Computers in Human Behavior 28 (2012) 1321–1331

Contents lists available at SciVerse ScienceDirect

Computers in Human Behavior

journal homepage: www.elsevier.com/locate/comphumbeh

Exploring regulatory processes during a computer-supported collaborative learning task using process mining

Cornelia Schoor [a,*], Maria Bannert [b]

[a] Psychology of Learning and Instruction, Institute of Psychology 4, TU Dresden, 01062 Dresden, Germany
[b] Institute of Human-Computer-Media, Educational Media, University of Wuerzburg, Campus Hubland Nord, Oswald-Külpe-Weg 82, 97074 Wuerzburg, Germany

ARTICLE INFO

Article history:
Available online 11 March 2012

Keywords:
Computer-supported collaborative learning
Social regulation
Research methods
Self-regulated learning
Process mining

ABSTRACT

The purpose of this study was to explore sequences of social regulatory processes during a computer-supported collaborative learning task and their relationship to group performance. Analogous to self-regulation during individual learning, we conceptualized social regulation both as individual and as collaborative activities of analyzing, planning, monitoring and evaluating cognitive and motivational aspects during collaborative learning. We analyzed the data of 42 participants working together in dyads. They had 90 min to develop a common handout on a statistical topic while communicating only via chat and common editor. The log files of chat and editor were coded regarding activities of social regulation. Results show that participants in dyads with higher group performance ($N = 20$) did not differ from participants with lower group performance ($N = 22$) in the frequencies of regulatory activities. In an exploratory way, we used process mining to identify process patterns for high versus low group performance dyads. The resulting models show clear parallels between high and low achieving dyads in a double loop of working on the task, monitoring, and coordinating. Moreover, there are no major differences in the process of high versus low achieving dyads. Both results are discussed with regard to theoretical and empirical issues. Furthermore, the method of process mining is discussed.

0. Introduction

A collaboratively learning group has to regulate their behavior in a very similar way as a self-regulated learning individual: They have to analyze, plan, monitor and evaluate cognitive and motivational aspects during learning (Hadwin, Oshige, Gress, & Winne, 2010; Järvelä, Järvenoja, & Veermans, 2008; Volet & Mansfield, 2006). Whereas most research has concentrated on individual self-regulated learning and how it could be supported, e.g. by prompting measures (Bannert, 2006, 2009), so far little is known about social regulation of learning in groups.

In addition, the temporal order of collaborative learning activities has so far been widely neglected (Reimann, 2007). However, temporal information can play a crucial role in analyzing interaction during computer-supported collaborative learning (CSCL): When performed at the beginning of a discussion, some type of interaction can have a totally different influence on group learning than when it was performed at the end of the discussion (Kapur, Voiklis, & Kinzer, 2008). For example, Kapur et al. (2008) found that a high quality contribution at the beginning of a CSCL problem solving process did more good than those later during the discussion. Therefore, the temporal pattern within group interactions should be taken into account in further CSCL research.

In business research, there are methods to analyze process data in their temporal sequence (Agrawal, Gunopulos, & Leymann, 1998; Günther & Van der Aalst, 2007; Van der Aalst et al., 2003). This so called process mining includes both bottom-up and top-down methods. In this paper, we want to explore both social regulation in an exploratory way and the possibilities of process mining to contribute to our notion of temporal processes in social regulation. It is the aim of this study to further enhance our understanding of social regulation, thereby taking its temporal sequence into account.

In the remainder of this paper, we first give an insight into social regulation research showing that we so far know too little about social regulation during collaborative learning. Then, we present our own theoretical framework for analyzing social regulation. After that, we elaborate on the importance of the temporal sequence of learning behavior and on one specific method of process mining that can be used for analyzing the temporal sequence of learning behavior. We then explore social regulatory activities of dyads in a study on CSCL and apply the method of process mining in order to investigate the temporal patterns in these social regulatory activities.

* Corresponding author. Tel.: +49 351 463 39194; fax: +49 351 463 37294.
E-mail address: cornelia.schoor@tu-dresden.de (C. Schoor).

0747-5632/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.chb.2012.02.016

1. Social regulation

The terms used for regulatory aspects in collaborative learning vary as do the concepts these terms refer to (Volet, Vauras, & Salonen, 2009). Researchers use "social regulation" (Volet, Vauras et al., 2009), "co-regulation" (Hadwin et al., 2010), "other-regulation" (Vauras, Iiskala, Kajamies, Kinnunen, & Lehtinen, 2003) or "socially-shared regulation" (Vauras et al., 2003) for describing regulatory aspects in collaborative learning.

Social regulation as the broadest term refers generally to regulation in groups as opposed to self-regulated learning (Volet, Vauras et al., 2009). Volet, Summers, and Thurman et al. (2009) subsume under this term both other-regulation and socially-shared regulation. In this context, *other-regulation* refers to an unequal situation where one student takes a more active role in regulating the group process than the other(s) (Vauras et al., 2003; Volet, Summers et al., 2009). *Socially-shared regulation* on the other hand includes "constant monitoring and regulation of joint activity, which cannot be reduced to mere individual activity" (Vauras et al., 2003, p. 35). This is close to Roschelle and Teasley's (1995) definition of collaboration as a coordinated activity resulting from continuously constructing and maintaining a joint problem space. The term *co-regulation* is sometimes used synonymously to social regulation (e.g. Volet, Summers et al., 2009) but in a sociocultural context refers to a form of other-regulation (e.g. Hadwin et al., 2010).

