Metacognition in collaborative learning

Sanna Järvelä, Jonna Malmberg, Marta Sobocinski, & Paul A. Kirschner

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Abstract

Research has shown that metacognition plays a role in collaborative learning. We view metacognition as a central process supporting all modes of regulation (i.e., self-regulation, shared regulation, and co-regulation), as it enables learners to control and adapt their cognition, motivation, emotion, and behavior at both the individual and group levels. Our claim is that metacognitive monitoring and regulation of collaborative learning can help reduce the collaborative/transactive costs in collaboration and, therefore, contributes to success in computer supported collaborative learning (CSCL). In this chapter, we discuss the role of metacognition in CSCL and broaden the discussion to regulation. Since regulation in CSCL has been studied increasingly, we review the current state of the art in that research and conclude how technological and digital tools could be implemented for studying and supporting metacognition and regulation in CSCL.

Introduction

While collaborative learning has been of interest for a number of decades, it is often the case that learning teams function poorly. Effective collaboration is more than working in groups or completing a task assignment (Jeong & Hartley, 2018). The group, for example, may expend more effort than necessary to effectively or efficiently work together and learn, may encounter emotional and social problems that impede group processes and learning (Kreijns, Kirschner, & Jochems, 2003; Näykki, Järvenoja, Järvelä, & Kirschner, 2017), and/or may not be able to coordinate and execute the necessary learning activities between team members for proper learning (Rogat & Adams-Wiggins, 2014; Zambrano, Kirschner, & Kirschner, 2017). These problems are rooted in the fact that team members often cannot effectively regulate what they do, what they feel, and how they act (Järvelä & Hadwin, 2013). Research has shown that team members do not recognize challenging learning situations and their need for regulation, which restricts their activation of strategic adaptation behavior (Järvelä et al., 2016; Rogat & Adams-Wiggins, 2014). This is where metacognition plays a role in collaboration. We view metacognition as a central process supporting all modes of regulation (i.e., self-regulation, shared regulation, and co-regulation). Metacognition enables learners to control and adapt their cognition, motivation, emotion, and behavior at both the individual and group levels (Hadwin, Järvelä, & Miller, 2017). Only recently have we received evidence that it is not only an individual's but also a group's shared processes that matter (Järvenoja, Järvelä, & Malmberg, 2017; Järvelä, Malmberg, & Koivuniemi, 2016), and for this reason, regulating collaborative learning is critical for success. In this chapter, we discuss the role of metacognition in CSCL and especially point out how understanding and supporting metacognition and regulation in learning can make CSCL more successful. In this chapter, we first introduce the critical processes in collaboration for CSCL and focus on the important role of metacognition in learning in general and for CSCL specifically. After that, we broaden the discussion to regulation. Since regulation in CSCL has been studied increasingly, we review the current state of the art in that research. Finally, we conclude how technological and digital tools could be implemented for studying and supporting metacognition and regulation in CSCL.

Introduction and Scope

It has long been clear that what matters in collaborative learning is the effort required to construct shared knowledge, that is, the "motor" of collaborative learning (Schwartz, 1995). This includes the intensity of interactions required for detecting and repairing misunderstandings. Early research on collaborative learning (e.g., Dillenbourg, 1999) was especially interested in questions such as "Under which conditions do specific interactions occur?" or "Which interactions are predictive of learning outcomes?" Later research produced guidelines for designing collaborative learning and computer-supported collaborative learning by creating conditions and tools in which effective group interactions are expected to occur (e.g., Jeong & Hmelo-Silver, 2016). Many studies have reported increased knowledge-building activities in CSCL (Zang, Scardamalia, Reeve, & Messina, 2009) as well as that learners share surprisingly little knowledge after collaboration, even though they quickly adapt mutually in interaction (Fischer & Mandl, 2005; Jeong & Chi, 2007). The question "How do learners build a shared understanding of the task to be achieved?" has gotten more attention, as it points to co-construction of shared understanding (Roschelle & Teasley, 1995) and mental effort (Kirschner, Paas, & Kirschner, 2009; Kirschner, Paas, Kirschner, & Janssen, 2011). Bringing together a group of learners does not guarantee that they will work and learn properly, either as a group or individually. They must develop a shared mental model and/or a collective scheme of cognitive interdependence on how to effectively communicate and coordinate their actions so as to share group knowledge, appropriately distribute available task information, and exploit the quality of participation of each group member in the solution of the problem in hand (Fransen, Weinberger, & Kirschner, 2013).

