates reports and statistics specific to our instructional scenario. The main features provided by CollAnnotator include:

(1) View, annotate and categorize student contributions

The coders can visualize students' blog posts and tweets (in the original HTML format used by the student), as well as search and order them by author, team, date and title. They can subsequently use the extended CoI scheme to assign a primary and an optional secondary category to each post. An explanatory comment may also be added, such as specifying the indicator used for the particular category (e.g., Goal setting, Planning or Coordinating, delegating tasks to self and others for the Forethought & planning category; Expressing emotions, Use of humor, Self-disclosure, Use of unconventional expressions to express emotion, Expressing value for the Affective category (Shea et al. (2014)).

The unit of analysis is the blog post / tweet, based on the recommendations provided by several authors (Angelaina & Jimoyiannis, 2012a; Garrison et al., 2006; Sinnappan & Zutshi, 2011). The coder may also refer to a specific part of the post (i.e., word, sentence, paragraph), by using the highlight, comment and tag functionality provided by CollAnnotator; further justifications for the category selection, as well as a more detailed personal interpretation of the post may be included this way.

(2) Compare and negotiate assigned categories

CollAnnotator offers support for the negotiation phase, which may thus take place online, without the need for a face-to-face meeting between the coders. Each coder can view the categorization chosen by the other(s), as well as their comments, highlights and tags and may choose to change their initial category selection.

(3) Visualize reports and statistics

The researcher can use CollAnnotator to visualize the coding results in various formats: summarizing tables with frequency counts for each presence and category, percentage agreement between coders and Cohen's kappa coefficient, suggestive graphical visualizations of the distribution of presences and categories for each social media tool, over time, as well as at student and team level. Some of these visualizations may be seen in the following section (Figures 1-5).

4.2. Coding procedure

Content analysis was performed by two independent coders, in order to increase the reliability and validity of the results. They used CollAnnotator tool and the coding scheme proposed in (Shea et al., 2010; Hayes et al., 2015).

Each of the 479 blog entries and 1233 tweets were assigned to at least one category; due to the richness of some posts, the coders had the option of selecting also a secondary category. They also added justifications of their choice (e.g., the corresponding category indicator) and provided annotations at finer levels of granularity, using the highlight feature included in CollAnnotator.

Coding took place in two phases: first, all posts were annotated and classified independently by each coder, obtaining an agreement percentage of 85.28% (Cohen's kappa value: 0.818). Secondly, negotiation and discussion took place, and consensus was reached in 98.42% of the cases (Cohen's kappa value: 0.98). A detailed analysis of the coding results is included in the following section.

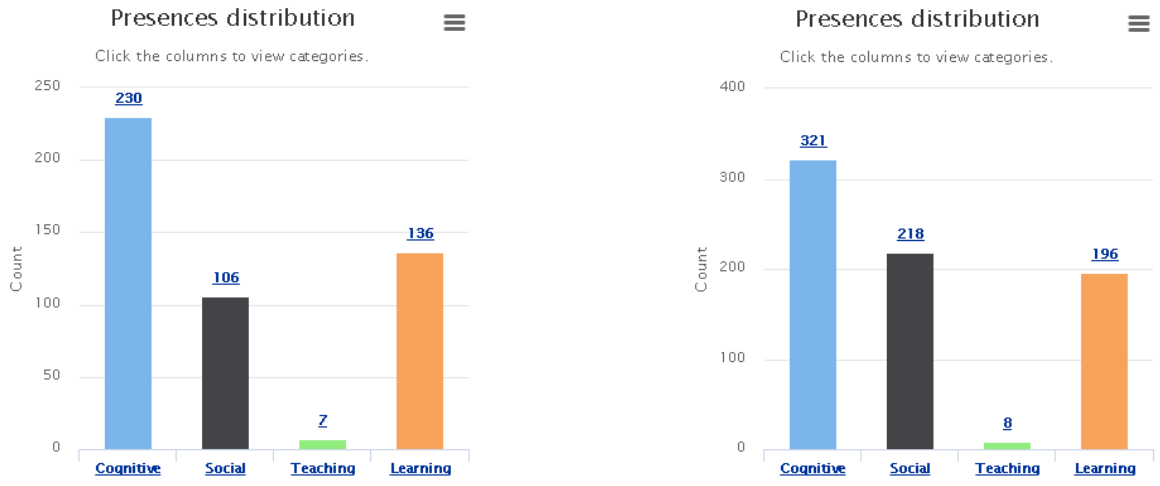
5. Data analysis results

5.1. Blog content analysis according to CoI model

We start by reporting the frequency of occurrence of each presence in the students' blog posts, as computed by CollAnnotator. The graphical distribution of the posts according to the four presences is depicted in Figure 1 and a detailed classification at category level is included in Figure 2.

