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# Cognitive Group Awareness Tools: versatile devices to guide learners towards discrepancies

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**Abstract:** Collaborative practices cover a vast variety of contexts and educational goals. Despite these differences, most means of support draw on between- and within-learner discrepancies as driving forces of individual and collaborative learning. These discrepancies are a focus of cognitive Group Awareness Tools, that process knowledge-related learner data and feed it back to the group to ease the interpretation of the learning situation thereby guiding collaborative learning activities. In this paper, we examine the features and different characteristics of these tools. Based on three exemplary cognitive Group Awareness Tools focusing on different types of knowledge discrepancies, we explore how data processing is adjusted to different settings and discuss whether cognitive Group Awareness Tools are suitable devices to be deployed throughout various educational contexts.

**Keywords:** Cognitive Group Awareness Tools, data processing, discrepancies, guidance

## 1. Discrepancies as a driving force of collaborative learning

Collaborative practices reach from small group interaction to mass collaboration, cover a vast variety of different contexts, such as schools, universities, or leisure time, and are used for very different educational goals, like acquiring domain knowledge or collaboration skills. However, learners need to overcome various challenges to successfully regulate their learning processes. Particularly, they have to register relevant internal and external conditions (e.g., their state of knowledge or their resources at hand) to validly interpret the learning situation and decide upon appropriate courses of action (Winne & Nesbit, 2009). Within collaborative learning settings, other learners are part of this learning situation and thus, learners need to be aware of each other's relevant cognitive states to interpret the collaborative situation appropriately (Bodemer, Janssen, & Schnaubert, 2018).

A central aspect relevant to regulating learning is the identification of discrepancies between current and desired states. These may be caused by information that is not compatible with the learners' existing cognitive structures (causing what Piaget called "disequilibrium"; Piaget, 1977), but also by learners experiencing underachievement in terms of their own learning goals when metacognitively monitoring their performance against their internal standards (e.g., Winne & Hadwin, 1998). Both types of discrepancies may activate resolution processes and activities to overcome them and while they are located within the individual, they can be provoked by external information in the social environment. From a group-level perspective, both discrepancies (between incompatible content or the extent of knowledge of learners) may also activate resolution processes regardless of a learner experiencing an intra-individual need for resolution, because learners may need to establish a shared knowledge base or common ground to collaborate (Clark & Brennan, 1991). This group perspective can also lead to the situation where learners may not even relate group-level information to themselves but identify discrepancies between other learners' cognitions and may be inclined to support resolution regardless of self-involvement. This is especially the case with controversies, which are incompatible assumptions existing within groups or communities (Johnson, Johnson, & Smith, 2000). Thus, within collaborative learning environments, we can distinguish between purely internal discrepancies, internal-external discrepancies, and external discrepancies, which ties in closely with existing definitions of cognitive conflicts, that include internal-internal, internal-external, but also external-external conflicts (Lee & Kwon, 2001). These discrepancies may be due to differences between incompatible content constituting some kind of conflict or controversy (a qualitative difference in ideas) but may also be due to differences between the extent of knowledge (a quantitative difference in knowledge) (see Figure 1).

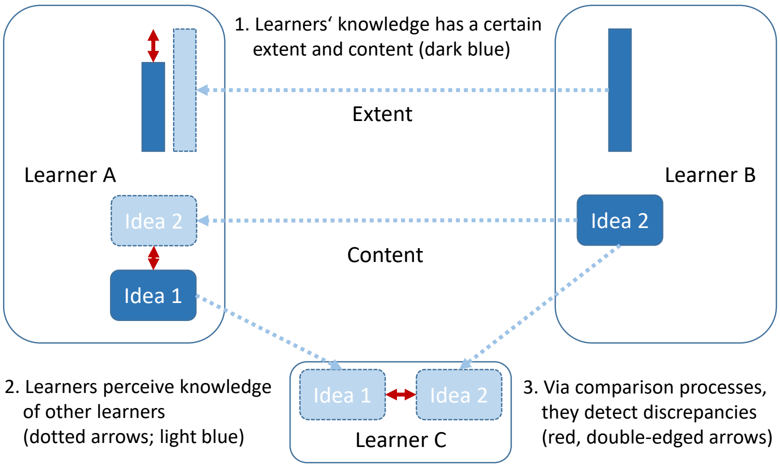


*Figure 1*. Discrepancies as perceived by learner A (internal-external) and C (external)

