Improving Educational Online Collaboration: A Psychological View on the Cognitive, Behavioral, and Emotional Effects of Implicit Guidance

Von der Fakultät für Ingenieurwissenschaften

Abteilung Informatik und Angewandte Kognitionswissenschaft

der Universität Duisburg-Essen

zur Erlangung des akademischen Grades

Doktor der Naturwissenschaften (Dr. rer. nat.)

genehmigte kumulative Dissertation

von

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Tag der mündlichen Prüfung: 08.02.2022

DOI: 10.17185/duepublico/75465
URN: urn:nbn:de:hbz:465-20220307-114045-9

Acknowledgments

All our dreams can come true, if we have the courage to pursue them.

Walt Disney

If someone had asked me a few years ago if I could ever dream of completing a PhD after my master's degree, the feeling of not being able to do so would probably have been too great. Even though the road over the last three years has sometimes been a hard one, I am overjoyed that I had the courage to take it. It has made me grow not only in terms of my skills but also as a person. That I am now writing these lines and that the handing in of my thesis is within reach is also thanks to several people who have accompanied me during these years. Without their collaboration, feedback, and encouragement, this work would not have been possible.

The biggest thanks go to my two supervisors. My first supervisor, Professor Dr. Daniel Bodemer, was the one who gave me the courage to choose the PhD path in the first place. Daniel, I am very grateful to you for the many pieces of advice you have given me over the years, which have always kept me positively challenged and made this thesis what it is. However, I am even more grateful for your emotional support, especially in situations of self-doubt and failure, where I could always count on you. Many thanks also to Professor Dr. Mohamed Amine Chatti, who agreed to evaluate my thesis as a second supervisor, which I greatly appreciate.

I am also deeply grateful to the co-authors of the papers integrated into this thesis: Dr. Sven Heimbuch, Olivia Venohr, Hannah Krajewski, and Cora Weisenberger. Without the successful collaboration with you, the subprojects and publications integrated here could not have been realized. Thank you for accompanying me on this journey. Thanks also to the reviewers and researchers at conferences who have contributed significantly to the quality of these works by providing valuable feedback.

As I was lucky enough to be part of two teams, I would like to thank both my team members at the department of Research Methods in Psychology – Media-Based Knowledge Construction and the Research Training Group (RTG) User-Centered Social Media. I had better not start trying to name everybody here, as there are far too many of you. However, I would like to make a special mention of my long-time office colleagues Dr. Melanie Erkens and Maribell Steiner. Thank you very much for the lively exchange on all kinds of topics. I am beyond happy to have had such great people

by my side. My appreciation also goes to Lydia Harbarth, and my favorite Thailand travel buddy, Christian Schlusche, who gave me valuable feedback on this cumulus. Also, the exchange in the interdisciplinary working groups of the RTG has broadened my theoretical and methodological horizon enormously, so here's to "quantified communities"!

And where would I be without my family and friends? I would not have reached this point. My thanks go especially (but not exclusively) to my unconditionally supportive parents, Birgit and Ernst Ollesch, my twin sister, Isabell Ollesch, and my best friend for 19 years, Jessica Jankowski. Thank you for always believing in me and for giving me fresh ideas when I was too absorbed in my own research.

To anybody who may feel forgotten, I am truly sorry! Having you all in my life – both those whom I have mentioned explicitly and those whom I hope can find themselves "between the lines" – is a true gift.

Abstract

Computer-supported collaboration and learning have attracted much attention, as working together all around the world is no longer a rarity for both students and employees. To exploit the potential of such settings in various contexts, several branches of research have investigated the extent to which the use of specific technologies promises to increase the user experience as well as learning outcomes, behavioral engagement, and social outcomes. Particularly worth mentioning here are so-called group awareness tools that can be implemented as a support method to capture and present user-related information, such as competencies, activities, or emotional states. These provide implicit cues that can guide collaborators, thereby improving educational online collaboration.

This thesis investigates the application of group awareness information at the cognitive (feedback about the amount of knowledge), behavioral (feedback about the amount of participation), and emotional (feedback about the amount of friendliness) levels as support for educational online collaboration and more specific social media environments. These environments are becoming increasingly popular in computer-supported collaborative learning; however, there is a lack of insight necessary to facilitate their use in educational contexts. The main aim of this thesis is, therefore, to investigate the specific effects and underlying mechanisms of different types of group awareness information systematically to make concrete recommendations for action. To fulfill this aim, an integrated theoretical framework was set up that illustrates the support potential of implicit guidance for educational social media environments via group awareness tools, which will inspire future research attempts.

Four empirical studies were conducted. In the first two studies, the user relevance of implementing different awareness information (knowledge, participation, and friendliness) in a collaborative setting was investigated using choice-based conjoint analysis (Study 1) and qualitative interviews (Study 2). The study results show that all three awareness types (cognitive, behavioral, and emotional group awareness information) are desirable by the potential target group, depending on the influence of personal characteristics. Individuals with a higher need for affect are more likely to value emotional group awareness support, whereas individuals with a higher social comparison orientation consider cognitive group awareness support more relevant for collaboration.

Study 3 systematically investigated the effects of cognitive and/or behavioral group awareness information on various processes and outcomes in a wiki-like learning environment, using eye-tracking to better picture the underlying attention processes of the guidance methods

implemented. Although information about knowledge levels and participation quantity of others shows positive effects in a single presentation regarding learning content selection and the behavioral engagement of users, the combination of both information types is particularly convincing in terms of increasing the quality of the content produced, which is classified as a learning outcome at the textual level.

Study 4 transferred the design of Study 3 to the systematic comparison of cognitive and emotional group awareness information. A special feature here was the use of a programmed sentiment algorithm to capture and present friendliness in written discussion posts. Although the results do not reveal positive interaction effects between cognitive and emotional group awareness information, they show that information about the knowledge levels of other collaborators can increase the quality of the resulting textual discourse, whereas information about friendliness levels can have a positive effect on social behavior in such discourse as well as on mental well-being.

Overall, the results illustrate that a holistic approach for supporting social media and related learning environments is beneficial for learning and collaboration, as cognitive, behavioral, and emotional group awareness information has various positive effects in such environments. These effects range from improved textual learning outcomes (quality of content produced) through increased number of contributions (behavioral engagement) to positive social outcomes (mental well-being). By adopting a systematic experimental approach and using a wide range of collection methods, this thesis brings together various types of awareness. It thus provides important insights for current and future research in the field of group awareness, computer-supported collaborative learning, and educational psychology in general. Concrete theoretical and practical implications for the application of such implicit guidance methods are derived.

Zusammenfassung

Computergestützte Kollaboration und Lernen gewinnen zunehmend an Aufmerksamkeit, da das gemeinsame Arbeiten auf der ganzen Welt sowohl für Studierende als auch für Arbeitnehmer*innen keine Seltenheit mehr darstellt. Um das Potenzial solcher Settings in verschiedenen Kontexten zu nutzen, haben einige Forschungszweige untersucht, inwieweit der Einsatz spezifischer Technologien erfolgversprechend ist, um die Nutzererfahrung sowie Lernergebnisse, behaviorales Engagement und Auswirkungen auf soziale Variablen zu steigern. Besonders erwähnenswert sind hier sogenannte Group Awareness-Tools, die als unterstützende Maßnahmen eingesetzt werden können, um nutzerbezogene Informationen wie Kompetenzen, Aktivitäten oder emotionale Zustände zu erfassen und darzustellen. Auf diese Weise liefern sie implizite Hinweise, die helfen können, Kollaborierende zu lenken und auf diese Weise die Online-Kollaboration im Bildungsbereich zu verbessern.

Ziel dieser Arbeit ist es, die Anwendung von Group Awareness-Informationen auf kognitiven (Rückmeldung über den Wissensstand), behavioralen (Rückmeldung über den Grad der Partizipation) und emotionalen (Rückmeldung über den Grad der Freundlichkeit) Ebenen als Unterstützung für die pädagogische Online-Kollaboration und noch spezifischer sozial-mediale Umgebungen zu untersuchen. Diese Umgebungen erfreuen sich zunehmender Beliebtheit für computergestütztes kollaboratives Lernen, jedoch mangelt es an Erkenntnissen, die ihren Einsatz in Bildungskontexten erleichtern. Hauptziel ist es daher, die spezifischen Wirkungen und zugrundeliegenden Mechanismen verschiedener Group Awareness-Informationen systematisch zu untersuchen, um konkrete Handlungsempfehlungen geben zu können. Um dieses Ziel zu erreichen, wurde ein integriertes theoretisches Framework aufgestellt, welches das Unterstützungspotenzial impliziter Maßnahmen für Social Media-Lernumgebungen in Form von Group Awareness-Tools verdeutlicht und zukünftige Forschungsansätze inspirieren soll.

Es wurden vier empirische Studien durchgeführt. In den ersten beiden Studien wurde die Nutzerrelevanz der Implementierung verschiedener Awareness-Informationen (Wissen, Partizipation und Freundlichkeit) in einer kollaborativen Umgebung mittels Choice-Based Conjoint-Analyse (Studie 1) und qualitativer Interviews (Studie 2) untersucht. Die Studienergebnisse ergeben, dass alle drei Awareness-Typen – kognitive, behaviorale und emotionale Gruppen Awareness-Informationen – von der potenziellen Zielgruppe erwünscht sind, was vom Einfluss persönlicher Merkmale abhängig ist. Personen mit einem höheren Affektbedürfnis schätzen eher emotionale Group Awareness-Unterstützung, während Personen

mit einer höheren sozialen Vergleichsorientierung kognitive Group Awareness-Unterstützung in der gemeinsamen Kollaboration als relevant erachten.

