Socially shared metacognition of dyads of pupils in collaborative mathematical problem-solving processes

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Abstract

This study investigated how metacognition appears as a socially shared phenomenon within collaborative mathematical word-problem solving processes of dyads of high-achieving pupils. Four dyads solved problems of different difficulty levels. The pupils were 10 years old. The problem-solving activities were videotaped and transcribed in terms of verbal and nonverbal behaviours as well as of turns taken in communication (N = 14,675). Episodes of socially shared metacognition were identified and their function and focus analysed. There were significantly more and longer episodes of socially shared metacognition in difficult as compared to moderately difficult and easy problems. Their function was to facilitate or inhibit activities and their focus was on the situation model of the problem or on mathematical operations. Metacognitive experiences were found to trigger socially shared metacognition.

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1. Introduction

This article aims to contribute to the still scarce evidence available on the social nature of metacognitive regulation of joint efforts in a collaborative problem-solving process, and to offer systematic means to operationalise and analyse shared regulation. The need and the rationale for studying social regulation are based on the view that the group is a social system (Vauras, Salonen, & Kinnunen, 2008), a qualitatively different entity from individuals working side by side, but on their own (Salomon & Globerson, 1989). Social regulation cannot be reduced to the group members’ individual characteristics such as self-regulatory activities, rather inter-relational characteristics and functioning are needed in order to understand group dynamics as a complex situational interplay across different systemic levels (Volet, Vauras, & Salonen, 2009). Both the self and social forms of regulation (other- and co-regulation) are needed in order to understand regulation of actual collaborative learning processes. In other words, the manifestation of inter-individual metacognition is not equivalent to individual metacognition, and should be conceptualised differently (Iiskala, Vauras, & Lehtinen, 2004; Vauras, Iiskala, Kajamies, Kinnunen, & Lehtinen, 2003). In addition to the generic term “co-regulation” (McCaslin, 2009; Volet, Summers, & Thurman, 2009; Volet, Vauras, et al., 2009), we have introduced the concept “socially shared metacognition” (or “shared regulation”) to refer to the consensual monitoring and regulation of joint cognitive processes in demanding collaborative problem-solving situations (Iiskala et al., 2004; Vauras et al., 2003). Socially shared metacognition can be considered the most profound social mode of regulation, because it refers to individuals’ metacognitive processes that operate as a genuine social entity, aimed at a single objective, that is, the fully shared goal of the activity (Volet, Vauras, et al., 2009).

However, despite growing agreement on understanding regulation as both an individual and a social process (see, e.g.,...
McCaslin, 2009; Nolen & Ward, 2008; Volet, Vauras, et al., 2009), empirical evidence on social regulatory processes pertaining to higher order learning is scarce and insufficient compared to the extensive conceptual analyses and empirical studies on individual metacognition for more than 30 years, starting from the seminal work of John Flavell and Ann Brown in the 1970s and 1980s (Brown, 1978, 1987; Flavell, 1976). In these studies, sophisticated operationalisations and methods to study individual metacognition have been introduced. However, the study of metacognition as a social phenomenon is characterised by a lack of clear operationalisation and methods of data analysis. The case studies of Iiskala et al. (2004) and Vauras et al. (2003) have clearly demonstrated that it is possible to distinguish social regulation processes from individual ones in collaborative learning contexts. To understand the functions and fluctuations of self- and social regulation in collaborative contexts, reliable methods to identify and analyse socially shared metacognition within large data sets of interactions are urgently needed. The main aim of the present study was to investigate whether and how this can be done, and to present a detailed analysis of the functions and foci of socially shared metacognition. This was studied by analysing high-achieving dyads’ collaborative mathematical problem-solving processes.

1.1. Shifting from individual to social processes in metacognition research

Metacognition has traditionally been understood as a person’s own knowledge about cognition and the regulation of cognitive processes (Brown, 1978, 1987; Flavell, 1976). Although the focus has been on an individual’s learning, early metacognition studies already referred to social aspects such as social interaction, social context, communication and role-taking as facilitators of metacognition (Brown, 1978; Brown & Palincsar, 1989; Flavell, 1976, 1979). Metacognitive regulation (i.e., regulation of cognition, see Brown, 1987; metacognitive skills, see Brown & DeLoache, 1983) refers to the executive processes which consist of activities used to oversee one’s learning. These kinds of activities comprise, for example, planning, identifying the problem demands, revising problem-solving strategies, monitoring ongoing activity, evaluating and criticising the learning material, reality testing, predicting the consequences, and checking outcomes (Brown, 1978, 1987; Brown & DeLoache, 1983; see also Efklides, 2006; Veenman, 2005). Thus, in most of the studies, metacognition has been treated mainly from an individual’s standpoint, and social processes have been seen as context variables which facilitate learning in individuals.

However, it is widely agreed that learning is not merely an individual process. A more complete picture of learning can be achieved when social and cultural aspects are taken into account (Lehtinen, 2003; Resnick, Levine, & Teasley, 1991; Salomon & Perkins, 1997; Vauras et al., 2008; Volet, Vauras, et al., 2009). Metacognitive reflection can be seen as the product of interaction between a person or persons and a surrounding context (see Hacker & Bol, 2004; Volet, Vauras, et al., 2009). Thus, in order to be adaptive, metacognition needs to be sensitive to contextual and situational factors; that is, metacognition needs to be conceived as being embedded in a social context (Efklides, 2009). For this reason, researchers of metacognition have increasingly begun to consider metacognition as a process which is both individual and social in nature (e.g., Efklides, 2008; Goos, Galbraith, & Renshaw, 2002; Hacker & Bol, 2004; Hogan, 2001; Iiskala et al., 2004; Jermann, 2004; Salonen, Vauras, & Efklides, 2005; Vauras et al., 2003; Whitebread, Bingham, Grau, Pino Pasternak, & Sangster, 2007).

Nonetheless, research on metacognition in collaborative situations is still rather scattered. For example, different concepts have been used, such as collective metacognition (Hogan, 2001), socially mediated metacognition (Goos et al., 2002), and socially shared metacognition (Iiskala et al., 2004). Despite the varying labels, the need for broadening the traditional view of metacognition from individual processes to collaborative ones can be seen. The same shift in emphasis is seen in more general views on regulation of learning, where the focus has been extended to co-regulation of multiple processes—including cognitive, motivational, and emotional aspects of regulation—in collaborative contexts (Salonen et al., 2005; Volet, Summers, et al., 2009; Volet, Vauras, et al., 2009).