Collaborative situations may be beneficial for learning, especially when discrepancies occur. But the occurrence of discrepancies in itself is not sufficient to activate beneficial learning processes, learners also need to become aware of these discrepancies (de Vries, Lund, & Baker, 2002). From a self-regulation perspective, learners have to register and validly interpret the learning situation, before they can conduct beneficial learning processes (Winne & Nesbit, 2009). Supporting these processes is often referred to as "guidance". Guidance may include activating or supporting favourable behaviours or processes, but also focussing activities on specific content (Bodemer, 2011). Thus, in this paper, we will take a closer look at one group of tools that seem particularly suited for this kind of instructional support: Cognitive Group Awareness Tools (cGATs).

## 2. Cognitive Group Awareness Tools

A key for learners to benefit from discrepancies within collaborative learning settings is to be aware of their occurrence and to interpret them validly to decide upon appropriate action. This relates to the concept of group awareness, which refers to being informed about relevant characteristics of group members or the group (Bodemer & Dehler, 2011). A group of tools designed to support this are cGATs (see Bodemer et al., 2018). These tools are designed to make learners aware of pre-selected socio-cognitive conditions. By purposefully collecting, transforming and presenting relevant data, they foster the learners' interpretation of the situation to facilitate appropriate action (Buder & Bodemer, 2008). Although the specific goals, content and processing steps used in cGATs differ greatly as well as the settings they are used in (Bodemer et al., 2018), they have specific commonalities: they process knowledge-related information on the extent or content of knowledge to facilitate the learners' identification and interpretation of relevant aspects of the collaborative situation by triggering and easing comparison processes and guiding learners towards discrepancies. By linking such discrepancies to specific content, they further activate content-related resolution processes beneficial for learning but rely on the learners' internal scripts to take it from there. Thus, they are a temporary aid guiding learners' attention and focus in an inherently complex situation. In the following, we will present three exemplary cGATs that have been used to guide collaborative learning in various settings.

*Tool 1: Metacognitive and cognitive awareness for dyadic learning*. This tool was developed to support co-located dyads of learners exchanging information and discussing learning material presented on a shared screen based on learning tasks designed to activate elaboration of content (see Figure 2). Such a collaborative situation provides the opportunity for learners to facilitate each other's individual learning processes by providing information and explanations to fill in gaps of knowledge or by mutually discussing diverging perspectives activating elaboration processes (e.g., de Vries et al., 2002). The educational goal in this scenario is to maximise individual knowledge gain by exploiting processes triggered by potentially beneficial knowledge distributions, i.e., discrepancies regarding extent or content of knowledge. The cGAT provides learners with two types of knowledge-related awareness information: cognitive information on the content and metacognitive information on the extent of knowledge (see Schnaubert & Bodemer, 2019). The tool collects the learners' assumptions about the learning material by asking them to answer binary questions (content) and the learners' metacognitive evaluations of their answers by asking them to provide binary confidence ratings (extent). It then feeds the information back to the learners by presenting it during learning using spatial- (content) and colour- (extent) coding to allow for simultaneous and independent comparison processes within and between learners. The tool thus supports the informational guiding function using representational mechanisms. We also developed adapted versions to explore the effects of self-, partner-, and group-level information on individual and collaborative learning of university students (e.g., Schnaubert & Bodemer, 2016, 2019). Empirical findings clearly suggest that (a) awareness information on the extent of knowledge guides learners to focus on content for which there are knowledge discrepancies with regard to a standard (i.e., knowledge gap), (b) awareness information on the content of learners' assumptions guides learners to focus on content for which there are discrepancies between the contents of the learners' knowledge (i.e., conflict), and (c) learners integrate available types of information (content and extent). However, effects on learning outcomes were rather small and inconclusive.


