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Variations in socially shared metacognitive regulation and their relation with university students' performance

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Abstract
The present study aims at investigating whether events of socially shared metacognitive regulation (SSMR) differ from each other when comparing their characteristics. These differences are labelled "variations in SSMR". The study is conducted in a peer tutoring setting at university and includes video data (70 h of video recordings) on the regulation behaviour of thirty students who participated in a semester-long peer tutoring intervention that was directed at knowledge co-construction. In addition to studying variations in SSMR, the current study aims at examining whether individual students' engagement in variations in SSMR is related to their performance on a knowledge test taken immediately after the peer tutoring intervention. Latent class cluster models were run to explore the presence of variations in SSMR. The trigger for SSMR, the number of students actively involved in SSMR, the level of elaboration during SSMR, and the function of SSMR in the collaborative learning process were included in the model as input parameters. A four-cluster model was selected as the best fitting model that demonstrated statistical significance. The four identified variations of SSMR were labelled as 'interrogative SSMR', 'affirmative SSMR', 'interfering SSMR', and 'progressive SSMR'. Regression analyses revealed that not all variations in SSMR are equally important for predicting students' performance. Students' engagement in interrogative SSMR was significantly positively related to students' performance on the knowledge test, whereas their engagement in interfering SSMR was negatively related. In contrast, the frequency of students' involvement in affirmative SSMR or progressive SSMR demonstrated no significant relation with students' performance. By unravelling the multifaceted character of SSMR, the present study allows to extend and to refine the emerging theory on shared regulation.

Keywords Shared regulation · Performance · Latent class cluster analysis · Collaborative learning · Higher education

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Introduction

Socially shared metacognitive regulation (SSMR) refers to metacognitive regulation activities in which multiple students reciprocally operate on each other's regulative acts when monitoring and controlling their cognition (Iiskala et al. 2015). It is manifested when students jointly orient, plan, monitor, or evaluate cognitive processes during collaborative learning. In line with strong self-regulators who strategically control and modify their individual learning and therefore often achieve better outcomes (Zimmerman 2002), engaging in SSMR during collaborative learning is expected to advance the learning outcomes of the students involved (Hadwin et al. 2017; Volet et al. 2017; Zheng et al. 2019). Empirical evidence in this respect is, however, still minor and rather distributed (Järvelä et al. 2016; Näykki et al. 2017; Panadero and Järvelä 2015; Schoor and Bannert 2012). The inconclusiveness of previous effect studies on SSMR could be related to a main focus on between-group differences in regulation behaviour and learning outcomes, while it seems plausible that SSMR is not necessarily a homogeneous process within collaborative learning groups. Events of SSMR can, for example, differ considerably from each other, based on their content or other characteristics such as the level of students' active contribution in SSMR or the role that SSMR plays in the ongoing interaction (Iiskala et al. 2015; Järvelä et al. 2013). Such potential differences between events of SSMR (across and within collaborative learning groups or group meetings) might, in their turn, impact the outcomes of collaborative learning differently, both for the group and its individual group members. It seems, for example, plausible that an active engagement of all group members in SSMR enhances the opportunity for students to pick up something from collaborative learning more, as compared to SSMR that is manifested by a minority of dominant students within the collaborative learning group (Vuopala et al. 2019). Similarly, SSMR in which students criticise each other's regulative thinking and discuss divergent perspectives on the organisation or content of collaborative learning probably lead to enhanced learning opportunities for the students involved, as compared to SSMR during which the collaborative learners immediately agree with each other's interpretation or suggestions (Koivuniemi et al. 2018; Volet et al. 2009). Although there are indications that SSMR is not homogeneous, differences in shared regulation have, to our knowledge, only limitedly been studied and were examined at the group level, aimed at classifying collaborative learning groups regarding their regulation behaviour (Järvelä et al. 2013; Rogat and Linnenbrink-Garcia 2011; Volet et al. 2009; Zheng et al. 2019). Unravelling the potential heterogeneity within SSMR requires, nevertheless, a more fine-grained analysis on the level of events of SSMR (i.e. units or utterances of SSMR). Comparing characteristics of events of SSMR and identifying differences in this respect, enables studying within-group differences and allows for a more refined conceptualisation of SSMR.

The current study holds a twofold focus. First, it investigates to what extent events of SSMR, demonstrated by university students collaborating in a peer tutoring (PT) context, differ from each other when comparing their characteristics. Potential differences between events of SSMR are labelled as "variations in SSMR" in the present study. Second, it examines whether students' involvement in different events of SSMR is related to differences in students' performance on a knowledge test after participating in a semester-long PT-intervention aimed at knowledge co-construction. Given the potential differences in what individual group members pick up from collaborative learning (Michinov and Michinov 2009) the present study takes an interest in the relation between variations in SSMR and individual students' performance after collaborative learning (i.e. PT). The study's innovative scope not only allows to extend the current literature on SSMR, but also to take future effect studies to a next level of investigating the differential impact of SSMR on students' learning outcomes.

Theoretical underpinnings

Socially shared metacognitive regulation

Theories on social forms of regulation are currently trending (Hadwin et al. 2017; Panadero and Järvelä 2015; Volet et al. 2017). Metacognitive regulation is no longer perceived as an activity that is demonstrated by individual students, focussing on checking and modifying their personal learning. There is, in contrast, consensus that metacognitive regulation can be demonstrated at interpersonal levels as well, for example as an event of socially shared metacognitive regulation (SSMR) during collaborative learning. SSMR refers to regulation activities that are manifested during the interactions between collaborative learners, when they collectively coordinate and regulate cognitive processes (Iiskala et al. 2015). Although initiated by individual students, SSMR is characterised by a subsequent involvement in metacognitive regulation of fellow students who reciprocally react to each other's regulative contributions when monitoring and controlling their cognition (De Backer et al. 2015). SSMR consequently differs from coregulation, given that it assumes a more or less equal participation of peers in regulating collaborative learning, whereas coregulation encompasses a regulatory mode in which one dominant peer scaffolds the regulation behaviour of another peer, ultimately aiming for a transition towards self-regulation of the supported student (Hadwin et al. 2017; Schoor et al. 2015). SSMR also differs from shared regulation since the latter can refer to joint regulation of cognition, motivation, emotion, or behaviour (Panadero and Järvelä 2015; Schoor et al. 2015), whereas SSMR is limited to collective regulation of cognitive activities within the collaborative learning group (Iiskala et al. 2015).

Emerging research on socially shared (metacognitive) regulation

Despite growing interest in social forms of regulation, empirical findings on facilitative conditions or on the effectiveness of shared regulation are currently still limited, yet valuable (Hadwin et al. 2017; Panadero and Järvelä 2015; Schoor et al. 2015; Zheng et al. 2019). With regard to the facilitative conditions, difficult tasks appeared more beneficial for students' adoption of SSMR as compared to (moderately) easy tasks (Iiskala et al. 2011). The reflection- and discussion-provoking nature of difficult tasks might explain their correlation with students' adoption of SSMR, for particularly high-level content processing (i.e., characterised by elaborative knowledge co-construction) appeared facilitative towards sharing metacognitive regulation (Khosa and Volet 2014; Volet et al. 2009). It has further been demonstrated that allowing students to extensively practice with regulation strategies and providing them with the time they need to evolve towards joint regulation with fellow collaborative learners, facilitates their involvement in SSMR (De Backer et al. 2015; Malmberg et al. 2015). With regard to the effectiveness of SSMR, the results of previous studies are less straightforward (Panadero and Järvelä 2015). Empirical evidence on self-regulated learning is clear that strong self-regulators are capable of strategically controlling and adapting their learning, and achieve better academically (Zimmerman 2002). Although similar positive outcomes on an interpersonal level are assumed for collaborative learners who engage in SSMR, it remains questionable whether it is legitimate to transfer empirical results on self-regulated learning of individual students to SSMR during collaborative learning. Shared regulation was found to be positively related to a higher performance or better learning outcomes for the students involved in some previous studies (e.g. Järvelä et al. 2016; Khosa and Volet 2014; Näykki et al. 2017; Volet, Vauras, Salo, & Khosa, 2017; Zheng et al. 2019), but this relation could not be confirmed in others (e.g. Iiskala et al. 2015; Schoor and Bannert 2012). This inconclusiveness raises questions regarding the characteristics of shared regulation, which might differ across events of shared regulation and which might affect the outcomes of the students involved, differently. Empirical evidence in this respect is, nevertheless, minor.

Group-based differences in socially shared metacognitive regulation

There are three studies that gave an impetus to studying the multifaceted nature of shared regulation across collaborative learning groups. First, Volet et al. (2009) proposed a conceptual framework on socially regulated learning, based on two continuous dimensions. The first concerns a social regulation dimension, ranging from individual regulation (i.e. individual students regulating the learning activity within the group) to coregulation (i.e. students' joint regulation of learning as a group),[1] whereas the second concerns a content processing dimension, ranging from high-level (i.e. constructing meaning by elaborating) to low-level content processing (i.e. exchanging knowledge without integration/elaboration). Taking both dimensions into account, four types of regulation can be distinguished. High-level coregulation, characterised by elaborative content processing and shared regulation of learning, is considered more beneficial for productive collaborative learning, as compared to low-level co-regulation, during which students superficially exchange ideas (Volet et al. 2009).