Studie 3 untersuchte systematisch die Auswirkungen kognitiver und/oder behavioraler Group Awareness-Informationen auf verschiedene Prozesse und Ergebnisse in einer Wiki-ähnlichen Lernumgebung, einschließlich der Nutzung von Eye-Tracking, um die zugrunde liegenden Aufmerksamkeitsprozesse der implementierten Unterstützungsmethoden besser zu verstehen. Obwohl Informationen über den Wissensstand als auch die Partizipationsquantität in einzelner Darbietung positive Effekte auf die Auswahl von Lerninhalten und das behaviorale Engagement von Nutzer*innen aufzeigen, überzeugt insbesondere die Kombination beider Informationstypen hinsichtlich einer erhöhten Qualität der produzierten Inhalte, was als Lernergebnis auf Textebene eingestuft wird.

Studie 4 übertrug das Design von Studie 3 auf den systematischen Vergleich von kognitiven und emotionalen Group Awareness-Informationen. Eine Besonderheit war hier der Einsatz eines programmierten Sentiment-Algorithmus zur Erfassung und Darstellung von Freundlichkeit in verfassten Diskussionsbeiträgen. Auch wenn die Ergebnisse keine positiven Interaktionseffekte zwischen kognitiven und emotionalen Group Awareness-Informationen aufzeigen, so wird deutlich, dass Informationen über den Wissensstand der anderen Mitwirkenden die Qualität des resultierenden textuellen Diskurses erhöhen können, während sich Informationen über den Freundlichkeitsgrad positiv auf das Sozialverhalten dieses Diskurses sowie das daraus resultierende mentale Wohlbefinden auswirken können.

Insgesamt illustrieren die Ergebnisse, dass ein ganzheitlicher Ansatz bei der Unterstützung von sozial-medialen und verwandten Lernumgebungen für das Lernen und die Kollaboration von Vorteil ist, da Informationen über kognitive, behaviorale und emotionale Aspekte in solchen Umgebungen verschiedene positive Effekte erzielen. Diese Effekte reichen von verbesserter Qualität der produzierten Inhalte (textuelle Lernergebnisse) über ein gesteigertes behaviorales Engagement (Anzahl der Beiträge) bis hin zu positiven Auswirkungen auf soziale Variablen (mentales Wohlbefinden). Durch die Wahl eines systematischen experimentellen Ansatzes und die Verwendung eines breiten Spektrums von Erhebungsmethoden bringt diese Arbeit verschiedene Arten von Group Awareness zusammen. Auf diese Weise liefert sie wichtige Erkenntnisse für aktuelle und zukünftige Forschung auf dem Gebiet der Group Awareness, des computergestützten kollaborativen Lernens und der pädagogischen Psychologie im Allgemeinen. Konkrete theoretische und praktische Implikationen für die Anwendung solcher impliziten Unterstützungsmethoden werden abgeleitet.

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List of Included Papers

The following papers have been published in various peer-reviewed scientific journals and conferences proceedings:

Paper 1 (Framework)

Ollesch, L., Heimbuch, S., & Bodemer, D. (2019). Towards an integrated framework of group awareness support for collaborative learning in social media. In M. Chang, H.-J. So, L.-H. Wong, F.-Y. Yu, & J. L. Shih (Eds.), *Proceedings of the 27th International Conference on Computers in Education* (pp. 121–130). Asia-Pacific Society for Computers in Education. Corrigendum in DuEPublico2: https://doi.org/10.17185/duepublico/74884

Paper 2 (Studies 1 and 2)

Ollesch, L., Heimbuch, S., Krajewski, H., Weisenberger, C., & Bodemer, D. (2020). How students weight different types of group awareness attributes in wiki articles: A mixed-methods approach. In M. Gresalfi & I. S. Horn (Eds.), *The Interdisciplinarity of the Learning Sciences, 14th International Conference of the Learning Sciences* (Vol. 2, pp. 1157–1164). International Society of the Learning Sciences. https://repository.isls.org/handle/1/6309

Paper 3 (Study 3)

Ollesch, L., Heimbuch, S., & Bodemer, D. (2021). Improving learning and writing outcomes: Influence of cognitive and behavioral group awareness tools in wikis. *International Journal of Computer-Supported Collaborative Learning*, *16*(2), 225–259.
https://doi.org/10.1007/s11412-021-09346-6

Paper 4 (Study 4)

Ollesch, L., Venohr, O., & Bodemer, D. (2022). Implicit guidance in educational online collaboration: Supporting highly qualitative and friendly knowledge exchange processes. *Computers and Education Open*, *3*, Article 100064.
https://doi.org/10.1016/j.caeo.2021.100064

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[1] Except of Figures 3 and 5, all figures are adapted from "Towards an integrated framework of group awareness support for collaborative learning in social media" by L. Ollesch, S. Heimbuch, and D. Bodemer, 2019, *Proceedings of the 27th International Conference on Computers in Education*, p. 127. Copyright 2019 by Asia-Pacific Society for Computers in Education.

1. Background and Research Summary

Nowadays, collaborative learning plays an important role in schools, higher education, and working places (Goggins & Jahnke, 2013; Mostafa, 2021; Sobko et al., 2020). Whereas earlier approaches often emphasized the transfer of content and knowledge from teachers or trainers to the individual learner, the focus in collaborative learning is on learners' social interaction and their active and independent construction of knowledge (Cress et al., 2021). Computer-supported collaborative learning and development, in particular, is becoming increasingly relevant, as this offers many advantages, such as lower barriers to entry due to temporal and spatial independence as well as multiple representations of learning content supporting different types of learners (Ainsworth & Chounta, 2021; Sundaresan & Zhang, 2020). Social media environments such as wikis (e.g., Wikipedia), social networking sites (e.g., Facebook), blogs (including a wide range of topics), and massive open online courses (e.g., Coursera) are particularly notable, and their widespread popularity makes them a focus of attention for computer-supported collaborative learning contexts (Lampropoulos et al., 2021; see section 1.1). The use of social media as educational technology is associated with increased potential for high-level knowledge generation over simplified content creation to positive effects on satisfaction and enjoyment (Al-Rahmi & Zeki, 2017; Cole, 2009; Reinhardt, 2019; see *2. Potentials of Collaborative Learning and CSCL* in Paper 1, Ollesch et al., 2019).

The application possibilities are diverse; for example, they can be applied in classic school education as blended approaches but also in flexible online vocational training settings. Most recently, this has been reinforced by new requirements imposed by the COVID-19 pandemic, in which not only companies and universities but also private persons have been confronted with the need to open to learning, working, collaborating, and networking through digital media. Although many institutions have moved to online formats during the pandemic (Moorhouse & Kohnke, 2021; Raza et al., 2021), they often fail to provide deep self-regulated learning opportunities (Shine & Heath, 2020). This is mostly due to challenges in relation to the lack of information about counterparts, which complicates the use of social media environments for educational purposes (see *3. Challenges in Collaborative Learning and CSCL* in Paper 1, Ollesch et al., 2019). First, such environments can contain many contributions, which makes it difficult to filter learning-promoting contributions, leading to insufficient or failing learning processes (Buder et al., 2015). Second, precisely because individual contributions are quickly lost in the enormous amounts of data, there is not always a willingness to participate actively or even to contribute at all. This may lead to people working in isolation, which prevents the development of a community (see Lin et al., 2019). Third, in addition to

finding contributions that are conducive to learning, it is also important to deal with such content in a way that is conducive to the group climate. This cannot be taken for granted, especially when a lot of people with different personalities come together, and it might interfere with learning processes (Näykki et al., 2014; Paper 1, Ollesch et al., 2019). This highlights the need for additional support.

Implicit guidance in the form of *group awareness tools* is considered a promising intervention to support collaborative learning processes by addressing the challenges mentioned above (see section 1.2). These tools guide collaborators through implicit incentives, providing awareness information on group aspects without giving explicit instructions on how people must behave, an approach that has already confirmed its value in various contexts (Buder et al., 2021). A distinction is made between cognitive (e.g., feedback about knowledge differences), behavioral (e.g., feedback about participation amount), and emotional (e.g., feedback about friendliness level) group awareness tools, which have shaped the further course of this work (see *4. Supporting Learning Processes in CSCL* in Paper 1, Ollesch et al., 2019). To increase the number of valuable insights, the extent to which personal characteristics influence the use of implicit guidance methods is also examined (see section 1.3). Systematic consideration of group awareness tool effects, including personal characteristics, is important to better understand both single group awareness tool mechanisms and their interplay. In the past, many studies have shed light on only one type of group awareness tool mechanism (e.g., Avry et al., 2020; Dehler et al., 2011) or have used a full-support versus a no-support strategy that hinders deeper insights into the specific effects of different types of group awareness information (e.g., Dado & Bodemer, 2018; Phielix et al., 2011). Further insights are especially important in the context of social media environments (Paper 1, Ollesch et al., 2019) associated with certain characteristics (see section 1.1.1).

As wikis have been shown to improve knowledge building through argumentative activities, in this thesis, a wiki-like context was chosen as a suitable, classical example of educational social media environments. In wikis, the articles (textual artifact pages on specific topics) represent the user-generated content, and the discussion pages (pages that discuss topics in more detail) provide an asynchronous opportunity to talk about the content and related controversies (see Za'za' & Ahmed, 2020). According to Wise and Schwarz (2017), much research has been put into small-scale and formal learning practices. However, it cannot be assumed that small-group interventions can be easily scaled up, which makes the empirical investigation of larger group intervention designs indispensable. To address this research gap, this thesis will focus on group awareness tool interventions in educational social media

environments. It gives an overview of the potentials, but also the challenges, of using such environments in the collaborative learning context (see section 1.1). Implicit guidance methods (i.e., group awareness tools) are presented and evaluated that are particularly suited for exploiting certain potentials of educational social media environments, particularly when various personal characteristics are taken into account (see sections 1.2 and 1.3). The overall research question, therefore, deals with the following aspects:

- The extent to which the use of single but also combined cognitive, behavioral, and emotional group awareness information can enhance cognitive, behavioral, and emotional effects on certain processes and outcomes that are characteristic of educational social media collaboration.
- The role of personal characteristics, in particular the need for cognition/cognitive closure, the social comparison orientation, and the need for affect, in interaction with these implicit guidance methods.