*Figure 2.* Learning tasks with cGAT: Cropped screenshot (left) and annotated zoom-in (right)

*Tool 2: Controversy awareness for collaborative knowledge construction in wikis*. We used colour-coded highlights for Controversy Awareness. The aim was to make discussion threads that contain exchanges of controversial arguments more salient to users who want to learn more about a subject matter (see Figure 3). It is common for wikis that the longer an article exists the more neutral the article itself becomes. Controversies about a subject matter are often "hidden" in the article's background. Thus, potentially relevant and interesting discussions containing meaningful controversies get easily buried in the sheer mass of discussions that are oftentimes not about the original article's content anymore. Therefore, it can be a frustrating experience for interested users to find the discussion content they are searching for potentially limiting effects on individual learning. For this awareness tool, we built upon research on representational guidance and signalling to implement specific visual highlights as implicit guidance for wikis. We used different colours for coding controversial discussion and their resolution states with the aim of leading students towards a more focused selection of relevant content-related topics covering the subject matter under investigation. As a first step, we assessed existing wiki discussion threads and then manually coded for their content, whether it contained a controversy that was related to the article's content and if it was led by evidence or dealing with off-topic matters (data transformation). Finally, we assigned colour-coded highlights to the discussion threads for two slightly different tool versions – one simply highlighting controversial exchanges of arguments in the thread (blue) and one further differentiating between resolved (green) and unresolved (red) controversies. We evaluated different codings of Controversy Awareness as implicit guidance in several studies in terms of effects on process variables, learning outcomes and quality of knowledge construction artefacts (Heimbuch & Bodemer, 2017, 2018). Our findings suggest that our signalling approach of highlighting content-related controversies has a direct impact on the navigation behaviour, the intensity of reading and on the likelihood of participating in a controversial topic. Furthermore, we found indirect effects on knowledge-related outcomes mediated through process variables.


*Figure 3*. Wiki talk page excerpt with and without controversy awareness information

*Tool 3: Text mining-based knowledge awareness for knowledge exchange in school*. This text mining-based tool was designed for efficiently guiding students' knowledge exchange in school settings which involve the joint solution of tasks in dyads (see Figure 4). In order to solve such tasks, the students are asked to discuss individual differences in prior knowledge or different perspectives on topics. Stimulating such exchange pursues the educational goal that learners uncover and fill their own knowledge gaps, better focus and cognitively elaborate learning content, and achieve better learning outcomes. Therefore, students need to be informed about their cognitive characteristics (Bodemer et al., 2018). Against this background, the discrepancy between one's own current knowledge extent and a higher goal state, revealed by the comparison with a more knowledgeable partner, can initiate attempts to fill one's own knowledge gaps to resolve this discrepancy. The text mining-based Grouping and Representing Tool (GRT; Erkens, Bodemer, & Hoppe, 2016) supports learners by providing them with knowledge-related information about their cognitive characteristics to support the identification of discrepancies. The tool collects learner-generated artefacts as input and transforms it by using text mining. The transformation has three main features (Erkens & Bodemer, 2019): processing the text to identify relevant concepts, pairwise determining the texts' differences for the group formation, and clustering the concepts to identify topics and determine values representing to which extent these topics are represented in each student's text. The presentation of information directly connects to these processes: The GRT lists topics offering information on what learning content to exchange knowledge about (based on the interpretation of concept clusters) and provides information about the learning partners as bar charts (how much both learning partners wrote about a topic within their texts). In a school setting, the usage of the GRT resulted in increased knowledge acquisition and knowledge convergence due to the exchange of knowledge between learning partners (Erkens et al., 2016). In a laboratory study, we found indirect effects on knowledge gains mediated through partner modelling and knowledge integration (Erkens & Bodemer, 2019). We have also found that the provision of GRT-generated information about learning content improves questioning, as it, in combination with the bars on one's own knowledge level, improves the focus on questions about topics with knowledge gaps. Thus, the GRT is suitable to guide students, resulting in better learning processes and outcomes.

