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Group awareness and regulation in computer-supported collaborative learning

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Abstract

Group awareness is of critical relevance for collaborative learning and interaction and is thus often referred to in CSCL research. However, the concept is only vaguely defined as some kind of understanding or perception of characteristics of learning partners or the collaborating group. Most CSCL research activities concerned with group awareness aim at modifying learners' awareness using so-called group awareness tools. However, there are much less attempts to measure group awareness and to conceptualize its formation. Thus, building on existing group awareness research, this article derives a conceptualization with six defining aspects of group awareness: (1) group awareness is cognitive, (2) group awareness is conscious, (3) group awareness is current, (4) group awareness is individual, (5) group awareness is social, and (6) group awareness is perceived as valid. Additionally, while it is often assumed that group awareness builds on self-regulatory skills, its role in regulating behavior and cognition within a social context is seldom explored. Thus, this article aims at defining and analyzing the concept of group awareness, specifying its relation to regulatory processes, and sketching possible research paths whilst building on, complementing, and informing tool-driven research.

Keywords Group awareness · CSCL · Metacognitive regulation · Partner modelling · Working memory

The concept of group awareness (GA) has received growing attention in collaborative learning in recent years, especially within computer-supported collaborative learning (CSCL). Within CSCL, GA is commonly understood to be some kind of understanding or perception of characteristics of learning partners or the collaborating group (e.g., Bodemer et al., 2018; Buder et al., 2021). However, while the concept is widely conceived to be of critical relevance for collaborative learning and interaction, there is no clear conceptual agreement on its defining aspects. Thus, a formal theoretical model of GA and its role within CSCL is still missing. In this paper, GA will be conceptualized from a psychological

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perspective and understood as the individual's awareness of the group (e.g., Engelmann et al., 2009) rather than a group-level construct (cf. Tenenberg et al., 2016). Focusing on individual mechanisms in CSCL complements group-level research and is vital for understanding the link between individual perception and social interaction.

Although conceptualizations of GA exist within CSCL research (e.g., Buder et al., 2021; Collazos et al., 2019; Engelmann et al., 2009; Janssen & Bodemer, 2013), this past work mostly focuses on a functional perspective whereas attempts to directly measure GA are rare (Bodemer et al., 2018). Most GA research revolves around the design and deployment of GA tools (see Bodemer et al., 2018). Those tools aim at fostering (computer-supported) collaborative learning by providing information necessary to make adequate learning decisions. GA tools have continuously been shown to be of great value for supporting CSCL (Janssen & Bodemer, 2013) and even attitudes towards collaborative learning (Yilmaz & Yilmaz, 2020). However, these tools are not theory-void mirrors of group information, but process GA information in a way to guide learners towards beneficial learning practices (Schnaubert et al., 2020a). Thus, they provide useful instructional aids that may exceed human capabilities in collecting and processing relevant learner data (Buder & Bodemer, 2008). Even if GA can be gained with the support of computers and is vital for collaborative learning, it is primarily a psychological concept and not an instructional or technological feature. Without a conceptual understanding of GA, tool-based research will reach its limits not only to explain collaborative learning processes, but to design GA tools. While there is research looking at GA from a functional perspective (e.g., Janssen & Bodemer, 2013), the concept of GA itself remains rather vague (see Bodemer et al., 2018; Ghadirian et al., 2016).

With regard to functions, GA research in CSCL frequently stresses the role of self-regulatory processes for learning with GA tools. It is thereby frequently assumed that GA builds on or is directly related to self-regulatory skills (e.g., Miller & Hadwin, 2015; Schnaubert & Bodemer, 2019). However, the precise role of GA in regulating behavior and cognition within a social context is seldom explored. While regulatory processes are an integral part of all learning, they seem especially relevant for CSCL practices. Not only does the collaborative situation add layers of regulation (co- and shared; e.g., Järvelä & Hadwin, 2013), but CSCL also has a strong focus on learning rather than instruction processes and the field deliberately balances learner agency and pedagogical effectiveness (see Tchounikine, 2019; Wise & Schwarz, 2017). Thus, CSCL approaches frequently stress the role of learner agency and self-guidance by trying to support learners while still allowing large degrees of freedom (e.g., Hesse, 2007). However, understanding the role of GA for regulatory processes relevant in CSCL requires a multifaceted and multi-layered view of regulation, as learners need to regulate their GA in order to use said GA to successfully regulate their social interaction and partner modelling processes during CSCL.

Taken together, this rich research field lacks a coherent and precise understanding of what GA and its defining features are. However, such a conceptual understanding is necessary for studying GA beyond tool-based research and to fully understand its role in CSCL. Further, the critical role of GA for regulatory processes during CSCL needs to be framed as well. Thus, the goals of this paper are twofold: (1) it will model and refine the concept of GA as a cognitive construct rather than as a technological and instructional feature of CSCL environments, and (2) it will refine how GA is an integral part of three regulatory cycles during CSCL. This will provide a basis for targeted theoretical and empirical research. It should be noted that the conceptual perspective is not meant to disregard the substantial empirical basis of tool-based research, but to provide a psychological foundation to inform the design of efficient collaborative learning environments with regard to didactic and technological features. Moreover, taking a psychological perspective and focusing on individuals in CSCL does not devalue social processes, but rather provides a basis to link individual perception and social interaction. Consequently, in this paper, we will not focus on processes of collaborative learning and social regulation, but on GA as an intermediary between the individual's perception and the social context in CSCL.

Conceptualization of group awareness (goal 1)

In the following, we will take a closer look at conceptual features of GA. Thereby, we will first look into defining features of the concept while deducing implications for GA research. In a second step, we will look into the role of the working memory for GA and its formation.

Defining aspects of group awareness

Within GA literature, the concept itself is mostly ill-defined since tools rather than the psychological construct itself have been the focus of most of this research. If definitions are proposed, they refer to the concept as "knowledge" (e.g., Kirsch Pinheiro & Souveyet, 2018; Strauß & Rummel, 2021; Yilmaz & Yilmaz, 2020) or "knowledge and perception" (e.g., Buder & Bodemer, 2008; Erkens & Bodemer, 2019), "understanding" (e.g., Ma et al., 2020, following Dourish & Bellotti, 1992), "information" (e.g., Kirsch Pinheiro & Souveyet, 2018; Ma et al., 2020) or "information that allows to understand" (e.g., Papadopoulos et al., 2018), "(state of) being informed" (e.g., Buder et al., 2021; Cheng et al., 2021; Lin et al., 2016; Schnaubert & Bodemer, 2019 following Bodemer & Dehler, 2011), "consciousness and information" (e.g., Li et al., 2021 following Gross et al., 2005) or "information that is mentally present" (Bodemer et al., 2018). Thus, to describe or even define GA, researchers often use a variety of terms related to awareness, but not quite capturing all facets. Consequently, they contain some of the central aspects of GA (e.g., its reference to cognition), but frequently disregard others (e.g., its consciousness or immediacy).

As the term thus seems to be used rather broadly in the literature regarding GA tools, it might be helpful to take a closer look at more detailed conceptualizations of GA. One of the most refined and frequently used conceptualizations of the term in CSCL describe GA as "being informed about aspects of group members or the group—for example, the group members' current locations, activities, knowledge, interests, or feelings" (Bodemer et al., 2018, p. 351, building on Bodemer & Dehler, 2011 and Gross et al., 2005). Thereby, GA is conceptualized as "valid information on a learner's group or its members that is mentally present (aware) within the individual learner. The information may be group- or partner-related, may contain situational and/or stable characteristics that may be classified within a wide range of psychological concepts (e.g., social, motivational, emotional, cognitive, behavioural)." (Bodemer et al., 2018, p. 356). Taking this general definition based on previous conceptualizations (e.g., Bodemer & Dehler, 2011; Buder & Bodemer, 2008; Gross et al., 2005) as well as further conceptualizations of GA and awareness as a basis, there are some conceptual implications that we will derive and discuss in the following: (1) GA is cognitive, (2) GA is conscious, (3) GA is current, (4) GA is individual, (5) GA is social, and (6) GA is perceived as valid (see Fig. 1).