1.2. Metacognitive regulation in high-level collaborative processes

The term “high-level collaborative processes” refers to the co-construction of meaningful knowledge and understanding in which the members of a group not only share information but are also engaged in representing each other’s mental activities used to process content knowledge (Volet, Summers, et al., 2009). Thus, in high-level collaborative processes one can find, for example, sharing of speculations, of justifications, of inferences, or of identified relations—rather than just sharing information or exchanging ideas, clarifying understanding or providing definitions without evidence of transformation or integration of the other’s mental representations with one’s own (Volet, Summers, et al., 2009; see also King, 1998). In collaborative problem-solving, groups in which participants monitor their own and their peers’ thinking seem to have an advantage over groups who do not (see Goos et al., 2002; see also Hurme, Palonen, & Järvelä, 2006). For example, Goos et al. (2002) have found very little difference in the proportion of metacognitive statements in successful versus unsuccessful problem-solving processes of small groups. Instead, differences were found in the proportions of transactive discussions, indicating that in unsuccessful problem-solving there was lack of critical engagement in monitoring each other’s thinking. This finding seems to imply that in studying the quality of high-level collaborative processes, individual metacognitive events are not so critical as the constellation of shared or transactive ones at the social level. This is what the notion of distributed expertise denotes (see Brown et al., 1993); that members of a community...
critically depend on each other, and meaning is negotiated as members of the community share their expertise.

High-level collaborative processes are more likely to occur in situations where the peers are at roughly the same proficiency level and are able to carry out similar actions, share a common goal and work together (Dillenbourg, 1999). Thus, high-level collaborative processes in learning situations differ from other-regulation of one’s learning, that is, from situations in which learning is fostered by a supportive other (see Brown, 1987; Pata, Lehtinen, & Sarapuu, 2006). On the contrary, interactivity, synchronicity and negotiability among the peers, as well as grounding and mutual modelling, characterise collaboration (Dillenbourg, 1999). In the same vein, Roschelle and Teasley (1995) regard a joint problem space as central to collaboration, that is, a shared knowledge structure supports problem-solving activity and integrates goals, description of the current problem state, awareness of available problem-solving actions and associations that relate to goals, features of the current problem state, and available actions.

The ability to understand the other’s thinking and its interpretative framework is also important as studies (Iiskala et al., 2004; Jermann, 2004; King, 1998; Salonen et al., 2005; Vauras et al., 2003) have shown that students give signals to their partner, for example, if they are not ready to move on in the process of problem solving. These signals are of a metacommunication nature and are present at a verbal and/or nonverbal level (e.g., glances, gestures) when partners coordinate their behaviours in interaction (Branco, Pessina, Flores, & Salomão, 2004). Nonverbal behaviour has been found to be important for shared regulation activity, for example, when a child draws his or her peers’ attention to an object that might be used to accomplish a mutually-agreed goal (Whitebread et al., 2007). However, it is not sufficient to examine only what kind of collaborative processes can be conceptualised as metacognitive. It is also crucial to identify the role of metacognition in collaborative learning processes and social regulation. Hogan (2001) found that in collaborative learning conceptual discussions, in which students talk about their ideas, arise mainly before or after metacognitive episodes.

1.3. Metacognitive experiences in collaborative processes

Metacognitive experiences (Flavell, 1979) are defined as a person’s subjective cognitive or affective experiences that monitor and inform a person about a feature of cognitive processing in relation to the task at hand (Efklides, 2001, 2006). They consist of metacognitive feelings, judgments/estimates and online task-specific knowledge (Efklides, 2006). Metacognitive feelings — such as feeling of familiarity, feeling of difficulty, feeling of knowing, feeling of confidence, and feeling of satisfaction — have a quality of pleasantness or unpleasantness (Efklides, 2001, 2006). They have an affective character, unlike metacognitive judgments/estimates which are cognitive in nature (Efklides, 2001). Both metacognitive feelings and metacognitive judgments/estimates — such as judgments of learning, source memory information, and estimates of effort or time — monitor features of task processing and the person’s response to it (e.g., lack of fluency in task processing that triggers feeling of difficulty and awareness of effort invested to restore fluency). On the other hand, online task-specific knowledge — such as awareness of task features and procedures employed — is task-driven, meaning that it focuses on the task rather than on the person’s response to the processing of the task (Efklides, 2006).

Metacognitive experiences, according to Efklides (2006, 2008), can be seen as an essential component not only of self-regulation but also of co-regulation in a collaborative learning situation, because although they are private events — inner subjective experiences one has — their manifest expressions (e.g., verbal expressions or frowning when experiencing feeling of difficulty) provide information to the partner regarding the quality of cognitive processing and progress towards the shared goals. Thus, in joint activity, metacognitive experiences may offer important information to the self and to the others and, therefore, have an impact on one’s cognition, as well as on the cognition of others (Efklides, 2006, 2008). Moreover, metacognitive experiences may trigger metacognitive regulation processes (Efklides, 2001, 2006, 2008; Flavell, 1979) addressed to the self and to the others such as exchanging thoughts, prompts, and clues (Salonen et al., 2005). Correspondingly, the evidence (see Salonen et al., 2005) also implies that misperception of the interacting partners’ metacognitive experiences may lead to failure in collaboration. However, the role of observable expressions of metacognitive experiences in the collaborative process, and especially in shared regulation, is still an empirically unexplored area.

1.4. Metacognition and task difficulty

Previous research has emphasised the importance of metacognition in mathematical problem-solving both in individual (Desoete & Veenman, 2006; Schoenfeld, 1987) and in collaborative problem-solving situations (Goos et al., 2002). Task difficulty is considered as an important factor in the elicitation of metacognitive processes, and mathematical problem-solving offers a domain in which task difficulty is relatively straightforward to control and manipulate. Metacognition is more likely to manifest during novel and reasonably difficult tasks. Prins, Veenman, and Elshout (2006) showed that metacognitive skills were activated by advanced learners in complex tasks where the learners were still operating within the boundaries of their knowledge. This was not the case in easy, or in extremely complicated tasks. In regard to metacognitive experiences, Efklides, Papadaki, Papantoniou, and Kiosseoglou (1998) found that objective task difficulty (e.g., computational complexity) affected the perceived intensity of metacognitive experiences and also the relations between metacognitive experiences and performance. The relationship between feeling of difficulty and task performance was significant in moderately difficult tasks but non-significant in very easy or very difficult tasks.
In collaborative contexts, the results of the case studies by Iiskala et al. (2004) and Vauras et al. (2003) similarly suggest that metacognition tends to emerge and to be socially shared more frequently in difficult problem-solving tasks than in easy tasks. There is no obvious need to collaborate in easy tasks—these can be rather routinely carried out. In general, previous research suggests that in order for metacognition to have an optimal effect, tasks should be located just beyond the point where a person functions proficiently independently, that is, in the "region of sensitivity" or "zone of proximal development" (ZPD) (Vygotsky, 1978). In collaborative contexts, we can talk about "collaborative ZPD" (Goos et al., 2002) which refers to a phenomenon where peers mutually attempt to challenge and coordinate their actions and views on a problem in order to progress. However, there is hardly any empirical evidence on the manifestation of metacognition at different task difficulty levels where collaborative processes are involved.