Answering the overall research question of this thesis will increase knowledge about group awareness tool use in social media contexts for both researchers and practitioners, with implications for instructors on how such learning environments should be designed to enhance the learning experience and cognitive, behavioral, and emotional effects. In total, five subprojects,[2] one theoretical and four empirical, have been integrated into this thesis to answer the research question (see section 1.4). Subproject 1 (Framework; Paper 1, Ollesch et al., 2019) presents the prevailing types of group awareness tools and future research directions. Subproject 2 (Studies 1 and 2; Paper 2, Ollesch et al., 2020) illustrates the relevance of the extracted group awareness attribute types for potential users. Subproject 3 (Study 3; Paper 3, Ollesch et al., 2021) systematically investigates the effects of cognitive and behavioral group awareness tools. Subproject 4 (Study 4; Paper 4, Ollesch et al., 2022) systematically investigates the effects of cognitive and emotional group awareness tools on various processes and outcomes. Section 1.5 summarizes the studies and methods used, including choice-based conjoint analysis, qualitative interviews, eye tracking, and sentiment analysis. Section 1.6 presents an integrated discussion of the findings and theoretical background, including theoretical and practical implications and an exemplary application case, before the integrated papers are listed (see sections 2, 3, 4, and 5).

[2] Note that I use the term *subprojects* because it is not only the empirical studies that were integrated into this PhD project.

1.1 (Computer-Supported) Collaborative Learning

The overarching context for this thesis is the field of *collaborative learning*. It is assumed that natural collaborative activities, such as explaining and asking questions, can expand both individual and collaborative cognitive structures (King, 2007). Furthermore, participation in collaborative learning is seen as a chance to gradually learn social practices such as working with others (Kolodner, 2007). The use of computer-supported collaborative learning environments is particularly promising and is therefore included in the focus of this thesis.

1.1.1 Computer-Supported Collaborative Learning Environments

Given the growing relevance of digital networks, *computer-supported collaborative learning (CSCL)* is increasingly popular (Boulos et al., 2006; Rimland, 2017). The relevance of computer-supported learning and teaching has intensified, not least against the backdrop of the current COVID-19 pandemic, in which institutions worldwide have been forced to move away from traditional face-to-face teaching and to offer distance learning instead (Dhawan, 2020). In CSCL, two or more learners work together on tasks or problems, supported with "learning environments based on educational technology" (Radkowitsch et al., 2020, p. 6). Social media environments provide specific technologies to support interaction and collaboration between users and allow them to build communities (Kimmerle et al., 2015). These types of learning environments enable users to generate and share media content individually or collectively, which is referred to as user-generated content (Kaplan & Haenlein, 2010), leading to a shift from media monologues (one-to-many) to media dialogues (many-to-many) (Russo et al., 2008). Compared to traditional media that emphasize unidirectional transmission and acquisition of knowledge, social media focuses on active participation, collaboration, and knowledge sharing among users (Greenhow & Lewin, 2016; Mao, 2014), turning them into media consumers and producers (Fuchs et al., 2010). Although the purpose of social media environments is not necessarily learning-related, their openness and user focus make them very attractive, especially for informal learning contexts (Wise & Schwarz, 2017). There are further specific characteristics of social media environments that make them beneficial for learning and argumentative activities. What is special about these types of computer-supported collaborative learning environments is that social media tools are the technical artifacts that are used. On the one hand, this offers the opportunity for many learners or collaboration partners to come together in remote settings. On the other hand, it makes it more challenging to work within a structure and learn together (Wise & Schwarz, 2017). The

growing popularity of social media has nevertheless motivated many researchers to use social media tools, services, and applications for activities in educational (research) contexts (e.g., Al-Qaysi & Al-Emran, 2017; Gikas & Grant, 2013; Tess, 2013).

A representative social media environment used for educational purposes is the wiki, also known as collaborative social media project (Kaplan & Haenlein, 2010). Wikis have great potential to support CSCL, as they enable users to collaborate with each other on knowledge artifacts independent of time and location (Chen et al., 2015). A wiki, previously also referred to as Web 2.0 tool or social software (van Osch & Steinfield, 2013; Za'za' & Ahmed, 2020), has been described as "a web communication and collaboration tool that can be used to engage students in learning with others within a collaborative environment" (Parker & Chao, 2007, p. 57). The focus of informational social media environments like wikis is very often on written or textual content for educational purposes, which is created by the users themselves, as well as discussions about that content. This context offers opportunities for argumentative activities about intended changes at a textual level, but at the same time, it generates less awareness than digital media with richer sensory channels (Weidlich & Bastiaens, 2019; Weinberger & Fischer, 2006). Nevertheless, wikis are one of the most popular Web 2.0 technologies that support collaborative learning, and they can be applied in formal and informal learning settings, companies, and organizations (Bhatti et al., 2018; Forte & Bruckman, 2009; X. Li & Chu, 2018). Wikis have specific properties that make them adequate tools for various use cases. They can be used very flexibly, for example, as a collaboration tool (Moskaliuk et al., 2012), a knowledge building tool (Cress & Kimmerle, 2008), or a collaborative writing tool (Za'za' & Ahmed, 2020). Given the three key characteristics of wikis, namely, free edits, version control, and a discussion forum, their potential to promote effective learning is attracting growing interest among educators (Roussinos & Jimoyiannis, 2013; B. Zheng et al., 2015). In a wiki, every user has the same rights and, therefore, the same freedoms to make changes, discuss unclear issues, and provide feedback on modified parts (Chen et al., 2015). The main goal is to share one's knowledge with the community at any time without major restrictions (Shih et al., 2008). Content can, in this way, be easily created, edited, extended, or deleted. In addition to textual content, images, audio files, and video files can be included without requiring users to have special programming skills (Sigala, 2007). Such activities occur on two pages: the wiki article page and the wiki discussion page, two levels that are especially relevant for this thesis. In wikis such as Wikipedia, contributors often edit the same article without contacting each other on the underlying discussion page, which is, however, necessary for a collaboration to work out as expected (Jeong & Hmelo-Silver, 2016).

To conclude, their writing and communication capabilities make wiki use promising for collaborative learning (Awada & Diab, 2018), and interactions on the discussion page are central to the learning process. Therefore, even though the findings of this thesis are not limited to such platforms, wikis have been used as working examples for social media environments throughout the studies (Papers 2 to 4, Ollesch et al., 2020, 2021, 2022).

1.1.2 Potentials: Processes Conducive to Collaboration and Learning

There are several potentials for social media usage in educational settings, ranging from the cognitive through the behavioral to the emotional. First, the *cognitive potentials* of social media environments include the collaborative collection and control of information by the users, through which sources of error are likely to be minimized, and more knowledge can be gained (Hsu & Lo, 2018). According to Hsu and Lo, social media environments allow easier identification of problems, resolution of controversies, and agreement on revisions. Wikis, in particular, enable the building of collective intelligence and collaborative knowledge capturing (Chatti et al., 2007). In this regard, controversial opinions or heterogeneous knowledge about (wiki) content may lead to so-called socio-cognitive (epistemic) conflicts. These result from conflicting perspectives between the self and one or more counterparts in a group and the demand for a shared understanding (Doise & Mugny, 1984; D. W. Johnson et al., 2000). Such conflicts are considered positive for knowledge gain; to achieve a shared understanding, it is necessary to rearrange one's own cognitions (Cress & Kimmerle, 2008; Paper 1, Ollesch et al., 2019). This can be achieved by looking for arguments and evidence that support one's own point of view or by adopting the opinion of the other group members, which is called perspective-taking (Newton & Zeidler, 2020). In addition, there may be a search for compromises between differing opinions, leading to a reorganization and restructuring of cognitions that are ultimately manifested in learning growth (Bell et al., 1985).

Second, the *behavioral potentials* include social interaction on the associated wiki article and discussion pages that makes it possible to actively exchange information about the posted, expanded, or edited content, and in this way to externalize different opinions and views (Cress & Kimmerle, 2008; Paper 1, Ollesch et al., 2019). Socio-constructivist learning theories assume that people learn best when they can actively construct their knowledge through social interactions like discussions instead of internalizing new information on their own (Cole, 2009). This is promoted with Web 2.0 technology and, more specifically, social media (Dang et al., 2014). Through collaborative text production, users can engage in in-depth discussion

that confronts different perspectives on an issue (Hodel & Haber, 2007). Wikis enable such beneficial behavioral processes because active discourse in asynchronous discussions and content creation through article editing can be realized (Paper 1, Ollesch et al., 2019).

Third, in addition to factual knowledge, the so-called soft skills (e.g., team and critical faculties) are promoted on social media, and they form an important prerequisite for successful collaboration in a professional context (Tadjer et al., 2020). Furthermore, socio-cognitive conflicts bring advantages not only on a socio-cognitive level but also on a socio-emotional level, which can be considered as *emotional potentials* (Paper 1, Ollesch et al., 2019). For example, through epistemic conflict, people may learn how to cope in conflict situations on a socio-emotional level (see Bell et al., 1985). (Computer-supported) collaborative learning, therefore, supports not only deeper learning but also the development of socio-emotional relationships and group cohesion (Hernández-Sellés et al., 2019).

1.1.3 Challenges: Processes Detrimental to Collaboration and Learning

According to Kirschner and Erkens (2013), the possibility for social interaction within a group does not guarantee that the group will work together, coordinate their activities, contribute to effective collaborative learning processes, or engage in argumentative discussions. A major drawback is the lack of social presence, which represents the extent to which counterparts are perceived as real persons (Kreijns et al., 2002). In CSCL, and in particular collaborative text-based exchanges in social media, which are the focus of this PhD project, nonverbal signals are missing, which makes communication more difficult (Kehrwald, 2008, Weidlich & Bastiaens, 2019). Jeong and Hmelo-Silver (2016) defined seven main affordances that are not automatically fulfilled by CSCL environments. These are (1) the establishment of a joint task (e.g., creating digital artifacts) and (2) the possibility of communicating (e.g., on discussion threads); incentives for (3) the sharing of resources, (4) engagement in productive processes, and (5) co-construction; the possibility of (6) monitoring and regulating such processes; and (7) the finding and building of groups and communities.