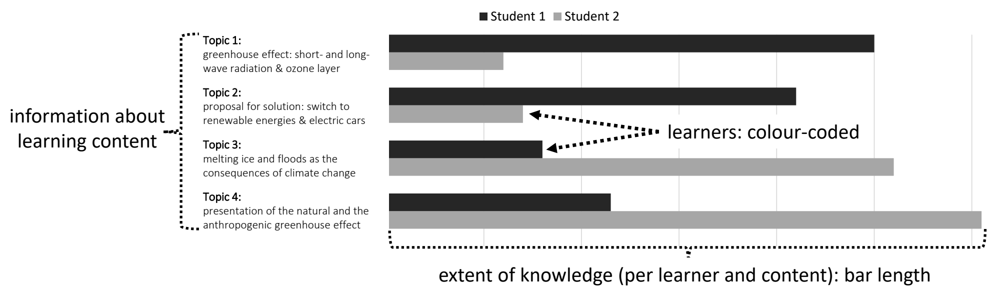


*Figure 4.* Information provided by the GRT (annotated)

## 3. Cognitive Group Awareness Tools as versatile devices

Based on theoretical assumptions and our empirical analyses, the preceding chapters illustrate the need for versatile support features of cGATs to support collaborative learning and the benefit that may be gained from making learners aware of knowledge discrepancies.

One of the major interests is the question of whether cGATs can be deployed in different settings towards a variety of goals. The examples above illustrate that cGATs are able to support learners in multiple contexts such as universities, schools, or social media across varying group sizes from dyads to large communities as has been stated previously (Bodemer et al., 2018). Although the empirical examples that we have provided look into different learning outcomes, the main educational goal throughout is individual knowledge gain. CGATs are seldom deployed for other purposes, for example, to foster the development of higher order skills like collaboration skills. Thus, they seem to be deemed especially suited to support content-specific knowledge exchange in some form to foster individual learning. This seems logical as one function of cGATs is to cue specific information (Bodemer & Scholvien, 2014) and thus, the awareness information selected usually refers to content-specific learning material (Bodemer et al., 2018).

Another key question is whether there are common features that suggest generic functions and make cGATs versatile. Our examples show that cGATs can foster regulatory attempts based on various types of discrepancies. Depending on setting and goal, the tools target information relating to the content (tools 1 & 2) or the extent of knowledge (tools 1 & 3). However, the guiding functions these tools use all rely on processing steps that simplify complex information, either by the way they are collected (tool 1) or by the way they are transformed (tools 2 & 3). Within small groups and internal-external discrepancies, cGATs usually do not break up the relationship between the selected awareness information and the individual learner during transformation. This makes learners easily identifiable fostering partner modelling and communication efforts (e.g., Dehler, Bodemer, Buder, & Hesse, 2011; Erkens & Bodemer, 2019). Tools 1 and 3 deal with such small groups and thus abstain from aggregating data across learners during transformation, which allows learners to differentiate self- and partner-information (e.g., Schnaubert & Bodemer, 2016, 2019), both of which may affect both learners' behaviour (Lin, Tsai, Hsu, & Chang, 2019). On the contrary, to identify controversies within wikis, identifiable individuals are of less importance than the overall state of knowledge within the community. Tool 2 takes this into account when pre-interpreting discussion threads by relating individual comments to transform them into one threefold measure, simplifying this highly complex information (e.g., Heimbuch & Bodemer, 2017). Regarding data presentation, the coding mechanisms used in cGATs support various types of basic cognitive operations, especially comparison processes. For example, tool 1 uses spatial coding to allow to easily detect a discrepancy between the content of the learners' knowledge, while tool 2 uses colour-coding for highlighting controversies. Tool 3 uses bar charts to support between-learner comparisons of the extent of the learners' knowledge on a continuum and additionally colour-codes the graphs to allow to easily relate a graph to a specific learner. Tool 1 on the other hand uses colour-coding (hatching) to represent information on the extent of knowledge and uses location to make the learners easily identifiable. Thus, all use various codes to convey different information. While there seems to be a lot of adequate ways to present the data, it can be argued that colour-coding may reach its limits when comparing continuous information as small differences may become less easy to compare than when using charts. However, with binary or ternary measures, colours may provide a powerful way to draw attention by flagging or highlighting specific information as hue can be easily identified by the low-level visual system (Healey & Enns, 2012). Thus, the colour spectrum may be used to code categorical information (like in tool 3) and brightness, saturation or hatching may even code ordinal information if the number of possible values is low (like in tool 1).