Task difficulty is a factor related also to the focus of metacognition. Specifically, the nature of task difficulty determines the point at which it is necessary for the person to regulate cognitive activities. For example, task difficulty may be topical (e.g., an operational or computational issue) or more general regarding the representation of the problem space and the formation of a situational model (van Dijk & Kintsch, 1983; see also, Cummins, Kintsch, Reussner, & Weimer, 1988). In their original model, van Dijk and Kintsch (1983) proposed that text comprehension goes beyond the analysis of propositions presented in the text (textbase) and requires the construction of a situation model (van Dijk & Kintsch, 1983; see also, Cummins, Kintsch, Reussner, & Weimer, 1988). In their original model, van Dijk and Kintsch (1983) proposed that text comprehension goes beyond the analysis of propositions presented in the text (textbase) and requires the construction of a situation model, which integrates existing world knowledge with information derived from the text. Cummins et al. (1988) did show that in complex mathematical word problems the straightforward formulation of mathematical operations on the basis of a problem text is not enough; first a situation model has to be constructed. Thus, in studying socially shared metacognition in mathematical word-problem solving it is important to take into consideration task difficulty, that is, to identify whether and when task difficulty impacts the socially shared metacognitive activities. Furthermore, it is important to distinguish the focus of metacognitive processes, that is, whether they refer to the formation of the situation model or to specific operations.

Finally, the function of socially shared metacognition has to be delimited. Specifically, as metacognition is the monitoring and control of cognition (Flavell, 1979), socially shared metacognition should play a similar role but in a way that impacts the shared problem space and the shared cognitive processes applied to the problem at hand. That is, the function of socially shared metacognition is to facilitate the building of a shared representation of the problem by confirming the consensually reached one or to activate processes that can lead to one. Another function of socially shared metacognition could be to execute control processes, namely to inhibit inappropriate conceptualisations or representations of the problem and to turn attention to others.

1.5. The present study

The focus of the present study was on socially shared metacognition in dyads of high-achieving pupils collaborating on mathematical word-problem solving processes. The aim was to explore whether episodes of socially shared metacognition can be reliably identified in pupils’ collaborative problem-solving interactions. Previous case studies by Iiskala et al. (2004) and Vauras et al. (2003) demonstrated that, in collaborative processes, it is possible and conceptually even necessary to identify distinct episodes which indicate genuine socially shared metacognition and which, therefore, cannot be reduced simply to individual-level self-regulatory processes (cf. Volet, Vauras, et al., 2009). Four main research questions were posed.

First and foremost, is the question of whether there are episodes of socially shared metacognition during collaborative problem-solving processes. Based on the previous case studies (Iiskala et al., 2004; Vauras et al., 2003) it was expected that there would be such episodes in collaborative problem-solving. Moreover, the prediction was that the frequency of such episodes will vary according to task difficulty. Therefore, the hypothesis was that there will be more episodes of socially shared metacognition in problems of more difficulty as compared to easy problems (Hypothesis 1).

The second research question regarded the function of socially shared metacognition, that is, its role in the collaborative problem-solving process. Based on considerations of the role of metacognition in the regulation of cognition, the hypothesis was that the function of socially shared metacognition is to facilitate a shared representation of the problem or inhibit activities that are not conducive to reaching a shared solution to the problem (Hypothesis 2). However, due to lack of prior research on the conditions that facilitate or inhibit shared regulation no hypothesis was formulated on when exactly during the collaborative problem-solving process and at which level of task difficulty the facilitating or inhibitory role of socially shared metacognition will manifest.

The third research question concerned the initiation of socially shared metacognition episodes. Based on previous research (Cummins et al., 1988) the hypothesis was that the focus would be either on the situational model or on the operations to be applied in the problem-solving process (Hypothesis 3). However, again due to lack of data, no hypothesis was formulated on whether the easy, the moderately difficult, or the difficult problems would favor the focusing on the situational model as compared to the operations.

The last research question concerned the initiation of episodes of socially shared metacognition, that is, whether metacognitive experiences are present at the beginning of the episodes. Specifically, whether the episodes start with observable expressions of metacognitive experiences. Based on previous research (Efklides, 2006, 2008; see also Efklides, 2001; Flavell, 1979; Salonen et al., 2005) the hypothesis was that metacognitive experiences would be present in the beginning of episodes of socially shared metacognition (Hypothesis 4).
2. Method

2.1. Participants

Eight pupils, that is, four high-achieving dyads (two girl and two boy dyads) participated in the study. The average age of the pupils was 10 years and 3 months at the beginning of the problem-solving sessions. The eight high-achieving pupils were selected from among 393 fourth graders who were following the regular national curriculum. High-achieving pupils were selected (for selection criteria see subchapter 2.2) because metacognition is typically seen as a sign of high-level thinking (see Meichenbaum & Biemiller, 1998). Thus, the high-achieving pupils were assumed to have the possibility to use metacognition in collaborative mathematical word-problem solving. The selected participants attended an urban primary school that could be described as mainstream in terms of its teaching and learning environment; that is, pupils did not have extensive experience of collaboration in school work. Their parents and teachers gave written consent for them to take part in the study, and the pupils themselves were willing to participate.

2.2. Selection criteria

The eight participants were selected on the basis of the two main screening measures (mathematical word-problem solving and reading comprehension tests; see measures below), which were administered to the whole classes. All the selected pupils ranked in the top 11% of their schoolmates and performed approximately at the same level in the two measures. Mathematical word problems and a reading comprehension test were used as selection measures because of the importance of metacognition in mathematical problem solving (De Corte, Verschaffel, & Op’t Eynde, 2000; Desoete & Veenman, 2006) and in reading comprehension (Annevirta, Laakkonen, Kinnunen, & Vauras, 2007; Garner, 1987; Kinnunen & Vauras, 1995; Paris & Jacobs, 1984).

2.2.1. Mathematical word problems

There were 23 one- and multi-step mathematical word problems (see Kajamies, Vauras, & Kinnunen, in press), which were based on problem types identified in earlier studies (Verschaffel, Greer, & De Corte, 2000). These problems demand consideration of the reality of the situation described and many of them cannot be solved by using straightforward arithmetic operations. The total number of correct solutions was used as an indicator of performance on mathematical word-problem solving. The Kuder-Richardson (KR-20) coefficient of internal consistency for this measure was .76.

2.2.2. Reading comprehension

Reading comprehension was assessed with the Finnish Standardized Reading Test (Lindeman, 1998). The pupils were given 24 multiple-choice questions on two texts they had read. The sum of the scores ranged from 0 to 24. The total number of correct choices was used as an indicator of the pupil's reading comprehension. The Kuder-Richardson (KR-20) coefficient of internal consistency for the test was .87 (Lindeman, 1998).

2.3. Collaboration environment

The dyads were formed with pupils of the same gender from the same school. Thus, the pupils within a dyad already knew each other. They worked in the computer-supported, game-format mathematical learning environment “Quest of the Silver Owl” (QSO; Vauras & Kinnunen, 2003; see also Kajamies et al., in press). The study took place in a separate room in the school. The four dyads solved altogether 251 mathematical word problems during 56 sessions. Each dyad solved from 49 to 72 mathematical word problems during 14 sessions, which lasted 30–45 min each and took place twice a week. Furthermore, before the testing sessions, two sessions were used to acquaint the dyads with the game rules and context. Some implicit sets of executive decisions, which were assumed to require metacognitive regulation, were built into the game (cf. Perkins, 1993). These included requirements about writing the solution in a specific form on the screen, that is, expression(s), solution, and unit. For example, the pupils were required to identify the demands of the problem. The game structure and goals, an adventurous frame story, freedom of choice in the selection of task difficulty, free pacing, multiple feedback on progress, and an attractive graphic environment, were designed as the main motivational incentives.

