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Socially shared regulation of learning in CSCL: understanding and prompting individual- and group-level shared regulatory activities

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Abstract The field of computer supported collaborative learning (CSCL) is progressing instrumentally and theoretically. Nevertheless, few studies examine the effectiveness and efficiency of CSCL with respect to cognitive, motivational, emotional, and social issues, despite the fact that the role of regulatory processes is critical for the quality of students' engagement in collaborative learning settings. We review the four earlier lines in developing support in CSCL and show how there has been a lack of work to support individuals in groups to engage in, sustain, and productively regulate their own and the group's collaborative processes. Our aim is to discuss how our conceptual work in socially shared regulation of learning (SSRL) contributes to effective and efficient CSCL, what tools are presently available, and what the implications of research on these tools are for future tool development.

Keywords Computer supported collaborative learning · Self-regulated learning · Learner dashboards · Self-regulation tools · Prompting

Introduction

The field of computer supported collaborative learning (CSCL) is progressing, both instrumentally in terms of tools and systems to enhance CSCL, and theoretically. Theoretical and empirical advances have been made, with respect to enhancing cognitive performance,

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stimulating knowledge construction, and scripting collaborative interaction processes (O'Donnell and Hmelo-Silver 2013). In contrast, limited research has examined the quality of CSCL in terms of socio-emotional engagement problems (Näykki et al. 2014). In collaborative learning, for example, many emotional reactions are social in nature, as they relate to interpersonal interaction, personality differences, or the dynamics and processes experienced within the collaborative group (Rogat and Adams-Wiggins 2014; Van den Bossche et al. 2006). Those problems point to the critical role of regulatory processes in the quality of students' engagement in collaborative learning settings (Rogat and Linnenbrink-Garcia 2011; Volet et al. 2009).

Research on group regulation has been carried out for collaborative group processes in task performance showing that in order to achieve common goals, a group needs to coordinate group efforts and resources in effective ways (Fransen et al. 2011, 2013; Janssen et al. 2012; Kwon et al. 2014; Saab 2012).

Research in CSCL has also been dealing with the quality of knowledge construction. This research area does not deal with regulatory processes, but with knowledge co-construction and the kind of knowledge that is and can be collaboratively constructed in a group (Van Aalst 2009). These studies show that the goal of collaboration, namely to improve understanding and to construct new knowledge, is not easy to achieve (Kuhn 2015), and that true knowledge creation is rare (Siqin et al. 2015). Even in the context of CSCL environments, where the goal is to support learners in the effective learning, knowledge construction is rare (P.A. Kirschner et al. 2014). One reason for this is the problem group members have regulating their own learning processes as well as those of the team. Research grounded in self-regulated learning (SRL) theory in collaborative learning settings (Hadwin et al. 2011; Järvelä & Hadwin 2014) Q2 focusing on students' success in the regulation of their own and the group's learning processes point to a need for students' metacognitive awareness and the productive adaptation of their learning behaviors to their situated cognitive, motivational, and emotional challenges (Järvenoja et al. 2015).

Recently, Kirschner and Erkens (2013) proposed a CSCL research framework and argued for more research in three dimensions of CSCL research, namely the level of learning (cognitive, social, and motivational), the unit of learning (individual, group/team, and community) and pedagogical measures that can be implemented (interactive, representational, and guiding). In this paper our aim is to deliver a consistent "story" about how socially shared regulation of learning contributes to effective and efficient CSCL, what tools are presently available, and the implications of research on these tool are for future tool development.

Conceptual progress in understanding regulated learning

Our theoretical definition of regulated learning in CSCL is grounded in self-regulated learning (SRL) theory, especially the regulation of learning not as solely an individual process, but also as social and contextual processes (Hadwin et al. 2011).

Regulation of learning and performance is as an intentional, goal-directed, metacognitive activity in which learners take strategic control of their actions (behavior), thinking (cognitive), and beliefs (motivation, emotions) towards the completion of a task (Zimmerman and Schunk 2011). According to our understanding, regulation of learning is effortful for the individual student, especially in collaboration, since metacognitive resources are needed (Hadwin et al. 2016). Much of the cognitive activity among individuals and in between the collaborating group members, is implicit. Learners are infrequently aware of their cognition, such as goals, plans, knowledge and strategies (Janssen et al. 2010; Winne 2011). Also in terms of cognition in collaboration regulation requires the expenditure of transaction costs in terms of the communication and coordination of activities (Kirschner et al. 2009; P.A. Kirschner et al. 2014), and places a burden on working memory (Kirschner et al. 2009). Throughout the phases of SRL, learners are required to metacognitively monitor properties of information, processes, and developing knowledge in collaborative interactions.

In the context of carrying out collaborative tasks, three types of regulation are posited to be required for achieving success: (a) *self-regulated learning (SRL)* in which group members take control of their own thinking, behavior, motivation, and emotion in the collaborative task, (b) *co-regulated learning (CoRL)* in which each other's engagement in self-regulatory processes within the task is transitionally supported by group members, technologies, or contextual features of the environment, and (c) *socially shared regulation of learning (SSRL)* in which group members work together to regulate their collective cognition, behavior, motivation and emotions together in a synchronized and productive manner (Järvelä and Hadwin 2013; Hadwin and Oshige 2011; Hadwin et al. 2011).