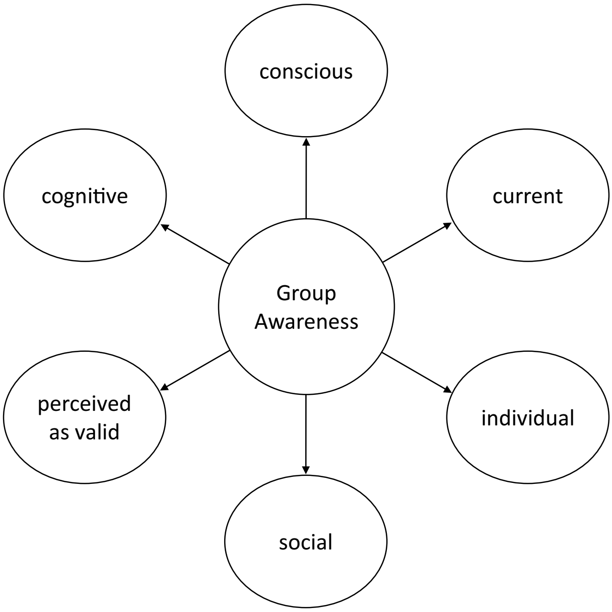

Fig. 1 Defining aspects of group awareness

(1) GA is cognitive. While definitions of GA within the literature do vary, there is a certain consensus that GA is a cognitive construct. Consistent with research on other types of awareness that view awareness as a cognitive prerequisite to navigating complex situations (e.g., situational awareness; Endsley, 1995), GA is mostly defined in terms such as "knowledge", "understanding", "perception" or "being informed" (see above). While these cognitive constructs refer to various aspects of the social context, which may be reflected in respective types of GA distinguished in literature (i.e., emotional, behavioral, motivational, cognitive or metacognitive GA; Bodemer et al., 2018; for a literature review see Ghadirian et al., 2016), GA in itself remains a (purely) cognitive concept. Thus, it does not include affective evaluations and feelings towards specific persons like affection or fondness (however, the content of these cognitions may include affections within a group). It does – therefore – not define a relationship between persons, but the (conscious) perception of characteristics of another person or group (possibly including their relationship within the group).

Its cognitive nature connects GA to human memory structures and thus, GA research may be related to various connected research areas in- and outside of the Learning Sciences. There is a large body of research on the formation and regulation of cognitive processes during learning within cognitive and educational psychology. Especially metacognition research is concerned with how individuals regulate their cognitive processes and even how they monitor and regulate other learners' cognitions (i.e., social metacognition; see Chiu & Kuo, 2009; Efklides, 2008; Salonen et al., 2005). Thus, research on the formation and regulation of GA during CSCL may build on groundwork from these areas.

(2) GA is conscious. Apart from perceiving characteristics of fellow learners, the term "awareness" further implies a certain level of consciousness with regard to the information in question. Within cognitive psychology, the distinction between perception and awareness is consciousness (usually measured via the ability to report back or discriminate between

information; e.g., Merikle et al., 2001). Here, it is assumed that awareness enables intentional behavior as it is accompanied by conscious experience. Within metacognition research, consciousness is believed to be an important aspect making metacognitive experiences explicitly usable for learners within the learning process and thus making metacognitive monitoring an integral part of the causal chain for learning processes (Nelson, 1996; Nelson et al., 1994). From a GA perspective (and in line with conceptualizations of other forms of awareness; e.g., situational awareness; see Endsley, 1995), a minimum of conscious processing thus forms the basis of adaptive social behavior. This is not to say that all available information must be actively processed during social interaction, but that a certain level of (conscious) awareness is necessary to identify relevant characteristics of a specific person or group (e.g., for identification) to activate long-term memory structures and to allow for behavioral adaptation. Automated processes of adaptation (e.g., using simpler language when talking to a child) may thus be a consequence of but are not equal to GA.

Thus, GA carries a notion of consciousness that does not align with full automatization. While one may habitually act and react within social situations and partners may be well aligned with quasi-automated collaboration processes, such acts may simply not require high levels of GA. This distinction is critical for GA research as it distinguishes observable behavior from the cognitive experience. Additionally, it means that research designs intended to assess GA may build on self-report as methodology as consciousness may be viewed as a key (although not sole) prerequisite for self-report-based measurements. While such an approach comes with various methodological issues and reliant self-report hinges on more than awareness (see Nisbett & Wilson, 1977), it can complement objective measures by integrating an individual learner's experience.

(3) GA is current. GA can be distinguished from stable long-term memory structures like cognitive schemata allowing to efficiently assess a social situation by organizing singular chunks of information. While these structures are necessary to truly understand and interpret a social situation, GA focuses on aspects that are currently consciously perceived and can thus be connected to online monitoring of the social environment (Buder, 2011). Social schemata or partner models stored in long-term memory may ease the burden of processing bits and pieces of available information and may be a precondition for a level of GA necessary to function within social situations at all, but are distinct from the actual information activated within the moment. While in theory all social schemata are relevant for forming GA and interacting with the social environment, GA within CSCL focuses on specifics of educational/pedagogical situations and thus is less concerned with general human aspects of social cognition (e.g., theory of mind, see Byom & Mutlu, 2013, for an overview). Instead, the focus is on aspects specifically relevant to educational situations like a person's content-related thoughts, opinions, knowledge or learning motivation. To allow for adequate social interaction processes, GA needs to provide a current snapshot of the social situation in line with its dynamic nature (Engelmann et al., 2009). While this may include awareness of rather stable characteristics of group members (like awareness of prior knowledge; e.g., Sangin et al., 2011), it may also include relevant dynamic aspects like where group members are or what they are currently focusing on (e.g., through gaze awareness; Hayashi, 2020; Schlösser et al., 2015).

The volatile nature of GA has important implications for research as it restricts the assessment of GA to the current situation. As described by Bodemer et al. (2018), GA cannot comprehensively be measured "after the fact" by merely assessing information stored in long-term memory, because it would be unclear if and how this information was actually activated during interaction. While having knowledge about a person may imply that there had been some kind of awareness with regard to this person at some point, it does not imply the presence of awareness at a specific point in time within the collaborative situation. Conversely, a lack of knowledge does not imply a lack of awareness in previous collaborations. Especially under high working memory load conditions, it seems reasonable to assume that intensive processing of GA information and especially integrating it into long-term memory structures may not be feasible and severely restricted, thus hindering post-collaboration retrieval.

(4) GA is individual. As a cognitive concept, GA is located within the individual, meaning, although it is related to (social) characteristics of the environment, it is firmly situated within the individual's cognitive system. As described by Engelmann et al. (2009), this sets it apart from concepts that require overlap or mutuality between partners like shared mental models or common ground, and serves as contextual information helping learners to interact during collaborative learning (Engelmann et al., 2009).

This subjective perspective on intersubjectivity has important implications for GA research since studying the concept itself does not necessarily require another social entity to be present or even to exist. Thus, besides investigating authentic group interactions, it allows for pseudo-collaborative studies that can strictly control the information about the learning partner and (bogus) "interaction" processes. While disabling the dynamics of true collaboration does have severe consequences for interpretation and generalization of the studied processes and their application to CSCL practice (Dehler Zufferey et al., 2011), it may complement CSCL research by allowing for a high level of internal validity when studying GA in the laboratory. Further, an individual perspective on GA enables studying how learners align their individual group perceptions to gain a shared understanding of the group and its members. This puts GA in an intermediary position between individual- and group-level processes (see below).