Second, Rogat and Linnenbrink-Garcia (2011) revealed that variations in students' socioemotional and collaborative interactions gave rise to differences between collaborative learning groups' shared regulation behaviour. Both positive socioemotional interactions (i.e. active listening, respectful communication, active involvement of all group members, and high group cohesion) and collaborative interactions (i.e. two or more group members share ideas to solve the group task at hand) were characteristic for collaborative learning groups that demonstrated "high quality shared regulation". In contrast, negative socioemotional interactions (i.e. discouraging students to contribute, criticizing or ignoring peers' contributions, and low group cohesion) and non-collaborative interactions (i.e. individuals working separately on parts of the group task) appeared characteristic for collaborative learning groups that hardly demonstrated shared regulation.

Third, Järvelä et al. (2013) identified group profiles, based on students' involvement in group processes that influenced the group's engagement in socially shared regulation. They more specifically unravelled strong, moderate, and weak shared regulation groups, based on students' reported challenges during collaborative task solving and their deep- versus routine-level adoption of regulatory sub-processes (e.g. planning, cognitive processing, external help seeking, motivation regulation). Strong shared regulation groups targeted deeper-level regulatory processes and collectively monitored and revised their problem solving when being challenged. Moderate shared regulation groups adopted routine-level regulatory strategies but collectively addressed

[1] Volet et al. (2009) adopt the term 'coregulation' to refer to multiple students' monitoring and regulation of joint activity at the group level. In line with Hadwin et al. (2017), the current study conceptualizes this behaviour as 'socially shared regulation'. Despite a difference in names, both constructs refer to comparable regulation activities.

experienced challenges, whereas weak shared regulation groups implemented routine-level regulation processes and showed no awareness in how to optimally deal with challenges.

Although the abovementioned studies provide us with valuable insights, they all take a group-oriented approach, focussing on holistic differences of shared regulation between collaborative learning groups. However, given the temporal nature of SSMR (Isohätälä et al. 2017; Malmberg et al. 2017; Näykki et al. 2017), it can be assumed that events of SSMR can differ considerably within a collaborative group, for example based on the particular timing of sharing regulation during the course of collaborative learning (e.g. when encountering conceptual confusion versus when routinely applying regulatory strategies that appeared successful in the past). It appears therefore both legitimate and promising to take events of SSMR as unit of analysis and consequently to compare characteristics that typify these events in order to unravel the potential heterogeneity in SSMR.

Potential differences between events of SSMR

Although characteristics that typify events of SSMR have, to our knowledge, not yet been dealt with explicitly, the available literature on collaborative learning groups reveals interesting directions that are worth further examination. Below, four characteristics that have shown their value in explaining differences in cognitive and/or regulative activities between collaborative learning groups, are outlined. It seems plausible to assume that these characteristics not only explain between-group differences in shared regulation, but might also be decisive for differences among events of SSMR within collaborative learning groups. The characteristics outlined below refer to both aspects at the start of SSMR (i.e. the trigger) and features that are exposed during the course of SSMR (i.e. an active engagement of students, the level of elaboration, the function of SSMR). Potential differences between events of SSMR based on these characteristics are referred to as “variations in SSMR” in the present study.

The number of students involved in SSMR Events of SSMR can either be characterised by a full engagement of all group members or be carried out by only a subpart of students (Iiskala et al. 2015; Isohätälä et al. 2019; Rogat and Linnenbrink-Garcia 2011). It seems likely that an engagement of the full group in SSMR maximises the chance that alternate perspectives on the content and organisation of collaborative learning are discussed, which might enhance individual group members’ gains in content knowledge (Isohätälä et al. 2017). In contrast, SSMR in which only a subgroup of students is involved might result in less discussion, limited exploration of alternative ideas, and merely benefit active students’ knowledge construction (Iiskala et al. 2011).

The trigger for SSMR It could be assumed that one student’s utterance of metacognitive regulation that triggered other peers to join the metacognitive regulation taking place, establishing SSMR, might influence the subsequent reactions within an event of SSMR (Iiskala et al. 2015). Previous studies demonstrated, for example, that the action by one student can directly influence the reaction by another student (e.g. asking a factual question often results in a factual answer whereas a thought-provoking question often elicits an elaborated explanation – Roscoe and Chi 2008). It could be assumed that this mechanism of ‘corresponding triggers and reactions’ might be transferable to students’ regulative contributions during SSMR. This would imply that the action triggering students into SSMR can determine the subsequent regulative exchanges between students and consequently, that different triggers might evoke different types of SSMR (Iiskala et al. 2011). For example, a factual trigger that merely suggests a basic step to be taken might evoke less critical reactions, whereas a thought-provoking trigger that suggests an alternate interpretation of the learning content or that introduces a new problem solving strategy might encourage peers to react with similar thought-provoking contributions. Although this hypothesis has not been examined previously, it seems plausible to assume that both kinds of triggers might elicit different levels of understanding for the students involved, at both the declarative (i.e. content-knowledge) and the procedural (i.e. collaborative learning strategies) level.

The level of elaboration during SSMR Previous research revealed that taking up and building upon peers' contributions are important for learning collaboratively (Iiskala et al. 2015; Vuopala et al. 2019). The level of elaboration during SSMR could therefore be another characteristic that might differ between events of SSMR. It could be expected that events of SSMR in which students merely paraphrase each other's regulative thinking are inviting students less to explore multiple directions (e.g. diverse interpretations on the learning content, alternative problem solving strategies), as compared to events of SSMR during which students elaborate on peers' regulative contributions (Khosa and Volet 2014; Roscoe and Chi 2008). Given that this might elicit less or more learning challenge and strategic adaptation of the collaborative learning process (Koivuniemi et al. 2018), it could be assumed that the level of elaboration in events of SSMR could influence the degree to which students pick up insights from collaborating with peers.

The function of SSMR It should be noted that when students share regulation, they direct the ongoing interaction in a particular way (i.e. regulation cannot be isolated from peers' non-regulative interactions and always has consequences for these interactions – Isohätälä et al. 2017). Identifying differences between events of SSMR consequently requires taking into account the function of SSMR, referring to its role in the collaborative learning process (Iiskala et al. 2015). Previous research in this respect by Iiskala et al. (2015), demonstrated that SSMR can (a) confirm the ongoing interaction, (b) activate contributions that take the learning process one step further, (c) slow down the continuation of previous activity, (d) change its direction, or (e) reach a dead end and stop the interaction. It could be expected that particularly events of SSMR that activate new lines of thinking and events that change the ongoing interaction provide opportunity for students to discuss divergent perspectives on both the content and organisation of collaborative learning, potentially increasing the learning opportunities for the students involved.

SSMR during peer tutoring

The present study investigates differences between events of SSMR, demonstrated by university students during reciprocal peer tutoring (RPT). Peer tutoring concerns a particular type of collaborative learning during which students either take the role of peer tutor or the role of tutee (Topping 2005). Both roles imply different responsibilities during collaborative learning. The peer tutor is more knowledgeable (i.e. because he/she is older, is more experienced, or is provided with additional background information by the instructor) and is expected to facilitate learning within the group by asking questions, providing explanations and feedback, and coordinating peers' discussions. The students taking the tutee role are expected to predominantly focus on constructing knowledge, for example by solving a group assignment (Topping

2005). During reciprocal peer tutoring (RPT), the role of peer tutor is exchanged among students, implying that each student acts both as tutee and (at least once) as peer tutor during the course of the collaborative learning intervention (De Backer et al. 2015). Although peer tutors often take the lead within the group and frequently operate as metacognitive models for tutees, requiring students to alternate between the tutor and the tutee role during RPT generally makes them attribute more equal social status to both roles (Topping 2005), which can encourage tutees to initiate and, in time, to share regulation. A previous study demonstrated that, initially, metacognitive regulation is predominantly demonstrated by the peer tutor who instructs tutees to adopt regulation, but that tutees progressively initiate and participate in metacognitive regulation as they gain more experience in the RPT-setting, more domain-specific expertise, and more confidence in their own competence to regulate learning (De Backer et al. 2015). This increased initiative for regulation by tutees was, moreover, followed by a significant increase in students' adoption of SSMR during the second half of a middle-long term RPT-intervention. The changing dynamics between the peer tutor and the tutees consequently appeared to have lowered the threshold for tutees to contribute to (jointly) regulating collaborative learning. Although positive time-bound evolutions in RPT-participants' adoption of SSMR have been revealed, little is known about the potentially heterogeneous character of SSMR, neither about its relation with students' performance after participating in RPT.