Regrettably, many learners lack the needed regulatory skills and struggle to develop them when they work on complex collaborative tasks (Malmberg et al. 2015). This combination of carrying out the task along with developing the needed regulatory skills leads to an increase in cognitive load / mental effort which can have a deleterious effect on both processes (Van Merriënboer & Kirschner 2013). Without support, learners often fail to both effectively carry out the task and interact productively in their groups. For that reason, an increasing emphasis has been placed on harnessing CSCL environments to guide and support regulation and not just knowledge construction (Järvelä and Hadwin 2013).

Review of supporting and prompting SRL in CSCL

CSCL environments offer learners opportunities to guide and support their own learning, and also allow researchers to study different forms of regulation. Increased understanding of the important role of socially shared regulation in CSCL has sparked both emerging empirical research focused on understanding and supporting the role of regulation in collaboration (Järvelä and Hadwin 2015), as well as the development of technological tools to prompt and support regulation of collaborative learning (Järvelä et al. 2014). Four lines in developing support in CSCL can be recognized.

The first line examines the functionality and usability of available technological tools and environments for *sharing information and co-constructing* solutions to problems that may involve globally distributed participants (e.g., Scardamalia et al. 1994), and also investigates the quality and efficiency of knowledge construction processes and outcomes within these environments (e.g. Fischer et al. 2013). These tools and systems have specifically been developed for supporting knowledge co-construction (Stahl 2006).

The second productive research line studies the support of *group awareness and sociability* in collaborative learning with the goal of positively affecting social and cognitive performance in CSCL environments (Kirschner et al. 2004). Kreijns and Vermeulen (2013) introduce a theoretical framework for CSCL consisting of three core elements, namely sociability, social space, and social presence, along with their relationships with group members' mental models, social affordances, and learning outcomes. These core elements implemented in tools and widgets (e.g. Janssen et al. 2011) influence the social interaction needed for collaborative learning and the emergence of a social space to facilitate learning in teams.

The third line of research develops adaptive *computer based pedagogical tools or pedagogical agents* to support self-regulated learning, especially the metacognition involved in those processes (Azevedo and Hadwin 2005; Perry and Winne 2006). The idea behind computer-based pedagogical tools is that learners possess self-regulated learning skills, but do not necessarily activate those skills when needed. These adaptive system elements have the potential to react ‘on the fly’ to learner activity and provide tailored targeted support for SRL (Azevedo et al. 2010). Pedagogical tools can vary from being relatively short-time reminders to goal-setting and planning tools that depend on the learning phase (Bannert and Reimann 2012).

The fourth and final line of research studies tools or widgets that can be used within CSCL environments to support students in *becoming aware and understanding* their own behavior as well as the behavior of their fellow students when working together on a task over a period of time. These techniques in CSCL find their root in Computer Supported Collaborative Work (CSCW). Dourish and Bellotti (1992) saw awareness as an important concept in CSCW for achieving optimal coordination between and within loose- and tight group activities, that is, between and within collaboration. It is in their words “an understanding of the activities of others, which provides a context for your own activity” (p. 107). In CSCL, tools originally made use of history awareness and group awareness (Kreijns et al. 2002). *History awareness*, according to Kirschner and Kreijns (2005, p. 182–183) is “the structured collection of all traces caused by the various activities group members were engaged in as a means for bridging the time gap imposed by working and learning in a time-deferred mode”. *Group awareness* (Kreijns 2004, p. 99) is “the condition in which a group member perceives the presence of the others and where these others can be identified as discernible persons with whom a communication episode can be initiated”. These ideas have been used in mirroring tools that collect, aggregate and reflect data back to the users about individual and collective interaction and engagement (Buder and Bodemer 2008; Leinonen et al. 2005; Soller et al. 2005).

In sum, though the range of research in CSCL support has been productive in terms of both theories and frameworks for supporting regulation in CSCL, there has been a lack of work on integral and integrated tools, prompts, and scaffolds to support individuals in groups to engage in, sustain, and productively regulate their own and the group’s collaborative processes (Järvelä and Hadwin 2013). Support for regulated learning in collaboration has often been underrepresented, if it exists at all, in CSCL environments (Miller and Hadwin 2015a, b). Earlier knowledge co-construction tools attempt to support collaborative knowledge building (Scardamalia et al. 2014), but do not cover either the prerequisite metacognitive awareness or regulatory processes (Winne et al. 2010). Sociability tools have been successful in facilitating social, socio-emotional and cognitive group functioning, but they too lack regulation support (Winne et al. 2010). Metacognitive tutoring and agents focus on individual learners cognitive and metacognitive aspects, and are thus not applicable for supporting shared processes of collaborative learning. What is also missing is motivation and emotional regulation support in individual and group level of collaboration. In comparison to other forms of support, prompting SSRL requires both individual and group metacognitive awareness of the tactical or strategic value of information, feelings, and intentions. This is to provide real-time feedback to individuals and groups that mirror its processes.