(5) GA is social. GA does not directly target information about a subject domain or learning content, but cognitions about a social entity, which may be a learning partner, a whole group, or even a community. This is the main distinction between GA and situational awareness that focuses on situational characteristics (Buder & Bodemer, 2008). For CSCL, this implies that while GA may be connected to a certain domain or domain-knowledge (as individuals may position another person within a domain-specific content model), GA itself relates to cognitions about the social entity or configuration. Even if there are no universal assumptions about what constitutes a social entity and social interaction within CSCL research, we assume processes regarding GA to be similar for para-social and some other social scenarios as long as the para-social processes trigger social schemata or processes of social interaction (see also Schneider et al., 2022). Within social psychology, impression formation is concerned with using social schemata to enrich the current understanding of a social situation by category-based processes (e.g., activating stereotypes; Oakes & Turner, 1990). These immediate and automatic processes allow fast judgments of a situation, and it is widely assumed that individualizing initial impressions is effortful and depends on goals and situational needs (Fiske, 1993; Fiske et al., 1999). Impression formation thus forms a continuum from category-based to individuating processes (Fiske & Neuberg, 1990), with

the former being assumed to dominate when interpersonal information and interaction is restricted due to distributed settings (Johri, 2012).

This link to broader social schemata has implications for the concept of and research on GA, because it somewhat detaches GA from a specific entity or group within a given social situation. It implies that GA may be built even without identifying information about "the group" as social schemata may be activated that replace person-specific partner models. While these may be heavily biased (stereotypes) and highly inaccurate (group heuristics), they may provide a sound enough basis for at least some collaborative processes, depending on the learning task and task affordances at hand. Further, it relates GA research to other research areas beyond the Learning Sciences like the broader field of social psychology (e.g., with regard to research on social cognition). Additionally, while pertinent to CSCL, the inclusion of para-social interaction also extends the role of GA to more individual learning in socio-technological systems.

(6) GA is perceived as valid. While GA information does not need to be completely attuned with reality, individuals have to give it credit. Mere fantasies or games of make-believe not related to the acute social situation are not the focus of GA. However, unlike knowledge, which is generally believed to require a certain level of truth, justification and confidence (for an extensive philosophical discussion on the concept of knowledge and its tripartite nature, see Lehrer, 1990), GA is individuum-focused and just requires the latter, meaning: it is concerned with an individual perception without requiring external qualifiers or justification. Thus, GA is not to be confused with knowledge about the group ("knowledge" being associated with a justified true belief, Hunt, 2003; for an overview, see Ichikawa & Steup, 2018), but concerns cognitions (true or false) about said group. Thus, its subjectivity is a core element of the concept and connects it closely to metacognition. Similar to metacognitive concepts that view metacognitions as the cognitions about one's own cognitions rather than accurate perceptions of one's own knowledge (e.g., Nelson & Narens, 1990), the actual accuracy of GA can be perceived as a characteristic of a specific GA rather than a defining feature of GA in general. GA accuracy thus refers to the extent that individually perceived GA coincides with actual group characteristics.

This has important implications. As it can be assumed that the accuracy of GA determines how well individuals interact with each other and that GA misalignment with reality or incompleteness may severely hamper collaborative learning efforts, GA accuracy becomes an important subject for CSCL research and practice. Even if there are so far no direct insights into GA accuracy based on current measurements, empirical research using GA tools to foster GA clearly suggests its relevance for effective CSCL, for example with regard to partner modelling (e.g., Sangin et al., 2011), learning processes (e.g., Schnaubert & Bodemer, 2019), and learning success (e.g., Bodemer, 2011). However, the role of GA accuracy is not confirmed yet and hinges on adequate and more direct measurement approaches of GA and its accuracy, which could take GA research a decisive step forward. As metacognition research on monitoring accuracy is also concerned with the realism of subjective perceptions, metacognition theory (e.g., Koriat, 1997; Nelson & Narens, 1990) and methodology (e.g., Schraw, 2009; Schraw et al., 2013) may enrich CSCL research traditions in this endeavor.

Group awareness as an individual, current, conscious, social cognition perceived as valid

The defining aspects of GA have various implications for research. The cognitive character links it to memory structures and allows a distinction between awareness and affective reactions. The conscious character manifests its role for intentional behavior while stressing the distinction between behavior and cognitive experience. The currency on the other hand is vital for learners to handle the dynamics of CSCL and not only puts a focus on how GA emerges within such a dynamic situation. It also explains how this flexibility may lead to challenges during CSCL and also for assessment. The individual focus stresses the role of individual perceptions and prerequisites during CSCL without diminishing the social character of CSCL. Rather, the subjective view on intersubjectivity shows that an individual might perceive social situations even without another human present, which extends its role and allows individual-focused research designs to complement collaborative designs. On the other hand, the social focus of the concept clearly distinguishes GA from concepts like situational awareness or metacognition and puts it center-stage for CSCL. Last but not least, the subjective validity of the concept also means that alignment with reality is not a defining facet of GA, but a characteristic of GA. Research here may incorporate methods of metacognition research into CSCL.

Group awareness and the working memory

The above described aspects position GA firmly within the cognitive system. GA – as an acute cognitive state – is thus closely connected to working memory processes as active processing is key to the information being present within the situation. Like Endsley's (1995) model of situational awareness, we assume long-term memory structures to contribute to the generation of GA in any given situation (i.e., partner or group models). Such structures may be activated by minimal external social triggers (e.g., a name of a specific person that may activate information about this person stored in long-term memory). However, GA itself is not a dormant structure or potentially useful knowledge stored in long-term memory, but the instant, salient perception and interpretation of (social) information. Thus, while the GA information may have longer standing implications, it is its currency that distinguishes (group) awareness from (group-related) knowledge. This conceptualization has implications. Most importantly, GA works within the realm of the limits of the working memory. As a consequence, when learning processes themselves require high working memory capacities, maintaining GA may be hampered and vice versa. Schnaubert and Bodemer (2019), for example, found learners to fall back to habitual learning strategies disregarding relevant knowledge constellations when not supported by external aids. They assume this to be at least partially due to the added strain that forming and maintaining (meta-)cognitive GA puts on the cognitive system during collaborative learning. Similarly, Roßnagel found that under high mental load conditions, speech adaptation towards the audience is hampered (Roßnagel, 2000) and that adaptation to changes in partner perceptions is diminished while speaking under high-load conditions (Roßnagel, 2004). This indicates that these processes require at least some amount of cognitive resources, especially when newly acquired information is inconsistent with prior assumptions about the partner. However, working memory load may be reduced by building on stable memory structures (e.g., partner models of known collaboration partners) minimizing processing costs, but they will still require at least minimal capacity (see Dillenbourg & Bétrancourt, 2006). Thus, comparable to metacognitive processes (Valcke, 2002), we assume forming and maintaining GA strains the working memory in addition to processing content-related information, which has been discussed in connection with related processes like partner modelling (e.g., Dillenbourg et al., 2016; Dillenbourg & Bétrancourt, 2006). This may potentially be minimized by tools to support GA, although empirical research has so far only indirectly examined these assumptions (e.g., Bodemer, 2011).

Formation of group awareness

The formation of GA can involve a variety of sources and processes. Determining that it is located within working memory helps to systematically describe the formation of GA. Key determinants here are (1) whether the formation processes access long-term memory structures or use information from the current (social) situation, and (2) whether the social information relates directly to the learning content or to other properties of an individual or a group.