Research questions

The present study aims at identifying potential variations in SSMR, by comparing and classifying events of SSMR demonstrated/verbalised by students during RPT, and at investigating the relation between students' adoption of variations in SSMR and their performance. The following research questions drive the study:

(1) Which variations in SSMR can be discerned when comparing the characteristics of events of SSMR (i.e. the trigger of SSMR, the number of students actively involved in SSMR, the level of elaboration during SSMR, and the function of SSMR), demonstrated by university students during RPT focussed on deepening content knowlegde?
(2) Is students' involvement in variations in SSMR related to their performance on a cued recall knowledge test after participating in an RPT-intervention that is focussed on deepening content knowledge?

Method

Participants and setting[2]

The study was conducted in a naturalistic university setting. Sixty-four first-year Educational Sciences students who already obtained a Professional Bachelor degree (12.5% males and

[2] The present study reports on secondary analyses on data which were originally collected for a previous study. The setting in which data were collected, is extensively described in De Backer et al. (2016). We therefore refer interested readers to this publication for more detailed information on the collaborative learning groups and the tasks students were engaged in.

87.5% females) participated in a semester-long RPT-intervention, as a formal component of the course ‘Instructional Sciences’. Participation in RPT was obligatory for all students enrolled in the course. All 64 students were randomly assigned to eleven small RPT-groups by the university staff member who was responsible for implementing and supervising the RPT-intervention. The current study is based on data collected from 30 out of the 64 RPT-participants (i.e. five groups of six students each).[3]

RPT-intervention

The face-to-face RPT-intervention consisted of one training session and seven successive content-related sessions (each taking two hours), during which students tutored one another in small and stable groups of six students (see Fig. 1). Whereas the training session was directed at practicing with a mix of generic tutoring skills, introduced during a preliminary training (see below), the content-related sessions aimed at deepening students’ understanding of theoretical frameworks, dealt with in the weekly lectures “Instructional Sciences”. The intervention was reciprocal in nature, implying that the peer tutor role was interchanged at each session within each RPT-group. The tutor role was randomly assigned to students by a university staff member. During each RPT-session, the peer tutor was expected to stimulate collaborative learning (e.g. through asking questions, explaining learning content, providing feedback, scaffolding, etc.). The tutees were merely focussed on exploring, deepening, and co-constructing domain-specific knowledge (i.e. through answering tutors’ questions, explicating their interpretations, illustrating theoretical notions, …) by solving the group assignment, in which they were expected to relate and apply theoretical concepts to authentic instructional cases. As a manipulation check, all RPT-groups were observed weekly to check whether students adequately enacted their roles.

Each content-related RPT-session was centred around one particular theme within the course “Instructional Sciences” (e.g. instructional behaviourism, constructivist didactical approaches, assessment, etc.). Groups were provided with open-ended group assignments, comprised of different sub-tasks, aimed at co-constructing theoretical knowledge (e.g. “Explain which theoretical statement is incorrect”, “Relate the illustrations to the theoretical constructs”) and applying the latter to instructional cases (e.g. “Design the outlines of a workshop for school leaders, based on the constructivist didactical approach and argue which constructivist assumptions/terminology you integrate”). Since the central learning content of each assignment was merely briefly addressed in a theoretical lecture one week before the respective RPT-session, tutees’ prior knowledge was limited. Solving the group assignments consequently required students to collaborate by sharing and discussing their interpretations on the theoretical notions addressed in the group assignments. The sub-tasks in each assignment were moreover too many in number to be completed by individual students.

One week before the onset of the RPT-intervention, all students participated in a compulsory tutor training during which students practiced with a mix of generic tutoring skills (e.g. establishing a safe learning climate, asking thought-provoking questions, stimulating reflection, providing constructive feedback, etc.). The outlines of the training were summarised in a

[3] In total, nine groups of six students and two groups of five students were involved in the RPT-intervention. For the current study only groups of six students were selected, to increase comparability between groups. We more specifically made a random selection of five groups of six students, due to infrastructure-related limitations. Since the groups worked simultaneously in different classrooms and only a limited number of camera’s was available, only video recording of five groups could be made.

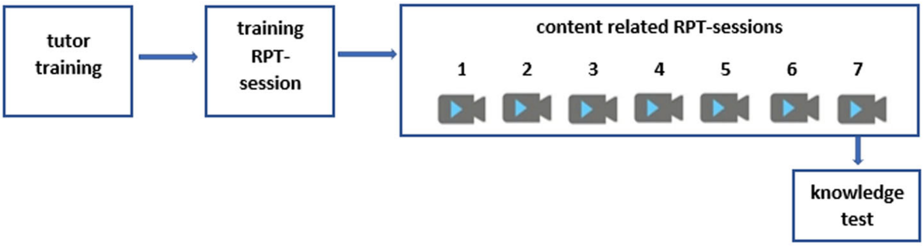

Fig. 1 Chronological representation of the RPT-intervention and data collection

manual provided to all tutors. Additionally, students taking the peer tutor role within a particular session, received a session-specific theoretical manual that summarized learning contents likely to be addressed during the RPT-session, in order to establish a difference in domain-specific content knowledge between the peer tutor and the tutees. Further, all RPT-participants were engaged in one interim supervision session (halfway the intervention) and group-specific feedback sessions (every two weeks). During the supervision session, students reflected upon their role-taking as peer tutor and tutee and exchanged tutoring practices with other RPT-groups. The group-specific feedback was provided by a university staff member and focussed on group dynamics, tutees' participation, and tutors' competence.

Collection and coding of video data

All seven content-related RPT-sessions of five randomly selected RPT-groups were videotaped (70 h of recordings). The video data provided real-time information on students' collaborative learning, including their (shared) metacognitive regulation.

Instruments In a first step, the RPT_MCR instrument (i.e. 'RPT-groups' metacognitive regulation' – De Backer et al. 2015), representing a model of metacognitive regulation in collaborative settings, was used to identify metacognitive regulation skills (i.e. orientation, planning, monitoring, evaluation) adopted by individual students within the RPT-group. Individual students' adoption of metacognitive regulation skills was demonstrated in students' verbalised metacognitive statements (see coding procedure outlined below). Based on the number of students involved and the reciprocity of their contributions when applying metacognitive regulation skills, events of SSMR were identified in a second step. In the current study, an event of SSMR is conceptualised as a sequence of interdependent metacognitive regulation statements that is characterised by a reciprocal involvement of multiple (i.e. at least three) students in a particular regulation skill (i.e. action-reaction-reaction-reaction-… exchanges referring to orientation, planning, monitoring, or evaluation that are verbalised by three or more students, who react to and build upon each other's verbalised metacognitive regulation). An event of SSMR is consequently manifested when students are collectively involved in orienting on, planning, monitoring, or evaluating the content and/or the organisation of the collaborative learning process (see De Backer et al. 2015 for more detailed information on how SSMR is embedded in collaborative learners' interactions; see Appendix 1 for illustrations of events of SSMR segmented in the current study). The start of an event of SSMR consisted of one student's verbalised metacognitive regulation that triggered peers to join in the initiated regulation, whereas the end of an event of SSMR was marked by the last verbalisation of metacognitive regulation that was directed at a joint engagement in regulation. The start and the end of an event of SSMR were traced back after analysing the metacognitive statements (and their interdependency) identified during the first step, in detail. In a third step, we used a coding instrument that allowed comparing characteristics of events of SSMR, in order to identify potential differences between events of SSMR. The instrument more specifically included the following coding categories: (a) the trigger for SSMR (Iiskala et al. 2011), (b) the number of students involved in SSMR (Iiskala et al. 2011); (c) the level of elaboration in students' regulative reactions during SSMR (Khosa and Volet 2014; Näykki et al. 2017); and (e) the function of SSMR within the collaborative learning process (Iiskala et al. 2015).[4]

Coding categories regarding the characteristics of SSMR With regard to (a) *the trigger for SSMR,* we checked the first regulative utterance of one RPT-participant that triggered fellow students to engage in SSMR (i.e. the first statement within an event of SSMR, indicating the start of that event) to investigate whether it concerned a factual trigger or a thought-provoking trigger (Iiskala et al. 2011). A factual trigger concerns a statement referring to previous activity/information, to practicalities, or to a basic next step to be taken within the collaborative learning process. A thought-provoking trigger builds on previous activity/information and invites students to think about/reflect upon a new direction, either content-wise or regarding the organisation of the collaborative learning process. The difference between both triggers concerns a differences in the profoundness of the verbalised metacognitive regulation statement.

Second, we counted for each event of SSMR how many students actively contributed (i.e. verbalised metacognitive regulation during SSMR) in order to gain insight into *(b) the number of participants involved in SSMR.*

Third, we investigated (c) *the level of elaboration in peers' regulative reactions* for each event of SSMR. This characteristic was conceptualised as the degree to which students added information to each other's regulative thinking (Khosa and Volet 2014; Näykki et al. 2017). In line with Roscoe and Chi (2008),[5] we differentiate between continuers (i.e. reactions without meaningful content, e.g. "okay" "mmm", "that's right"), paraphrasing reactions (i.e. contributions in which students react by repeating/reviewing peers' regulative thinking), and elaborative reactions (i.e. contributions in which students react by transforming/elaborating peers' regulative thinking).