Prompting SSRL in CSCL

Grounded on ours and others' research on collaborative learning and SSRL (e.g. Sinha et al. 2015), our approach has been to develop supports for acquisition of the regulation skills themselves along with the activation of regulatory processes during collaborative learning (Järvelä et al., 2014; Miller and Hadwin 2015a, b). While earlier efforts in the field have aimed primarily at individual support, our research has focused on promoting and sustaining SSRL-processes among group members beyond the introduction of collaborative knowledge building software tools (Järvelä et al., 2014; Miller and Hadwin 2015a, b).

The core idea in prompting learners to regulate their learning is that SRL can be supported when the learning environment provides second-order scaffolding (Van Merriënboer & Kirschner, 2013) that fosters metacognitive monitoring of regulation processes. Such scaffolding should be designed to encourage learners to externalize their developing understanding thereby enhancing metacognitive knowledge (Azevedo 2015). This approach directly addresses research indicating that learners find it difficult to productively self-regulate learning, primarily because of inappropriate metacognitive monitoring (Winne and Jamieson-Noel 2002). We posit that designing SSRL-supports that enable learners to increase awareness of their own learning processes and that of others should increase effectiveness and efficiency of learning both alone and in groups. We emphasize three design principles for supporting SSRL (Järvelä et al. 2014): (1) increasing learners' awareness of their own and others' learning process, (2) supporting the externalization of students' and others' learning process in a social plane and helping in sharing and interaction, and (3) prompting the acquisition and activation of regulatory processes.

During the past decade we have been working on understanding and following the conceptual progress of SSRL (Hadwin et al. 2011; Järvelä & Hadwin, 2014) while also developing tools and supports for socially shared regulation in CSCL that contribute to success in collaborative learning. In that period we have developed several tools for supporting goal setting, planning, and reflection in collaborative learning situations and implemented these tools to authentic collaborative learning tasks. Each of these regulation tools prompt students to negotiate and reflect (Kirschner et al. 2008) on the key SRL processes such as setting goals, making plans and adopting strategies (see Zimmerman and Schunk 2011). SSRL targets cognitive, metacognitive, motivational, and emotional processes. Regulation tools make the targets of the self-regulation visible for the group members and increase possibilities to develop socially shared regulation strategies. As such, they are awareness tools. Also, these tools offer a new way to store and make visible data about 'on-the-fly' processes of socially shared regulation which are not available in other ways (Molenaar and Järvelä 2014).

AIRE – adaptive instrument for regulation of emotions

One of our first efforts to understand the adaptive nature of individual and collective emotion regulation in socially challenging learning situations is an instrument, called *Adaptive Instrument for Regulation of Emotions* (AIRE; Järvenoja, Volet, & Järvelä, 2012). AIRE is designed to access students' experiences of individual and socially shared regulation of emotions in a specific group learning activity. When engaging in emotion regulation, the learner becomes aware of their own experienced emotions and strategically aims to direct or control them to ensure engagement in learning (Boekaerts 2011). Emotion regulation also includes having the capacity to understand others' emotions and being able to modify one's own and others' emotional experience when participating in a group social interaction (Järvenoja, Volet, & Järvelä, 2012; Whitebread and Basilio 2012). Actually, many emotional reactions are social in nature as they relate to interpersonal interaction, or include considerations of other people or social norms (Goetz et al. 2003; Hareli and Weiner 2002). The collaborative learning context creates a ground for socio-emotional challenges to emerge (Järvenoja and Järvelä 2009; Näykki et al. 2014). Group members interpret the situation from their own point of view based on their experiences and affective state. This demands coordinated emotion regulation to continue successful motivated learning and collaboration.

The aim of the AIRE is to identify the socio-emotional challenges, such as challenges in personal goals and priorities or in ways of communication or interacting (Järvenoja et al. 2013; Van den Bossche et al. 2006), that students experience while they participate in collaborative learning activities, and their individual and group level attempts to regulate the immediate emotions evoked in these situations. More specifically, the instrument seeks to: a) identify task-specific challenges of a social nature affecting group performance, and b) elicit students' subjective accounts of their regulation strategies to address them.

AIRE is sensitive to student's unique experience, but at the same time attempts to capture the adaptive nature of the regulatory process of the whole group. The instrument comprises four interrelated sections: Personal goals, Socio-emotional challenges, Regulation of emotions, and Reflections on perceived goal attainment. In AIRE, students are asked to rate (5-point Likert scale) the extent to which they experienced each of 14 socially challenging situations presented in a form of scenarios. These scenarios include a general description of the challenge and a few concrete examples of the possible situations. The 14 scenarios represent five different challenge types, namely challenges in *personal priorities*, *work and communication*, *teamwork*, *collaboration* and *external constraint*. After rating all challenges, students are asked to indicate which challenge triggered the most emotions in their group. This challenge is then taken into more detailed consideration. The student is asked to consider how the particular socio-emotionally challenging situation was regulated when it was faced with twelve sets of regulation items to each socio-emotional challenge. The items are on a Likert-scale from 0 to 4 (0 = It did not happen, 1 = did happen sometimes, and 4 = did happen a lot) covering different emotion regulation strategies that are administered on a self- and group level. Each group member rates each item in terms of whether that type of regulatory activities was used to control the specific socio-emotional challenge during group work.