The interplay of sources and processes to form GA happens in various everyday situations. As an illustrating example, imagine two students meeting up for a team-project in a research methods course, which involves planning and conducting statistical analyses. When setting up their shared workspace, one student (A) notices the other (B) having a neatly organized folder full of lecture notes from their statistics lecture on her computer. Student A is aware of this information about student B and – based on experiences with other students – additionally assumes that student B is well prepared. He concludes she may be rather knowledgeable in statistics (although they have not talked about statistics before). As student A knows what topics are covered in the lecture, he thus makes specific assumptions about the kind of topics B may be knowledgeable about. In this situation, he thus has highly specific knowledge-related or cognitive group awareness (awareness about other learners' knowledge and cognitions; Bodemer & Dehler, 2011). Student A also makes assumptions about more general characteristics of student B and concludes she is generally well organized and a highly motivated student. These assumptions may not all be salient at the same time, but may lead to student A perceiving student B as a generally motivated person at one moment, and A being aware of B's more detailed knowledge (e.g., on conducting multivariate statistical analyses) by zooming in on specific GA information at another. The example illustrates how in a specific situation, student A perceives GA information on the fly, both bottom-up from the social environment (i.e., lecture notes of student B) and top-down, enriched by activated long-term memory structures (e.g., about course content or "typical" students).

Now imagine student A having met the fellow student B before in a computer science class. He can then further enrich the GA information in the given situation with cues from his pre-existing partner model about B (also stored in long-term memory). Thus, even if he doesn't know much about her, he can already construct GA from different sources from the past and the present. Such information can be a direct link to possible learning content (e.g., presumed knowledge about inferential statistics) or a link to other properties of the fellow student (e.g., assuming she might be good with numbers or assuming she might be confident writing R scripts for conducting statistical analyses). Student A can further use the GA information to interact with student B, such as asking her to explain how to conduct an ANOVA. Throughout the learning episode, the student's GA is continuously refocusing on aspects that are immediately relevant while updating the partner model with newfound insights about his fellow student (e.g., confirming that she really is good with numbers, enjoys writing R code, and that her expertise in statistics complements his knowledge). Thus, during GA formation, information from the current social environment and from long-term memory becomes more integrated over time.

As the example shows, GA can be more or less related to the other person's knowledge, with knowledge-related GA being of specific interest in CSCL as it may be directly related to the learning content (e.g., Bodemer, 2011). It may thereby foster and/or stimulate collaborative learning processes, for example when GA helps interpret or appraise statements made by a fellow learner, or when awareness of complementary knowledge stimulates asking questions or providing explanations (e.g., Dehler et al., 2011). Whether knowledge-related information is actually relevant for individual or collaborative learning depends on the interaction goal and on the GA focus: for example, GA related to the preferred statistics environment for analyses may be peripheral when planning statistical analyses or learning about basics of statistics at the beginning of the session, but awareness of the information may be of increasing relevance when it comes to actually conducting analyses and might help the students in future encounters to efficiently and effectively ask for and explain learning content.

The illustrated process of forming a usable level of GA from different sources within a social situation requires internal regulation. In line with metacognitive theories about learning, we assume that learners need to metacognitively monitor their GA, identify inconsistencies and limitations in comparison to situational demands, and control activities in order to gain coherent GA.

The role of group awareness for individual regulation processes in CSCL (goal 2)

While conceptualizing GA and defining its facets is crucial for basic research on CSCL concepts, the role of GA during CSCL needs to be framed as well. There is a lot of research looking into the support of GA via GA tools and studying the effects on collaborative learning behavior (Ghadirian et al., 2016; Janssen & Bodemer, 2013). Bodemer and Scholvien (2014) suggest that the functions of GA tools in CSCL cover cognitive as well as behavioral aspects. Transferring this to GA itself and following the conceptualization outlined above, it seems reasonable that GA has its main function in regulating group-directed behavior and cognition during CSCL, but additionally needs to be regulated itself.

Attaining GA may thereby closely resemble attaining understanding of the learning content. However, there are also major differences: First and foremost, attaining GA is not the primary task within collaborative learning scenarios, but merely a means to an end (Gutwin & Greenberg, 2002). It is a background activity towards successful collaboration and learning and its long-term consequences, such as building a partner model, are therefore mostly a side effect rather than a distinct learning goal. Thus, efforts towards attaining GA are secondary to knowledge construction. Putting effort into GA formation may thus even be harmful to learning under certain circumstances (see collaboration load; Dillenbourg & Bétrancourt, 2006). Comparable to metacognitive activities during self-regulated learning (Seufert, 2018), GA has a crucial function as long as it serves, not hinders, successful learning. Moreover, GA is volatile in nature and thus not a skill-like concept. Accordingly, GA is not stable over time, but instead varies according to the current social situation. Thus, GA in itself serves its primary purpose in the moment, and if GA is not functional within this moment, the (scarce) cognitive resources devoted to it are squandered and may even distract from other goals. This stresses the role of effectively regulating individual GA in order to use it efficiently during CSCL.

When discussing regulatory processes with regard to GA, one can take two perspectives: (1) the regulation of GA itself, and (2) the role of GA for regulating other processes, specifically behavior and cognition directed at the social context during CSCL. It is crucial to point out that this perspective does not imply there are no other regulatory processes relevant to CSCL, but that the above mentioned are directly (not intermediately) related to GA as a cognitive concept connected to individual perception and regulation. While the first perspective stresses the cognitive character of GA and the need to regulate one's own cognitions (i.e., GA itself), the second stresses the social character of the concept and its implications for social cognition and behavior. Thus, in the following, we will first take a metacognitive perspective on regulation of cognitive processes in order to explain how GA itself may be regulated during CSCL. Afterwards, we will take a closer look at the functional role of GA during regulation of social interaction and building partner schemata. An overview of these processes is provided in Fig. 2.

Regulating group awareness

To be able to use GA within social interaction, individuals need to have a coherent perception of the social environment, which depends on situational demands. However, learners cannot rely on just automatically perceiving coherent, relevant information. As GA involves both long-term memory structures and information gained on-the-fly within the social situation, forming and maintaining coherent GA requires its continuous regulation. In line with research on metacognitive regulation (e.g., Efklides, 2008; Nelson & Narens, 1990; Winne & Hadwin, 1998), we assume GA regulation to be a goal-oriented process similar to regulating other (subject-related) cognitions.

Due to GA's cognitive nature, metacognitive models on self-regulation like COPES (Winne & Hadwin, 1998) are especially suited for application to GA regulation as they describe how cognitive processes are regulated. Not only do they define phases of regulated learning, but they also define the basic facets of the cognitive architecture involved,

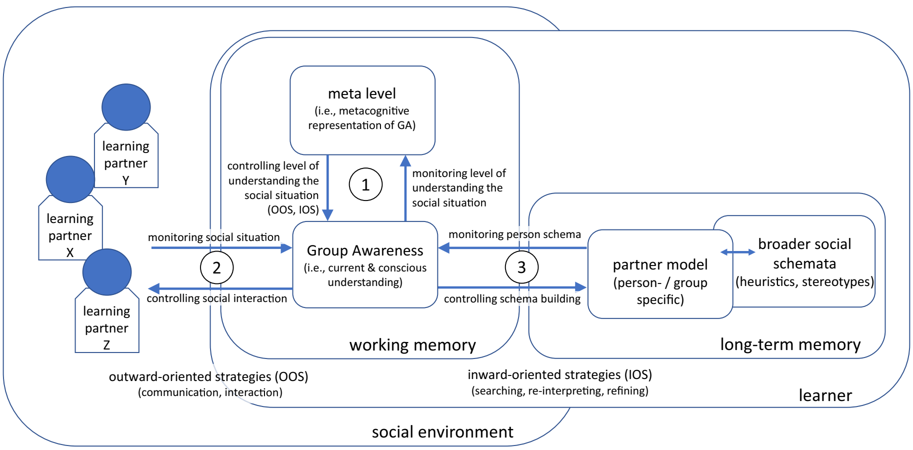

Fig. 2 Three types of regulation: (1) regulating GA, (2) regulating social interaction, (3) regulating partner schema building

which is central for a conceptual understanding of GA. Additionally, they stress the role of environmental and cognitive conditions that affect regulatory processes. During learning, these may include task constraints or strategic knowledge about learning processes (Winne & Hadwin, 1998). When applying the model to a dynamic concept like GA, these conditions may include factors like the availability of social information within the learning environment or knowledge about the learning task, personal goals and collaborative practices (i.e., collaboration scripts; see Fischer et al., 2013) which may all be used to derive standards for the optimal level of GA (please note that when learning is regulated, goals are not a precondition, but products of explicit goal setting and planning; however, when regulating GA, the learning goal becomes a pre-condition for GA regulation defining the situation rather than the process).