The dyads solved mathematical word problems of five, a priori determined, different difficulty levels, and the more difficult the problem was, the more points could be obtained. A variety of one- to multi-step problems was used (for details, see Kajamies et al., in press). All problems included information that was not necessary for solving the actual problem, and consideration of the reality of the situation described was important to solve the word problems successfully (see Verschaffel et al., 2000). Typically, the dyad chose the difficulty level of the problem it wanted to work on, although the most difficult problems were not available until a certain level of points had been earned. The 251 problems were categorised according to three difficulty levels for analysis, that is, 47 easy, 79 moderately difficult, and 125 difficult problems (see Appendix A for example mathematical word problem for each difficulty level). The easy level consisted of one-step addition, subtraction, multiplication and division problems. The moderately difficult level consisted of two-step addition, subtraction, multiplication, division problems and combinations of them as well as rectangular area, conversion (e.g., litres into decilitres), and Cartesian product problems. The difficult level comprised three- to four-step addition, subtraction, multiplication and division problems as well as combinations of them. It also comprised triangular area and transitive reasoning problems where the correct solution of the problem was not necessarily the result of the calculation but, for example, rounding off might have been needed.
Collaboration between the pupils in the dyads was emphasised, and the involvement of the tutor (the first author) was minimal to make room for peer collaboration, and to increase opportunities for the dyad to be aware of, to monitor and to regulate the collaborative problem-solving process. Within the sessions, there were no time restrictions on how long dyads could spend on a problem. All problem-solving sessions were videotaped by applying a mixer, which made it possible to get a synchronised picture of the computer screen and the upper bodies of the dyad.

2.4. Data analysis

The verbal transactions of the dyads were transcribed word for word, and nonverbal communications (e.g., eye contact, a pupil’s pointing his/her finger at the computer screen) were noted. In transcription, pupils’ communication within the dyad was denoted in terms of turns. A turn was defined as the pupil’s verbal comment or concrete action on the computer screen (e.g., writing or erasing the calculation, clicking the “Ready” button to show that the calculation is ready) until the other pupil took a turn writing on the computer or joining the other pupil’s turn (e.g., the pupils count in unison). A total of 14,675 turns were numbered and the nonverbal communication was attached in parenthesis to the numbered turns (e.g., a pupil’s nod, pupils look at each other). When possible, nonverbal communication was used to confirm specific actions (e.g., eye contact was used to confirm whether a pupil was looking at the other pupil and paying attention to him/her). Finally, in order to study socially shared metacognition, pupils’ turns within the dyad were analysed as a set of turns, that is, as an episode.

In an episode of socially shared metacognition, pupils had to jointly regulate a cognitive process towards a common goal. Hence, the dyad’s learning process — focusing on the problem and the mutual activity — had to proceed through both pupils’ regulatory involvement, so that the pupils’ reciprocal turns together affected the course of the process. Specifically, a first turn, that is, the starting point of the episode, was the trigger for the dyad to start regulating together—for example, the first turn revealed some information (e.g., cognitive or metacognitive) regarding the process and the other pupil reacted to this in his/her turn. In the process of data analysis, the first turn could be traced back after pupils’ reciprocal turns together indicated the presence of metacognitive regulation, that is, an episode of socially shared metacognition. The end of an episode was indicated by the turn in which pupils’ reciprocity in regulation ended; this was the last turn, that is, the jointly regulated process ended, meaning that the episode of socially shared metacognition ended. Everything in between the first and the last turn was considered part of the episode, meaning that within the episode there could be single turns which were not necessarily regulatory or reciprocal. Each episode had to involve a minimum of two turns but there was no upper limit to the number of turns included.

Each episode of socially shared metacognition was analysed in terms of function and focus. The function of the episode was classified according to whether it facilitated (activated, confirmed) or inhibited (slowed, changed, stopped) the dyad’s previous activity (see Table 1). The focus of the episode was classified into one of the following three categories, namely the situation model, the operation, or the incidental matter (see Table 2). The detailed function categories were data-driven and the focus categories originated from the models by Cummins et al. (1988) and van Dijk and Kintsch (1983).

The distinction of activities to cognitive or metacognitive was essential in identifying episodes of socially shared metacognition. A metacognitive activity was distinguished from a cognitive one based on the rationale by Nelson (1999) that metacognitive activity is one that either refers to or uses information from a cognitive activity or controls a cognitive activity by modifying it. Thus, the difference between metacognition and cognition was seen as relative rather than absolute (Nelson, 1999). For example, counting was defined as cognition, but the decision to check the result of the counting was defined as metacognition. Socially shared metacognition was also distinguished conceptually from other-regulation. In other-regulation, collaboration was seen as unbalanced; hence, it was assessed as an exchange of turns where one pupil

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilitate</td>
<td>The direction of the activity continues the same as previously and strengthens during the episode</td>
<td>—</td>
</tr>
<tr>
<td>Activate</td>
<td>Activating a new construct in line with previous direction</td>
<td>The dyad draws the problem on paper, analyses it and develops a model of the problem</td>
</tr>
<tr>
<td>Confirm</td>
<td>Confirming that the previous direction is correct</td>
<td>The dyad makes a decision to check the correctness of what it has previously done</td>
</tr>
<tr>
<td>Inhibit</td>
<td>The direction of the previous activity is interrupted during the episode</td>
<td>—</td>
</tr>
<tr>
<td>Slow</td>
<td>Slowing down a continuation of the previous direction</td>
<td>The dyad questions what it has done previously and continues doubtfully</td>
</tr>
<tr>
<td>Change</td>
<td>Changing the direction of previous activity</td>
<td>The dyad rejects what it has done previously and continues in a different way</td>
</tr>
<tr>
<td>Stop</td>
<td>Stopping the direction of previous activity but a new direction does not appear</td>
<td>The dyad reaches a dead end and does not decide how to continue</td>
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</tbody>
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Table 2
Focus of episodes of socially shared metacognition.

<table>
<thead>
<tr>
<th>Focus</th>
<th>Description</th>
<th>Example</th>
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<tr>
<td>Situation model</td>
<td>Attempt to regulate a situation model, cognitive representation of the events, actions, persons, or an analysis of the problem or different circumstances of the problem</td>
<td>The dyad discusses a real world situation outside the problem or the possible worlds (e.g., the fictitious world of the problem), draws on paper the givens of the problem, combines different circumstances to represent the whole problem</td>
</tr>
<tr>
<td>Operation</td>
<td>Attempt to regulate merely strategies or a local matter (e.g., of that moment) without considering the whole problem</td>
<td>The dyad discusses merely the mathematical operations without the situation model; the dyad may just decide to check whether its calculation is right or wrong but not whether the situation model has been constructed properly</td>
</tr>
<tr>
<td>Incidental matter</td>
<td>Attempt to regulate incidental or irrelevant issues</td>
<td>The dyad discusses whether it should write 90 cm or 90.0 cm even though it is not relevant in that case</td>
</tr>
</tbody>
</table>

supports and scaffolds another pupil’s learning process by directly regulating it. Furthermore, socially shared metacognition was conceptually differentiated from a metacognitive activity that was specific to one of the pupils, that is, when regulation was individual, located only in one pupil’s thinking and turns.