The AIRE data enables analyses that compare the coherence between individual group members' appraisals of the reasons for socio-emotional challenges, their personal goals, and their satisfaction with collaboration. It is also possible to analyze the connection between experienced challenges and their self- and group level regulation as well as the degree to which group engage in individual and/or social-regulation activities AIRE data reveals individual groups members interpretation of specific collaboration situations. Furthermore, when group members' responses to different components of the AIRE instrument are compared it is possible to form group-level interpretations of the situation. This can be done, for example, by forming group profiles according to the coherence of the responses. This will switch the focus to a group level and give an estimation of groups' joint understanding of the experienced socio-emotional challenges and their regulation.

Findings from the studies implementing AIRE show that there are both situational variations within as well as variations between the groups in terms of interpreting socio-emotionally challenging situation (e.g. Järvenoja and Järvelä 2009). The former refers to situations where the group members interpret the challenges differently from each other. The latter refers to situations where the group members agree with the reasons, but the reasons differ from group experience. Also, the groups can vary in the level and emphasis between individual and group level regulation (Järvelä and Järvenoja 2011). The ideas developed in AIRE, such as awareness of socio-emotional challenges, recognition of the reason or source that creates that challenge, and situational variation in emotion regulation, have been later adapted implicitly or explicitly in our SSRL tool development.

Building on the AIRE, Webster and colleagues developed The Socio-Emotional Sampling Tool (SEST; Webster & Hadwin, 2014). This scripting tool prompts students to metacognitively monitor and evaluate their current emotional state immediately before, during, and after a CSCL task (see Fig. 1).

The tool facilitates the construction of a self-narrative about one's feeling in the moment with respect to collaboration. In particular, students indicate: (a) a salient emotion they are experiencing related to working with their group, (b) the source of their emotion, (c) the intensity of their emotion, (d) whether their emotion is good or bad, (e) a goal for regulating their emotion, (f) the strategy they intend to use to regulate their emotion, and finally (g) if the strategy should be enacted individually or as a group (see Fig. 1). Rather than including a set of isolated questions, the SEST was designed with drop-down menus embedded in first-person sentences, enabling students to quickly create a cohesive narrative of their current emotional experiences. Data collected from this tool provide valuable information about students' perceptions of their emotional experiences and sets it apart from other commonly used emotion instruments. For example, rather than only indicating what emotion they are experiencing, students are prompted to evaluate their emotion as positive (good) or negative (bad), and to think proactively about what they (individually and collectively) can do to regulate that emotion. The SEST is a dual-purpose tool that simulates reflection and proactivity about emotions while simultaneously providing data to contextualize emotions in collaboration. Findings indicated that students: (a) felt positive about the collaborative tasks, (b) intended to increase or maintain positive emotions and decrease negative emotions, (c) intended to focus on the task or think positively to achieve their emotion regulation goals, and (d) believed emotion regulation strategies should be enacted by the group as whole rather than individually (Webster and Hadwin 2013). We believe tools such as these offer great promise. The next

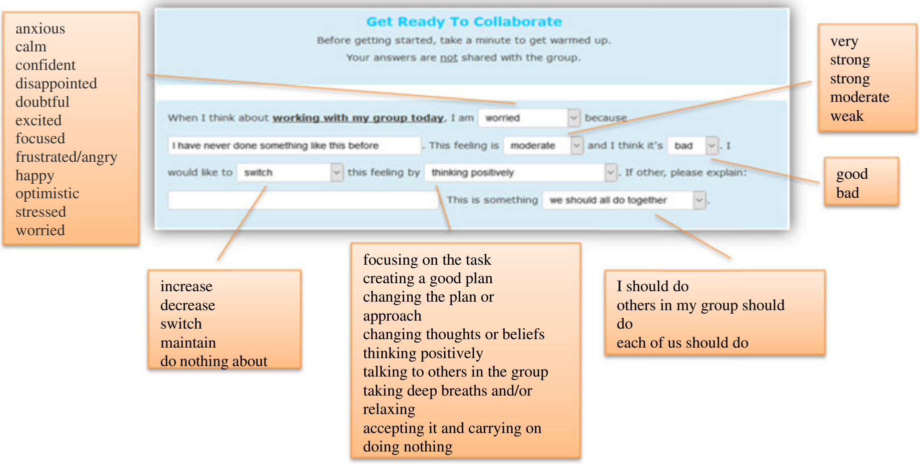

Fig. 1 Socio-emotional sampling tool (SEST)

challenge is to find ways of visualizing emotions across group members in ways that prompt shared regulation of emotions.

Individual- and shared planning tool

Hadwin and colleagues have drawn on theoretical frameworks of regulation (Hadwin et al. 2011; Järvelä and Hadwin 2013) to develop two tools facilitating individual learners and groups of learners to engage in critical planning and reflection processes for regulating in collaborative problem solving tasks. These tools aim to promote individual and group regulation of collaborative assignments as well as ultimately foster the development of skills for regulating collaboration in future tasks.