Transactive activities (Kirschner, Sweller, Kirschner, & Zambrano, 2018) play a crucial role in collaborative learning. These synchronous and asynchronous activities enable groups to acquire collective knowledge of who their other group members are, how they can deal with the task, the group's accuracy and willingness to carry out the task, and how all group members should coordinate what they are doing with each other to accomplish the task together by mediating the acquisition of individual and group domain-specific knowledge and shared generalized knowledge (Kalyuga, 2013; Prichard & Ashleigh, 2007). As stated by Popov, van Leeuwen, and Buis (2017) "learning is particularly likely to occur when the collaborating students engage in transactive discourse (i.e., critique, challenging of positions, and attainment of synthesis via discussion), because this form of discourse gives rise to cognitive activities that stimulate knowledge construction" (p. 426). As is clear, collaborative learning effort is influenced by how well students coordinate their activities across time and transact with each other's ideas. For example, Popov et al. (2017) studied whether the simultaneous alignment of student activities (i.e., temporal synchronicity) and students successively building on each other's reasoning (i.e., transactivity) predict the quality of collaborative learning products in computer-supported collaborative learning. They found that neither temporal synchronicity nor transactivity was directly related to the quality of group products, which pointed to a need for sociocognitive support for collaboration among group members.

In the short run, collaborative learning results in group members trying to successfully perform a certain learning task or solve a specific problem together. In the long run, as an instructional method, it is very important that all members of the group develop *effective experience* working together that facilitates every member in acquiring domain-specific knowledge from this combined effort (Kirschner et al., 2018). In all, whatever this *"effort" or "effective experience"* is, the issue is open to debate, highlighting that there are critical aspects of the success of collaborative learning that are still unknown.

History and Development

Metacognitive monitoring and regulation of collaborative learning can help reduce the collaborative/transactive costs in collaboration. In 1986, Kruger and Tomasello (1986) suggested distinguishing between three types of transacts: transactive statements (critique, refinement, or extension of an idea), transactive questions (requests for clarification, justification, or elaboration of ideas), and transactive responses (justification of ideas or proposals). Furthermore, these transacts can be self-oriented or other-oriented. As such, these activities help create shared task spaces and social spaces (Fransen et al., 2013) where teams can function more effectively, efficiently, and enjoyably, not only in terms of communication and coordination but also between interactive minds and with those fine-grained socioemotional processes that make collaboration and actions joint learning activities happen in CSCL.

Metacognition is a term originally defined by Flavell (1979) that refers to the conscious awareness of cognitive processes and also includes knowledge of self and different types of tasks, strategies, and metacognitive experiences that all are influential for learning alone or in groups. Self-regulation refers to the ways that learners systematically activate, sustain, and regulate their cognitions, motivations, behaviors, and affects toward attaining their learning goals. When metacognition is viewed from the perspective of self-regulated learning (SRL), it is considered an engine for regulation, cognition, motivation, emotion, or behavior in any phase of the SRL process (Wolters & Won, 2017). This is to say, metacognition is not the same as SRL. SRL has a broader focus than metacognition (Dinsmore, Alexander, & Loughlin, 2008) and the foundation of metacognition is in the mind of the individual, whereas SRL emphasizes the reciprocal interaction between personal factors, the environment, and behavior, which cannot be separated (Bandura, 1989). Thus, when metacognition is viewed from the perspective of SRL, the focus lies in *metacognitive* *monitoring*, which focuses on the individual student's qualities of thoughts and thinking (Winne, 2018) and goes beyond metacognition.

Metacognitive monitoring activities are the core processes in individual learning, but we also have an increasing understanding of how metacognition plays a role among peers (Volet, Summers, & Thurman, 2009) and on a group level (Malmberg, Järvelä, & Järvenoja, 2017). Metacognition, as such, is invisible, but it becomes visible via cognitive activities (e.g., using strategies) or externalizing thoughts to other group members (e.g., "I don't understand what this task is about") (Winne & Hadwin, 1998). Metacognitive monitoring is always an internal individual mental process, but when it is externalized in the context of collaborative learning, it can trigger co-shared and socially shared regulation of learning. In collaborative learning, this still does not mean that learners necessarily change the course of their activities or externalize their thoughts to other group members even when a need arises. Empirically and methodologically, we still cannot answer questions such as "What is the threshold when metacognitive monitoring triggers regulation in collaborative learning?" Theoretically, metacognitive monitoring can occur in any phase of regulated learning (Winne & Hadwin, 1998) and metacognitive monitoring does not have a clear position in terms of when it occurs, but it can be activated after each regulated learning phase (Sonnenberg & Bannert, 2016). Nevertheless, empirical studies have continuously evidenced that, if a focus on metacognitive monitoring causes collaborating learners to neglect or ignore group members' utterances, this can lead to dysfunctional group work and hinder the possibility of effective collaboration (Rogat & Linnenbrink-Garcia, 2011). For example, Volet, Vauras, Salo, & Khosa (2017) argue that it is not only individual contributions that make a difference in collaborative learning but also how group members react to their peers' contributions. They also suggest that, "if questions, doubts and hesitations are not addressed, but instead either ignored or treated as unreasonable, individuals tend to withdraw their participation or stop managing their uncertainty" (Volet et al., 2017, p. 90). Therefore, it is not only a case of metacognitive monitoring but also when and how peers react to it.