Finally, the presence of metacognitive experiences was examined at the starting point of the episode. The researcher coded whether the episode started with observable expressions of metacognitive experiences or not, and then the first turn of the episode was analysed. To classify the turn as a metacognitive experience, it had to refer (a) to feelings such as familiarity, difficulty, knowing, confidence or satisfaction; (b) to judgments/estimates such as judgments of learning, source memory information, estimates of effort or time; or (c) to online task-specific knowledge such as task features or procedures employed (Efklides, 2006). For example, turns like “We have had a rather similar problem earlier”, “This is an impossible problem”, or “This may be time-consuming to solve” represented metacognitive experiences, as did turns like “I’m confused...” or “I’m not sure if this is correct...”

2.5. Inter-coder agreement

After the principal coder had finished the coding process, a trained coder (a novice in metacognition research) was used to measure inter-coder agreement in 30% (n = 76) of the problems, which were randomly selected from each dyad and from each difficulty level. First, the second coder was asked to locate episodes of socially shared metacognition from the dyads’ problem-solving activities. The differences between socially shared metacognition, other-regulation, metacognitive regulation by only one pupil, and cognition had to be taken into account. In 23 problems, neither the principal coder nor the second coder found any episodes of socially shared metacognition. Each problem-solving activity of the dyad that was not categorised as episode of socially shared metacognition was counted as an agreement when both independent coders saw it as such. In the other 53 problems, episodes of socially shared metacognition were identified. In these problems the episode was counted as an agreement when both coders had identified the same episode as socially shared metacognition. The starting or ending turns of the episodes were not required to be exactly the same, but the exact location of the turn was negotiated if deemed necessary. A disagreement was counted when one coder had identified the episode as a socially shared metacognition but the other had not. At this first coding phase, the coders reached 86% (Cohen’s κ = .63) agreement; altogether 95 episodes of socially shared metacognition were acknowledged, and submitted to the next phase in the coding process.

Second, inter-coder agreement was also estimated by calculating the percentage of turns that both independent coders included in or excluded from the socially shared metacognition episodes in the randomly selected 76 problems (adapted from Volet, Summers, et al., 2009). Both coders agreed on 3030 of all 3502 turns, which represented 87% agreement. Disagreements emerged in situations where (a) one coder had identified a long episode and the other had identified many shorter episodes instead of one long one, (b) the exact starting or ending turn of the episode was different, or (c) one coder had identified the episode as a socially shared metacognition but the other had not.

Third, the second coder was asked to classify each episode of socially shared metacognition (n = 95) according to its function (activate, confirm, slow, change, stop) and focus (situation model, operation, incidental matter). The two coders reached 94% (Cohen’s κ = .87) and 98% (Cohen’s κ = .95) agreement, respectively.

Fourth, the second coder classified whether the episode started with observable metacognitive experiences (metacognitive experiences or not). An agreement of 96% (Cohen’s κ = .91) was reached. In all phases, the inter-coder agreement was no less than substantial (see Landis & Koch, 1977, p. 165), and the few disagreements were solved by negotiation.

3. Results

3.1. Examples of episodes of socially shared metacognition

Characteristic episodes of socially shared metacognition are illustrated with examples of coded data. The examples are labelled according to their function and focus category. In the examples, an episode of socially shared metacognition consists of a series of turns marked by arrows directed from a turn to the turn to which it responds (adapted from Sfard & Kieran, 2001). In the examples, turns which are not essential
for understanding the idea of socially shared metacognition are omitted from the episodes because of limited space.

### 3.1.1. Example 1: activate—situation model (see Fig. 1)

The dyad (pupils Sofia and Paula) is solving a moderately difficult problem (turns 794–861). In the problem, the dyad has to count how many different routes a boatman can row altogether (see in Appendix A the example of the problem of moderate difficulty). In the beginning of the episode, the dyad has no clear idea of the solution process. The first turns of the example episode (794 and 795) refer to a metacognitive experience (experience of difficulty, need to understand the problem) at least partly shared by the pupils. After that, the pupils exchange regulative verbal expressions and acts (796, 799, 800) which lead them to draw a model and to activate a situation model for the problem. Next, they check their mutual understanding of the drawings they had produced and the situation model (801, 802, 805, 806, 807, 808) and start to compute the number of roads again (811, 812, 816). Paula’s proposal (12 roads instead of the correct 48) triggers another metacognitive experience (817, 822) which results in new attempts to interpret the mathematical meaning of the situation model (825, 832, 835) and leads them to a correct understanding of the task.

In the example, the pupils activated a situation model together as a dyad, that is, they developed a cognitive representation of the problem by discussing the reality of the situation described, and by regulating the analysis of the problem by means of drawings. In this process, the pupils’ turns depended on the mutual dialogue, and they jointly and equally regulated cognitive processing towards their common goal by identifying the requirements of the problem and by monitoring the ongoing activity.

### 3.1.2. Example 2: confirm—situation model (see Fig. 2)

The dyad (pupils Joel and Oiva) is confirming a situation model in an easy problem (turns 2793–2802). In the problem, the dyad has to calculate the new record of the coachman