When metacognitively regulating, two processes are of focal importance: monitoring and control. They define the flow of information between the (content-related) cognitions to be regulated (object level) and their dynamic representation (meta level; Nelson & Narens, 1990). When regulating GA, content-related cognitions refer to cognitions about the partner as opposed to the learning content. Thus, the targets are highly dynamic social cognitions. This type of regulation is illustrated by cycle (1) in Fig. 2.

(1) Regulating Group Awareness: Monitoring. When regulating GA, learners need to specify standards for the level of GA and the GA accuracy required for a particular situation based on their understanding of the task and the cognitive conditions at hand. Social situations, tasks, or personal goals demand (and allow for) different levels of GA. Some situations may only require low level information to be handled appropriately, while others necessitate a higher level of GA and GA accuracy. For example, simple and rather cooperative tasks may only require a rough understanding of the distribution of knowledge within the group, while transactive interaction during shared knowledge construction often requires a deeper socio-cognitive and socio-emotional understanding (see Dillenbourg et al., 2016). Additionally, environmental factors may restrict the level of awareness possible (e.g., asynchronous communication or a poor internet connection may not allow for immediate information about learning related activities of a learning partner).

Against these standards, individuals may measure their current (conscious) state of understanding of the social situation in order to identify a need for action. To understand their current level of awareness, learners thus have to metacognitively monitor their understanding of the social situation by examining current perceptions, thoughts and assumptions about the social environment to identify a possible need for regulating their comprehension of the social environment. This need may result for two reasons. First, it may be due to a perceived lack of awareness about the learning partner for the task at hand. This is associated with metacognitively monitoring one's own level of understanding of the social environment and comparing it to task-specific standards. As a result of too low GA, learners may perceive difficulties in performing relevant social interaction processes or experience unexpected behavior from learning partners. Second, it may be due to low GA accuracy. In this case, learners monitor GA and may recognize inconsistencies between their understanding and incoming social information. For example, when an utterance or behavior of a learning partner contradicts specific expectations based on a partner model, this may lead to a partner-related socio-cognitive conflict similar to other cognitive conflicts (see G. Lee et al., 2003). Although the example focuses on perceiving inconsistencies within GA based on differences between bottom-up and top-down information, conflicting information does not necessarily need to involve both sources of information. However, if learners do not notice inconsistencies or do not monitor their own GA (e.g., due to a lack of cognitive resources), GA – whilst perceived as valid – may be inaccurate, which in turn may interfere with collaborative learning efforts.

Both processes are related to metacognitive monitoring and thus metacognition research, albeit the monitored cognitions (object level) concern the learning partner or social environment rather than one's own content-related knowledge. One of the founding papers of metacognition research by Flavell (1979) views social aspects as a central target of metacognitive processes, as individuals need to learn that insufficient information may hinder the understanding of a social situation. These assumptions seem closely linked to social metacognition. However, while social metacognition is concerned with monitoring and controlling other learners' cognitions (e.g., Chiu & Kuo, 2009), regulating GA is concerned with monitoring and controlling one's own partner-related cognitions. Thus, when it comes to cognitive GA, they may involve similar processes (with both being concerned with monitoring and modelling the other learner's cognitions), however, regulating one's own GA puts GA at the object level of one's own regulatory processes, whereas social metacognition is at the meta level of regulating other persons' cognitions.

(2) Regulating Group Awareness: Control. Once learners have understood their current state of GA and have compared it to a (task- and situation-appropriate) standard, they may either be satisfied and may not see a need for further activities to foster GA or, if learners perceive necessary partner-related information to be missing or incoherent, they may regulate their comprehension of the social environment by actively trying to make sense of the available information.

Individuals who encounter conflicts within their social understanding or perceive that they are lacking relevant information, may therefore use GA-related monitoring outcomes to regulate their GA. In this regard, we assume processes similar to metacognitive regulation, where learners regulate their comprehension and learning based on metacognitive monitoring (e.g., Nelson & Narens, 1990; Thiede et al., 2003). Consequently, we assume that when learners find their GA to be inadequate, they may control their GA-related cognitive processes and behaviors by initiating, continuing or adapting strategies in order to gain an adequate level and accuracy of GA or alternatively terminating said strategies when satisfied. This may be done in various ways. Similar to other forms of knowledge or conflict regulation, this may include outward- and inward-oriented strategies.

Outward-oriented resolution strategies are strategies that involve initiating or adapting behavior to gain additional information to resolve the conflict or uncertainty. While these strategies include cognitive processing, they also include activities to access additional information from the environment. Such activities may be rather unidirectional (like paying close attention to and closely monitoring certain aspects within the environment, e.g., group behavior) or involve overt interaction processes designed to retrieve information, for example, by initiating interaction with the learning partner (like asking the learning partner or group a direct question "does anyone have expertise in this kind of subject?") or the environment (like accessing a chat history or information from GA tools). Thus, these strategies often involve changes in behavior that may be the subject of direct observation not only for learning partners but also for researchers. They also may be more or less linked to and interwoven with the current interaction process. It is important to notice that these changes in behavior may not only be beneficial but also effortful and disruptive to the collaborative learning process, for example if transactive interaction processes are repeatedly disturbed by activities designed to gain a necessary level of GA.

Inward-oriented resolution strategies, on the other hand, are strategies that deploy mainly cognitive mechanisms to reduce the level of conflict or uncertainty. While this may include processing the information within the social environment, primarily it describes strategies of searching and interpreting information in long-term memory. For example, learners may actively search for additional information concerning a specific learning partner in long-term memory (e.g., trying to remember past experiences), but they may also use a group heuristic or other similarity-based heuristics to deduce information about the learning partner (e.g., thinking about the typical skill level of students of a specific study course). Alternatively, they may solve the cognitive conflict by conducting a variety of cognitive response behaviors associated with conflict resolution (e.g., dismiss information; see for example Chinn & Brewer, 1998). While these activities may include some level of outward focused activities (monitoring and re-interpreting partner behavior), they are still mainly cognitive strategies and thus not readily observable during social interaction or in the laboratory. They may require explicit and potentially reactive methods such as think-aloud or cued retrospective reporting to analyze.

The deployment of these strategies severely depends on situational demands and opportunities (affordances and constraints). For example, in an asynchronous learning situation, it may sometimes not be useful to ask the learning partner for clarifying information (e.g., about their expertise with regard to a specific topic), but might be more useful to infer the information (e.g., based on existing knowledge about their education). On the other hand, within face-to-face communication, it might be useful to observe and closely analyze the social environment within the interaction process to infer the needed information or even ask questions to clarify a status quo. Thus, task demands and technological setup (including support tools, especially communication and awareness tools) may severely affect how learners regulate their GA. However, while GA tools may assist by providing information about learning partners, they do not replace the metacognitive regulation processes involved.