Fourth, we investigated (e) *the function of each event of SSMR*, referring to the role SSMR plays in the collaborative learning process (Rogat and Linnenbrink-Garcia 2011). In line with Iiskala et al. (2015), we more specifically distinguished events of SSMR that confirm, activate, slow down, change, or stop the ongoing interaction. During SSMR that confirms collaborative learning, ongoing interaction is continued in the same direction. During SSMR that activates collaborative learning, a new activity or a new way of thinking in line with the direction of the

[4] We would like to clarify that the present study reports on secondary analyses of video data that were previously collected and coded in order to analyse time-bound evolutions in RPT-participants' SSMR (see De Backer et al. 2015).The events of SSMR that were previously segmented, served as a starting point for the coding and analysis that was undertaken in the current study. Consequently, the first and the second step outlined in this paragraph are described in detail in De Backer et al. (2015), whereas the third step concerns coding that was exclusively (and from scratch) undertaken for the present study.

[5] It should be noted that the original classification of Roscoe and Chi (2008) refers to types of reactions (given by tutors and tutees) on the cognitive level (i.e. during knowledge construction). In the current study, we merely adopt the conceptualization of continuers, paraphrasing reactions, and elaborative reactions, but exclusively apply this to RPT-participants' regulative reactions during events of SSMR.

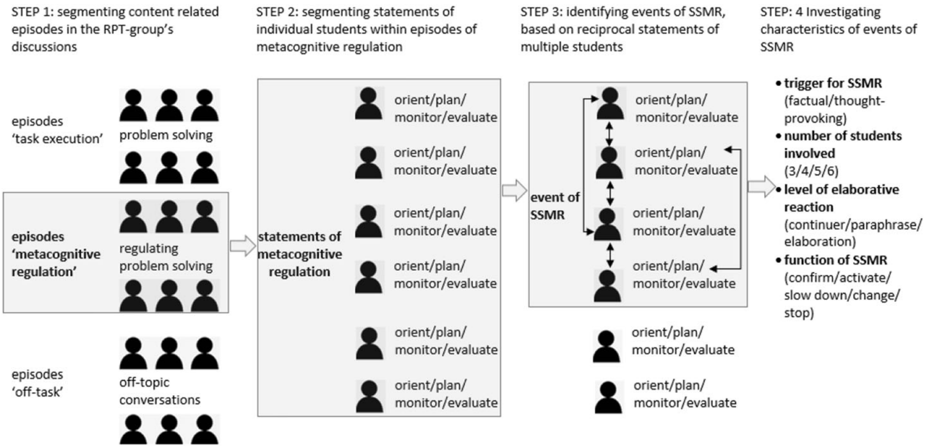

Fig. 2 Schematic overview of the coding procedure

ongoing interaction, is introduced. During SSMR that slows down collaborative learning, ongoing interaction is questioned at first, but students easily compromise and agree to continue previous activity or the way of thinking afterwards. In contrast, during SSMR that changes the ongoing interaction, previous activity or ways of thinking are questioned to the extent that the collaborative learning process takes an alternate direction. Finally, SSMR that stops collaborative learning interrupts the ongoing interaction briefly without any meaningful consequence for the continuation of the collaborative learning process. Appendix 1 exemplifies the coding categories that were adopted to code the characteristics of events of SSMR.

Coding procedure Coding the video data was exclusively focussed on RPT-participants' verbalised interaction. The coding procedure followed subsequent steps (see Fig. 2). First, each RPT-session was segmented into episodes (i.e. multiple conversational turns referring to a particular topic of discussion), which were labelled as either task execution, metacognitive regulation, or off-task conversations.

Second, episodes labelled as metacognitive regulation, were segmented into statements of metacognitive regulation, verbalised by individual RPT-participants. A statement of metacognitive regulation referred to verbalisations of single regulative actions (by a single student) at each turn within the episode of metacognitive regulation. All statements of metacognitive regulation were coded with the RPT_MCR instrument (De Backer et al. 2015). Each statement was given both a general code (indicating whether it concerned orientation, planning, monitoring, or evaluation) and a more differentiated code (referring to the specific regulation strategy it addressed).[6] Further, we coded which particular student verbalised the segmented statement.

Third, we checked for sequences of reciprocal action-reaction exchanges across statements of metacognitive regulation, in order to segment events of SSMR. An event of SSMR comprised of multiple statements verbalised by multiple (i.e. three or more) RPT-participants, who react to each other's regulative statements in a spiral-like fashion. SSMR was always focussed on one particular

[6] In the RPT_MCR coding instrument, task analysis, activation of prior knowledge, planning in advance, interim planning, comprehension monitoring, monitoring of progress, evaluation of learning outcomes, and evaluation of the learning process are distinguished as regulation strategies.

regulation skill (i.e. orientation, planning, monitoring, or evaluation). The start of an event of SSMR consisted of a student's regulative statement that triggered peers to join in the regulation, whereas the end was marked by the last regulative statement referring to joint regulation. For illustrations of events of SSMR, we refer to Appendix 1.

Fourth, for each event of SSMR, four characteristics were checked and coded (i.e. the trigger for SSMR, the number of students engaged in SSMR, the level of elaboration during SSMR, and the function of SSMR), in order to identify possible differences between events of SSMR, labelled as "variations in SSMR". Regarding (a) *the trigger for SSMR*, the first statement within each event of SSMR was analysed and coded as either 'factual trigger' or 'thought-provoking trigger'. Additionally, depending on (b) *the number of students involved in SSMR*, each event of SSMR was given a code ranging from three (i.e. half of the RPT-participants, which was considered the minimum to conceptualise joint regulation as SSMR) to six (i.e. complete RPT-group). Further, (c) *the level of elaboration during SSMR* was coded and scored on a scale ranging from one to three. Depending on the degree to which students elaborated on each other's regulative thinking during SSMR, each event of SSMR was coded as (1) continuer, (2) paraphrasing reaction, or (3) elaborative reaction. Last, the (d) *function of SSMR* was analysed for each event and coded on a scale ranging from one to five, depending on whether the event of SSMR (1) confirmed, (2) activated, (3) slowed down, (4) changed, or (5) stopped the ongoing interaction. The codes referring to characteristics of events of SSMR during the fourth step of the coding procedure, were mutually exclusive.

Segmenting and coding SSMR in the recorded video data was accomplished by two independent coders in a previous study (De Backer et al. 2015). They double coded 25% of the recorded RPT-sessions. Cohen's Kappa indicated good agreement beyond chance for coding events of SSMR ($\kappa = .82$). The coding of (a) the trigger for SSMR, (b) the number of students involved, (c) the level of elaboration, and (d) the function of SSMR (i.e. step 4 in the coding procedure) was accomplished by two other trained coders, who double coded 15% of the previously segmented events of SSMR. Cohen's Kappa indicated high interrater reliability for coding the number of students involved ($\kappa = .93$) and good agreement beyond chance for coding the trigger for SSMR ($\kappa = .78$), the level of elaboration ($\kappa = .81$), and the function of SSMR ($\kappa = .77$).

Assessing RPT-participants' performance

The last RPT-session was selected as measurement occasion regarding students' performance. Since previous research demonstrated that collaborative learners need time and practice to adapt to the peer tutoring context and to optimally take the peer tutor/tutee role (Topping 2005) as well as to demonstrate SSMR to a significantly higher extent (De Backer et al. 2015), students' performance was measured and related to their SSMR behaviour during the last RPT-session in order to maximize their familiarity with each other, the peer tutoring setting, and with (collectively) regulating collaborative learning. Immediately after completing the last RPT-session, all RPT-participants individually conducted a cued recall knowledge test (paper and pencil), capturing students' level of understanding of the academic learning content tackled in the last RPT-session (see Fig. 1). The knowledge test comprised of ten open questions directed at recalling theoretical concepts (e.g. "What is the difference between enactive and iconic representations?") and applying the latter to instructional cases (e.g. "In the STEM lesson discussed in the newspaper excerpt, the teacher's role can be typified as guiding practitioner."). All questions were scored using a predefined answer key, with correct and more elaborate answers resulting in a better test score. For each question, we assigned the following scores: (0) when no or an incorrect answer was given, (1) when the answer was correct but merely contained basic information; (2) when the answer was correct and contained more elaborate information. Two coders double-coded 26% of the performance tests independently from each other. Cohen's Kappa indicated good agreement beyond chance for scoring the performance tests ($\kappa = .79$).

Test scores varied between 6.0 and 16.0 out of 20, with a mean score of 11.56. The obtained scores on the cued recall knowledge-test taken by the students ($n = 30$) within the five randomly selected RPT-groups for video analysis, were included as individual students' performance measure in the current study.