The *establishing of a joint task* is relatively simple in educational social media environments. In the case of wikis, the task is mostly to write a wiki article collaboratively. There are also *communication* possibilities in wikis, notably the discussion page that is the basis of the article to be produced. However, further affordances are not necessarily guaranteed. Recently, I named and systematically described three challenges that are dominant in various contexts from state-of-the-art research. The aim was to draw an overall picture of the main

challenges for educational social media environments, which have so far been considered in isolation from each other. These are labeled as cognitive, behavioral, and emotional challenges (Paper 1, Ollesch et al., 2019), and they map onto some affordances of Jeong and Hmelo-Silver (2016), as demonstrated in what follows.

First, one of the most serious problems faced in the use of CSCL environments is the *cognitive challenge* (see *3.2 Cognitive Challenge: Dealing with Meaningful Content* in Paper 1, Ollesch et al., 2019), including uncertainty about the current level of knowledge of the group, which complicates the engagement in *productive* and *co-constructed processes*. To overcome this, it is important to engage with content beyond superficial learning activities, building on the contributions of others (Jeong & Hmelo-Silver, 2016; Paper 1, Ollesch et al., 2019). Within CSCL, individuals must not only understand the contributions of others but also be able to distinguish such contributions (Buder et al., 2015). According to Buder et al. (2015), especially in large-scale online forums, this can lead to information overload when individuals are forced to determine the current state of knowledge of group members by filtering processes in often extensive online learning forums.

Second, the *behavioral challenge* (see *3.1 Behavioural Challenge: Contributing* in Paper 1, Ollesch et al., 2019) is another obstacle to the implementation of CSCL methods. Very often, learners interact little or not at all within CSCL environments. Providing environments like wikis is, therefore, not enough to trigger contributions (Lattemann & Stieglitz, 2007). This issue is linked to the affordances of *productive* and *co-constructed processes*, as well as the willingness to *share resources* (knowledge) to solve a joint task (Jeong & Hmelo-Silver, 2016). In general, information sharing within a computer-based collaborative learning environment is seen as a social dilemma, since creating contributions to a learning forum is associated with costs in the form of mental effort and fear of embarrassing oneself in front of others; at the same time, one's own level of knowledge is dependent on the commitment and contributions of other group members (Cress & Kimmerle, 2007). In addition, phenomena such as social loafing and free riding must be considered. Social loafing is the tendency not to contribute to group work if one's individual performance is not clearly visible (Latané et al., 1979). Free riding occurs when individuals benefit from an overall group effort without making a corresponding contribution (Isaac & Walker, 1988). According to Isaac and Walker, a high number of free riders can lead to an activity like knowledge building not being carried out at all since everyone relies on the others.

Third, it can be difficult to maintain a positive group climate, which is considered an *emotional challenge* (see *3.3 Emotional Challenge: Maintaining a Positive Group Climate* in

Paper 1, Ollesch et al., 2019) that must be overcome in a functioning collaboration (Kreijns et al., 2013). Examples of such interpersonal problems can be found in socio-emotional (relational) conflicts. Like socio-cognitive conflicts, these represent discordance between the social environment and the individual and may be a negative side effect of socio-cognitive conflicts where people not only differ on a content level but also disagree on a relational level (De Dreu & Weingart, 2003; Näykki et al., 2021). A socio-emotional conflict is one that involves negative emotions, such as being frustrated within a group (De Dreu & Weingart, 2003). Groups in which socio-emotional conflicts occur focus less on the task and the solution of content-related or socio-cognitive conflicts (Näykki et al., 2014), making it difficult for *groups and communities* to be fully *built*. Moreover, *productive* and *co-constructed processes* might be hindered when discussants lose themselves in off-topic conflicts, as highlighted by Jeong and Hmelo-Silver (2016). It follows that socio-emotional conflicts should be avoided or quickly resolved to achieve successful collaboration.

Given these challenges, it is not surprising that the perceived effectiveness of social media (wiki) environments on project-based learning varies across contexts and disciplines, ranging from very active to nonactive editing behavior (Chu et al., 2017). According to Chu et al. (2017), this is caused by different workload perceptions as well as motivational differences, factors that depend on the previous experiences and technical backgrounds of users, as well as the instructional design of wiki tasks. To ensure more consistent results, users should therefore be able to *monitor and regulate* their activities. For this purpose, awareness tools are beneficial (Jeong & Hmelo-Silver, 2016; Paper 1, Ollesch et al., 2019).

1.1.4 Summary

The previous sections presented the field of (computer-supported) collaborative learning, including social media environments and wikis as popular representations of this field. Their potentials were outlined, including the cognitive, behavioral, and emotional potentials. However, given the challenges identified, when used for educational purposes, current social media environment infrastructures are dependent on an additional degree of guidance to stimulate social interactions in general (behavioral challenges) and in a meaningful and desirable way, at both the cognitive (cognitive challenges) and emotional (emotional challenges) levels. In what follows, implicit guidance methods in the form of group awareness tools are presented with a view to addressing these challenges.

1.2 Guiding Computer-Supported Collaborative Learning

Guiding collaboration and learning is crucial for CSCL platforms to be effective (Radkowitsch et al., 2021; Yilmaz & Yilmaz, 2020). There is a consensus that a certain degree of guidance is necessary to trigger active discourse and knowledge construction (Daspit & D'Souza, 2012; van Merriënboer & Kirschner, 2018), with two main ways to guide CSCL. On the one hand, it is possible to influence the process of collaboration through explicit guidance in the form of collaboration scripts, for example, by providing concrete instructions or prompts (Fischer et al., 2013). However, this is sometimes inflexible and brings the danger of over-scripting or under-scripting, which means a formulation of the task that is too rigid or too weak (Fischer et al., 2013). On the other hand, CSCL can be supported implicitly through the provision of *group awareness* information, which is a way of addressing the challenges mentioned above without forcing learners to behave in a specific way (Janssen & Bodemer, 2013). Group awareness is a collection of aspects that learners need to structure their own learning processes and group work, such as their skills, activities, and emotions (Bodemer et al., 2018; Buder et al., 2021). In face-to-face and smaller group interactions, achieving such awareness is relatively unproblematic (Buder & Bodemer, 2008). However, in interactions within a larger digital environment, difficulties can arise, as the required group awareness information is often not directly viewable (Gutwin & Greenberg, 2002).

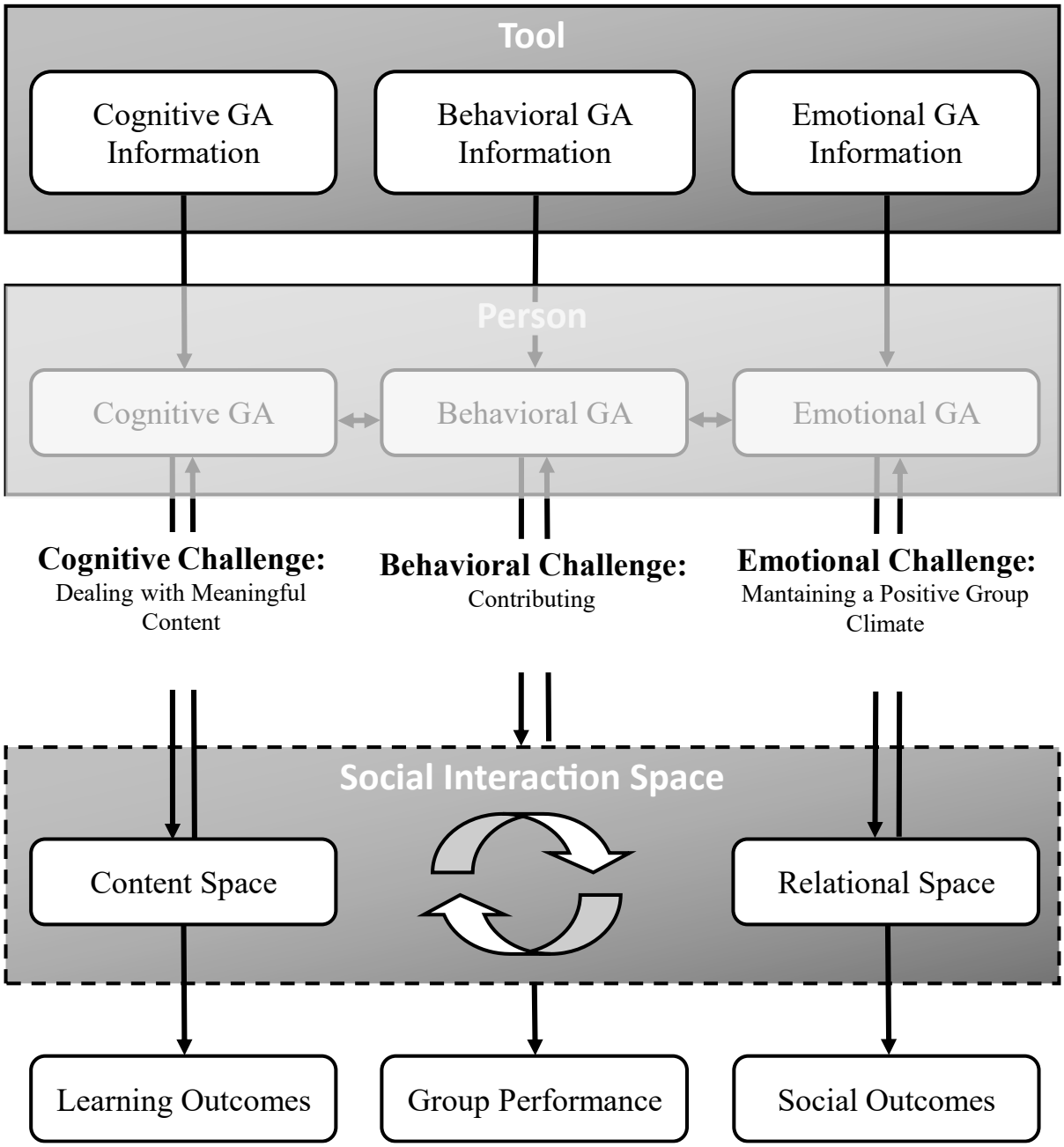
To achieve or promote such awareness within CSCL environments, so-called *group awareness tools* are used, which systematically collect, transform, and present information on how much group members know, how much they contribute, or how they feel within an interaction (Bodemer et al., 2018). Accordingly, these can be differentiated into *cognitive*, *behavioral*, and *emotional* group awareness tools (Paper 1, Ollesch et al., 2019). Implicit collection methods of group awareness are particularly promising for textual exchange, as they enable the collection of such information, for example, via computer algorithm without interrupting the users in their actions, as is the case with explicit collection methods like subjective assessments (Buder, 2011). In this way, group awareness tools help to reveal the status quo of a group collaboration (Yilmaz & Yilmaz, 2020) and facilitate various learning and collaborative processes and outcomes in different interaction spaces, namely the content and relational spaces (Barron, 2003; Slof et al., 2010; see Figure 1). The content space contains the actual cognitive tasks to be fulfilled, including knowledge building processes, whereas the relational space includes emotional activities related to team building, including social behavior amongst the participants (Slof et al., 2010).