Due to the number of possibilities of tool deployment, there is a need for systematic research. The empirical findings suggest that processing information to allow for easy comparisons between learners (tools 1 & 3) or even pre-interpreting discrepancies (tool 2) guides learners towards tackling those discrepancies (e.g., Erkens & Bodemer, 2019; Heimbuch & Bodemer, 2018; Schnaubert & Bodemer, 2019). How they tackle them seems to depend largely on affordances defined by the setting and it is thus not surprising, that the effects on learning gains are less straightforward and vary between tools. It becomes apparent that – while cGATs seem to be quite versatile and may guide collaborative learning efforts towards potentially beneficial social conditions like various knowledge discrepancies in various contexts – their effective employment largely depends on a number of decisions an educator has to make with regard to their specific setup. Unfortunately, no guidelines exist to support educators who want to use group awareness-support within a specific context. This is largely because research on cGATs has up until now been a rather desultory endeavour with every new study developing effective but essentially new tools with specific features and no overarching framework. Thus, the diversity of the field is its biggest assets, but also one of its biggest issues. Altogether, there seem to be a vast amount of possibilities to process data within cGATs, making them highly adaptable. However, there also seem to be boundaries for specific processing steps and thus, guidelines can be developed that support tool development and employment. To draw on this feature, we thus need systematic research looking more deeply into generic functions of cGATs to develop guidelines for tool processing. These guidelines need to consider the educational goal, but also the intended learning processes in conjunction with the specific learning situation. This includes ideas about the discrepancies the tool is set to highlight and the processes and activities these discrepancies are meant to trigger (e.g., argumentation, knowledge exchange). We argue that the tools' processing steps (data collection, data transformation, data presentation) may be used as a framework for this kind of systematic approach as they comprise the basic decisions an educator or tool designer has to make and allow to systematically include other research areas such as computer science and research on human information processing.

## References


Bodemer, D. (2011). Tacit guidance for collaborative multimedia learning. *Computers in Human Behavior*, *27*(3), 1079–1086. https://doi.org/10.1016/j.chb.2010.05.016

Bodemer, D., & Dehler, J. (2011). Group awareness in CSCL environments. *Computers in Human Behavior*, *27*(3), 1043–1045. https://doi.org/10.1016/j.chb.2010.07.014

Bodemer, D., Janssen, J., & Schnaubert, L. (2018). Group awareness tools for computer-supported collaborative learning. In F. Fischer, C. E. Hmelo-Silver, S. R. Goldman, & P. Reimann (Eds.), *International Handbook of the Learning Sciences* (pp. 351–358). New York, NY: Routledge/Taylor & Francis.

Bodemer, D., & Scholvien, A. (2014). Providing knowledge-related partner information in collaborative multimedia learning: Isolating the core of cognitive group awareness tools. In C.-C. Liu, H. Ogata, S. C. Kong, & A. Kashihara (Eds.), *Proceedings of the 22nd International Conference on Computers in Education ICCE 2014* (pp. 171–179). Nara, Japan: APSCE.