The *Individual Planning Tool* (IPT, Miller et al. 2013) supports learners' personal planning for a collaborative task (Fig. 2, left side). Using a series of question prompts, the IPT scripts learners to (a) explore and define personal task perceptions about the task components and purpose (i.e., *what is my group being asked to do in the collaborative assignment* and *why are we doing the collaborative assignment*), (b) set goals for the task (i.e., *what things are MOST important to me during the collaborative assignment*), and (c) generate plans for embarking on the task (i.e., *how do I think my group should go about completing the collaborative assignment in the short time we have*). The IPT further prompts learners to draw on previous experiences to reflect on challenges and identify ways to circumvent or overcome difficulties in the upcoming task (e.g., *what do I anticipate will be a challenge for my group* and *in this assignment, we need to do a better job of...*).

The *Shared Planning Tool* (SPT, Hadwin et al. 2013) supports groups to collectively negotiate shared task perceptions, goals, and plans for the task (Fig. 2, right side). This tool is provided to groups during a shared planning session prior to the task. Question prompts in the SPT are identical to those in the ITP, however groups are tasked with negotiating a single

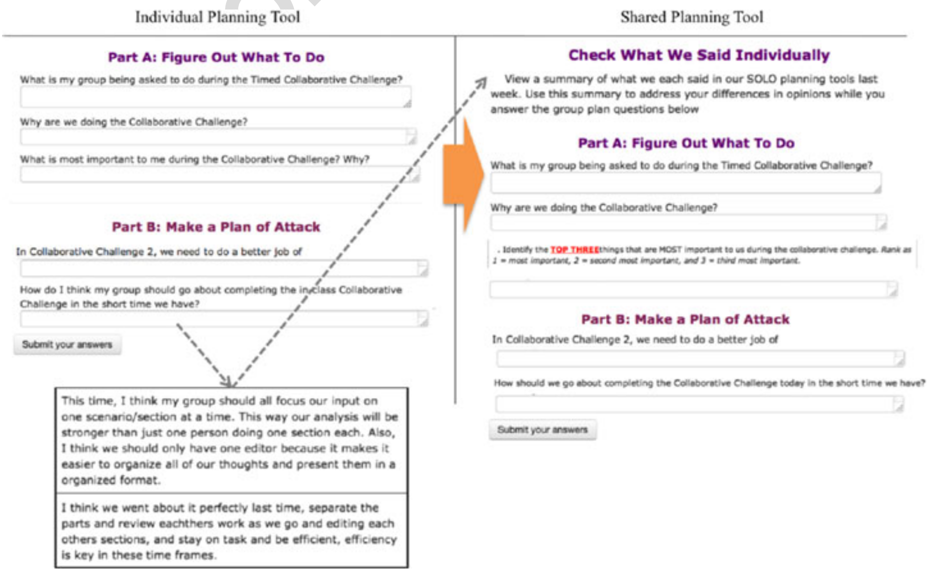

Fig. 2 Left: individual planning tool. Right: shared planning tool. Bottom: summary of example IPT responses displayed in the SPT

set of responses for the group. To help groups become aware of and discuss similarities and differences among members' personal task perceptions, goals, and plans, members' IPT responses are displayed to the group. Groups are prompted to "*check out what we said individually*" and use the summary to help complete the SPT questions.

While CSCL tools often target communicative-coordination processes for knowledge construction, the IPT and SPT prompt activation of planning and reflection processes as a basis for regulating cognition, behavior, motivation, and emotions. By supporting learners and groups to generate, evaluate, and negotiate task perceptions, goals, and plans, these tools provide groups with a solid foundation on which to (a) select and choose strategies for taking control of the collaborative task, and (b) create shared standards against which to monitor and evaluate their progress and products (Miller and Hadwin 2015a). Furthermore, by having groups consider their IPT responses as they complete the SPT, tools support group members to become aware of and make use of members' personal planning as a basis for helping the group regulate together during the task.

In our current research, we have been examining how different levels of support or structure affect group planning and collaboration. In a recent investigation Miller and Hadwin (2015b) examined the effect of different levels of scripting support in the IPT and SPT on groups' planning and collaboration in a first year undergraduate course. The low support versions of the IPT and SPT were comprised of open-ended question prompts. In the high support versions, question prompts were pre-stocked with potential responses. For instance, task perception questions asked learners to identify the correct task requirements and purposes among ten possibilities. Five potential responses were a direct match with the task at hand and five were common misperceptions about the task observed in our past work (cf., Miller and Hadwin 2012).

Findings indicated that, regardless of the level of individual support, a high level of shared planning tool support helped groups construct more accurate shared task perceptions, capitalize on one another's accurate interpretations about the task, and more transactively negotiate shared task perceptions. While our research thus far has primarily focused on planning processes, we suggest that scripts offer much promise to support and promote a wide range of key processes for regulating collaboration.