One theory that explains the effects of group awareness tools is the theory of social comparison, which has its origins in the work of Festinger (1954). This theory assumes that people compare themselves with other people to evaluate their own opinions or abilities; for example, in learning situations, learners are continuously confronted with incentives to make social comparisons. A distinction is made between upward and downward comparisons (Festinger, 1954). In downward comparisons, to feel better, one tends to compare oneself to people who are less successful; in upward comparisons, improvement is the desired outcome, and this type of comparison seems to dominate in the learning context (Dijkstra et al., 2008). Such social comparison processes can be emphasized by providing awareness information, further highlighting different aspects of collaborators (Neugebauer et al., 2016).

The concrete effects and underlying theoretical concepts of the different types of group awareness tools that are considered in the framework (Paper 1, Ollesch et al., 2019) and thesis are illustrated and explained below (see Figure 1). Note that terms such as group awareness "tools," "information," "support," "attributes," and "bars" are different expressions of the same notions in the context of the thesis. As an addition to the framework, this cumulus links to theories that play a role in explaining the various effects of such tools. These are primarily (but not exclusively) the theory of cognitive development (Piaget, 1977) and the co-evolution model (Cress & Kimmerle, 2008) with respect to cognitive group awareness tools; social and, more specifically, descriptive norms (Asch, 1955; Reno et al., 1993) with respect to behavioral group awareness tools; and emotional contagion (Barsade, 2002) with respect to emotional group awareness tools. Regarding possible interaction effects of group awareness tool combinations, theoretical assumptions about social constructivism and knowledge building (Scardamalia & Bereiter, 2006; Vygotsky, 1978) are referred to, alongside assumptions on the dual spaces (Barron, 2003; Slof et al., 2010), control-value theory (Pekrun, 2006) and cognitive-affective theory of learning with media (Moreno, 2006).

Figure 1

Excerpt from the Integrated Framework of Group Awareness Support



Note. Adapted from Paper 1, Ollesch et al., 2019, p. 127. The person layer will be discussed in a later section. GA = Group awareness.

1.2.1 Cognitive Group Awareness Tools

Cognitive group awareness tools provide information concerning the content space of collaboration, including the knowledge and opinions of group members, thus addressing the cognitive challenge (Bodemer et al., 2018; Paper 1, Ollesch et al., 2019; see Figure 1). Knowledge, in particular, is a widely applied group awareness attribute and, therefore, within

the scope of this thesis (e.g., Dehler et al., 2011; Lin et al., 2015). Knowledge awareness information brings an increased potential for cognitive conflicts or disequilibrium, which are seen as prerequisites for individual learning (Piaget, 1977). According to Piaget's theory of cognitive development, there is a constant interaction between inner development and experience with the world. To achieve equilibrium, learning occurs in two ways, first by internalization or adding new information to existing ideas, a process known as assimilation, and second by altering or restructuring existing cognitive schemas to match with the new information, a process known as accommodation (Piaget, 1977). A model that transfers the concept of cognitive conflicts to a socio-cognitive level and focuses on social media environments such as wikis is the co-evolution model (Cress & Kimmerle, 2008). This model describes processes that occur both in the social system of such a platform and in the cognitive system of the user. Social systems are based on and influenced by cognitive systems since communication would not be possible without individual thoughts (Cress & Kimmerle, 2008; Kimmerle et al., 2010). According to Cress and Kimmerle (2008), individual learning in wikis occurs through internal processes of internal assimilation and accommodation (see Piaget, 1977). Changes in the system represent parallel activities of external accommodation and assimilation. In collaborative knowledge building, there is an interplay or co-evolution of both systems, which is activated by processes of disequilibrium (Kimmerle et al., 2010). These can occur, for example, when an individual's knowledge differs from the knowledge provided by a wiki. This imbalance can then be resolved by integrating the new information with one's own knowledge (Cress & Kimmerle, 2008). Another option is to externalize one's individual knowledge into the wiki and edit it quantitatively (external assimilation) or qualitatively (external accommodation), for example, by reorganizing entire sections, which leads to deeper processing of learning content (Cress & Kimmerle, 2008; Kimmerle et al., 2010). In addition to wiki learning contexts, various other (computer-supported) collaborative learning scenarios focus on the emergence of socio-cognitive conflicts (D. W. Johnson et al., 2000). Therefore, generating such conflicts in the respective guidance design, a technique known as constructive controversy, is recommended, as it leads to higher-quality problem-solving as well as better perspective-taking compared to classical teaching methods (D. W. Johnson & Johnson, 2009; D. W. Johnson et al., 2000). Constructive controversy can be realized via cognitive group awareness support that points out cognitive inequalities between learning partners or groups. In this way, socio-cognitive conflicts are likely to arise because such tools steer learners in the direction of discussing knowledge or opinions that are differently expressed (Heimbuch & Bodemer, 2017).

Besides their ability to trigger socio-cognitive conflicts, cognitive group awareness tools are also beneficial for partner modeling processes. According to Dillenbourg et al. (2016), partner modeling involves inferring the mental states of others and is an important prerequisite for successful collaboration. In this way, cognitive group awareness tools trigger not only cognitive but also behavioral processes by identifying where a learning partner needs or can provide help (Dehler et al., 2011; Erkens & Bodemer, 2019; Schlusche et al., 2019; Schnaubert & Bodemer, 2019). However, a display of cognitive group awareness information might also lead to individuals not sharing their expertise as a form of strategically favorable behavior such as withholding information (Ray et al., 2013).

In the context of the collaborative cognitive load theory, cognitive group awareness tools reduce the coordination effort and collaborative load by increasing knowledge of others' expertise as well as the transactive memory system of the group (Janssen & Kirschner, 2020; Kirschner et al., 2018). Although knowledge awareness and transactive memory systems both contain information about the knowledge levels of others, the concept of the transactive memory system goes one step further; it is located at the group level, whereas knowledge awareness is primarily promoted at the individual level and does not depend on existing knowledge awareness of other group members (Engelmann et al., 2009). To keep the (collaborative) cognitive load as low as possible, splitting attention should be avoided, and group awareness information should be directly presented in the learning environment (Buder, 2011), which is realized in this thesis.

As well as the underlying theoretical constructs that point to a high level of effectiveness of cognitive group awareness tools, the empirical findings so far are impressive. At the process level, results range from improved selection behavior or social navigation in online and wiki discussion forums to higher-quality discussions and arguments in a written discourse (Buder et al., 2015; Heimbuch & Bodemer, 2017; Ma et al., 2020; Zhang et al., 2016). At the outcome level, the results suggest enhanced outcome quality of textual products as well as higher (knowledge test) learning outcomes (Gijlers & de Jong, 2009; Sangin et al., 2011). Whereas process-level effects appear to be relatively stable, outcome-level effects are not consistently detectable for cognitive group awareness support (Bodemer et al., 2018). An objective of this thesis is to reinforce existing findings for knowledge awareness tools in the social media context, which have become increasingly prominent in recent years. This thesis enriches the preliminary theoretical considerations, not least by testing the assumptions of the co-evolution model and socio-cognitive conflicts in practice. Additional information and

concrete examples of the cognitive group awareness tools used can be found in Papers 1 to 4, Ollesch et al. (2019, 2020, 2021, 2022).

1.2.2 Behavioral Group Awareness Tools

Behavioral group awareness tools function as a source of motivation for quantitative social interaction, thus addressing the behavioral challenge and interactions in both spaces (Paper 1, Ollesch et al., 2019; see Figure 1), for example, by visualizing the number of contributions made by group members (Janssen et al., 2011). To facilitate comparisons between one's own contributions and those of other group members, both the group members' and the individual's participation should be presented (Kimmerle & Cress, 2008). Thus, behavioral group awareness tools help to establish social standards or descriptive norms that are helpful specifications of expected behaviors, especially when there is uncertainty about how to behave (Asch, 1955; Reno et al., 1993). This is particularly the case in CSCL environments when no concrete guidelines have been established. One possibility is to make visible the number of individuals' contributions to the group (Cress & Kimmerle, 2007). This helps individuals to estimate how many contributions are desired from each member of the group and adjust their own participation accordingly (Lin et al., 2015), thereby avoiding potentially negative evaluations of the group and maintaining a positive self-image (Janssen et al., 2011).

The need for a positive self-presentation in computer-mediated scenarios, which is triggered through motivational and feedback factors (Janssen et al., 2007), plays the dominant role in behavioral group awareness tool effects, especially in the context of the hyperpersonal model of Walther (2007). This model assumes that, in computer-mediated exchange, the sender can strategically control his or her effect on the receiver based on missing face-to-face cues. The sender can use this to manage relationships and to steer receivers' impressions in a certain direction by means of specific message formulations and actions (Walther, 2007). Even if CSCL situations do not necessarily take place at a distance, this is a common and widely used variant that is also within the scope of this thesis. Behavioral group awareness information can thus be used to maintain a positive image of one's own contribution, from which the whole group will benefit.