Because metacognition plays an important role in group learning, technologies have been developed that focus specifically on supporting metacognition in the context of CSCL. The support is not only for individual metacognitive processes but also to raise the group's metacognitive awareness in terms of shared regulatory activities, such as planning, task performance, monitoring, and reflection. Typically, the support has been provided in the form of scripts or prompts that are used to facilitate learners' awareness of their metacognitive processes at the individual and group levels. For example, Wang, Kollar, & Stegmann (2017) investigated the effectiveness of adaptable collaboration scripts in an asynchronous text-based CSCL environment in the higher education context. The adaptable script allowed students to modify parts of the script based on their self-perceived needs while solving complex cases related to psychological theory. They found that the adaptable script increased students' use of monitoring and reflection activities, but it did not have an effect on planning. They concluded that adaptable collaboration scripts actually decreased the need for planning, but at the same time, it provided more opportunities for monitoring the progress of the task. Thus, the results showed that the adaptable script facilitated learners' use of self-regulation through the promotion of co-regulation processes. Iiskala, Volet, Lehtinen, & Vauras (2015) studied how socially shared metacognition manifested during asynchronous CSCL science inquiry among 12-year-old primary school students. The results showed that socially shared metacognition was present in all the phases of the inquiry activities, and their main function was to maintain the perceived appropriate direction of the ongoing cognitive process. In their study, Su, Li, Hu, & Rosé (2018) investigated college students' regulatory behaviors in CSCL. Participants completed wiki-supported collaborative reading activities in the context of learning English as a foreign language over a semester. The analysis consisted of content analysis and sequential analysis of the students' chat logs. Results showed that high-performing groups demonstrated more instances of content monitoring (defined as checking, elaborating, revising, and improving group members' task response) and higher proportion of evaluation. The sequential analysis revealed that high-performing groups showed a pattern of content monitoring, organizing, and process monitoring. Low-performing groups instead showed a pattern of organizing a set of limited regulatory skills, highlighting the necessity of adaptive scripts in CSCL that would facilitate groups' co-shared and socially shared regulation of learning.

State of the Art

We have been working with a concept of socially shared regulation in learning for understanding what constitutes "sharing" cognition, motivation, and emotions among members in collaborative learning groups. Collaborating requires negotiating beliefs and perceptions regarding the collaborative goals and plans about how to achieve the task. This is a complex process of co-construction of goals and plans, where metacognition and regulation processes of collaborating individuals need to be exchanged, negotiated, and aligned to achieve shared or joint regulation (Järvelä & Hadwin, 2013).

Effective collaboration requires group members to ensure that they work toward the shared goals and reveal to each other when they become aware that their collaboration is not heading toward the shared goals. This means that, during collaboration, learners need to negotiate shared goals to ensure they all work toward the same outcome (e.g., Järvelä, Malmberg, Haataja, Sobocinski, & Kirschner, 2018), maintain a positive socioemotional atmosphere to ensure fluent collaboration (e.g., Lajoie et al., 2016), and finally, coordinate and ensure that each member is responsible for the joint outcome of their collaborative task (Rogat & Linnenbrink-Garcia, 2011). During collaboration, learners engage in metacognitive monitoring, focusing on their cognition ("Am I understanding this?"), motivation and emotions ("Are my feelings or thoughts disturbing my learning progress?"), behavior ("Do I have all the things I need to perform this task?"), and finally, coordination of the collaboration ("Is my group progressing with this task?").