First of all, we can notice that a large number of blog posts received both a primary and a secondary category (264 out of 479, or more than 55%). This can be explained by the fact that many posts include more than one idea, sometimes belonging to different categories; furthermore, the social component was present in many posts, with a secondary role, as discussed later.

In what follows, we analyze the blog content according to the primary category it belongs to (see Figure 1(a) and Figure 2). Thus, the largest number of posts (230 out of 479, or 48%) belong to the *cognitive presence*. More than half of these (almost 59%) refer to the *integration* phase of learning, as students regularly report on the solutions they created and present various connected ideas and syntheses. The *exploration* phase is also relatively well represented (almost 36% of the posts), with many students sharing interesting resources and ideas (information exchange) or providing suggestions for consideration. On the other hand, the *triggering* phase is scarcely represented (less than 6% of the posts), as students tend to post not when they encounter a problem or puzzlement, but rather when they have a solution or idea to share. Finally, the *resolution* phase is not documented on the blog; this is understandable, as complete, fully-fledged solutions are generally presented and defended on the wiki.



(a) (b)

Figure 1. Number of blog posts pertaining to each presence (*Note:* The graphical representation is generated by CollAnnotator; the left chart (a) takes into account only the primary category associated to a post, while the right chart (b) takes into account both the primary and the secondary category, when available.)

The *learning presence* accounts for more than 28% of the blog posts. Most of these (over 85%) refer to the *monitoring* category, as students frequently report their progress and note the completion of tasks. The rest belong mainly to the *forethought & planning* category (almost 13%), with students setting goals, making plans

and assigning project tasks; *strategy use* and *reflection* are scarcely present, as these do not seem to be explicitly verbalized by the students.

Blog Statistics (based on both categories)

Classification Table for Blog Posts & Comments

Presence	Category	Count
Cognitive	Triggering event	17 (13 P + 4 S)
	Exploration	95 (82 P + 13 S)
	Integration	209 (135 P + 74 S)
	Resolution	0
Social	Affective	41 (13 P + 28 S)
	Open communication	89 (42 P + 47 S)
	Group cohesion	88 (51 P + 37 S)
Teaching	Design and organization	6 (5 P + 1 S)
	Facilitating discourse	0
	Direct instruction	2 (2 P + 0 S)
	Assessment	0
Learning	Forethought & planning	44 (17 P + 27 S)
	Monitoring	142 (116 P + 26 S)
	Strategy use	7 (2 P + 5 S)
	Reflection	3 (1 P + 2 S)

Figure 2. Blog summary report (*Note:* The tabular view is provided by CollAnnotator; numbers in parentheses refer to the primary category (P) and the secondary category (S) respectively.)

Social presence is also visible on the blog, in over 22% of the posts. Most of them belong to the *group cohesion* category (over 48%), with many students addressing or referring to the group in their posts. *Open communication* is also well represented (almost 40%), including answers to peers' posts, asking questions, complimenting and expressing appreciation. Only few posts (12%) express emotions or use humor (*affective* category), as students prefer to use the blog in a slightly more formal manner.

Finally, the *teaching presence* is scarcely exhibited by the students, in less than 2% of the blog posts. However, this is counterbalanced by the instructor's blog posts (that were not included in this analysis), which clarify the design and organization of the course, provide direct instruction and educational material, offer feedback and formative assessment.