<table>
<thead>
<tr>
<th>No.</th>
<th>Sofia</th>
<th>Paula</th>
</tr>
</thead>
<tbody>
<tr>
<td>794</td>
<td>How is it even possible to count (looks at Paula) … but?</td>
<td>Hmm (thinking)</td>
</tr>
<tr>
<td>795</td>
<td></td>
<td>I draw here, two, three, four, five, six (glances at Sofia and begins to draw), nice one (smiles)</td>
</tr>
<tr>
<td>796</td>
<td>There are six (with emphasis) routes from the Ferry Bank</td>
<td>Here is Lake Beaver, the Beaver Fall (Sofia looks at the notebook)</td>
</tr>
<tr>
<td>799</td>
<td>How many routes, what, there’s a terrible number to count, so six, how can one go different routes, oh dear (begins to draw)</td>
<td>Oh, aah</td>
</tr>
<tr>
<td>800</td>
<td></td>
<td>This is the Middle Island (draws)</td>
</tr>
<tr>
<td>801</td>
<td>No, no, the Ferry Bank, silly (looks at the notebook)</td>
<td>Look now, six safe routes from the Ferry Bank to the Middle Island (points with her finger at the computer screen), from there, two routes to the Beaver Fall (both draw)</td>
</tr>
<tr>
<td>802</td>
<td></td>
<td>How many routes can the ferryman take? (Sofia looks at the notebook)</td>
</tr>
<tr>
<td>803</td>
<td>One, two, three, four, five, six</td>
<td>One, two, three, four (counts simultaneously with Paula from the notebook)</td>
</tr>
<tr>
<td>804</td>
<td></td>
<td>Four, five, six, seven, eight, nine, ten, eleven, twelve (counts from her own notebook)</td>
</tr>
<tr>
<td>805</td>
<td>What on earth are you doing, the Middle Island? (looks at the notebook)</td>
<td>Oh boy (smiles) …</td>
</tr>
<tr>
<td>806</td>
<td></td>
<td>Then it goes from here, then from here, and then from here, then it goes so, it goes here, then it goes, aah (both smile), then it goes from here</td>
</tr>
<tr>
<td>807</td>
<td></td>
<td>Two multiplied by six …</td>
</tr>
<tr>
<td>808</td>
<td>Okay, the Middle … (both draw)</td>
<td>Please count twelve multiplied by four</td>
</tr>
<tr>
<td>811</td>
<td></td>
<td></td>
</tr>
<tr>
<td>812</td>
<td>One, two, three, four (counts simultaneously with Paula from the notebook)</td>
<td></td>
</tr>
<tr>
<td>816</td>
<td></td>
<td></td>
</tr>
<tr>
<td>817</td>
<td>It can’t be so (looks at Paula)</td>
<td></td>
</tr>
<tr>
<td>822</td>
<td>But let’s look … (Paula looks at Sofia)</td>
<td></td>
</tr>
<tr>
<td>825</td>
<td></td>
<td></td>
</tr>
<tr>
<td>832</td>
<td></td>
<td></td>
</tr>
<tr>
<td>835</td>
<td>Awful (counts from the notebook and gives a laugh)</td>
<td></td>
</tr>
<tr>
<td>840</td>
<td></td>
<td></td>
</tr>
<tr>
<td>846</td>
<td>(stops counting from the notebook and looks at Paula) Forty-eight …</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1. Example 1 of an episode of socially shared metacognition.
when he drives at 20 m per second along a road which is 800 m long (see in Appendix A the example of the easy problem). The example episode describes the boys’ discussion at the end of the solving process when they have already written the correct answer (40 s) into the computer programme but have not yet confirmed it. They do not stop the solving process but reflect together on whether the solution (quite a fast record) is possible (2793, 2794, 2795) refers to a metacognitive experience. After that, the discussion refers to the activation of a situation model: horses can run fast (2796, 2797). Both pupils make complementary comments and the episode ends in agreement (2798–2802). Thus, the confirmation of the solution is a jointly regulated process.

In the example, together as a dyad the pupils confirmed the situation model that they had previously constructed, that is, the dyad saw a need to check the correctness of what it had previously been done by discussing the solution in relation to the fictitious world of the problem. In this process, metacognitive regulation was manifested when the dyad was testing reality, checking and evaluating the outcome as a consequence of the previously created cognitive representation of the problem. Both pupils are involved in the process and together, their reciprocal turns affected the course of the process.

3.1.3. Example 3: change—situation model (see Fig. 3)

The dyad (pupils Jonna and Titta) is working on a difficult problem. The dyad has to find out how many 2-m-long bridge planks can be sawn from six planks when each plank is 5 m long (see in Appendix A the example of the difficult problem). The dyad has already incorrectly solved the problem (6 × 5/...
2 = 15) and the solution is visible on the screen. During the episode (turns 909–932), the dyad changes its previous incorrect solution to the correct one. The first turns (909, 910, 911) show unpleasantness, which is a sign of metacognitive experiences. After Jonna’s doubtful thought (909), Titta also starts reflecting (910) and first repeats the incorrect direct numerical solution (912) but then starts thinking about the task in terms of a situation model (914). In the following turns (915–920), the dyad constructs a cognitive representation of the problem where the focus is on the situation model. On the basis of the model, they can easily compute the correct answer (921–932).

In the example, the pupils together as a dyad changed a situation model, that is, they changed the direction of their previous activity by rejecting how they had analysed the problem previously and by continuing in a different way. In this process, the dyad monitored and regulated its cognitive processing when it revised the cognitive representation of the problem. Activities such as evaluating the dyad’s own cognitive process, identifying the problem again, reality testing and deciding to change the situation model were carried out. The metacognitive experience was shared by the pupils and the subsequent process was jointly regulated by both of them. The pupils’ reciprocal and intertwined turns were needed for changing the situation model.

3.2. Frequency of episodes of socially shared metacognition

The frequency, that is, the number and length of episodes of socially shared metacognition within a problem was calculated. In total, 385 episodes were found in 187 (75%) problems out of all the 251 problems. Altogether 4295 (29%) of all the 14 675 turns were classified as belonging to episodes of socially shared metacognition.

The number of episodes per problem at the different difficulty levels was compared with the Kruskal–Wallis test with exact distributions (parametric assumptions were not justified). There was a significant effect of difficulty level, \( \chi^2(2, N = 251) = 47.37, p < .001 \) (see Table 3). The easy, moderately difficult, and difficult problems were also compared with the Mann–Whitney U-test applying the Bonferroni correction at alpha level .001. Post hoc comparisons confirmed that socially shared metacognition episodes were found significantly more often in the difficult than in the easy problems, \( U = 1349.0, p < .001 \), and in the moderately difficult problems, \( U = 2731.0, p < .001 \). There was no significant difference between the easy and the moderately difficult problems in this respect.

The Kruskal–Wallis test also indicated that the length, that is, the number of turns in episodes within a problem, differed significantly, \( \chi^2(2, N = 251) = 52.36, p < .001 \), between problems of different difficulty levels (see Table 3). Post hoc analyses confirmed that the episodes were significantly longer in the difficult than in the easy problems, \( U = 1064.5, p < .001 \), and the moderately difficult problems, \( U = 2806.5, p < .001 \). There was no significant difference in the length of episodes between the easy and the moderately difficult problems.

3.3. Function and focus of episodes of socially shared metacognition

The episodes of socially shared metacognition were categorised in the analyses according to their function and focus as already shown in subchapter 3.1. A cross-tabulation was used. Fisher’s exact test was performed instead of Pearson’s chi-square test because of small expected values in some of the cells.

There was a significant relationship between the function and the focus of the episodes, Fisher’s exact test (Monte Carlo method\(^1\)) = 83.66, \( p < .001 \) (see Table 4). Table 4 shows that in episodes of socially shared metacognition, the dyads’ activities mostly facilitated, that is, confirmed, operations. Furthermore, they confirmed and activated situation models and activated operations. Regarding inhibition, the dyads’ activities mostly changed the situation models, but hardly ever facilitated or inhibited incidental matters.

When the relationship between the difficulty level of the problems and the function of the episodes was investigated, a significant relationship was found, Fisher’s exact test = 18.85, \( p < .05 \) (see Table 5). Regarding the function of the episodes of socially shared metacognition at the easy level, the dyads did not activate their previous activity in the episodes but more often confirmed it. Furthermore, Table 5 shows that at the moderately difficult and the difficult levels, the dyads’ socially shared metacognition activated a line of reasoning, and at the difficult level, they slowed down continuation of a previous direction.