VCRI + SSRL tool - OurPlanner and OurEvaluator

Based on the three design principles for supporting SSRL (awareness, externalization, and prompting regulation), Järvelä et al. (2014) tailored an existing online tool that promoted collaborative work to enhance SSRL. The Virtual Collaborative Research Institute (VCRI; Jaspers et al. 2004) has been often used to enhance collaborative work, helping the students self-assess themselves and peer-assess others with higher accuracy and by making their judgments explicit (Phielix et al. 2011). Within the VCRI, we used already existing features (Radar and Chat) and reformulated another (Co-writer) to create two new ones (OurPlanner and OurEvaluator) which were based on the original idea of Personal Planning Tool (PPT) by Hadwin et al. (2012a, b). Q12

Radar is a diagram with six different axes, with a 101-point Likert scale organized along number-lines with five values (0–4). Radar is meant to enhance awareness of group members' social, motivational and cognitive behavior, and in turn, support social, motivational, and cognitive group performance, providing users with anonymous information on how their cognitive, motivational and social beliefs are perceived by themselves, their peers, and the group in a current learning situation (See in more detail: Phielix 2012). Figure 3 illustrates the dimensions implemented in Radar. The selected dimensions focused on a) group efficacy beliefs, “My group is capable of doing this task” b) Task understanding, “I understand the task”, c) Cognitive strategy use, “I know how to do this task” d) Interest “This task is interesting” e) Emotions, “My feelings influence my working”, and f) Self-efficacy beliefs “I feel capable of doing this task”. I am capable of doing this task”. By asking students to rate those dimensions, they were provided a means and the tools to increase their awareness of group members’ social, motivational and cognitive beliefs. However, Radar used alone does not *prompt* the acquisition and activation of regulatory processes.

Prompting, acquiring, and activating regulatory processes were supported via OurPlanner and OurEvaluator. The purpose of *OurPlanner* was to prompt students to plan their collaboration, whereas the purpose of *OurEvaluator* was to prompt them to reflect on their collaboration. Both of these tools invite externalizing aspects of SSRL by prompting groups to explicate their a) Task understanding, “Describe your current task, What is the purpose of the current task?”, b) Goal setting, “What is your goal for this task?”, c) Planning, “Describe what you need to do to achieve that goal”, d) Challenge, “What is the main challenge facing you as a group?”, and e) SSRL strategy, “What are you going to do as a group to overcome this challenge?”. OurEvaluator had the same questions, except they were formulated in the past tense.

Three design principles were used when tailoring VCRI + SSRL tools to promote socially shared regulated learning. The first was to increase learners’ *awareness* of their own and others’ learning process. This was done by Radar and its visualization. At the individual level, the group members had to first think about their own SRL in a learning situation. Group level awareness was increased with a visualization of how the other members were thinking (cognitive) and feeling (motivation and emotions) about the current learning situation. The

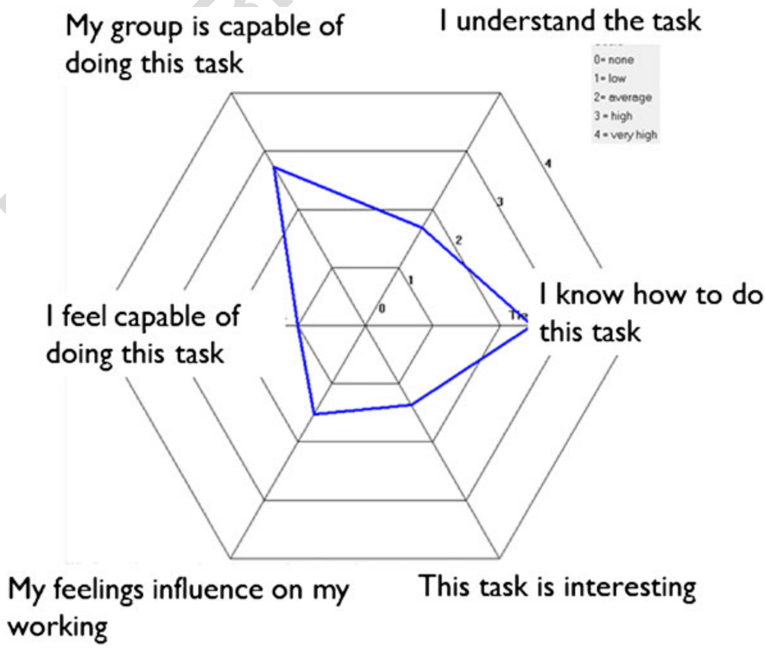

Fig. 3 Radar + SSRL support

second and third principles were *supporting externalization* of students' own and others' learning process in a social plane and helping in sharing, and interaction and *prompting* the acquisition and activation of regulatory processes. These two principles are promoted via OurPlanner and OurEvaluator, as both tools make explicit the group strategies and shared task goals. By externalization strategies and goals, the different group members can elaborate and activate the joint strategies by interacting with their peers.

VCRI + SSRL tool has been implemented as a part of pedagogical design for supporting SSRL in CSCL in a university level course on multimedia that lasted for 2 months (Malmberg et al. 2015). During the collaborative sessions, the groups used the VCRI environment to complete their collaborative task assignment. Our interest was on the groups' responses to OurEvaluator focusing on challenges ("What was the main challenge your group confronted during your collaboration") and following SSRL strategy ("What did your group do to overcome that challenge?"). Asking these two questions helped us to trace the challenges and SSRL strategies of collaborating groups, and how they may differ with respect to their learning achievement as the course progress. Our study (Malmberg et al. 2015) shows that at the early phases of the course, the collaborating groups confronted mostly external challenges (such as technology) but eventually the SSRL focus shifted towards regulating the cognitive and motivational aspects of their collaboration. Also, socially shared regulation of motivation provided opportunities to engage in cognitive regulation towards task execution. The groups that did not succeed in their learning tended to ignore or reject activation of motivation regulation.

