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Methodological Reviews

A review of methodological applications of social network analysis in computer-supported collaborative learning

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A R T I C L E I N F O

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A B S T R A C T

Social network analysis (SNA) is a promising research method for analyzing relational ties in computer-supported collaborative learning (CSCL)—activities in which learners interact towards a common learning goal with the aid of computers—because they share the same underlying assumption that learning and behavior are influenced by one's relations. This methodological review examines whether CSCL research (n = 89) (1) reflects the diversity of actors (learners and artifacts) and relational ties that are important in CSCL environments; and (2) relates these relational ties as measured by SNA indices to CSCL learning outcomes. The results suggest that SNA applications in CSCL (1) do not reflect this diversity of CSCL actors and relational ties, investigating only one-mode networks of learners connected by communication-based relational ties; and (2) are limited to a descriptive reporting of SNA results. Future directions for CSCL are focused on filling these gaps by (1) integrating technical, instructional and knowledge artifacts as SNA actors, and (2) relating SNA findings to cognitive, social and motivational CSCL outcomes using statistical analysis.

1. Introduction

Studying learner interactions and relations is the key to understanding how learning occurs in computer-supported collaborative learning (CSCL) settings. As technologies for CSCL become more advanced, there is a greater call for analysis methods that can derive insights about learner interactions from large amounts of computer-generated data, such as log files, messages, and other artifacts (Jeong, Hmelo-Silver, & Yu, 2014). Techniques from computer science and learning analytics could be a step in the right direction in addressing these issues (Martin & Sherin, 2013). One such technique is social network analysis (SNA), an application of graph theory which allows for the analysis of patterns of relationships between actors that interact with each other (Sie et al., 2012; Wasserman & Faust, 1994). SNA has had a long history predating the use of computers; nevertheless, promising SNA findings have already led to meaningful insights and future directions in educational research and technology-enhanced learning (Cela, Sicilia, & Sanchez, 2015). However, the ways in which SNA has been and could be valuable in CSCL research has not yet been explored systematically. The present review examines trends in the applications of SNA as a research method for analyzing learner interactions during CSCL.

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1.1. Summary of important SNA concepts

In SNA, the relationships that link individual actors in a community are of central importance. In educational settings, these *actors* could be learners, groups of learners and teachers, as well as non-human agents such as classes, courses, learning materials, or features of the learning environment that persons interact with or participate in Carolan (2014). Social networks can be composed of actors of the same type (e.g., learners) or of two or more types (e.g., learners and learning materials), these are called one-mode and two/multimodal networks, respectively. An actor is connected to another actor by the presence of at least one type of *relation* between them; some common relational ties in education include interaction and communication (e.g., talking or sending messages to each other), association (e.g., taking the same courses), and social relations (e.g., friendships). In computer-mediated learning settings, information about these relations can be collected by asking actors about their relationships within the network (e.g., "Who did you talk to in class today?") or from digital trace data (e.g., a chat log that shows who talked to whom). Given these elements, *SNA is concerned with the structure of relational ties between a group of actors* and the implications of these structural patterns on learners' behavior and attitudes. SNA allows for the study of relationships among actors that interact with one another and/or their environment in a particular way.

Relational data can be measured on several levels (Carolan, 2014). Local (egocentric) level analysis emphasizes how individual actors are embedded in the network in relation to other actors (e.g., "Who is the most active learner in the discussion forum?"). Global level analysis provides a "snapshot" of the network structure by describing the patterns of relations in the network (e.g., "How engaged are the learners in discussions with each other?"). Networks can be further analyzed by detecting subgroups of actors that are connected to each other at a high rate (e.g., "Do learners communicate with certain learners more than with others?") and positions of actors that occupy the same place or have similar patterns of relations with others (e.g., "Which learners have yet to establish a relationship with each other?").

SNA data may be represented in two ways: visually using node-link representations and mathematically. Graphical representation of networks is achieved using network graphs, known as sociograms, whereby actors are represented as nodes and the relational ties as lines connecting nodes to each other, which may be weighted depending on the strength or frequency of the relationship. This provides an intuitive display of the patterns of relationships in a group. Based on the number of actors and number, strength or frequency of relations in the network, different *local* and *global measures* or indices can be calculated to succinctly quantify characterize network relations. Some of the most common SNA measures, particularly in the social sciences, are centrality as a local measure and density as a global measure (Knoke & Yang, 2008). Centrality is calculated based on the number of relational ties an actor has: a highly central actor is one that is directly connected to many actors (degree centrality), has the shortest connections to many actors (closeness centrality), or serves as a mediator between two groups of actors (betweenness centrality). It is often used to determine the most prominent and important participants in the network (Carolan, 2014). The density of the network refers to the total number of ties in the network divided by the number of all possible ties (Carolan, 2014). The density value ranges from 0 to 1; the closer the value is to 1, the denser and more cohesive are the nodes in the network.

1.2. The role of SNA in CSCL research

1.2.1. Definition of CSCL

CSCL can be described as activities in which two or more learners interact and are mutually engaged towards the accomplishment of a common learning goal with the support of information and communication technologies (Lipponen, 2002; Suthers, 2012). The emphasis on *mutual engagement* helps to distinguish CSCL from other technology-enhanced learning such as e-learning, commonly defined as the use of technology to deliver information for learning purposes (Sangrà, Vlachopoulos, & Cabrera, 2012). Although e-learning platforms may have interactive elements, e-learning activities themselves do not have to be collaborative in nature in order to result in effective e-learning outcomes (Sun, Tsai, Finger, Chen, & Yeh, 2008). For example, e-learning interventions may include videos explaining a topic followed by a quiz to test the learner on the videos' content, which can be completed successfully without interacting with other learners (Lahti, Hätönen, & Välimäki, 2014). Moreover, the role of computers in CSCL is supportive in that it facilitates interaction and stimulates learning, which does not exclusively mean information delivery. This means CSCL interactions may occur face-to-face (e.g., working together using a multitouch table), remotely (e.g., online distance courses) or a combination of both (e.g., blended classrooms, Jeong et al., 2014).

CSCL extends where the definition of e-learning stops at "deliver information for learning purposes" by encompassing activities designed to foster productive learner interactions in an effort to establish a shared understanding of the learning task (Dillenbourg, Järvelä, & Fischer, 2009). Different forms of CSCL interactions exist (Suthers, Dwyer, Medina, & Vatrapu, 2010). Effective *direct* interaction, whether through synchronous or asynchronous communication, is necessary to achieve joint information processing during collaboration (Rummel, Deiglmayr, Spada, Kahrimanis, & Avouris, 2011). However, learning also occurs when learners engage in *mediated* or indirect interaction via engaging in shared artifacts and objects relevant to the learning tasks. These artifacts may be technological (e.g., web applications through which learners