Regulation can be realized in CSCL through different types of regulation. Within collaborative groups, co-regulated learning occurs when learners' regulatory activities are guided, supported, shaped, or constrained by others in the group (Volet, Summers, & Thurman, 2009). Co-regulation plays a role in shifting groups toward more productive learning, and it can create affordances and constraints for productive SRL and shared regulation of learning in the forthcoming learning situations (Hadwin et al., 2017). For example, in CSCL, support can come from one person, group members, or affordances from the technological tools. Then, co-regulation serves as a mechanism for shifting regulatory ownership to an individual or group, implying that regulatory expertise is distributed and shared across individuals and evoked when necessary by and for whom it is appropriate (Hadwin, et al., 2017).

When groups engage in socially shared regulation, they extend their regulatory activity from the "I" to the "we" level to regulate their collective activity in agreement (Järvelä & Hadwin, 2013). Shared regulation is a collectively agentic process in which group members adopt joint goals and standards. They work together to complement and negotiate shared perceptions and goals for the task; they coordinate strategic enactment of the task and collectively monitor group progress and products; and they make changes when needed to optimize collaboration in and across tasks. Socially shared regulation differs from co-regulation to the extent that joint regulation emerges through a series of transactive exchanges amongst group members; therefore, it contributes to the transactive costs of collaborative learning. In all, both regulation types, combined with individuals' self-regulation, play a part in collaborative learning. CSCL involves multiple people sharing responsibility for a collective task and, ideally, simultaneously shifting between self-regulation, co-regulation, and shared regulation in time (Järvelä & Hadwin, 2013). Through metacognitive monitoring and shared evaluation, learners recognize how the learning process is progressing, and through these regulatory acts, learners are able to respond to the new situations and challenges by optimizing the collaborative processes, standards, and products (Hadwin et al., 2017).

Regulation in CSCL has been increasingly studied, especially in high school and higher education CSCL learning contexts, and the research evidence points to the most critical aspects of regulation in collaboration. This evidence deals with learners' awareness of the need for regulation, time, and adaptation and recognition of the the motivational and social aspects of collaboration. Learners do not recognize the opportunities for socially shared regulation (Malmberg, Järvelä, Järvenoja, & Panadero, 2015; Miller & Hadwin, 2015). For example, Malmberg et al. (2015) used planning tools asking learners the type of challenge they confronted as a group and the regulatory strategy they used to tackle the challenge. The researchers found that the groups that outperformed the others identified a variety of cognitive and motivational challenges and also invented strategies to tackle those challenges, whereas the groups who were not that successful repeated the same types of "superficial" challenges, such as time management or challenges with technology, and were not able to identify either cognitive or motivational challenges in their collaboration. Also Sobocinski, Malmbert, & Järvelä's (2017) study showed that, when the temporal order of regulatory phases and types of interaction were compared in groups participating in high- and low-challenge sessions, high-challenge session groups switched between forethought and the performance phase more often, which is a sign of metacognitive monitoring.

There is research evidence showing that time and adaptation is important in progress of regulation (Järvelä, Järvenoja, Malmberg, & Hadwin, 2013; Malmberg et al., 2015). Järvelä et al. (2013) used a qualitative lens to explore how groups progress, or do not progress, in their socially shared regulation. Their detailed analysis revealed that regulation develops over time and may relate to the degree of collaborative success, as measured by the quality of a collaborative product. Malmberg et al.'s (2017) study suggests similar findings. The study examined the temporal sequences of regulated learning processes of groups collaborating over two months. The temporal analysis showed that collaborative interactions focusing on task execution lead to socially shared planning and that metacognitive monitoring facilitate task execution. The conclusion is that, in order for socially shared regulation to occur, there needs to be a distributed regulated learning process (co-regulation) and joint understanding of a task (knowledge construction) before group members can set the stage for socially shared regulated learning.

It has also been noticed that recognizing social and motivational aspects of collaboration and successful regulation of those challenges is favorable for learning performance (Järvelä, Malmberg, & Koivuniemi, 2016; Näykki, Järvelä, Kirschner, & Järvenoja, 2014;). For example, Järvelä et al. (2015) conducted a temporal analysis of log data and chat discussions in CSCL. Their study focused both on individual and group regulation processes. The study revealed that individual student SRL activities focus on the metacognitive aspects of learning (e.g., task understanding and monitoring), whereas socially shared regulation involves the coordinative activities of collaboration, such as planning and strategy choices. It was also found that the socially shared regulation of motivation is important in maintaining productive collaboration. Bakhtiar, Webster, & Hadwin (2017) conducted a cross-case analysis of two groups collaborating on an online text-based assignment. The findings underline the importance of emotion regulation during planning to achieve a positive socioemotional climate and point to negative emotions serving as a constraint for shared adaptation in the face of challenges.