S-REG tool

With recent developments in technology, researchers have started to explore how mobile devices, social media or personal learning environments can support or promote SRL (Kitsantas and Dabbagh 2011; Laru and Järvelä 2014)). Following these technology trends, our most recent SSRL tool is mobile web app called S-REG Laru et al. (2015). *S-REG tool* extends our previous work by providing targeted support for SSRL based on the challenge the groups have identified in their collaborative learning tasks. S-REG is a visual HTML5 iPad application that displays group members' cognitive, motivational and emotional state with a goal of developing awareness. In doing so S-REG tool combines our previous work with AIRE and planning tools by explicitly making students conscious of the cognitive, motivational, and emotional aspects of regulated learning.

The S-REG tool consists of five different phases. In phase 1, students are asked to individually evaluate and identify beliefs of efficacy related to their cognitive (*I know what I am supposed to do*), motivational (*I am willing to work*), and emotional (*I feel fine*) abilities at that exact moment of time. The evaluations are done visually by drawing a circle with iPads (See Fig. 4, phase 1). The purpose of this phase is to identify individual group members' starting point for group work, so that the groups could locate the possible cognitive, motivational or emotional challenges in that specific group work session.

In phase 2, based on the individual students' evaluations, the S-REG tool generates a merged visual representation for the whole group (See Fig. 4, phases 3–4). This representation uses a "traffic light" metaphor as an indicator of group's cognition, motivation and emotional state. Each focus area gets a separate traffic light, resulting three different lights each representing one area of focus. A green light indicates that everything is going fine in that specific area. An amber light indicates there may be some problems within the group, and a red light indicates serious problems within a group in a particular area.

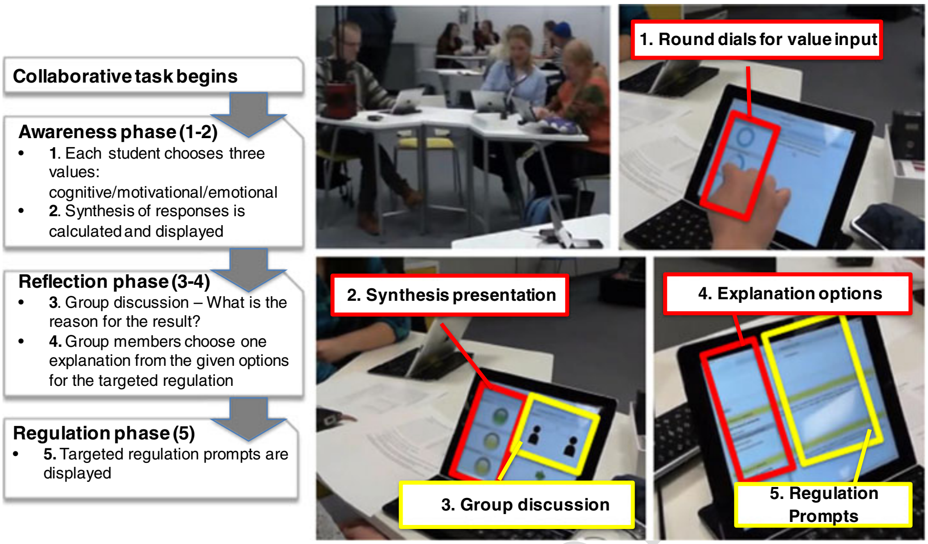

Fig. 4 S-REG tool and its' use in collaborative task

In phase 3, after getting a groups' shared traffic lights, the S-REG tool prompts the group members to discuss and explicate the possible reasons amongst themselves for all three traffic lights.

In phase 4, based on this discussion, the group is asked to come up with one joint reason for challenges that they encountered in the group. If the traffic light indicator was amber or red the group selected the reason for the experienced challenge from a ready-made list. Each of the three areas of focus had four possible reasons to select from (Table 1). If the traffic light was green the collaborating groups were asked to specify reasons for the group doing well in that area of focus by writing the reason in an empty template in S-REG tool.

The *fifth and sixth* phases of the S-REG tool are meant to provide the collaborating groups with the possibility for active regulation. That is, related to the groups selected reason for a challenge in each three areas, the S-REG tool provides first a prompt of a regulation strategy or activity that the group could activate to overcome their challenge (See Fig. 4, phases 4–5). The use of the tool ends up with a request to discuss of the prompt or other alternatives to regulate the challenge in question.