At the process level, feedback about contributions leads to individuals making their behavior conform to that of the group (Janssen et al., 2011; Kimmerle & Cress, 2008). Using such tools repeatedly over a semester leads to denser networks and increased online participation among students (Lin et al., 2015, 2019). At the outcome level, better (knowledge

test) learning outcomes of individual learners and improved quality of group writing have already been confirmed for behavioral group awareness support (Lin et al., 2015; Liu et al., 2018), variables that are also considered in this thesis. However, consistently positive effects on learning outcomes or content quality have not been found or have not been the focus of relevant research (Bodemer et al., 2018; Buder et al., 2021; Lin et al., 2019). The aim of this thesis is, therefore, to transfer the expected mechanisms from descriptive norms to behavioral group awareness tools as an application in a large-group educational social media context. This will help to advance state-of-the-art research on descriptive norms, facilitating the use of behavioral group awareness tools in educational social media environments. Learning outcomes, often neglected (Buder et al., 2021), are also considered, especially in interaction with cognitive group awareness tools (explained in more detail in section 1.2.4). Additional information and concrete examples of behavioral group awareness tools can be found in Papers 1 to 3, Ollesch et al. (2019, 2020, 2021).

1.2.3 Emotional Group Awareness Tools

Emotional group awareness tools have the potential to improve the group climate in the relational space, thus addressing the emotional challenge (Paper 1, Ollesch et al., 2019; see Figure 1) by broadening awareness of the emotions of others, which enables participants to interact within the most positive learning environment possible (Eligio et al., 2012). The influence of emotional group awareness information on collaborative learning should be greater in the context of designing and evaluating CSCL settings, as it is particularly relevant for educational social media contexts that involve a larger number of participants. When negatively balanced emotions or expressions occur during a socio-cognitive conflict, group members might be less motivated to solve their assigned tasks and might perform less well (Ayoko et al., 2008; Correia, 2020).

The effectiveness of emotional group awareness tools is inter alia based on the stimulation of emotional contagion processes (Molinari et al., 2013). This is the phenomenon of feeling the same emotions that one perceives in other people, in either the positive direction (happiness) or the negative direction (sadness) (Barsade, 2002). Emotional group awareness tools might also trigger a feeling of being accepted by others through emotional transparency as well as emotional co-regulation processes (Avry & Molinari, 2018; Molinari et al., 2013). Co-regulation of emotions is the attempt to adapt the emotional states of the group in a common exchange that might be facilitated with tools enabling the sharing of emotions (Avry et al.,

2020). This process includes adjusting (to) the emotional state of others and, in the best case, improving it, which is relevant in social media contexts, where heated debates may take place (McCaslin & Vega, 2013). Also, in wiki-like environments, emotional problems occur frequently, with so-called edit wars arising when several persons with different views work on a document (Tsvetkova et al., 2017; Yasseri et al., 2012). These issues underline the need to support users in solving socio-emotional problems to enable successful collaboration.

At the process level, the experience of positive emotions should be fostered, as it can expand the individual's consciousness in ways that contribute to social outcomes like mental well-being (Fredrickson, 2004). Furthermore, emotional sharing regulates the collaborative actions of collaborators (Avry et al., 2020). In the context of this thesis, the friendliness level of discussants is considered as a relevant emotional group awareness attribute because the way arguments are presented and answered can be of critical importance in whether the group moves forward or fails (Ludvigsen, 2016; Polo et al., 2016). Friendliness (awareness) plays a role in satisfaction and the willingness to respond to others in group settings (Burke & Kraut, 2008; H. S. Park, 2008). Accordingly, Phielix et al. (2011) have already surveyed and visualized self-assessed friendliness patterns, with promising results for group work outcomes regarding team development and lower conflict levels. Further results at the outcome level illustrate positive effects of emotional group awareness tools on social outcomes like positive affect and on group performance (Eligio et al., 2012; L. Zheng & Huang, 2016). However, it should be noted that learning outcomes have rarely been the focus of this stream of research (Buder et al., 2021). Also, the usage of subjective (explicit) collection methods may be subject to social desirability effects (Buder, 2011). Another aim of this thesis is, therefore, to apply emotional group awareness tools in the form of automatic (implicit) friendliness detection to a textual discourse in an educational social media environment. Sentiment analysis is promising for identifying and visualizing emotional expressions in such an educational discourse (Arguedas et al., 2015), with potentially positive relationships between students' emotion awareness and learning outcomes (Arguedas et al., 2016). There is evidence that textual messages on Facebook can trigger emotional contagion processes, manifested in higher well-being (Kramer et al., 2014); however, this needs confirmation in learning contexts where emotional group awareness support is involved. Such emotional group awareness support could also be regarded as an amplifier for cognitive group awareness support, a notion that is concretized in section 1.2.4. Additional information and concrete examples of emotional group awareness tools can be found in Papers 1 and 2, Ollesch et al. (2019, 2020) and Paper 4, Ollesch et al. (2022).

1.2.4 Interplay of Different Group Awareness Tools

All three types of group awareness tools have already shown impressive results in the CSCL context in a single presentation (Paper 1, Ollesch et al., 2019). However, positive effects on cognitive, behavioral, and emotional variables have not always been confirmed and are not even the focus of many studies (Bodemer et al., 2018). In the papers of this thesis, it was postulated that the *combination of different types of group awareness tools* might be particularly beneficial for educational social media environments, focusing on cognitive and behavioral (Paper 3, Ollesch et al., 2021) as well as cognitive and emotional group awareness tool combinations (Paper 4, Ollesch et al., 2022). Cognitive support was chosen as the common denominator in both studies, as it is one of the most important and widespread elements in the group awareness or learning field in general (Bodemer et al., 2018; Garrison et al., 2000). It is therefore contrasted with the other types (behavioral and emotional).

In general, group awareness tool combinations are promising because the challenges (see section 1.1.3) cannot easily be addressed by one type of group awareness information alone (Paper 1, Ollesch et al., 2019). Just because a group awareness tool shows how much others know; the individual might not have the motivation to contribute actively. Likewise, an individual may be inhibited from contributing if he or she receives only awareness information about participatory states with no further indication of what content one should focus on in terms of potentials for learning or supporting others (Paper 3, Ollesch et al., 2021). Emotional group awareness support could therefore provide a decisive stimulus for knowing which manners prevail before entering a collaborative discourse (Paper 4, Ollesch et al., 2022). Studies that consider cognitive, behavioral, or emotional group awareness information in combination are rare and, most importantly, permit very few conclusions about the specific single and interaction effects of elements of such tools (e.g., Lin et al., 2019; Phielix et al., 2011). Relevant work that explores different types of group awareness tools on social networking sites has been carried out by Dado and Bodemer (2018), who showed that information about cognitive aspects (discussion points/argument stance) and social aspects (names of group members) offers potential for increased interpersonal relationships as well as the integration of foreign perspectives. However, since in their study, only a control condition was set against a full-tool condition, it is difficult to draw conclusions about the exact mechanisms of specific types of group awareness information. I assume that the cognitive, behavioral, and emotional processes underlying the corresponding tool subcomponents suggest that the interaction of different types of awareness information is particularly desirable in educational social media environments, an idea that will be concretized in what follows.

Even if one assumes promising effects of single cognitive and behavioral group awareness support on cognitive and behavioral outcome variables (see sections 1.2.1 and 1.2.2), it can be expected that their combination amplifies the effects of both awareness types (Paper 3, Ollesch et al., 2021). This is because cognitive processes cannot be separated from the social context, and actions contribute significantly to supporting cognitive presence (Caskurlu, 2018; Kozan & Richardson, 2014). Social interaction or active participation is therefore essential for learning processes (Galikyan & Admiraal, 2019), especially in relation to highly qualitative thinking skills (Daspit & D'Souza, 2012). Stahl (2014) illustrates the importance of social group cognition, which can be achieved in CSCL and goes beyond individual cognition. This can emerge only when group members build actively on other group member's contributions, and it is deeply rooted in assumptions about social constructivism and knowledge building, according to which knowledge is preferably generated collectively through social interactions in a sociocultural setting (Scardamalia & Bereiter, 2006; Vygotsky, 1978). According to Scardamalia and Bereiter (1994), knowledge building must be explicitly distinguished from individual learning, as it is an externalized social product that goes beyond the individual's knowledge. Even though social media environments offer the opportunity to engage in social exchange and externalize knowledge, the occurrence of these processes is not guaranteed; for example, single items of cognitive group awareness information may induce passive internalization behavior (Paper 3, Ollesch et al., 2021). Behavioral group awareness information could increase the effects of cognitive group awareness information, as it is known to trigger active engagement with content (Janssen et al., 2011). Conversely, it can be assumed that cognitive group awareness information enhances the effects of behavioral group awareness tool effects, as it enables more goal-directed participation and points to content that triggers beneficial socio-cognitive conflicts, mentioned earlier as highly desirable (Heimbuch & Bodemer, 2017; Schnaubert et al., 2021). This supports the assumption that the interaction of both group awareness attributes will be profitable since deficiencies or low expressions of one type of awareness information (e.g., little displayed knowledge or participation) could be compensated by the other awareness information. The assumptions of social constructivism and knowledge building (Scardamalia & Bereiter, 2006; Vygotsky, 1978) can therefore be transferred to a learning context that includes implicit guidance in the form of group awareness tools. In the context of this thesis, it is assumed that cognitive and behavioral group awareness tools have positive effects on cognitive (knowledge posttest learning outcomes) and behavioral (produced content quality) outcomes on their own, but that these effects are disproportionately strengthened by the joint presentation of this information (Paper 3, Ollesch et al., 2021).