The role of group awareness for regulating social interaction and cognitions

While GA is regulated by controlling memory and interaction processes during CSCL, GA itself is in turn necessary for regulating the behavior and interaction processes of learners within the social environment as well as memory processes with regard to social information (i.e., partner model). These two distinct functions put GA in a key position in CSCL, for regulating both acute interaction processes as well as partner schema building for recurring or long-term collaboration. In the following, we will look into the functional role of GA for these CSCL processes.

(1) Regulating social interaction. To be able to collaborate, individuals need to have sufficient GA about others within their social environment. Although what is "sufficient" may severely depend on the task, it seems reasonable to assume that some level of GA is relevant for all targeted forms of social interaction. Research on the use of GA tools in CSCL assumes that GA affects how individuals interpret and behave in social situations (Janssen & Bodemer, 2013). Thus, guiding interaction processes is seen as a key function of GA and respective tools (see Bodemer, 2011) and it has also been related to (shared) regulatory activities (e.g., Järvelä

et al., 2016; Rojas et al., in press). Based on their current GA, individuals may decide how to act and react within social situations and how to collaborate. For example, GA information may support learners' identification of knowledge gaps or conflicting assumptions within the group, thereby triggering learning and interaction processes to fill knowledge gaps or resolve conflict (e.g., Schnaubert & Bodemer, 2019). The script theory of guidance assumes these interaction processes are guided by internal collaboration scripts (Fischer et al., 2013). While empirical research on the role of GA in script activation and regulation is scarce, it is assumed that awareness of social conditions may not only activate internal collaboration scripts, but may also play a role in regulating script implementation and adaptation (Schnaubert, et al., 2020b). Thus, the act of monitoring social conditions in order to initiate and adapt interaction processes may be viewed as part of a regulatory cycle guiding collaborative learning and interaction processes. This may not only include monitoring socio-cognitive conditions to focus on resolving conflicts or controversies (e.g., Gijlers & de Jong, 2009) or guiding communication based on content-related prior knowledge (e.g., Erkens & Bodemer, 2019; Nückles et al., 2005) or understanding (Dehler et al., 2011), but may also include coordinating activities based on behavioral awareness (e.g., Janssen et al., 2011; Strauß & Rummel, 2021) or regulating emotions and socio-emotional conflict (e.g., Eligio et al., 2012; Järvenoja et al., 2020; Näykki et al., 2014). Some of these cited examples deploy static awareness tools not intended to catch the dynamics of collaboration (Engelmann et al., 2009) and thus not suitable to support the full cycle of regulatory processes (e.g., by adapting or "fine-tuning" activities; see Buder, 2011). However, the underlying assumptions are that learners are not only guided to focus on relevant content, but also monitor resolution processes in order to terminate or adapt collaborative learning processes when required. These adaptations may involve self-, co- and shared regulation processes (Hadwin et al., 2018; Järvelä & Hadwin, 2013), when learners perceive a deficit or misalignment between a partner's and their own learning processes. For example, when noticing differences in task understanding, they may choose to co-regulate learning partners or negotiate a common strategy and awareness tools may support this process (e.g., Järvelä et al., 2015; Kwon, 2020; Malmberg et al., 2015). Thus, regulating social interaction based on GA may target interaction processes that serve co- and shared regulation during various phases in CSCL. Another example of adapting social interaction would be that when noticing a misalignment in understanding with regard to a key concept in the learning domain, learners may choose to discuss the concept, potentially leading to conflict resolution (Bodemer, 2011). For this, they may use various strategies, like presenting and justifying their own understanding (e.g., Melzner et al., 2020). Once being aware of the conflict to be resolved, learners may terminate conflict resolution and move on to a different topic (e.g., Bodemer & Scholvien, 2014). Alternatively, through monitoring group understanding, they may become aware that their resolution strategies do not work and choose to adapt their interaction processes accordingly. Thus, GA serves a similar function in collaborative learning as metacognition serves within the individual, however, it may relate to group functioning on a relational level as well as learning processes within the content space (Janssen & Bodemer, 2013). Apart from acutely regulating collaborative learning and interaction processes, learners may thereby gain metacognitive knowledge on usefulness of the resolution or learning strategy. Through such processes, they may adapt their internal collaboration scripts, considering not only the deployed strategies and their success, but also conditional knowledge gained from being aware of social conditions during collaboration. This type of regulation is illustrated by cycle (2) in Fig. 2.

(2) Regulating partner schema building. Although regulating the acute learning situation may be the most relevant function of GA within CSCL, it may also serve a more sustainable

social purpose. Especially in stable social settings (like classrooms or informal learning groups), learners may also be inclined to form a sustainable representation of a collaborating partner. GA –as a snapshot of the current state of social information within working memory– requires cognitively processing social information. Such processing may be used within the current social situation (see above), but may additionally be stored in long-term memory for later usage (see also Bodemer et al., 2018). Partner modelling –the process of inferring another person's mental state (Dillenbourg et al., 2016)– is a key to forming stable knowledge structures about another person. This is grounded in GA as GA comprises the salient perceptions of social information on which partner modelling processes are based. To our knowledge, there is currently no research studying the relationship between GA (vs. GA information provided by GA tools) and sustainable partner models. However, GA, as a current mental representation of social information, can be assumed to play a distinct role in forming sustainable memory structures about the learning partner or group as it is based on integrating information perceived during social interaction and said memory structures. Empirically, GA information provided externally has been shown to affect the refinement of partner models, i.e., their accuracy (Sangin et al., 2011). During social interaction and based on GA, these structures – partner models – are being refined and corrected. When learners enter a collaborative situation, social and situational schemata form the basis of expectations within the situation. These may be person-general (e.g., when a person needs to judge a social situation based solely on group heuristics) or rather person-specific (for known collaborators). Especially with unknown partners, heuristics can lead to severe biases that can hamper partner modelling accuracy (e.g., egocentric bias, Epley et al., 2004; or similarity heuristic, Nickerson, 1999) and also collaborative learning (Sangin et al., 2008) or providing adequate explanations (Wittwer et al., 2010). With increasing experience, social information based on heuristics may be replaced by person-specific partner models, when learners gradually build a mental representation of the specific partner (Molinari et al., 2009). In this context, GA acts as an intermediary between the social environment and long-term memory structures and may thus not only be necessary to regulate content-related but also person-related learning processes. Here, building GA may be conducive to partner modelling rather than social interaction. When partner schemata are seen as a relevant cognitive structure and thus a target for learning processes during CSCL, a learner may regulate acquiring said structure via monitoring partner schemata and controlling refinement. Here, GA as a current representation of activated social information, can be used to monitor the accuracy of information in long-term memory by comparing it to information from the environment. This information can be used to refine and correct memory structures to build a coherent and accurate partner model allowing for building reliable knowledge structures useful for ongoing or repeated collaborative learning episodes. This type of regulation is illustrated by cycle (3) in Fig. 2.

Regulating learning in CSCL – A matter of perspective

The above-mentioned regulatory processes focus on cognitive and behavioral processes from an individual perspective. Thus, they describe the role of GA for the individual (self-)regulation of cognition and behavior directed at the social context. This may not be confused with the vital role of self-, co- and shared regulatory processes of group learning during CSCL (see Hadwin et al., 2018). Rather, it puts a lens on the individual processes needed to regulate behavior and cognitions during CSCL. As ultimately these processes are directed at others, this makes GA a socially-focused concept integral to

CSCL. Learning regulation as a group process can be viewed as an extension or rather an instantiation of this perspective. Within the above described framework, these processes are part of the socio-cognitive and socio-behavioral activities, which may include activities co-regulating a co-learner or jointly regulating the learning process. Schnaubert et al., (2020b) propose that regulatory processes interact with CSCL script components on various levels, with scripts containing regulatory activities directed at the group while their implementation in turn is regulated on a higher level. Similarly, we propose that learners regulate their social cognition and interaction processes based on GA and that these interaction processes may include regulating learning as a group. The distinct GA of an individual thus plays a central role in regulating individual behavior and cognitive processes directed at the group.