In her paper on metacognition in relation to self-regulation and co-regulation, Efklides (2008) includes in addition to a personal-awareness level and a nonconscious level a *social level of metacognition* in her model. It is this social level on which we assume social regulation to take place. During social regulation, not only individual metacognition occurs on the social level, but also the cognition of the group members' cognition (which could be named "group metacognition"). Thereby we follow the wording of Volet, Vauras et al. (2009) by using the term "social regulation" for all regulatory activities on the group level (other- and socially-shared regulation) in contrast to self-regulation.

In this line of research, the main concern is to identify events of socially-shared regulation and their benefits for learning (Lajoie, 2008). For example, Vauras et al. (2003) conducted an extensive case analysis of a dyad of high-achieving girls who collaboratively solved math problems. They found that the concepts of self-regulation and other-regulation were not enough to understand regulation in collaboration but that the notion of socially-shared regulation was needed as well. Iiskala, Vauras, and Lehtinen (2004) continued this work with another case analysis and the development of an interaction flowchart to visualize metacognitive action. Iiskala, Vauras, Lehtinen, and Salonen (2011) extended this research by relating events of socially-shared regulation to task difficulty and the process of problem solving. They found that events of socially-shared regulation occurred more often in difficult tasks and that their function was most often that of confirming operations followed by confirming or activating situation models. Volet, Summers et al. (2009) included in their theoretical framework not only the dichotomy of individual versus co-regulation within a group but also the dimension of low-level (acquiring knowledge) versus high level content processing (constructing meaning). They found that the occurrence of high level co-regulation differed across groups and meetings. Additionally, they found that "high-level co-regulation was most commonly preceded by a question or an explanatory statement" (Volet, Summers et al., 2009, p. 140).

Other researchers (e.g. De Jong, Kollöffel, Van der Meijden, Staarman, & Janssen, 2005; Liu & Hmelo-Silver, 2010) start from self-regulated learning (SRL) and transfer the notion of different self-regulatory activities like orienting and planning to social regulation. SRL comprises a complex interplay of cognitive, motivational, cognitive regulatory (metacognitive) and motivational regulatory components (Boekaerts, 1997). More successful learning seems to go hand in hand with more regulatory activities (e.g. Azevedo, Guthrie, & Seibert, 2004; Manlove, Lazonder, & De Jong, 2007; Moos & Azevedo, 2009). According to Bannert (2006), ideal cognitive regulatory activities during learning include orientation in order to get an overview over the task and resources, planning the course of action, evaluating the learning product and monitoring and controlling all activities. This notion is closely related to Winne's (1996) conception of self-regulated learning. De Jong et al. (2005) also adopt a very similar conception of regulatory activities encompassing orienting, planning, monitoring, testing, restoring/directing, evaluating and reflecting. In their study on CSCL, they additionally included the category of grounding. They found this category to be the most frequent by far followed by monitoring and planning. However, De Jong et al. (2005) did not relate these social regulation activities to group performance. Liu and Hmelo-Silver (2010) analyzed the effects of two different hypermedia structures on co-regulated learning. They differentiated co-regulated learning into planning, monitoring and evaluation and found differences in the discourse of groups using different hypermedia structures. A very similar study is that of Manlove et al. (2007) who analyzed the differential effect of two software versions on the use of planning, monitoring and evaluation tools (within the software) by the learning groups. They also found differences between the groups regarding these activities. Järvelä et al. (2008) concentrated on socially-shared motivation regulation and identified motivation regulation strategies in two groups during three tasks. Winters and Alexander (2011) conceptualized collaborative regulatory activities in terms of forethought, strategy (referring to performance), monitoring and motivation which they derived amongst others from Zimmerman's (2000) concept of self-regulated learning. They found positive relations of the collaborative regulatory process categories *strategy* and *monitoring* with performance.

All in all, research on the kind of regulatory activities performed in CSCL groups and their linkage to group performance is scarce (De Jong et al., 2005). However, first results indicate that also in a group situation, regulatory activities are related with performance. In order to further explore this relationship, we developed a theoretical framework for analyzing social regulation on the basis of SRL conceptions and the concept of negotiation (see also Dillenbourg, Baker, Blaye, & O'Malley, 1996).

2. Theoretical framework

According to Efklides (2008, p. 283), monitoring at the social level "can take the form of reflection [and] leads to a ... negotiated representation of the person-in-context". Vauras et al. (2003) also associate social regulation with negotiation both at the task level and on a meta-communicative level. In our theoretical framework (Fig. 1), we take this idea of negotiation on. We assume that what we can observe of social regulation is a kind of negotiation (Dillenbourg, Baker, Blaye, & O'Malley, 1996) and thereby building a common ground (Clark & Brennan, 1991) referring to regulatory aspects of the group task like orientation, planning, or evaluation. Fig. 1 represents our notion of social regulation in the case of a two persons group. At the individual (self-regulatory) level, we follow Bannert (2006) by assuming apart from the processing of the task the metacognitive activities orientation, planning, and evaluation as well as monitoring and controlling of all these activities. On the group level, we expect to observe the negotiation of a joint understanding of orientation, planning, and evaluation as well as monitoring and controlling. This could be other-regulation but also true socially-shared