There was also a significant relationship between the difficulty level of the problem and the focus of the episode, Fisher’s exact test = 29.07, \( p < .001 \) (see Table 6). The dyads regulated incidental matters more often, and situation models less often, in the easy problems. By contrast, in difficult problems, the dyads’ regulation was focused more often on situation models and less often on incidental matters.

3.4. Metacognitive experiences as triggers of episodes of socially shared metacognition

The initiation of episodes of socially shared metacognition was studied, that is, whether episodes started with observable expressions of metacognitive experiences. Metacognitive experiences were found to be present at the beginning of 208 (54%) episodes. To investigate the metacognitive experiences in more detail, cross-tabulations and the chi-square test were performed. Cramér’s V correlation coefficient was used to test associations (see Siegel & Castellan, 1988).

There was a significant relationship between the presence of metacognitive experiences and the function of the episode, \( \chi^2(4, N = 385) = 20.68, V = .23, p < .001 \) (see Table 7). \(^1\) The Monte Carlo method was used because of computational demands.
When there were no observable metacognitive experiences at the beginning of the episode, the function of the episode was more often to confirm previous activity, and when there were observable metacognitive experiences at the beginning of the episode, the function of the episode was more often to change or stop previous activity.

A significant relationship was also found between the presence of metacognitive experiences and the focus of the episode, \( \chi^2(2, N = 385) = 20.31, V = .23, p < .001 \) (see Table 8). When there were no observable metacognitive experiences at the beginning of the episode, the episode focused more often on operations, while when there were observable metacognitive experiences at the beginning of the episode, the episode focused more often on situation models.

Finally, there was no significant relationship between the difficulty level of the problem and the presence of metacognitive experiences, \( \chi^2(2, N = 385) = 1.08, ns \).

### 4. Discussion

The aim of the present study was to examine metacognition in collaborative problem-solving processes, that is, to identify and investigate the nature of socially shared metacognition. According to the findings, it can be concluded that metacognitive experiences and regulation emerge in collaborative processes in a way that cannot be reduced to the individual level only. Besides activities indicative of individual-level metacognition or other-regulation, the interaction process data consisted of a substantial number of episodes which can be classified as socially shared metacognition. In these episodes, the participating pupils shared experiences that were triggered by their joint problem-solving process, and used regulatory processes which were metacognitive in nature. Socially shared metacognition by definition cannot be reduced only to individual expressions (or turns) of the problem-solving process; hence the unit of analysis used was collaboration episodes that involved at least two turns. This implies that socially shared metacognition can only be studied within a collaborative context at the dyadic or at the group level with a wider unit of analysis, such as an episode.

One of the main findings of this study was that socially shared metacognition episodes can be identified and classified in a highly reliable way by independent observers. Thus, according to the findings of the present study, it is possible, empirically and systematically, to identify socially shared metacognition from a large data set of collaborative processes. In other words, the pupils were able jointly to monitor and regulate a cognitive process towards a common goal. The dyad’s learning process proceeded through both pupils’ regulatory involvement so that the pupils’ reciprocal turns, focusing on the problem and the mutual activity, together affected the course of the process. Hence, the pupils’ reciprocal turns together formed an entity which represents metacognitive regulation.

A clear relationship was found between problem difficulty and the manifestation of socially shared metacognition. Episodes of socially shared metacognition were identified more often and were longer in duration in the difficult problems than in the easy and moderately difficult problems. This is in line with previous metacognition research (Iiskala et al., 2004; Prins et al., 2006) which has shown that metacognition becomes activated more in difficult problems. Thus, the first hypothesis, namely that there would be more episodes of socially shared metacognition in more difficult problems as compared to easy problems, was verified. This suggests that in order to reveal socially shared metacognition in a collaborative problem-solving process, the problems should be rather difficult and demanding for the participants. However, previous research (see Efklides et al., 1998; Prins et al., 2006) has suggested that extremely difficult tasks are not optimal for the

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### Table 3
Means, medians, and standard deviations of number and length (number of turns) of the episodes of socially shared metacognition within problems at the three different difficulty levels.

<table>
<thead>
<tr>
<th>Difficulty level</th>
<th>Number per problem</th>
<th>Length</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>Mdn</td>
<td>SD</td>
</tr>
<tr>
<td>Easy ( (n = 47) )</td>
<td>.79</td>
<td>1</td>
<td>.81</td>
</tr>
<tr>
<td>Moderately difficult ( (n = 79) )</td>
<td>1.01</td>
<td>1</td>
<td>1.19</td>
</tr>
<tr>
<td>Difficult ( (n = 125) )</td>
<td>2.14</td>
<td>2</td>
<td>1.74</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>Mdn</td>
<td>SD</td>
</tr>
<tr>
<td>Easy ( (n = 47) )</td>
<td>2.72</td>
<td>2</td>
<td>3.58</td>
</tr>
<tr>
<td>Moderately difficult ( (n = 79) )</td>
<td>13.46</td>
<td>3</td>
<td>38.21</td>
</tr>
<tr>
<td>Difficult ( (n = 125) )</td>
<td>24.83</td>
<td>12</td>
<td>50.35</td>
</tr>
</tbody>
</table>

* Min was zero when there were no episodes of socially shared metacognition in a problem.

---

### Table 4
Frequencies and (percentages) of episodes of socially shared metacognition in terms of function and focus.

<table>
<thead>
<tr>
<th>Focus</th>
<th>Function</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Activate</td>
<td>Confirm</td>
</tr>
<tr>
<td>Situation model</td>
<td>40 (10)</td>
<td>43 (11)</td>
</tr>
<tr>
<td>Operation</td>
<td>27 (7)</td>
<td>192 (50)</td>
</tr>
<tr>
<td>Incidental matter</td>
<td>0 (0)</td>
<td>6 (2)</td>
</tr>
<tr>
<td>Total</td>
<td>67 (17)</td>
<td>241 (63)</td>
</tr>
</tbody>
</table>

---

### Table 5
Frequencies and (percentages) of episodes of socially shared metacognition at the three different difficulty levels of the problems in terms of function.

<table>
<thead>
<tr>
<th>Difficulty level</th>
<th>Function</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Activate</td>
<td>Confirm</td>
</tr>
<tr>
<td>Easy ( (n = 37) )</td>
<td>0 (0)</td>
<td>33 (89)</td>
</tr>
<tr>
<td>Moderately difficult ( (n = 80) )</td>
<td>15 (19)</td>
<td>49 (61)</td>
</tr>
<tr>
<td>Difficult ( (n = 268) )</td>
<td>52 (19)</td>
<td>159 (59)</td>
</tr>
</tbody>
</table>
manifestation of metacognition. Therefore, extremely difficult problems, where the dyads would not be able to operate beyond the boundary of their capacity (see Prins et al., 2006; Vygotsky, 1978), were not included in the present study. The function and the focus of socially shared metacognition was also determined in the present study. The second hypothesis, that is, the function of socially shared metacognition facilitates or inhibits the dyads’ activities, was verified. Similarly, the third hypothesis, that is, the focus of socially shared metacognition would be on the situation model or on the operations, was verified. Socially shared metacognition episodes were rarely focused on incidental matters in the present study. Had there been frequent focus on incidental matters, it might have detracted the dyads’ attention, for example, from the situation model. Joint confirmation of conducted operations was the most frequently observed episode of socially shared metacognition. This may indicate a social process of feedback and this finding may be partly due to the nature of the problems used in the present study. Each problem had one correct solution and the dyads wanted to confirm the operations they had performed in the episodes.