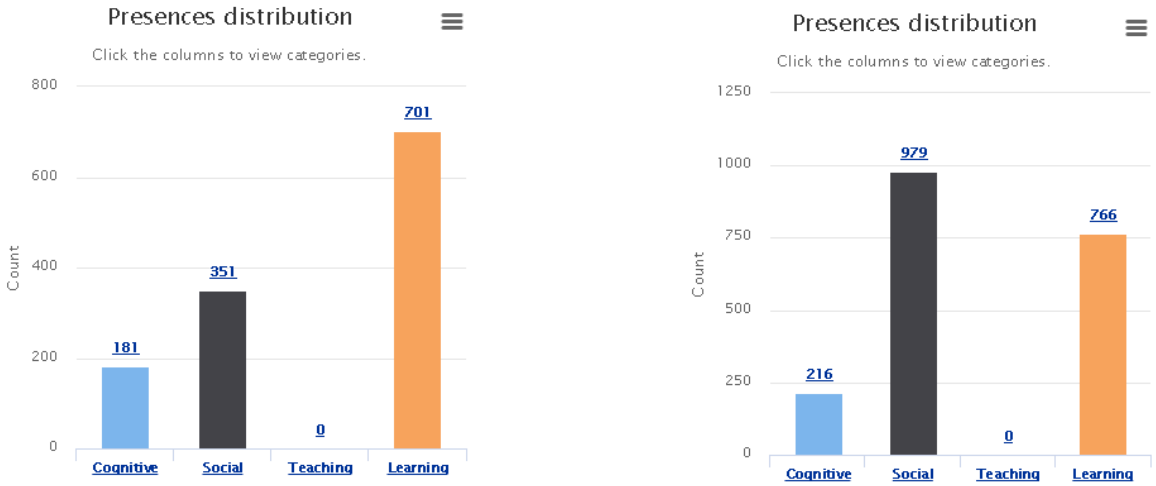
When the secondary category is also taken into account (Figure 1(b)), a sharp increase is seen in the *social presence* posts. This can be explained by the fact that many blog entries with a dominant cognitive or learning component also include some social aspects (group reference, salutations and greetings, asking or answering peers' questions). While these do not represent the main focus of the post, they play an important role for strengthening group cohesion and communication. A special mention should be made regarding the *integration* category of the *cognitive presence*; we considered it secondary whenever the student would simply point towards the solution described elsewhere (i.e., on the wiki, in the project documentation), rather than explicitly presenting it within the post. Hence, the number of blog entries belonging to the integration phase of learning significantly increased when taking into account also the secondary category.

5.2. Twitter content analysis according to CoI model

As far as Twitter is concerned, the graphical distribution of tweets according to the four presences is depicted in Figure 3, while a detailed classification at category level is included in Figure 4.

Just as in case of blog posts, a large number of tweets received both a primary and a secondary category (728 out of 1233, i.e., 59%). The secondary purpose of the tweets is in most cases (over 86%) a social one, which is in

line with the nature of the medium; students use Twitter for strengthening the group cohesion, by directly addressing their peers (using the *mention* functionality), sending salutations and greetings and sharing various information unrelated to the course.



(a) (b)

Figure 3. Number of tweets pertaining to each presence (*Note:* The graphical representation is generated by CollAnnotator; the left chart (a) takes into account only the primary category associated to a tweet, while the right chart (b) takes into account both the primary and the secondary category, when available.)

Twitter Statistics (based on both categories)

Classification Table for Tweets

Presence	Category	Count
Cognitive	Triggering event	17 (14 P + 3 S)
	Exploration	79 (72 P + 7 S)
	Integration	114 (89 P + 25 S)
	Resolution	6 (6 P + 0 S)
Social	Affective	111 (82 P + 29 S)
	Open communication	194 (176 P + 18 S)
	Group cohesion	674 (93 P + 581 S)
Teaching	Design and organization	0
	Facilitating discourse	0
	Direct instruction	0
	Assessment	0
Learning	Forethought & planning	128 (114 P + 14 S)
	Monitoring	603 (555 P + 48 S)
	Strategy use	32 (29 P + 3 S)
	Reflection	3 (3 P + 0 S)

Figure 4. Twitter summary report (*Note:* The tabular view is provided by CollAnnotator; numbers in parentheses refer to the primary category (P) and the secondary category (S) respectively.)