Regarding the link between emotional and cognitive group awareness tools, Vygotsky (1978) proposed an interrelatedness of cognition and emotion in language development. In this thesis, less-symmetrical relationships are assumed for cognitive and emotional group awareness tool combinations than for cognitive and behavioral group awareness tool combinations. No notable effects of emotional group awareness information on learning and quality outcomes in a single presentation are assumed per se in comparison to no guidance support, given the low empirical density in this regard (Paper 4, Ollesch et al., 2022). Also, in terms of the supportive effects of cognitive group awareness information for emotional group awareness information on emotional processes and outcomes, an exploratory approach was chosen. However, emotional group awareness information is counted as a key variable in the interaction with its cognitive group awareness information equivalent to enhance the effects on cognitive process and outcome variables (knowledge posttest learning outcomes and content quality; Paper 4, Ollesch et al., 2022). These assumptions are made because collaboration is viewed as a dual-problem space (Barron, 2003), with emotions strongly involved in cognitive discourse (Slof et al., 2010). Activities in the relational space are necessary for the success of activities in the content space (Barron, 2003). Therefore, as Kreijns et al. (2013, 2014) noted, establishing a sound social space (network of strong interpersonal relationships) is important, as it results in effective information exchange, group cohesion, and a sense of belonging. In the following, two theories are shortly presented that might explain the potential for cognitive and emotional group awareness tool combinations more deeply.

The first relevant theory is the control-value theory of Pekrun (2006), which assumes that an achievement situation is strongly influenced by evolving emotions. These achievement emotions can be distinguished regarding their valence (positive versus negative) and activation (activating versus deactivating). Positive and activating emotions, in particular, can have a positive influence on the motivation to learn and should therefore be promoted in learning settings (Pekrun, 2006), something an emotional group awareness tool might allow. Moreover, these emotions can be activity-related or outcome-related. In this thesis, the former case is addressed: emotions that arise and are expressed on a textual level during a (pseudo-) collaborative activity (Pekrun, 2006). The theory further postulates that the degree of subjectively perceived control over the performance situation and its value (importance) for the individual determine the experience of certain emotions. Regarding the control component, in particular, informal learning with emotional group awareness support might offer a high degree of control, as users regulate such situations and information largely by themselves, which is in line with the control-value theory (Pekrun, 2006). The second theory, Moreno's

(2006) cognitive-affective theory of learning with media (CATLM), can also explain the potential of emotional group awareness tool processes for cognitive group awareness tool processes. This theory is complex, and therefore only the part relevant to this thesis will be introduced below. Further assumptions about processing channels, limited working memory capacity, and dual coding can be found in the relevant literature (Moreno, 2006). According to this theory, emotional factors play a dominant role in multimedia learning. It is assumed that the capacity of the working memory is limited and that factors such as affective reactions to media designs (but not exclusively) can increase or decrease cognitive engagement (Moreno, 2006; Moreno & Mayer, 2007). From this assumption, it is empirically illustrated that emotional designs facilitate cognitive processes and outcomes, even without considering cognitive or emotional group awareness tools so far (B. Park et al., 2015). The use of emotional group awareness tools is worthwhile to reinforce the processes triggered by cognitive group awareness tools, thus improving the emotional design of multimedia learning environments. Emotion awareness can increase the perception of socio-cognitive processes and learning outcomes so that supportive effects of emotional group awareness tools for cognitive group awareness tools are also to be expected (see Arguedas et al., 2015; Avry et al., 2020). Especially when cognitive group awareness information visualizes different knowledge or disagreements, appropriate emotion regulation is essential to keep task engagement and group performance at the highest possible level (see Jiang et al., 2013; Näykki et al., 2014), which in turn may be facilitated by emotional group awareness information (Avry & Molinari, 2018; Eligio et al., 2012). Since group awareness research has mainly considered socio-cognitive rather than socio-emotional methods, this thesis addresses this gap, investigating how the cognitive design of an educational social media environment (realized via cognitive group awareness tools) can be enriched using emotional group awareness tools (Paper 4, Ollesch et al., 2022). The assumptions of the dual spaces, control-value theory, and CATLM (Barron, 2003; Moreno, 2006; Pekrun, 2006) are thus to be transferred to implicit guidance in the form of group awareness tools. Notably, textual emotional expressions or sentiments in discussions have received little attention in the context of emotional group awareness tools but may also be hypothesized to trigger emotional contagion processes, influencing learning and group performance (see Molinari et al., 2013; L. Zheng & Huang, 2016).

To conclude, several theories assume the interconnection of cognitive and behavioral processes in the learning context (Scardamalia & Bereiter, 2006; Vygotsky, 1978), which suggests that the interaction of these two types of awareness information, triggering such processes, should also be promoted. In terms of interactions between emotional and cognitive

group awareness tools, the former provides the potential for enhanced cognitive group awareness tool effects based on the connections of emotional and learning processes (Barron, 2003; Moreno, 2006; Pekrun, 2006). Of course, for both expected interaction effects, it is important for the single group awareness tool mechanisms to achieve the expected effect. Thus, cognitive group awareness support should lead to improved selection behavior with a focus on content relevant for learning, behavioral group awareness support should lead to higher behavioral engagement, and emotional group awareness support should lead to a higher social behavior (Papers 3 and 4, Ollesch et al., 2021, 2022). That makes it even more important to examine interactions between different guidance visualizations, as they strongly depend on the effect of the single components. For example, if persons do not behave appropriately despite emotional group awareness information (for example, behaving rudely when exchanging information), this could produce the opposite scenario, with a negative impact on learning processes and leading to avoidance behavior (van Kleef et al., 2010).

1.2.5 Summary

It can be concluded that group awareness support with information on a single dimension or on multiple dimensions can have positive effects when applied in educational social media environments. Various theories and empirical findings from different areas were consulted and examined in terms of their applicability in the group awareness field. The different ways that behavioral and emotional processes might support cognitive processes in collaborative learning settings were outlined, indicating that the interaction of these equivalent types of group awareness tools could be crucial for enhancing their effects. Cognitive group awareness tools are very complex in nature and are within the scope of the current thesis regarding possible interactions with emotional and behavioral group awareness tools.

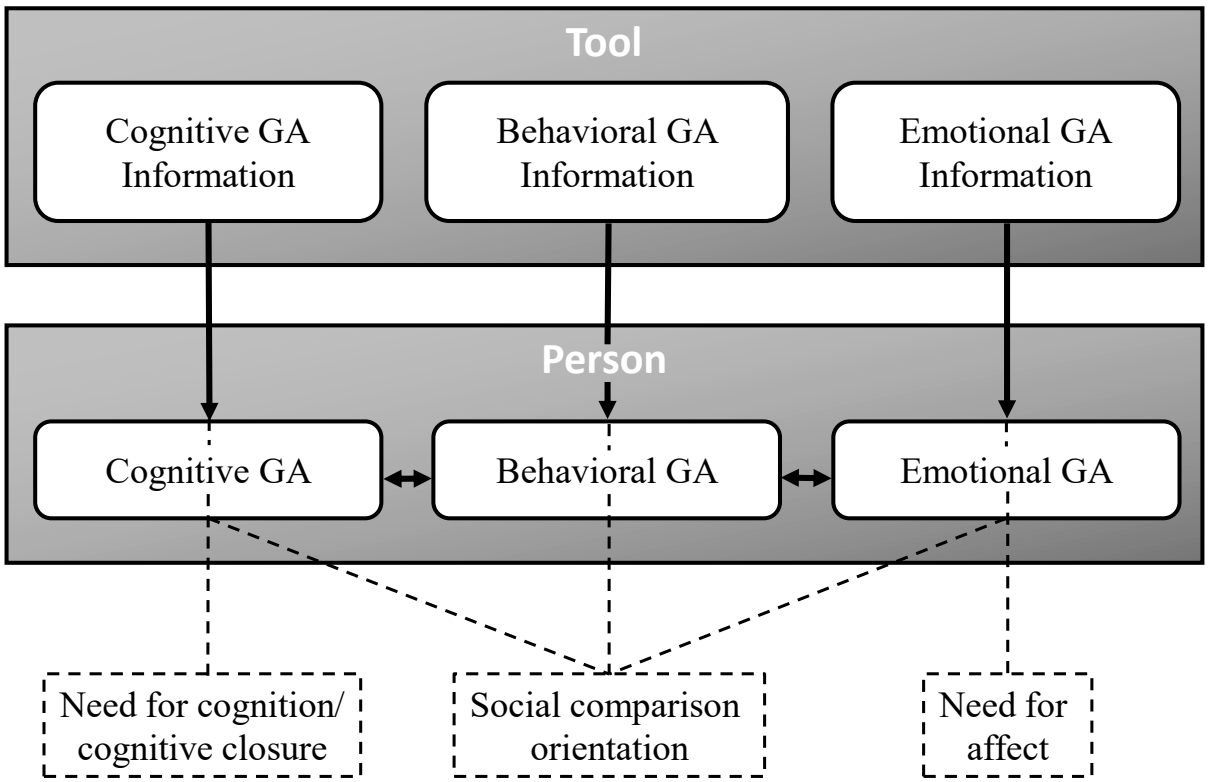
1.3 Personal Interaction with Awareness Tools

When using group awareness tools within computer-supported collaborative learning, it is important to look not only at the tool level but also at what is happening inside the person. The personal interaction with such tools should not be ignored as it might influence learning, social, and group outcomes in learning settings (Paper 1, Ollesch et al., 2019; Tchounikine, 2019). Therefore, a person layer was added below the tool level in the framework of Paper 1 (Ollesch et al., 2019; see Figure 2). This layer includes *differential personal variables* that may act as influences of such tool effects on assumed processes and outcome patterns (e.g., on the

subjective user relevance of the individual group awareness information, written contributions, and learning-related variables). This addition will allow for better differentiation of the results on different types of users (Paper 1, Ollesch et al., 2019). It also allows for potential mediation effects of perceived group awareness anchored in the person (Bodemer et al., 2018); however, because of the complexity of the other foci, investigating this topic falls outside the scope of this thesis. Instead, influences of personal characteristics are considered extensively in the papers (Papers 1–4, Ollesch et al., 2019, 2020, 2021, 2022). The following section introduces the personal characteristics that are potentially relevant in the field (see also Figure 2). Note that not every variable is addressed, but only the main variables of the thesis: need for cognition/cognitive closure, social comparison orientation, and need for affect.