Data analysis

After coding, the frequency of occurrence of metacognitive regulation statements and of events of SSMR was calculated for each RPT-group and RPT-session. In total, 14,968 metacognitive regulation statements and 397 events of SSMR (consisting of 3380 metacognitive regulation statements) were identified. Regarding the first research question, analyses are exclusively based on 395 of the segmented SSMR events. Two missing cases (i.e. events of SSMR for which not all of the four characteristics were coded during the last step of the coding procedure outlined above) were removed. Latent class cluster analysis was conducted on a dataset representing the 395 coded events of SSMR, in order to explore the presence of variations in SSMR based on the abovementioned characteristics. Latent class cluster analysis allows to characterise a multidimensional discrete variable based on a cross-classification of observed categorical variables (Vermunt and Magidson 2003). It aims at classifying cases into classes that are considered relatively homogeneous within themselves while being heterogeneous to each other, based on a set of input parameters. Unlike K-means cluster analysis, latent class cluster analysis is a model-based technique, implying that the decision to adopt a particular cluster model is less subjective but based on statistically tested model fit. The software package Latent Gold ® 5.1 was used to conduct the latent class cluster analysis. The function of SSMR (nominal), the number of active students during SSMR (ordinal), the trigger for SSMR (nominal), and the level of elaboration during SSMR (ordinal) were included as parameters in the latent class model. Selection of the best fitting cluster model was primarily based on the Log Likelihood and the p value of the generated models. In addition, the number of parameters, classification error, and an analysis of the residuals of the corresponding models were taken into account.

Based on the results of the latent class cluster analysis (RQ1), the predicted cluster membership for each event of SSMR was added as a variable to the initial dataset. In order to test the relation between individual students' engagement in each of the identified variations in SSMR and their performance on a cued-recall knowledge test (RQ2), an individual-level engagement variable was computed by counting per student the number of their individual metacognitive statements per event of SSMR. This allowed to acknowledge a student's weaker/stronger involvement in an event of SSMR when analysing the data (instead of merely taking into account that the student did/did not contribute to the event of SSMR).[7]

[7] For example, when a group participated in five events of SSMR that were identified as interrogative SSMR, but one of the students did not contribute to these events, his/her score would be zero, while a very active student who contributed in each of the events of interrogative SSMR with three metacognitive statements, would receive a score of 15.

Since the last RPT-session served as measurement occasion for students' performance on a cued recall knowledge test, we filtered out the segmented events of SSMR demonstrated by the videotaped RPT-participants during this last session ($n = 125$ events of SSMR, comprising of 1020 metacognitive regulation statements), of the complete dataset which was used for the first research question ($n = 395$ events of SSMR). This implies that analyses for the second research question were conducted on a dataset representing (a) the frequency of individual students' ($n = 30$) involvement in each of the identified variations in SSMR during RPT-session 7 and (b) individual students' score on the cued recall knowledge test after completing RPT-session 7. To verify whether students' engagement in variations in SSMR was related to their performance on the knowledge test, regression analyses were performed. Despite the nested structure of the data (i.e. students at level 1 and RPT-groups at level 2), the variance at level 2 appeared not to be significantly different from zero ($\chi^2 = 0.02$, $df = 1$, $p = .986$). Therefore unilevel regression analyses were performed, with students' performance as dependent variable and (a) their adoption of SSMR, respectively (b) the frequency of students' engagement in each of the four identified variations of SSMR as predictor variables. Pre-analysis investigations were conducted to check the linearity of the relationship between RPT-participants' SSMR and performance (i.e. by visual inspection of the scatter plot), the assumption of normality (i.e. by means of Shapiro-Wilk test and visual inspection of normal P-P plot), homoscedasticity of the residuals (i.e. by visual inspection of the scatter plot), and the absence of multi-collinearity (i.e. based on the Tolerance and VIF-values). Despite the rather small sample size, all assumptions were met. The significance level was set at .05 for all analyses. To obtain a better understanding of the relative impact of the significant predictors, standardized regression coefficients (*SD*) were used as a measure of the size of the effects (Cohen 1977).

Results

Descriptive analyses on RPT-groups' SSMR during the complete RPT-intervention

RPT-groups are preoccupied with task execution (53.2%) and metacognitive regulation (43.6%), whereas they only limitedly engage in off-task conversation (3.2%). Regarding the groups' metacognitive regulation behaviour, Table 1 reveals that SSMR is dominantly demonstrated during monitoring (85.82%) and to a lesser extent during orientation (9.88%). Shared evaluation (3.29%) and planning (1.01%) are, however, scarce. In general, a majority of students (i.e. 4 and 5 out of 6) is actively involved in SSMR (30.6% and 43.5%, respectively). Sharing regulation with the complete group is, nevertheless, rather exceptional (8.1%). Table 1 further reveals that events of SSMR are mainly triggered by a thought-provoking statement made by one of the group members (55.4%), whereas peers' regulative reactions during SSMR are often elaborative by nature (47.1%). Last, Table 1 reveals that SSMR mainly confirms ongoing interaction (31.6%) or questions the latter by slowing down (25.8%) or changing (21.8%) previous activity.

Variations in SSMR

Latent class cluster analysis was conducted to explore the presence of different cluster solutions in the events of SSMR. Since there was no theoretically expected number of clusters,

Table 1 Descriptive results on the characteristics of RPT-participants' adopted SSMR (frequencies and percentages)

	frequency	*%*
Events of SSMR		
shared orientation	39	9.88
shared planning	4	1.01
shared monitoring	339	85.82
shared evaluation	13	3.29
Total	*395*	*100*
Trigger for SSMR		
factual trigger	176	44.6
thought-provoking trigger	219	55.4
Total	395	100
Number of students involved in SSMR		
shared among 3 RPT-participants	70	17.7
shared among 4 RPT-participants	121	30.6
shared among 5 RPT-participants	172	43.5
shared among 6 RPT-participants	32	8.1
Total	*395*	*100*
Level of elaboration in regulative reactions during SSMR		
continuer	53	13.1
paraphrasing reaction	156	39.5
elaborative reaction	186	47.1
Total	*395*	*100*
Function of SSMR in collaborative learning process		
confirm	125	31.6
activate	46	11.6
slow down	102	25.8
change	86	21.8
stop	36	9.1
Total	*395*	*100*

an initial run of one to five clusters was analysed (Vermunt and Magidson 2003), with the four characteristics outlined above as variables of interest. Table 2 provides evaluative information on the initial analysis of the potential models. Although the three-cluster model demonstrates the lowest BIC value, only the four-cluster model and the five-cluster model appear to be statistically significant (both $p > .05$). Whereas the log-likelihood value for the five-cluster model is the lowest, both its number of parameters and its classification error are rather high, as compared to the four-cluster model (see Table 2). Closer examination of the five-cluster model, moreover, reveals very limited differences between two clusters within the model, which are theoretically rather difficult to interpret/distinguish.[8] Therefore, the four-cluster model is selected as the best fitting statistically significant model ($\chi^2(85) = 203.95$, $p < .001$, *standard* $R^2 = .898$). Closer examination of the bivariate residuals in the four-cluster model confirms a good fit (see Table 3). Its proportion of misclassified cases is moreover limited (4.3%). It is further revealed that each of the included parameters (i.e. trigger for SSMR, number of students involved in SSMR, level of elaboration during SSMR, and function of SSMR) contributes in a significant way to the discrimination of the four clusters (all $p < .001$) and that the four-cluster model clearly explains part of the variance of each parameter ($R^2_{\text{trigger SSMR}} = 0.76$; $R^2_{\text{active students}} = 0.62$, $R^2_{\text{level elaboration}} = 0.61$; $R^2_{\text{function SSMR}} = 0.41$).

[8] In the five-cluster model, two clusters merely differ in the probability of categories from the parameter 'function of SSMR', whereas the probabilities of all other parameters are quasi identical.

Table 4 provides more detailed information regarding the profile of the different classes within the four-cluster model (i.e. class size and probabilities for each response category across classes). After examining the particularities of each class, we define the following variations of SSMR: (1) interrogative SSMR (cluster 1), (2) affirmative SSMR (cluster 2), (3) interfering SSMR (cluster 3), and (4) progressive SSMR (cluster 4). First, majority of the events of SSMR can be classified as *interrogative SSMR* (49.7%). This type of SSMR is characterised by the active involvement of a large majority of group members ($M_{number\ of\ students} = 5.03$) and high probabilities of slowing down and changing the direction of the collaborative learning process (see Table 4). Furthermore, interrogative SSMR is more likely to be elicited by a thought-provoking trigger by one student, on which peers generally react with elaborative contributions ($M_{level\ of\ elaboration} = 2.81$). Second, 28.5% of the events of SSMR are classified as *affirmative SSMR*. The latter is characterised by a high probability of confirming peers' way of thinking or the current direction of the collaborative learning process (see Table 4). It is further more likely to be elicited by a factual trigger, which is followed by mainly paraphrasing reactions of peers ($M_{level\ of\ elaboration} = 2.00$). In general, a small majority of students is involved in affirmative SSMR ($M_{number\ of\ students} = 3.76$). Third, we distinguish *interfering SSMR*, encompassing 13.4% of the events of SSMR. This type of SSMR is characterised by a high probability of stopping/interrupting the course of the collaborative learning process (see Table 4). In general, only a limited number of students is actively involved in interfering SSMR ($M_{number\ of\ students} = 3.04$). The latter is moreover likely to be elicited by a factual trigger on which students react with rather meaningless contributions ($M_{\text{level of elaboration}} = 1.01$). Fourth, the smallest proportion of events of SSMR is classified as *progressive SSMR* (8.3%). This type of SSMR is characterised by a high probability of activating a new way of thinking or taking the collaborative learning process in a new direction, building on previous activity (see Table 4). It is more likely to be evoked by a thought-provoking trigger, which is answered by peers' elaborative contributions ($M_{\text{level of elaboration}} = 2.82$). Progressive SSMR is further characterised by the active involvement of a small majority of group members ($M_{number\ of\ students} = 4.18$).