In what follows, we analyze the tweet content according to the primary category it belongs to (Figure 3(a) and Figure 4). Thus, the largest number of tweets belong to the *learning presence* (almost 57%), especially the *monitoring* category; students tweet whenever they complete a task, but also when they set a goal, make a plan or distribute tasks to peers.

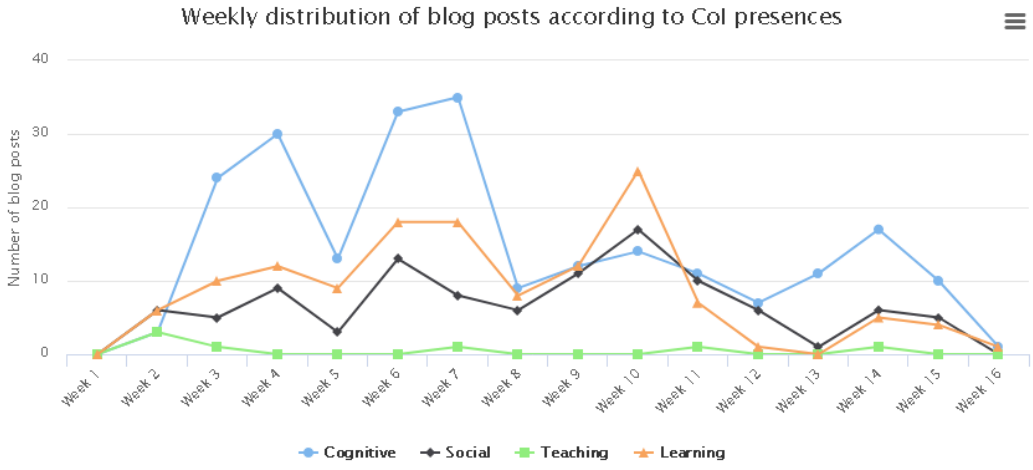
The *social presence* is also well represented on Twitter, being the primary focus of over 28% of the tweets. *Open communication* category is supported in more than 50% of them, with students using the *reply* functionality

frequently, and also asking questions, expressing agreement or disagreement. *Group cohesion* and *affective* categories are also present in the tweets; students directly refer to the group, use humor and express emotions in unconventional ways.

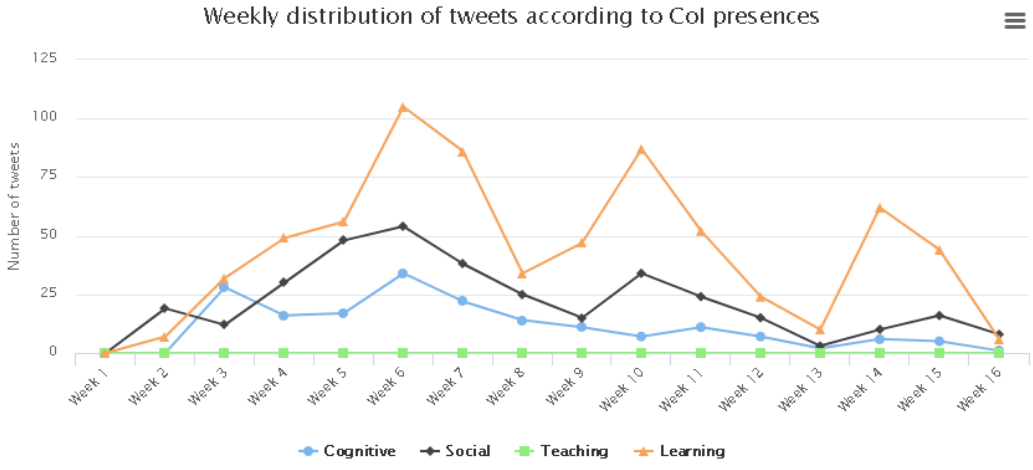
The *cognitive presence* is only apparent in less than 15% of the tweets; students mostly point to created solutions (*integration* category) and share useful educational resources (*exploration* category). Finally, the *teaching presence* is not supported on Twitter, as students do not get involved in any direct instruction, course design or assessment tasks.