Various regulatory processes play a role within CSCL. In that way, self-regulation is an integral foundation of social regulation processes (Hadwin et al., 2018; Järvelä & Hadwin, 2013). For example, by being aware that co-learners have a different understanding of the task at hand, a learner may initiate a discussion about the task that may ultimately lead to shared task perception. Similarly, learners may identify that their co-learners are uncertain about their task solution (metacognitive group awareness; Schnaubert & Bodemer, 2019) and provide them with explanations (Dehler et al., 2011). While we subsume activities to co-regulate learning partners or jointly negotiate the collaborative learning process under an individual's "social interaction", this perspective does not diminish the value of shared regulatory processes (and respective research), but instead aims to clarify the role of an individual's GA when navigating the social dynamics within CSCL. Of course, these regulatory processes may be different during different phases of the learning process. Phase-models of learning regulation (e.g., B. J. Zimmerman, 2000) specify activities relevant for regulating learning at different times which may require different GA information. Thus, while not in focus of the current paper, differentiating these processes is vital for understanding (shared) regulation in CSCL. Follow-up research may study the nature of GA regulation required for different phases within the learning process and may also focus on a more collective perspective on shared regulatory activities.

Theoretical, empirical and practical implications

In this paper, we have conceptualized GA as conscious cognition about a social entity or group that an individual perceives as valid in the moment during CSCL. Thereby, GA is associated with working memory processes and is formed via integrating information acquired by bottom-up and top-down processes. Within this framework, GA is an integral part of three distinct regulation cycles. First, GA itself is being metacognitively regulated as various task and situational demands necessitate various levels of GA. Second, GA is used to regulate social interaction, as being aware of the acute social situation helps navigate and interact with the social context. Third, GA has a central function in regulating partner schema building as it can be used to monitor and adapt person-specific social schemata. While these processes are interwoven during CSCL and may seem similar at first glance, they are distinct with regard to the goals of the process and the sustainability of the information regulated. Further, these regulatory processes may be viewed as taking place on different metacognitive levels (regulating GA and using this GA to regulate interaction and partner modelling), which is consistent with a multi-level view of metacognitive regulation (e.g., Efklides, 2008; Nelson & Narens, 1994).

The outlined framework conceptualizing GA and placing it at a focal point in three regulation cycles in CSCL has various implications for research and practice. First, it connects GA to working memory and thus to research concerned with researching its limits and allocation of working memory resources. Second, it distinguishes regulatory functions, which may allow for more targeted research into the design of GA tools and other support for GA in CSCL. Third, defining its facets allows for various methodological approaches to study and critically test assumptions built on these premises. These may advance fundamental research into GA by opening up connections to other research areas. Last but not least, the framework firmly places GA in between individual and social aspects of CSCL. It can thus be seen as the intermediary connecting individuals and their collaborating group.

(1) Working memory and GA. With a defined conceptualization of GA in working memory come several implications that may be systematically tested, for example how building and maintaining GA affects working memory resources for germane learning activities and vice versa, or how working memory capacity affects CSCL beyond effects on individual learning. This connects GA research to other research areas concerned with cognitive capacities during CSCL. For example, there is growing research connecting cognitive load theory to CSCL (see Collaborative Cognitive Load Theory [CCLT]; Janssen & Kirschner, 2020; Kirschner et al., 2018). More decisively connecting research on GA with current approaches in CCLT would benefit both research fields as it would allow explicating the effects of GA on cognitive load as well as high load on GA and effects on social interaction and partner modelling. Further, in building on cognitive load theory as well as multimedia principles and implications for multimedia representations (see Mayer, 2001; Mayer & Moreno, 2003), this work enables design of GA tools that not only provide theoretically beneficial GA information, but also account for the cognitive processes needed to process and integrate relevant social information during CSCL (Janssen et al., 2011). Especially in highly dynamic collaborative settings, processing costs of GA need to be weighed against their effectiveness in promoting collaborative learning. Further, apart from a net gain required, learners need to be aware that the effort is worthwhile before dedicating their limited cognitive resources towards gaining GA. Consequently, perceived usefulness of GA becomes an important factor, and this also applies to the use of GA tools (e.g., K. Chen et al., 2020; Janssen et al., 2011). GA tools may support learners in gaining GA, but providing GA information may not always be enough. The information also needs to be provided in a way that reduces processing costs while encouraging germane efforts (Bodemer, 2011). Thus, costs and benefits of processing GA information (with or without tool support) need to be considered. However, this may depend strongly on the task and the need to regulate social interaction based on social information. Possible research questions would thus include: (a) what constitutes a sufficient level of GA in what learning situation, (b) do learners set appropriate GA standards to regulate their GA accordingly, and (c) how can processing efforts be focused. Thus, GA research needs to take a closer look into task conditions to identify when a subjective need for and objective benefit of GA will actually outweigh the processing costs. These considerations also need to include potential long-term benefits that may arise from building stable partner models for recurring CSCL practices. GA tool deployment should thus always carefully consider constraints and affordances of the task, technological setup, and collaborative situations before providing GA information of any kind, since a minimalistic approach may sometimes be even more beneficial than providing additional information.

(2) Regulatory functions and the design of GA support. The three regulation cycles described above are each of critical importance for CSCL and CSCL research. First, the processes of forming and maintaining GA as well as setting standards and evaluating own

levels of GA against these standards will ultimately determine if the resulting GA is sufficient and sufficiently accurate to allow for effective collaborative learning processes. As a lack of GA may severely hamper CSCL (e.g., Janssen & Bodemer, 2013) and metacognitive processes may put an additional strain on already stretched working memory resources (see Dillenbourg & Bétrancourt, 2006; Valcke, 2002), supporting these processes requires specific efforts. GA tools may provide some support, but how the information provided is used to form an idiosyncratic understanding of the current situation is unclear. A metacognitive perspective may provide a framework to study (a) how the individual perception of a situation and derived GA standards may lead to learners actively searching for information on learning partners, (b) when learners stop allocating additional resources towards understanding social aspects of the situation, or (c) what strategies they use to gather the information. Possible research questions would thus include when and how learners decide to dedicate resources to specify their GA or how low GA accuracy may be identified and subsequently corrected. While GA tools may provide GA information useful for regulating social processes, regulating GA itself may require different means of support. Metacognitive prompts have been shown to increase metacognitive activities (Berthold et al., 2007) and occasionally learning outcomes (Bannert, 2006; Wichmann & Leutner, 2009). Hence, similarly to supporting metacognitive processes, providing prompts to set task-specific standards for the required GA may trigger relevant metacognitive processes. Additionally, GA tools may include information on task-specific standards (if available) and filter information accordingly to support learners in efficiently regulating their GA. From a skill perspective, setting task-specific GA standards for a given CSCL situation and purposefully collecting the information may be part of external CSCL scripts to scaffold GA formation and regulation in an adequate manner. GA research has repeatedly shown that GA information may trigger specific CSCL practices (see Janssen & Bodemer, 2013). However, the relationship between GA and CSCL scripts and how formation and regulation of GA as part of CSCL scripts can be scaffolded has not been studied yet. Such scaffolds may nevertheless eventually be a vital addition to build sustainable collaboration skills (Schnaubert et al., 2020b).