Relation between students' involvement in variations in SSMR and performance

To answer the second research question, the predicted cluster membership (revealed after latent class cluster analysis) for each event of SSMR identified during the last RPT-session, was copied in each statement within a respective event of SSMR. This allowed to calculate how often each student contributed to an event of SSMR (i.e. how many statements of that student were included in that event of SSMR), resulting in a frequency measure of engagement in SSMR ($M = 34.00$, $SD = 16.08$) and in each of the four identified variations in SSMR per student. This was related to students' performance on a cued recall knowledge test, taken by individual RPT-participants immediately after the last RPT-session. Descriptive results are presented in Table 5. A total of 125 events of SSMR (consisting of 1020 statements) was revealed during RPT-session 7. Majority of these events of SSMR was interrogative (45.6%) or affirmative (34.4%). Only a limited number of the events of SSMR was progressive (10.4%) or interfering (9.6%).

A regression model with the frequency of adopting SSMR as predictor demonstrated good fit ($F(1,28) = 10.90$, $p = .003$) and accounted for 25.5% of the variance. Although adopting

Table 2 Model fit evaluation information latent class cluster analysis

	LL	BIC (LL)	AIC (LL)	Npar	L^2	df	p	class error
1-cluster	−1734.107	3528.002	3488.213	10	1150.645	109	<.0001	0.000
2-cluster	−1304.164	2715.947	2644.327	18	290.759	101	<.0001	0.008
3-cluster	−1222.162	2599.774	2496.323	26	126.7550	93	.012	0.008
4-cluster	−1210.230	2623.741	2488.459	34	102.891	85	.091	0.043
5-cluster	−1199.560	2650.234	2483.120	49	81.552	54	.340	0.183

SSMR appeared significant ($p = .003$), its effect on students' performance remains moderate ($SD = 0.52$).

A second regression model that included the frequency of students' involvement in each of the identified variations in SSMR as predictor variables, demonstrated good fit as well ($F(4,25) = 10.98$, $p < .001$) and accounted for 47.9% of the variance in students' performance. Table 6 reveals, nevertheless, that not all variations in SSMR are equally important for students' performance. Only students' engagement in interrogative SSMR is significantly positively related to their performance on the knowledge test ($p = .022$). Its effect size is moderate ($SD = 0.51$). Students' adoption of interfering SSMR appeared significantly negatively related to their performance ($p = .036$). Its effect size is, however, small ($SD = 0.29$). The frequency of students' involvement in affirmative and progressive SSMR does not show a significant relation with their performance ($p = .654$ and $p = .271$, respectively).

Discussion

The multifaceted character of SSMR

The present study focussed on analysing characteristics of events of SSMR, aimed at unravelling differences between events of SSMR, which we label as "variations in SSMR". The results clearly demonstrated that SSMR is multifaceted by nature. Based on differences in what triggered students to share regulation, the number of actively involved students, the level of elaboration during SSMR, and the function of SSMR, we distinguished 'interrogative SSMR', 'affirmative SSMR', 'interfering SSMR', and 'progressive SSMR'.

SSMR due to resolving difficulty Majority of the events of SSMR were *interrogative*. This type of SSMR slows down or changes the direction of collaborative learning, is most likely to be evoked by a thought-provoking trigger that is generally followed by elaborative reactions, and is generally shared among a large majority of students. This finding appears to imply that SSMR particularly occurs when collaborative learners are faced with some kind of difficulty in

Table 3 Bivariate residuals from the four-cluster model

Parameter	function of SSMR	number of students	trigger for SSMR
function of SSMR			
number of students	0.078		
trigger for SSMR	0.616	0.486	
elaboration during SSMR	0.818	0.110	0.159

Table 4 Profile of the four-cluster model: cluster size (percentages) and probabilities for each category of the parameters in the four clusters

		Cluster 1	Cluster 2	Cluster 3	Cluster 4
cluster size		49.7%	28.5%	13.4%	8.3%
parameter	**categories**				
trigger for SSMR	factual trigger	0.044	0.968	0.978	0.005
	thought-provoking trigger	0.956	0.032	0.022	0.995
number of students involved	3 students	0.005	0.399	0.956	0.187
	4 students	0.112	0.443	0.043	0.453
	5 students	0.723	0.156	0.001	0.351
	6 students	0.160	0.002	0.000	0.009
level of elaboration during SSMR	continuer	0.000	0.003	0.991	0.000
	paraphrasing reaction	0.191	0.994	0.009	0.184
	elaborative reaction	0.809	0.003	0.000	0.816
function of SSMR within collaborative learning (CL)	confirm CL	0.098	0.929	0.302	0.016
	activate CL	0.033	0.031	0.001	0.613
	slow down CL	0.497	0.037	0.001	0.008
	change CL	0.371	0.001	0.020	0.362
	stop CL	0.001	0.002	0.676	0.001

the collaborative learning process (e.g. miscomprehension by being confronted with peers' differential understanding of content-knowledge, students realising that the remaining time is too limited to successfully finalise the assignment at the group's current pace, students becoming aware that the ongoing problem solving process is no longer in line with the learning objectives put forward, …) that creates an impasse (Koivuniemi et al. 2018; Järvelä et al. 2013). Resolving this impasse might have stimulated multiple students to regulate their own and each other's learning in an attempt to realign the collaborative learning process (Isohätälä et al. 2017; Malmberg et al. 2015), eventually evoking interrogative SSMR. Since it seems plausible to assume that the group explores multiple alternate directions or interpretations when trying to overcome experienced difficulties, it should not be surprising that interrogative SSMR is shared among a large majority of group members, who all feel encouraged to confirm or correct their regulative thinking based on the suggested alternatives within the group (Iiskala et al. 2011).

SSMR due to agreeing with and building on peers' input The results further revealed the presence of *affirmative SSMR* and *progressive SSMR*. Whereas the first confirms the ongoing direction of collaborative learning (e.g. activating prior knowledge on multiple related constructs), the latter takes the joint problem solving process one step further by introducing a new direction that builds on the ongoing interaction (e.g. after activating

Table 5 Descriptive results on students' SSMR and performance during RPT-session 7

	frequency of events of SSMR (%)	*frequency of statements in events of SSMR*	*M*	*SD*	*min.*	*max.*
interrogative SSMR	57 (45.6%)	465	15.80	8.61	0	32
affirmative SSMR	43 (34.4%)	351	11.13	7.45	1	29
interfering SSMR	12 (9.6%)	98	2.77	1.07	0	12
progressive SSMR	13 (10.4%)	106	4.30	3.53	0	19
total SSMR	125 (100%)	1020	34.00	16.08	0	69
performance	–	–	11.56	2.36	6	16

Table 6 Regression analyses for assessing the relation between students' involvement in (variations of) SSMR and their performance

	B	*sd*	*Beta*	*t*	*p*
Model 1: SSMR as predictor of performance					
CONS	9.01	0.87		10.34	<.001
SSMR	0.08	0.02	0.52	3.30	.003
Model 2: variations of SSMR as predictors of performance					
CONS	9.66	0.83		11.68	<.001
interrogative SSMR	0.14	0.06	0.51	2.45	.022
affirmative SSMR	0.02	0.04	0.06	0.45	.654
interfering SSMR	−0.23	0.11	−0.29	−2.21	.036
progressive SSMR	0.12	0.11	0.22	1.13	.271

prior content knowledge additionally activating prior strategic knowledge). Both variations of SSMR are characterised by the active involvement of a small majority of group members. This appears to suggest that SSMR which is confirming or activating the course of collaborative learning, without the group being faced with difficulties or with the need to resolve issues, encourages students less explicitly to participate in SSMR, possibly reducing the chance that quasi all group members actively share regulation (Iiskala et al. 2015; Rogat and Linnenbrink-Garcia 2011; Vuopala et al. 2019). Affirmative SSMR is further triggered by a factual statement by one peer, which is followed by paraphrasing reactions of fellow students, whereas progressive SSMR is generally elicited by a thought-provoking statement that triggers students mainly into elaborative reactions to each other's regulative thinking. This finding suggests that the mechanism of "corresponding actions and reactions", previously revealed in process-oriented analyses of knowledge co-construction during collaborative learning (e.g. Roscoe and Chi 2008), is also applicable to regulative contributions during SSMR. Events of SSMR that are triggered by a factual contribution are generally followed by peers paraphrasing each other's regulative thinking (e.g. affirmative SSMR), whereas events of SSMR that are more likely to be evoked by a thought-provoking contribution, are often typified by subsequent elaboration upon peers' regulative acts (e.g. interrogative and progressive SSMR).