5.3. CoI presences distribution throughout the semester

CollAnnotator also provides us with the temporal evolution of students' contributions on blog and Twitter, as illustrated in Figure 5. First of all, we can notice that the weekly amount of posts follows a somewhat similar pattern both on blog and Twitter. Furthermore, within each tool, the weekly patterns of each presence are relatively similar, showing a balanced distribution throughout the semester. As far as the blog is concerned, we notice that the *cognitive presence* is the dominant one in most of the weeks, as expected. Similarly, the *learning presence* is the dominant one on Twitter almost every week.



(a)



(b)

Figure 5. Temporal distribution of students' blog posts (a) and tweets (b) (Note: The graphical representation is generated by CollAnnotator; the four presences are based on the primary category associated to each student contribution.)

Overall, we can see that students used the social media tools throughout the semester, contributing in a continuous manner to the formation and growth of the community of inquiry. Generally, students have the tendency to postpone most of the work for the end of the semester, just before the due deadline (Zacks & Hen, 2018). Our aim was to discourage academic procrastination by means of the instructional scenario proposed, as described in section 3. Thus, the four intermediary milestone presentations encouraged students to work in a

sustained manner throughout the semester. Of course, there are some variations over time, as students worked from home, at their own pace; furthermore, learners were enrolled in five other courses, each with their specific time requirements. However, there was some activity recorded every week of the semester, even during the winter holidays (weeks 12 and 13), indicating students' continuous engagement in the community of inquiry.

To sum up, the overall distribution of presences is different on the two social media tools. Thus, when taking into account only the primary category, the *cognitive presence* is dominant on the blog (accounting for 48% of the blog posts), being less apparent on Twitter (accounting for less than 15% of the tweets). Conversely, the *learning presence* is dominant on Twitter (accounting for almost 57% of the tweets), and less represented on the blog (accounting for just over 28% of the blog posts). When considering also the secondary category, the *social presence* becomes dominant on Twitter (almost 50% of the codes), while being less prominent on the blog (just over 29% of the codes). Finally, the *teaching presence* is scarcely exhibited by the students on both social media tools (accounting for less than 2% of the contributions).

6. Discussion and conclusions

According to the content analysis, the blog plays the primary role of a content space, as the cognitive components clearly outweigh the social and learning components. Twitter, on the other hand, is mostly a discussion space, supporting especially the learning presence and the social presence, while the cognitive presence is less strong. Hence, we can conclude that each tool fulfills its own distinct role in the learning space, providing complementary support to the community of inquiry.

The blog results are in line with the findings in (Angelaina & Jimoyiannis, 2012a; Jimoyiannis & Tsiotakis, 2017; Yang et al., 2016), all indicating that cognitive presence plays the most important role, followed by social presence and lastly by teaching presence. The results obtained by Piffare et al. (2014) are different, stating that social presence is the dominant one. This finding can be explained by the fact that only blog comments were analyzed in that study, not also the original blog posts, which likely contained more cognitive elements.

Regarding Twitter, our results are significantly different than those reported by Sinnappan and Zutshi (2011), who found a very strong cognitive presence in students' tweets. Two potential explanations arise: first, only tweets explicitly related to the course (i.e., containing the course hashtag or replying to one of the peers) were included in that analysis; according to the authors, other discussions took place during the study period, which were not related to the scheduled teaching activities. It is likely that these additional tweets had a more social nature, including sharing of information unrelated to the course, personal details, emotions and humor, or communication with purely social function. Secondly, the instructional scenario reported in (Sinnappan & Zutshi, 2011) includes only Twitter as communication tool; so, all questions and problems, suggestions and opinions, information exchanges, solutions and syntheses had to be shared by means of tweets. In our scenario, students could choose the blog for sharing these cognitive issues, while using Twitter more for the social aspects.

A special mention should be made regarding the teaching presence. This was very weak in our study, which is in line with findings from (Angelaina & Jimoyiannis, 2012a; Sinnappan & Zutshi, 2011; Shea et al., 2014). Furthermore, most of the teaching-related posts in these studies originated from the instructor. In our case, teacher's posts were not considered in the analysis, hence the even lower percentage of teaching presence recorded. Nevertheless, the instructor played an important role, as guide, facilitator and observer throughout the semester; her posts helped clarify the design and organization of the course, provided direct instruction, educational materials, feedback and assessment.