Apart from the regulation of GA, we have specified two further regulatory cycles. From these, further practical implications may be derived. Looking into the regulation cycles it seems clear that GA serves various distinct purposes in CSCL, which may in turn require different means of support. For example, supporting social interaction may require GA tools that are not only a match for the dynamics of CSCL, but also deliver targeted and timely support that may take load off the learners' shoulders. On the other hand, supporting long-term memory structures about learning partners may be better supported by aggregating some fine-grained time-relevant information to larger and more stable units of meaning (like expertise or prior knowledge) that may abstract from the precise situation and may thus be generalizable towards different situations (e.g., Dörner et al., 2007; Sangin et al., 2011). While GA tools vary extensively with regard to how they process and present GA information (Schnaubert et al., 2020a), it is important to tailor the information to the purpose.

(3) Methodological approaches to the measurement of GA. Conducting fundamental research on GA hinges on empirical access to the concept. Existing research mostly relies on the use of GA tools, but because these tools may serve multiple distinct functions within CSCL going beyond supporting formation of GA (Bodemer & Scholvien, 2014), it remains unclear how this research strategy affects research outcomes. This is a central issue of GA research currently unresolved (see also Bodemer et al., 2018). GA research needs a research paradigm

to allow for systematically studying GA. While this may include observing social interaction (e.g., Dehler et al., 2009) or assessing partner schemata (e.g., Sangin et al., 2011), these may only complement approaches to access GA as a dynamic and volatile concept. Lacking methods to holistically access GA, the above discussed premises (cognitive, conscious, current, individual, social, perceived as valid) may also be studied separately and in detail. For example, studying the role of consciousness may build on research done in cognitive psychology with regard to awareness and perception, where research paradigms exist (e.g., Merikle et al., 2001). Working memory premises may be studied using dual-task paradigms (Brünken et al., 2002), which may also be used to study assumptions about the disencumbering influence of pre-existing partner schemata. This is especially possible when using pseudo-collaborative settings to conduct highly controlled experiments. Such studies allow specification of partner characteristics in advance for the purpose of testing very precise hypotheses about the effects of GA (Dehler Zufferey et al., 2011). Social psychology also offers a wide range of research on social processing (e.g., on impression formation, see Fiske et al., 1999) that can be utilized for GA research. Additionally, think-aloud protocols can be used in asynchronous communication settings, which has been done with regard to layperson-instruction for understanding how experts form a mental model of their communication partner (Nückles et al., 2006), and which has been done when studying processes of self-regulated learning in computer-based learning environments (e.g., Greene & Azevedo, 2009). Cued retrospective reporting techniques may produce similar results (van Gog et al., 2005) and may thus be used to retrospectively access the content of GA for studying how it affects social interaction within synchronous CSCL settings. Additionally, advanced student modelling techniques based on trace data as used to analyze self-regulation may complement these approaches (e.g., Biswas et al., 2018; Geden et al., 2021).

Such insights may inform theory building towards formation of a more holistic picture of the mechanisms of GA. Furthermore, they may be complemented by more data-driven approaches from learning analytics or educational data mining to model a learner's GA and relationship to collaborative learning processes during CSCL.

(4) GA as intermediary between social and individual processes. Last but not least, the conceptualization of GA from a psychological perspective focusing on cognitive processes not only adds to understanding the concept of GA and its characteristics, but also places boundaries on the concept. Thus, GA itself equals the view from the individual onto the group and is thus, by definition, void of a conception of mutuality. This is in line with prior definitions (e.g., Bodemer & Dehler, 2011) and conceptualizations of GA (e.g., Engelmann et al., 2009) and related awareness concepts (esp. Endsley, 1995, 2015), and distinguishes GA from intersubjective constructs like group cognition (Stahl, 2006, 2016) or shared aspects of cognition like shared mental models (see also Engelmann et al., 2009). The conceptualization identifying both individual and social characteristics of GA thus puts it in an intermediate position between the individual and the collaborating group, bridging the gap between what is individual and what is social and thus (albeit up until now theoretically) contributing to solving one of the central challenges in CSCL, namely the integration of interaction processes with an individual's subjective premise (Järvelä et al., 2019). Understanding others or the group –which is in the core of GA– is a necessary (although not sufficient) condition for navigating complex social contexts. This is vital for understanding not only individual processes, but also mutuality. While we did not focus on mutually shared assumptions and intentions (e.g., we-awareness, Tenenberg et al., 2016), the focus on conceptualizing GA as a subjective perspective on intersubjectivity provides a basis for taking a group-level view

of collaborative learning. Indeed, mutuality of GA is of vital importance for CSCL as it is related to grounding processes (Clark & Brennan, 1991; Dillenbourg et al., 2016) and other shared cognitions (see Engelmann et al., 2009) and socially shared regulation requires reciprocity and mutual regulatory activities (Järvelä et al., 2019). However, this hinges on the individual learners regulating and adapting their GA towards a mutually accepted (and at times explicitly negotiated) understanding of the social situation. Thus, focusing on shared aspects, shared and co-regulatory processes with regard to GA come into play. Extending the self-regulation of GA by including co- and shared regulatory processes to align GA might be fruitful for follow-up research, but requires a sound basis and thus conceptualization of GA itself. Our conceptualization provides a first step towards this as it sets the stage for follow-up research – both individual and collaborative. Possible follow-up research questions could thus include how GA about other's GA and an alignment of GA within the group may affect co- and shared regulatory processes and social interaction during CSCL.

Conclusion

From a theoretical perspective, the conceptualization offered in this article brings forward not only functional perspectives on GA, but also pinpoints problems that may arise during CSCL. If we perceive GA not as (relatively) stable information, but a dynamic maintenance of partner- or group-information relevant for the learning process, we must recognize that the way learners form and regulate GA is of central importance. Here, GA research may build on research from social psychology regarding the way social cognitions are formed, but also on research on metacognitive regulation (from cognitive and educational psychology) regarding the way learners regulate their understanding of the social situation and the way they use this information to regulate social interaction and partner modelling. For example, conceptualizing GA as a current cognitive process that requires regulation stresses the need for adequately analyzing situational demands and deriving GA standards during collaboration. This may require knowledge about the specific CSCL practices in question. However, strategic knowledge and CSCL skills have not been studied in conjunction with GA and thus, the relationship between the concepts has been widely neglected in CSCL research. This also forms the bridge to other fundamental research areas within the Learning Sciences like collaboration scripts and self-regulation (e.g., Kielstra et al., in press; Vogel et al., in press; H. T. Zimmerman & Land, in press; Rojas et al., in press).

This paper also opens avenues for concrete empirical research allowing future research to study the concept of GA in real-life contexts without manipulating it, which has been a limiting factor of existing GA research so far (Bodemer et al., 2018). While GA is fairly often addressed in empirical research in CSCL, most research activities have so far focused on the design of GA tools. This is of vital importance for practice and also provided important theoretical insights in the past. However, we argue that this perspective should be complemented by research focusing on more fundamental mechanisms of GA in CSCL to better understand its role during collaborative learning. While one research design may not always allow for studying the concept as a whole, the framework enables pinpointing and potentially isolating GA characteristics as well as functions of GA for regulating cognition and behavior during CSCL. This may set the stage for research into mechanisms relying not only on individual GA, but on a mutually negotiated understanding of group characteristics and processes.

Finally, this conceptualization of GA and its role for regulatory processes during CSCL is meant to provide a basis for a vibrant discussion of GA and its features, but also to empirically test assumptions about its role in CSCL and integrate them into intersubjective and collaborative processes in CSCL. Thereby, a Learning Sciences perspective on GA may include various fields of psychology (e.g., cognitive, social, and educational psychology) while building on and extending more applied research conducted in computer science and education. This will allow for a focus on fundamental processes and mechanisms relevant to CSCL, but also to derive practical implications to support the various regulatory functions of GA.

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