SSMR that is limitedly picked up by peers Last, the present study revealed the presence of *interfering SSMR*, which takes a rather isolated position within the collaborative learning process, given that neither preceding activities nor activities subsequent to interfering SSMR seem to be related to students' adoption of this type of SSMR. Interfering SSMR is triggered by a factual contribution that is followed by limited reactions without meaningful content (e.g. "hmm", "okay"). Given that the content of initial actions directly influences the chance for fellow students to react during collaborative learning (Isohätälä et al. 2019; Roscoe and Chi 2008), it should not be surprising that interfering SSMR is most likely to be demonstrated by a minimum of students (i.e. half of the group). Taking the above into account, it appears that interfering SSMR might be based on self-regulation impulses of individual students that are only superficially picked up by a small subgroup of fellow students and, as a result, do not truly impact the group's collaborative learning.

Variations of SSMR in relation to students' performance

The present study investigated whether students' engagement in variations in SSMR is related to their performance on a cued recall knowledge test, taken after a RPT-intervention that was focussed on deepening students' content knowledge. The results demonstrated that only students' active engagement in interrogative SSMR is significantly positively related to students' performance. This finding appears to confirm the importance of 'challenge' during collaborative learning (Koivuniemi et al. 2018; Järvelä et al. 2013) or elaborative thinking (Khosa and Volet 2014; Näykki et al. 2017) for promoting students' knowledge comprehension. It seems plausible to assume that disagreeing with alternate perspectives on the organisation and the content of collaborative learning during critical discussions with a majority of group members (i.e. during interrogative SSMR) and aiming for compromise afterwards, not only encouraged students to question and elaborate upon each other's contributions (Iiskala et al. 2011), but also created the opportunity to restructure or deepen one's knowledge comprehension. In its turn, this might have enhanced students' performance on the cued recall knowledge test. The finding that progressive SSMR, which is equally characterized by elaborative exchanges among collaborative learners, was not related to students' performance, could be due to the fact that its frequency of occurrence was too limited to be unravelled as a significant predictor. Further, it could be assumed that affirmative SSMR, during which a subgroup of peers is mainly paraphrasing each other's contributions in order to continue ongoing learning and regulation, provided less opportunity to rethink one's comprehension but rather resulted in quick consensus building or confirmation of one's content knowledge (Khosa and Volet 2014; Näykki et al. 2017). This might explain why students' involvement in affirmative SSMR was not significantly related to their performance. Last, given that interfering SSMR generally comprises of rather meaningless exchanges among few collaborative learners, which do not impact successive collaborative learning activities, it should not be surprising that this type of SSMR negatively contributed to students' performance.

Implications for educational practice

The current findings not only advance the literature on shared regulation, but also provide teachers and lecturers with relevant insights on collaborative learners' regulation behaviour. By unravelling variations in SSMR, the present study makes it clear that collaborative learners engage in shared regulation for diverse purposes. This implies that teachers or lecturers should not necessarily aim at maximising the frequency of occurrence of SSMR in itself, but rather at identifying which variations of SSMR students do/do not engage in, especially since only interrogative SSMR appeared significantly positively related to students' performance. Consequently, teachers or lecturers should aim at scaffolding the collaborative learning process in such a way that students are encouraged to question each other's thinking and to elaborate upon each other's contributions when trying to overcome the challenge/impasse that was created when confronting diverse perspectives on how to interpret learning content or how to organise the collaborative learning process. In order to stimulate collaborative learners' involvement in interrogative SSMR, teachers or lecturers could, for example, provide collaborative learning groups with open assignments that allow discussions regarding multiple problem solving options; or design collaborative learning environments in which students are given roles, demanding them to ask critical questions, or in which metacognitive scaffolds (or metacognitive agents in computer-supported collaborative learning) are integrated which trigger students to consider, discuss, or adopt and share regulation strategies.

Limitations of the present study and suggestions for future research

Whereas the present study advances our understanding of the multifaceted nature of SSMR, it reflects some limitations as well.

Specific research setting Although the cluster variables included in the present study might be transferable to alternate collaborative learning settings that put forward other learning objectives or that are based on other design principles, it should be acknowledged that the differences between events of SSMR in the current study are based on detailed analyses of shared regulation processes in a particular study setting (i.e. face-to-face RPT with university students, aimed at knowledge co-construction). There is, consequently, a need for validating the conceptualisation of interrogative, affirmative, interfering, and progressive SSMR in a variety of collaborative learning contexts in future research. It would be interesting to investigate whether SSMR is equally heterogeneous in other collaborative learning formats (e.g. inquiry based learning, collaborative writing, computer-supported collaborative learning, etc.) or when involving different learners (e.g. primary school students with less experience in regulating learning) in future studies. Additionally, it should be mentioned that SSMR demonstrated in the current study was predominantly directed at jointly monitoring comprehension and progress within the collaborative learning group. This could be due to the learning objectives of the RPT-intervention that were directed at deepening students' understanding of domain-specific knowledge regarding Instructional Sciences. It remains, however, questionable whether the identified differences in events of SSMR could be confirmed during collaborative learning which pursues alternate learning objectives (e.g. design-based activities during STEM lessons, collaborative writing of argumentative texts) or when other regulation skills become shared much more frequently among collaborative learners. It would additionally be interesting to explore whether possible alternative characteristics of students' regulation processes can explain variations in SSMR. More fine-grained variations might be unravelled when taking into account, for example, the synergy among collaborative learners during SSMR (Rogat and Linnenbrink-Garcia 2011); the length of or the number of turns in events of SSMR, or the correctness of students' thinking during SSMR (Iiskala et al. 2015).

Process-oriented measures Further, the present study mainly concentrated on unravelling variations in SSMR, without comprehensively grasping the dynamics (e.g. activities, experiences, processes at the cognitive, regulative, or social level) that elicited or resulted from students' adoption of SSMR (Iiskala et al. 2015: Isohätälä et al. 2017). It remains therefore unclear which particular learning activities or experiences evoked SSMR or whether the four variations of SSMR revealed in the current study, are generally preceded or followed by other collaborative learning activities. Future research should preferably take a broader scope (e.g. including detailed coding and analysis of cognitive and social processes at play during collaborative learning) as well as adopt alternate data analysis techniques that provide us with insight into the dynamics of shared regulation during collaborative learning. Social network analysis or process mining techniques could, for example, visualise whether variations in SSMR are centred around different 'critical moments' or around particular students within the group, or whether different types of SSMR represent different sequences of cognitive and regulative exchanges (Iiskala et al. 2015; Isohätälä et al. 2019). Since students have demonstrated to be in need of time and practice before sharing regulation (De Backer et al. 2015), it would additionally be interesting to investigate whether similar evolution patterns can be discerned for their adoption of interrogative, affirmative, interfering, and progressive SSMR as well. Given that thought-provoking triggers or elaborative exchanges might first require a basic understanding of both content knowledge and how to productively learn collaboratively (Volet et al. 2009), it could for example be that students' adoption of interrogative or progressive SSMR grows at a different pace as compared to their engagement in affirmative or interfering SSMR. Future research taking a developmental, process-oriented perspective on time-bound evolutions in collaborative learners' competence in/adoption of different types of SSMR would consequently be worthwhile (Rogiers et al. 2020).

Variables included in the research design Although students' regulation is generally influenced by characteristics of the learning setting (Isohätälä et al. 2019; Malmberg et al. 2017; Rogat and Linnenbrink-Garcia 2011), the potential impact of particularities of the group's collaboration or composition, or the RPT-setting, on students' involvement in the different events of SSMR was not taken into account in the present study. Neither did it acknowledge that individual learner characteristics could have been at play when student did/did not engage in particular variations of SSMR (Volet et al. 2017) Future research identifying the correlates of variations in SSMR is consequently needed. Accordingly, more insight is required in how and when to foster particular events of SSMR, by conducting effect studies on instructional interventions or scaffolding tools that aim to optimize students' SSMR (Järvelä et al. 2016; Malmberg et al. 2015).

Further, it should be noted that the performance measure included in this study was rather specific/narrow, given that it merely included individual RPT-participants' score on a cued recall knowledge test immediately after the last RPT-session. Alternative and more fine-grained outcome measures such as, for example, the correctness or completeness of co-constructed knowledge or students' ability to transfer (meta)cognitive processes that were adopted and trained during RPT, to other learning settings, might yield alternate findings on differences in events of SSMR and their relation with students' outcomes/performance after RPT. It should further be mentioned that the current study did not take into account peer tutors' increased prior knowledge (by being provided with a theoretical manual when preparing for taking the peer tutor role), as compared to tutees', when analysing the relation between students' involvement in variations in SSMR and their performance. Future studies should preferably include the administration of a prior knowledge test by PT-participants/collaborative learners, in order to control for potential a priori differences in students' understanding of the learning content that will be addressed in the PT-session and/or in a knowledge test after collaborative learning. Future studies should additionally take into consideration that the outcomes of collaborative learning for the group versus its individual members can vary considerably (Michinov and Michinov 2009). Effect studies on students' engagement in variations of SSMR should therefore preferably be directed at learning outcomes for both individual students and the collaborative learning group, implying the integration of performance measures on both the student and the group level. Furthermore, it should be noted that duplicating event-based codes on SSMR (decided upon based on multiple students' regulative exchanges) to students' metacognitive statements in order to determine individual students' involvement in variations in SSMR did probably not result in the most optimal measure of students' regulation as predictor of their performance. Future studies preferably include individual students' actual participation in SSMR (e.g. initiative taking for regulation versus reacting to regulative cues of fellow peers, the elaborative versus repetitive content of their metacognitive statements, operating as peer tutor versus tutee, …), when analysing the relation between regulation behaviour and individual performance.