The learning presence, on the other hand, was apparent in numerous blog posts and tweets. This supports the findings of Shea et al. (2012), who ascertain that learning presence is more apparent when students are asked to actively collaborate through instructional design. Indeed, students exhibited significant self-regulation and effort regulation behavior, monitoring their progress, setting goals and distributing project tasks. Hence, the decision to integrate this complementary construct in our coding scheme appears well justified. Further research on learning presence in social media-based educational environments could shed more light on its role and relationship with the other presences.

In addition, further studies on the role played by the social media tools in the development of communities of inquiry are welcome. Different learning scenarios, educational tasks and instructor guidelines may influence student participation and distribution of presences, independently of the employed tools. In the current PBL scenario, students had a high degree of freedom and flexibility in using the social media tools for their

communication and collaboration activities. While brief guidelines regarding the use and expected role of each tool were provided at the beginning of the semester, no additional scaffolds or prompts were included. Nevertheless, the PBL tasks were complex, challenging and authentic and students worked relatively autonomously, with the teacher playing the role of facilitator. They had to collaborate in various design, problem-solving, decision making and investigative activities, which may explain the dominance of the cognitive and learning presence. Furthermore, the scoring took into account all students' contributions on the social media tools, as a way of assessing collaborative work throughout the semester; this may have been another factor boosting students' engagement in the community of inquiry.

Overall, our study showed that students' contributions in the social media-based learning environment can be characterized in terms of the four extended CoI presences. It also illustrated the potential of the proposed environment to support students in creating an online community conducive of self-regulated collaborative learning. Thus, on one hand, the paper adds to the limited research literature on the extended CoI model, proving its applicability in social media-based learning settings. On the other hand, the current research contributes to a better understanding of students' collaborative processes in an online learning community.

A potential limitation of our study is that the collected and analyzed data was restricted to blog posts and tweets. Of course, students used also other private communication channels, like email, chat, phone calls or face-to-face meetings. These may have played an important role for some of the teams, but they could not be monitored and analyzed. However, students were informed that their contributions on blog and Twitter would be used to follow and evaluate their collaboration throughout the semester, and as a way of documenting the progress of the project. Hence, a large part of student communication did take place on these social media tools. We therefore argue that the blog and microblog posts provide a reliable reflection of the community of inquiry formed by the students.

The study sample, while not very large (75 students who generated 479 blog entries and 1233 tweets), is more substantial compared to similar reports. Thus, there are 21 students and 131 blog posts and comments analyzed in (Angelaina & Jimoyiannis, 2012a), 15 students and 87 blog comments in (Pifarre et al., 2014) and 47 students and 324 tweets in (Sinnappan & Zutshi, 2011). Furthermore, all posts were analyzed by two coders, with high inter-reliability rates; CollAnnotator support tool was used, instead of a manual approach for content analysis. This provided essential features such as: support for multiple coders and the negotiation process, comprehensive annotation functionality, support for multiple categories per unit of analysis, detailed statistics and reports with graphical visualizations, all in an intuitive and easy to use interface.

As future work, we plan to investigate also the contribution of individual students / teams to the community of inquiry, based on the functionalities offered by CollAnnotator. Indeed, the tool provides support for more in-depth analyses, by generating reports at student and team level. All the tables and charts computed for the whole community are also generated for each individual learner and each team. We could thus investigate the profiles of individual students / teams, the proportion of each presence they exhibit and their contribution for the construction and maintenance of the community of inquiry. Furthermore, exploring the relationship between the presences exhibited by the students and their learning outcomes would be a valuable endeavor.

The investigation could be extended also with social network analysis (as in Jimoyiannis and Angelaina (2012), Shea et al. (2013), and Shea et al. (2014)) or learning mapping (as in Angelaina and Jimoyiannis (2012b)). We have already designed a knowledge extraction framework for a social learning environment and used SNA to investigate students' collaboration patterns in eMUSE platform, for a different student cohort (Becheru et al., 2018). Furthermore, alternative coding schemes could be integrated in CollAnnotator, to provide a more comprehensive analysis of the student generated content (e.g., discourse categories proposed in Fu et al. (2016), and Ioannou et al. (2015)). Finally, extending the study to different instructional scenarios and social media settings in various educational contexts would be a worthwhile research direction.

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