Buder, J., & Bodemer, D. (2008). Supporting controversial CSCL discussions with augmented group awareness tools. *International Journal of Computer-Supported Collaborative Learning*, *3*(2), 123–139. https://doi.org/10.1007/s11412-008-9037-5

Clark, H. H., & Brennan, S. E. (1991). Grounding in communication. In L. B. Resnick, J. M. Levine, & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 127–149). Washington, DC: APA.

de Vries, E., Lund, K., & Baker, M. (2002). Computer-mediated epistemic dialogue: Explanation and argumentation as vehicles for understanding scientific notions. *Journal of the Learning Sciences*, *11*(1), 63–103. https://doi.org/10.1207/S15327809JLS1101_3

Dehler, J., Bodemer, D., Buder, J., & Hesse, F. W. (2011). Guiding knowledge communication in CSCL via group knowledge awareness. *Computers in Human Behavior*, *27*(3), 1068–1078. https://doi.org/10.1016/j.chb.2010.05.018

Erkens, M., & Bodemer, D. (2019). Improving collaborative learning: Guiding knowledge exchange through the provision of information about learning partners and learning contents. *Computers & Education*, *128*, 452–472. https://doi.org/10.1016/j.compedu.2018.10.009

Erkens, M., Bodemer, D., & Hoppe, H. U. (2016). Improving collaborative learning in the classroom: Text mining based grouping and representing. *International Journal of Computer-Supported Collaborative Learning*, *11*(4), 387–415. https://doi.org/10.1007/s11412-016-9243-5

Healey, C., & Enns, J. (2012). Attention and visual memory in visualization and computer graphics. *IEEE Transactions on Visualization and Computer Graphics*, *18*(7), 1170–1188. https://doi.org/10.1109/TVCG.2011.127

Heimbuch, S., & Bodemer, D. (2017). Controversy awareness on evidence-led discussions as guidance for students in wiki-based learning. *The Internet and Higher Education*, *33*, 1–14. https://doi.org/10.1016/j.iheduc.2016.12.001

Heimbuch, S., & Bodemer, D. (2018). Interaction of guidance types and the Need for Cognitive Closure in wiki-based learning. *PeerJ*, *6:e5541*. https://doi.org/10.7717/peerj.5541

Johnson, D. W., Johnson, R. T., & Smith, K. A. (2000). Constructive controversy: The educative power of intellectual conflict. *Change: The Magazine of Higher Learning*, *32*(1), 28–37. https://doi.org/10.1080/00091380009602706

Lee, G., & Kwon, J. (2001). What do we know about students' cognitive conflict in science classroom: A theoretical model of cognitive conflict process. In P. A. Rubba, J. A. Rye, W. J. Di Biase, & B. A. Crawford (Eds.), *Proceedings of the Annual Meeting of the Association for the Education of Teachers in Science* (pp. 309–325). Costa Mesa, CA: Association for the Education of Teachers in Science.

Lin, J.-W., Tsai, C.-W., Hsu, C.-C., & Chang, L.-C. (2019). Peer assessment with group awareness tools and effects on project-based learning. *Interactive Learning Environments*, *0*(0), 1–17. https://doi.org/10/gf2qm6

Piaget, J. (1977). *The development of thought: Equilibration of cognitive structures*. Oxford, United Kingdom: Viking Press.

Schnaubert, L., & Bodemer, D. (2016). How socio-cognitive information affects individual study decisions. *Transforming Learning, Empowering Learners: The International Conference of the Learning Sciences (ICLS) 2016*, *1*, 274–281. International Society of the Learning Sciences.

Schnaubert, L., & Bodemer, D. (2019). Providing different types of group awareness information to guide collaborative learning. *International Journal of Computer-Supported Collaborative Learning*, *14*(1), 7–51. https://doi.org/10.1007/s11412-018-9293-y

Winne, P. H., & Hadwin, A. F. (1998). Studying as self-regulated learning. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 277–304). Mahwah, NJ: Lawrence Erlbaum.

Winne, P. H., & Nesbit, J. C. (2009). Supporting self-regulated learning with cognitive tools. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Handbook of metacognition in education* (pp. 259–277). New York, NY: Routledge.