Data analysis techniques Last, although the present study succeeded in unravelling variations in SSMR based on statistically testing the significance of cluster models by means of latent class cluster analysis, the limitations of the latter should also be acknowledged. Latent class cluster analysis provides multiple evaluative indicators (e.g. Log Likelihood, Bayes Information Criterion, Akake Information Criterion, *p* value, classification error, …) for selecting the appropriate number of *k* classes, which moreover do not necessarily appoint the same cluster model as best fitting to the data (Vermunt and Magidson 2003). Despite its model-based character, latent class cluster analysis still leaves the decision on the appropriate number of clusters up to some level open for interpretation by individual researchers. It is therefore recommended to test the stability and overall quality of the current four-cluster model on variations of SSMR, by replicating the study in a different sample. In line with this, it is recommended to enlarge the sample size, and particularly the number of level 2 units in future studies, in order to enable multilevel analyses with sufficient power.

Conclusion

By comparing characteristics of events of SSMR, the present study succeeded in unravelling variations in SSMR. Its findings refine current conceptualisations of shared metacognitive regulation and shed more light on the sometimes inconclusive findings regarding the effectiveness of shared regulation as well. This not only extends the literature on shared regulation, it also provides a novel theoretical base for developing a coding instrument that aims at identifying differences in shared metacognitive regulation in a variety of collaborative learning settings. Although more research is needed to advance our understanding of the outcomes and influencing factors of students' adoption of variations of SSMR, the current findings take the emerging research on SSMR an important step further. The present study further emphasises the place that SSMR takes in the broader collaborative learning process, by suggesting that variations in SSMR can serve multiple purposes during collaborative learning and are probably evoked at specific 'critical moments', which can differ among events of SSMR. This implies that, as researchers or instructors, we should not necessarily aim for students' increased adoption of SSMR at all times, but rather acknowledge the diversity within their shared regulative acts and aim at a better understanding of when and why variations in SSMR can optimise collaborative learning.

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Compliance with ethical standards

The study involved human participants. Active written informed consent was given by them prior to data collection. The study was conducted in accordance with the General Ethical Protocol of the Ethical Committee of the Faculty of Psychology and Educational Sciences at Ghent University, Belgium.

Conflict of interest The author's declare that they have no conflict of interest.

Appendix 1 Illustrations of the characteristics 'trigger for SSMR, 'level of elaboration in SSMR', and 'function of SSMR'

Trigger for SSMR	
factual trigger	*t1:* "We are asked to develop a discovery learning activity. It means it should be based on the constructivist guidelines the tutor just explained, right?" *t4:* "I guess… students should actively discover knowledge without much interference from the teacher. So that's constructivist-based not so?" *t2:* "Well there will be some guidance by the teacher, but that will take the form of hinting and scaffolding, not so? Certainly not strictly scripting students' learning, right?" T**:** "Yeah… that's right. Scripting is too restrictive to be considered constructivist."
thought-provoking trigger	*t2:* "I don't think our answer is sufficient. We only focussed on reducing students' extraneous cognitive load when constructing declarative knowledge, but the range of cognitivist constructs is much larger. I think we should also illustrate 'dual channel theory' and 'advance organiser' or at least all types of cognitive load." *t3:* "But we cannot integrate all theoretical constructs in our learning activity. I think our answer is sufficient, it's narrowly focussed but it can correctly be called an illustration of cognitivism, as was requested." *t4:* "Maybe we can just add a second illustration which is focussed more on procedural knowledge? What we have so far is correct, I think, but I do agree that we could have opted for more variation in the illustrations we provided." *t2:* "But even then the problem remains that our answer is too narrowly focussed. I agree with tutee #2. We didn't do anything with half of the theoretical concepts. So I really think our answer is currently of poor quality and even if we add an illustration based on procedural knowledge, it will still not be what the lecturer wants to read."
Level of elaboration in students' regulative reactions during SSMR	
continuer	*T:* "So far we have completed two subtasks and we still have 30 min. Remaining for evaluating the session. Maybe we can review our answer on the first subtask before we start evaluating, because tutee 3 felt it was incomplete?" *t4:* "Okay. Fine by me." *t2:* "Perfect!"
paraphrase	*T:* "This session is about instructional cognitivism. What do you know about it? Which concepts can you recall from the theoretical lecture? *t1:* "Extraneous cognitive load? Due to limited capacity of the working memory. And the importance of clear presentations?" *t2:* "Yes! Presenting information in keywords, schemes, and Mind Maps such that it becomes manageable and does not overload the working memory." *t5:* "Grouping information in chunks to avoid overload of the working memory. Working memory can handle seven chunks."
elaboration	*t2:* "Is the third statement not an example of scaffolding?" *t3:* "But the help is given by a computer-supported tool. And it concerns very strict instructions such that the student merely executes what the tool instructs. Isn't that more an example of the learning machines from instructional behaviourism?" *t5:* "I am not sure about the learning machines but I don't see scaffolding indeed. There is no discovery learning and was scaffolding not always aimed at discovery learning? But in statement 3 students don't decide what to discover, the tool does." *t1:* "And the tool immediately informs whether students' answer is right or wrong. I do think that is behaviourism. Something like feedback, contingent feedback, no?"
Function of SSMR in the collaborative learning process	
confirm CL	*T:* "I suggest that we check our final answer before closing the session." *t4:* "Good idea because I am unsure whether I sufficiently integrated all the things that we discussed in our answers. A final check to control for mistakes is needed." *t2:* "We can also check whether the answers are in line with the learning objectives." *t1:* "Is it okay if I start reading the objectives and then we check statement by statement whether our answer is correct and if something is missing?" *T*: "Okay, let's start."
activate CL	

	T: When I say 'assessment', then what is the first thing you are thinking about? Or what do you remember from the lecture last week?" *t1:* "Marking process and product." *t5:*"Summative versus formative. Assessment by the teacher, a peer, or oneself." *t3*: "It really helps to freshen up concepts that we have seen before. It helps me understand the new terminology." *T*: "On top of that, I think it is also good to think about how we solved the previous session, which went smoothly. I think that was because we took time to explain and fully grasp the theory before making the assignment." *t4*: "For me it was also helpful that each of us was given a different concept by the peer tutor and was asked to come up with an example of our own at the end of the session." *t5*: "Yeah, it would be good to include such an exercise in this session as well."
slow down CL	*t2:* "In the fourth example the teacher makes use of portfolio-based evaluation. We said that it was formative assessment. I am not sure but isn't it also process evaluation?" *t4:* "I don't think so because the portfolio implies interim evaluation but it is still focussed on the outcomes. So I would think that it is an example of product evaluation… on a formative base. No?" *t3:* "I'm not sure … but your explanation makes sense. The portfolio doesn't shed light on the learning process, does it? So it would be strange to call it process evaluation, not so?" *t2:* "I mistakenly assumed that formative assessment and process evaluation are the same, but I guess they are not. The portfolio indeed evaluates the learning products. So we stick to our answer that it is an example of formative product assessment?" *t3:* "I would do so."
change CL	*T*: "Let's first summarize why some of us think that rubrics are behavioristic and why others think they are not." *t2*: "Rubrics operationalize behavior in small steps. And small steps, operational learning objectives are behavioristic, not so? *t4*: "But they are used as formative assessment techniques, not so? That why we think that they are constructivist." *t1*: "I really think that we should end this conversation. We have few time left for the remaining of the session and on top of that, we are now discussing something which will not even be included in our answer. The question was whether the illustration meets the standards of a good rubric. *t5*: "I actually agree with tutee #1. It is interesting to gain deeper insight and to elaborate on the items that are mentioned in the questions but we should focus on solving the questions and writing down our answers to the questions. The assistant will evaluate our work based on our answers and our report, not on the discussions we have here." *t3*: "That's right. Let's move over to the next sub-task instead of continuing this discussion."
stop CL	*[T, t1, t2, and t3 are discussing their conflicting understanding of the concept direct instruction']* *t4:* "I think we should continue with the last sub-task. We only have 15 min left." *t3:* "Is it already that late?" *t5:* "Uhum." *t3:* "Okay then." *[T, t1, t2, and t3 heard the comments by their group mates but continue their discussion]*

Note: T = tutor, t = tutee, CL = collaborative learning. Although the examples in A frequently concern events of SSMR that are initiated by the peer tutor, it should be noted that only 36.2% of the events of SSMR segmented in the present study is tutor-initiated whereas 63.8% is tutee-initiated

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