Future

The main interest in CSCL is supporting the fine-grained processes that make collaboration and actions in joint learning activities happen. CSCL asks how technological and digital tools can be designed in order to support learners' cognition and transactional activities in such a way that they mutually influence each other (Cress, Stahl, Rosé, Law, & Ludvigsen, 2018). Looking at the major problems encountered when using CSCL in practice, one can conclude that many of them might be solved if we had tools at our disposal that could help the participants in CSCL groups regulate learning within the group. In the future, technology can also play a major role both in helping researchers understand the complex invisible processes of metacognition and in regulating the learning and supporting of groups for more efficient collaboration.

Our approach has been to develop technological supports and tools for the acquisition of regulation skills (see Järvelä, Kirschner, et al., 2016, for a review). However, the problem is that these tools are not enough for achieving lasting skills in SRL, coRL, and SSRL. Support can be designed that enable learners to increase awareness of their own learning processes and that of others to enhance metacognitive awareness. We emphasize three design principles for supporting SSRL: (1) increasing learners' awareness of their own and others' learning processes, (2) supporting the externalization of students' and others' learning processes in a social plane and helping in sharing and interaction, and (3) prompting the acquisition and activation of regulatory processes. Additional support for the process of collaboration has been received for implementing group awareness tools (Chapter xxx) as well as for designing learning environments so that they can support or provoke metacognition, for example, by fostering group awareness (see Chapter xx), implementing scripting for CSCL (see Chapter xxx), or structuring groups for collaboration (see Chapter xx).

Since metacognitive monitoring is an internal process, analytical methods that focus on learners' externalization of metacognition can, at this moment, only partly capture metacognition (e.g., Malmberg et al., 2017). Thus, our current understanding of collaborative processes is based on research focusing on limited objective or subjective measures of collaboration (e.g., self-reports, video, and chat logs, and then analyzing the discourse and/or looking at the products of group work). Iiskala et al. (2015), for example, used qualitative content analysis to identify learners' externalized metacognition related to regulatory activities and then focused on detailed analysis of the discourse. Similarly, Su et al. (2018) used chat logs and analyzed them qualitatively to identify various aspects of metacognitive monitoring along with regulatory activities. At present, this is the main data source to identify how and when regulation of learning—along with metacognitive monitoring in collaborating groups—takes place. It is still human-powered, time-consuming qualitative content analysis.

Understanding how CSCL technology can aid in data collection can help. Since the data are often collected in the context of CSCL, learner interactions (focusing on regulation or metacognitive monitoring) are often time-stamped. This provides opportunities to explore not only the qualities of regulation but also how regulatory activities associated with metacognitive monitoring are temporally sequenced (Molenaar & Järvelä, 2014). This is achieved through the use of, for example, lag sequential analysis (Malmberg et al., 2017; Su et al., 2018), process discovery (Malmberg et al., 2015; Sobocinski et al., 2017), or social network analysis (Järvelä et al., 2013) to investigate how a group of students collaboratively build their regulation as collaboration proceeds.

Methodologically, the analytical approaches described in this chapter are time consuming and labor intensive. Temporal and sequential analytical methods along with qualitative content analysis methods have been effective in describing the functional and interactive aspects of collaboration, but they often lack the power to explain how the integrated metacognitive or socially shared acts play a role in the collaborative learning process. Recent advances in technology and computation are now making it possible to add a set of new process-oriented instruments, real-time measures, and physiological indicators to the data sets (Järvelä et al., 2019), as well as computational analytical methods for data mining, analytics, and visualization (Rosé, 2018). Triangulation of these kinds of data, such as videos, physiological measures, eye tracking, log data, or facial expression detection, can reveal information heretofore unavailable when studying metacognition and regulation in collaboration and CSCL. These new data sources have the potential to reveal hidden processes underlying collaboration, such as engagement (e.g., eye tracking), emotions (facial expression data), or physiological synchrony between the group members (physiological measures). The advantage of this type of temporal data is that it can simultaneously trace a range of cognitive and noncognitive processes that are parallel and overlap. Yet, combining these data sources requires sophisticated analysis methods and theoretical understanding of what the critical processes are in CSCL and how these new unobtrusive data sources can reflect regulation of learning. Since we already have an emerging understanding of how to use such multimodal data to understand the role of metacognition in CSCL (Haataja, Malmberg, & Järvelä, 2018; Malmberg et al., 2018), future research may bring us new ways to capture internal and partly invisible processes of metacognition and make it visible for the students, for example, via dashboards.

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