We are currently implementing the S-REG tool in our empirical studies and findings to date indicate that collaborating groups used the tool purposefully. For example, the S-REG tool was implemented in a study where second-year teacher education students participated in a mathematics pedagogy course that lasted for 2 months involving collaborative groups tasks (Malmberg et al. 2013, 2015). Before each group-work session, students were asked to use S-REG tool to

Table 1 Challenge options to select from the S-REG tool

Cognition	Motivation	Emotion
Previous knowledge	Interest	Frustration
Task understanding	Efficacy beliefs	Boredom
Planning and strategic knowledge	Goals	Worrying
Time management	Task Value	Irritation

support shared-regulation of learning by helping students become aware of their situated cognition, motivation, and emotions, and serve as grounds for discussing possible problems in the groups. The traffic lights prompted awareness, since in 87 % of the situations where groups used S-REG tool, they discussed the reasons for the traffic light that their group received. However, preliminary results indicate that the increased awareness does not automatically result in active regulation; the prompt for activating proper regulation to address the challenge was discussed only in 27 % of the learning situations. However, when the groups decided to engage with the regulation prompt, the quality of the regulation was typically at a high level. We still need a deeper understanding of how to support students to incorporate an awareness of the collaboration challenges and their regulation into actual regulation activity.

Conclusions

Grounded in our theoretical research on self-regulated learning and collaboration (Järvelä and Hadwin 2013; Hadwin et al. 2016), along with increasing empirical findings on socially shared regulation in collaborative learning (Järvelä and Hadwin 2015), we have presented suggestions for refining the design of support for regulating learning in collaboration, especially with respect to metacognitive awareness of individual and group level regulation processes. When considering success in CSCL, the evaluation criteria are often the outcomes of learning during the execution of the collaborative learning task. Examples of such outcomes, which are often seen as standards for successful CSCL, are: knowledge construction, knowledge convergence, and knowledge creation (Van Aalst 2009). Other research disregards such outcomes and concentrates instead on the processes. Our claim is that the regulation of learning is not an outcome but a cognitive and metacognitive process whereby progress in achieving SSRL sets a stage for better collaboration (Hadwin et al. 2016) and thus better (i.e., more effective, more efficient, and/or more enjoyable) learning. Simply supporting knowledge construction, convergence, and creation is not enough, since the regulation of learning also covers supporting motivation, emotion, and metacognition. In other words, SSRL for successful collaborative learning includes constructing metacognitive knowledge about cognition, motivation, emotion within collaborative learning processes, such as negotiating and aligning representations of task requirements, goals, and strategies (Winne et al. 2013).

As research on collaborative interaction has shown, “groups don’t learn”, but interacting individuals as a group make progress in shared understanding and learning (Miyake and Kirschner 2014), and group interactions have a learning or knowledge constructing effect (Cress et al. 2015). Our own studies have pointed out that individual students as well as groups can be supported in regulation, such as socially shared motivation regulation (Järvelä et al. 2013; Järvenoja et al. 2015), or by helping individuals in their socially shared task perceptions and planning (Miller et al. 2015; Malmberg et al. 2015). We have also found that groups using multiple regulatory processes achieve better shared understanding, thereby supporting their collaborative processes (Järvelä et al. 2015). We posit that individual and socially shared regulation plays critical roles in successful collaborative learning. This process can be supported by the SSRL tools, but there is no evidence yet about the contribution of such tools to the quality of collaborative learning. Further research is needed to examine how supports can better facilitate collaborative performance.

The origin of regulated learning is individual metacognition (Winne 2011), and it is difficult to determine what exactly signals the need for self-regulated learning, especially when taking into account varying task types, situations, and characteristics of a learner. Our approach in supporting SSRL has been to integrate tools for prompting and researching SSRL in pedagogical designs for authentic learning situations with the goal of investigating "situated beliefs in action" (Järvenoja et al. 2015). The real situated learning challenges in collaboration (e.g. social conflicts, weak task understanding, mismatch in goals) raise students' metacognitive awareness and invite regulation. Prompting SSRL in those situations supports students' regulation, but also gives opportunities to capture the process for further investigations.

Finally, we conclude that the challenges learners confront during their collaborative learning create opportunities for strategic adaptations in SRL (Järvelä et al. 2013). Strategic adaptations occur, for example, when learners change and adjust their task perceptions, goals, or strategies as a result of the metacognitive monitoring of behavior in collaboration. However, not all the forms of regulation of learning are equally effective in overcoming challenges encountered in such situations (Malmberg et al. 2013). Future research should focus on strategic adaptation in regulation of collaboration and the situated challenges of how learners strategically adapt their task perceptions, goals, and strategies in varying learning situations.

To understand more about strategic adaptation of regulation, our future prospects deal with collecting multimodal data, as well as covering subjective and objective traces of regulatory processes (Bannert et al. 2014). Physiological measures, such as electro dermal activity data resulting from skin galvanic conductance sensors (Harley et al. 2015) can, for example, be used to determine and track moments of challenge. This is also true for facial recognition of affective triggers. Also, video observation has the potential to inform the sequential and temporal dynamics of SRL before and after moments of challenge in collaboration. Triangulation of multichannel data provides fundamentally new approaches, including objective and subjective means, through which to capture critical phases of SRL as they occur in challenging learning situations. New data driven analytical techniques (e.g., learning analytics) could be applied to this data to better support the ways learners strategically regulate their own and their group's cognition, motivation, and emotion.

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