It is also interesting that the dyads confirmed their previous activity more in the easy problems than in the other problems. Thus, relatively easy tasks seem to trigger rather narrow and simple forms of socially shared metacognition, in the sense of shared confirmation that the (sub)goal was reached because the operations used were appropriate and the outcome of the problem-solving process correct. Another aspect of confirmation as a feedback process to a joint activity is the confirmation that a possible operation (solution) can be implemented, that is, passing from planning to execution of the operation. In moderately difficult and difficult problems, confirmation of operations was also the most frequently appearing episode of socially shared metacognition, but the percentage of other kinds of episodes of socially shared metacognition was substantially higher than in easy problems; specifically, activating episodes were more frequent in difficult problems than in easy problems. Thus, getting the dyads to activate a joint construct, for example, to analyse a problem and develop a construction of the problem space together, does not seem to be needed in the easy problems. More importantly, in difficult problems, the episodes of socially shared metacognition did not only focus on simple operations; a large part of them focused on pupils’ attempts to formulate a general situation model beyond the given word problem. This is crucial in solving mathematical word problems. For example, Cummins et al. (1988) found that pupils’ miscomprehension of the problem (lacking or erroneous situation model) often caused solution errors, and the “errors” were, in fact, “correct answers” to miscomprehended problems. Thus, socially shared metacognition seems to be crucial when there is individual failure to formulate the situation model, and this is more probable to happen in difficult rather than in moderately difficult or easy problems.

Another important finding of the present study regards the nature of metacognitive experiences. The fourth hypothesis, that metacognitive experiences would be present in the beginning of episodes of socially shared metacognition, was verified. Although metacognitive experiences are individual subjective states, in some cases it seemed that they were shared by both pupils of the dyad. This is understandable as the same input (e.g., ineffective solution, lack of understanding the problem) was present in the collaborating pupils and triggered the same metacognitive experience at the same time. These shared metacognitive experiences seem to play a fundamental role in triggering episodes of socially shared metacognition, since over half of the episodes began with observable expressions of metacognitive experiences. This is in agreement with the assumption of Efklides (2006, 2008), who regards metacognitive experiences as important in the shared regulation of cognition because they provide information about the progress of cognitive processing. In the present study, when the episode of socially shared metacognition started with metacognitive experiences, the dyads regulated their previous activity by changing it and focusing on a situation model more often than in the episodes that did not start with metacognitive experiences. In these episodes, the function of socially shared metacognition was more often to confirm and the focus was on operations. Thus, individually or jointly experienced doubts about the dyad’s previous activity may act as a trigger for the pupils in the dyad to start to
question what they have done previously and to change their understanding of the problem. The finding that even an individual’s observable metacognitive experiences can trigger episodes of socially shared metacognition indicates that individual level metacognition and socially shared metacognition are not mutually exclusive but, instead, they may be intertwined. This relationship, as well as the relationship of an individual’s regulation and other-regulation with socially shared metacognition during the collaborative process, should be examined in depth. For example, a microgenetic analysis emphasising the relation between an individual’s metacognition, other-regulation and socially shared metacognition would be useful. Further, to encourage pupils to express during collaboration their subjective cognitive or affective experiences about cognitive processing regarding the task at hand may arouse a process of socially shared metacognition.

4.1. Limitations of the study

Socially shared metacognition was examined in the present study by relying only on the dyads’ ongoing and observable problem-solving activities, which means that some significant information regarding socially shared metacognition may have been missed. For example, De Grave, Boshuizen, and Schmidt (1996) state that verbal interaction reflects only part of the metacognitive processes on which it is based. Further, Veenman (2005) proposes a multi-method approach in studying metacognition. Besides verbal communication, like Whitebread et al. (2007, 2009), we took account of nonverbal behaviour to gain a more complete picture of socially shared metacognition. However, nonverbal behaviour is also open to various interpretations and therefore caution is needed. We have also conducted interviews, such as stimulated recall interviews. Taking into account the criticism against retrospective methods in the study of metacognition (Veenman, 2005), we have not reported the interview data in this article, but we regard it as important in the future to investigate the usefulness of stimulated recall interviews in studying socially shared metacognition.

Furthermore, although we described socially shared metacognition at the dyadic level within the mathematical word problem-solving in this study, it can be assumed that somewhat similar findings can also be found in small groups and in other contexts. However, more research is needed in other types of contexts. Finally, in the present study, the dyads consisted of high-achieving pupils but it would be interesting to study whether similar episodes of socially shared metacognition can also be found in average and low-achieving dyads’ problem-solving processes.

4.2. Conclusions

Based on the findings of the present study it is not possible to draw strong conclusions about how important socially shared metacognition is for the quality of collaborative problem-solving and learning. However, the evidence provided here opens the way for the investigation of the relations between socially shared metacognition and quality of problem solving; such a line of research is compatible with the literature on the features of productive and successful collaboration (Barron, 2003; Volet, Summers, et al., 2009). In the episodes of socially shared metacognition the dyads were able to correct an erroneous strategy or to create a needed situation model. However, in some of the episodes of socially shared metacognition the dyads reached a dead end and were not able to find an alternative strategy with which to approach the problem. More research is needed on the effects of socially shared metacognition on the quality of problem solving and learning.

Much problem solving and learning occurs in social situations, and social relations afford and facilitate these processes in many ways. However, previous research has mostly neglected to consider metacognition from the social point of view. On the basis of the findings of the present study, we propose that socially shared metacognition is a useful and justified concept which should be added to the conceptual tools of learning research.

Acknowledgements

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Appendix A. Example of mathematical word problem for each of the three difficulty levels

Easy problem

Although the coachman has often been forbidden to drive recklessly when he chauffeurs children to school, he gives in to the temptation to drive recklessly on his way back alone. One day, he got excited when he was on the road empty of traffic, and he drove his horses at full speed. Fallen branches and stones went flying as the coachman flew down the road, at even 20 m a second! The road, where he drives recklessly, is 800 m long. The coachman is excited when he breaks the record. What is his record? (800/20 = 40; 40 s)

Moderately difficult problem

Only experienced boatmen can row on Lake Beaver because it is full of beavers’ nests. You look amazed at the map of Lake Beaver. It is marked to show how six safe routes leave from the Ferry Bank to the Middle Island. From there there are only two safe routes to the Beaver Fall, and from there you get four routes to the shore of the Beaver Lake school. By how many different routes can the boatman transport pupils from the Ferry Bank to the school? (6 × 2 × 4 = 48; 48 routes)
**Difficult problem**

The Prince of the Fire Land asks you to build a strong bridge for fear that someone would fall in among the electric fishes of the witch. You get six strong planks of 5 m each. How many bridge planks of 2 m can you saw from them? \(5/2 = 2.5\); \(6 \times 2 = 12\) planks)

**References**