Figure 2

Main Personal Characteristics Included



Note. Adapted from Paper 1, Ollesch et al., 2019, p. 127.

1.3.1 Need for Cognition and Need for Cognitive Closure

In the learning context, the inclusion of cognitive characteristics is indispensable, which is why this thesis considers the *need for cognition* and the *need for cognitive closure*.

Need for cognition is the need to engage in deep learning activities and has been associated with a strong focus on task-related cues rather than on peripheral information when strongly pronounced (Cacioppo & Petty, 1982). This was considered as relevant for the interaction with cognitive group awareness support and was therefore investigated in Studies 1 (Paper 2, Ollesch et al., 2020) and 3 (Paper 3, Ollesch et al., 2021). Many studies have concluded that need for cognition is positively associated with higher study satisfaction (Coutinho & Woolery, 2004) and with lower levels of stress in college (Epstein et al., 1996), as persons with a high need for cognition enjoy engaging in cognitive activities (Cacioppo et al., 1996). Moreover, the results of a study by Cazan and Indreica (2014) showed that a high need for cognition leads to the use of deep-thinking strategies such as critical processing and analyzing in comparison to a low need for cognition. These are strategies needed to grasp the information presented by cognitive group awareness tools.

During this thesis, however, it transpired that *need for cognitive closure* could play a greater role regarding cognitive group awareness support, as it is related to need for cognition (Fortier & Burkell, 2014) but more specific to knowledge creation in discussion contexts that include several perspectives (Webster & Kruglanski, 1994). This variable is understood as the pursuit of a definite answer to an issue, rather than ambiguity (Webster & Kruglanski, 1994), and it involves a motivational continuum from a strong need for cognitive closure to avoidance of such closure (Schlink & Walther, 2007). Need for cognitive closure is known to influence interaction with cognitive group awareness support in discussion forums (Heimbuch & Bodemer, 2019) and was therefore included in Study 4 (Paper 4, Ollesch et al., 2022). A high need for cognitive closure leads to quick decisions on controversies without integrating the opinions of others (DeBacker & Crowson, 2009), whereas a low need for cognitive closure leads to searching for new information before addressing an issue and a higher chance for epistemic change (Choi et al., 2008; Rosman et al., 2016; Schlink, 2009). In this respect, individuals with a high expression of need for cognitive closure are more likely to be easily persuaded by other learners (Schlink & Walther, 2007). In contrast, individuals with a low need for cognitive closure bring new arguments into a discussion and reflect more deeply on issues (Schlink & Walther, 2007), processes that should be triggered when implementing cognitive group awareness support.

1.3.2 Social Comparison Orientation

Group awareness tools promote social comparison processes and help learners to obtain information about the self and others that is not employed equally intensive by everybody (Neugebauer et al., 2016). The tendency to compare oneself with others is described in a construct called *social comparison orientation* (Gibbons & Buunk, 1999). Individuals with a higher social comparison orientation are more likely to be attracted to information that enables social comparison (Kimmerle & Cress, 2009). They better apply group awareness information and set higher goals, for example, when made aware of their partners' higher knowledge (Neugebauer et al., 2016). However, individuals with a higher social comparison orientation might also share less information with less-informed learning partners when made aware of their partner's knowledge (Ray et al., 2013). Given its relevance to group awareness tool mechanisms, social comparison orientation has been integrated as a potential influencing variable in Studies 1 (Paper 2, Ollesch et al., 2020) and 3 (Paper 3, Ollesch et al., 2021). Furthermore, there are various motives for social comparison. These include self-evaluation, for which similar comparison partners are used (Festinger, 1954); self-enhancement, which involves the desire to feel satisfied with one's own states and achievements (Buunk et al., 2007); and self-improvement, which is used to gain information about how to improve current performance by using others as standard (Dijkstra et al., 2008; Helgeson & Mickelson, 1995). The motive of self-improvement can be fulfilled inter alia by choosing a better learning partner, as they can offer more help and thus improve one's own performance (Ray et al., 2017). Based on its relevance for increased learning processes, this motive was also brought into the focus of Study 1 (Paper 2, Ollesch et al., 2020).

1.3.3 Need for Affect

The *need for affect* can be seen as the opposing personal characteristic to the need for cognition (Appel et al., 2012). It refers to the motivation to approach or avoid activities that are emotional (Maio & Esses, 2001). It may therefore be relevant for interaction with emotional group awareness information (Papers 2 and 4, Ollesch et al., 2020, 2022), as it describes how individuals deal with emotion-provoking situations (Maio & Esses, 2001). According to Appel and Richter (2010), need for affect is a trait-like attitude toward one's emotions (Bartsch et al., 2008). Persons with a high expression of need for affect prefer emotional situations as well as emotional media (Bartsch et al., 2010; Maio & Esses, 2001). They also show deeper processing of emotional messages in comparison to persons with a low need for affect (Appel et al., 2012),

who prefer cognition-promoting information (Haddock et al., 2008). A high need for affect involves the wish to experience and make sense of emotional information in relation to the self and other people (Bartsch et al., 2010), which might include emotional group awareness information. Unlike the concepts presented in the previous sections, need for affect has, to my knowledge, not been studied in the collaborative learning context in conjunction with group awareness tools. However, such a study is recommended, as need for affect is known to influence various domains (Conner et al., 2011; Leone & Chirumbolo, 2008). Moreover, collaboration and respective guidance visualizations can arouse emotions that may be addressed in different ways, which is why this variable is integrated into two subprojects (Papers 2 and 4, Ollesch et al., 2020, 2022).

1.3.4 Summary

Personal characteristics have been introduced that can be instrumental in increasing the predictive accuracy of group awareness tool effects on the cognitive, behavioral, and emotional dimensions, and that might be considered as influencing variables when applying group awareness tools. Social comparison orientation was investigated in relation to all three types of group awareness support (Papers 2 and 3, Ollesch et al., 2020, 2021); need for cognition and need for cognitive closure regarding cognitive group awareness tools (Papers 2 to 4, Ollesch et al., 2020, 2021, 2022); and need for affect regarding emotional group awareness tools (Papers 2 and 4, Ollesch et al., 2020, 2022). By integrating personal characteristics, this thesis addresses a research gap, as these characteristics have received little attention so far, which has hindered further insights in this respect. Whereas comparative and cognitive influence variables have already been integrated to a greater extent, there remains a need to focus on emotional influences, which is what this thesis aims to do.

1.4 Research Questions

This section presents the integrative research questions that apply across all the studies. The thesis aims to shed light on the effects of single and combined group awareness tools on improving learning and collaboration in CSCL, especially in large-scale social media environments. Many previous findings, although very insightful, come from smaller group scenarios (e.g., Dehler et al., 2011; Engelmann & Hesse, 2011; Sangin et al., 2011) and include oral and nonremote collaboration (discussion) phases (e.g., Bodemer & Scholvien, 2014; Schnaubert & Bodemer, 2019). There have been fewer empirical attempts in relation to wiki

learning or other social media environments in large-group contexts (e.g., Dado & Bodemer, 2018; Heimbuch & Bodemer, 2018), which complicates their implementation in such settings. In an online group context with an exchange that is primarily textual, awareness information may be even more difficult to generate.

Within the framework of this research, three central group awareness tool types have been identified that might be relevant for educational social media environments: cognitive (e.g., Lin et al., 2015), behavioral (e.g., Liu et al., 2018), and emotional (e.g., Avry et al., 2020) group awareness tools. All three group awareness tool types offer potentials for collaboration and learning, as illustrated in the integrated framework (Paper 1, Ollesch et al., 2019). The first step was to find out whether these types of group awareness information are considered valuable by the potential target group or the recipients of such implicit guidance methods. Therefore, it should be determined to what extent the three-way division of the framework (Paper 1, Ollesch et al., 2019) applies and whether the three group awareness attributes are important to CSCL users (Paper 2, Ollesch et al., 2020). These considerations lead to the following research question:

RQ1: How relevant do users perceive cognitive, behavioral, and emotional group attributes in educational social media environments?

Moreover, to better understand and apply group awareness tools as implicit guidance methods for knowledge exchange in such environments, the aim was to investigate, systematically and comparatively, the single and interaction effects of these different types of group awareness information on several processes and outcomes, focusing on group awareness tool combinations (Papers 3 and 4, Ollesch et al., 2021, 2022). Therefore, based on RQ1, the second research question considers the specific effects of group awareness tools on cognitive, behavioral, and emotional user interaction patterns in CSCL and how they can be used to improve educational online collaboration in social media. Even though there is already very valuable research considering different types of group awareness information (e.g., Erkens & Bodemer, 2019; Lin et al., 2015; Schnaubert & Bodemer, 2019), further research is needed to identify precisely the single and interaction effects of cognitive, behavioral, and emotional group awareness support in larger online group or social media contexts and to uncover the theoretical and practical implications for such settings (Papers 3 and 4, Ollesch et al., 2021, 2022). This research gap is addressed by the following research question:

RQ2: What are the single and interaction (combined) effects of group awareness tools on cognitive, behavioral, and emotional processes and outcomes in educational social media environments?

In this thesis, the focus is on the links between cognitive and behavioral (Paper 3, Ollesch et al., 2021) as well as cognitive and emotional group awareness tool combinations (Paper 4, Ollesch et al., 2022). An expectation was that single cognitive group awareness information is mainly linked to the cognitive challenge by improving the selection of learning-promoting content in the content space of social interactions (Janssen & Bodemer, 2013). Moreover, single behavioral group awareness information is mainly linked to the behavioral challenge through the presentation of behavioral activities, leading to equal participation patterns in the social interaction space (Kimmerle & Cress, 2008). Lastly, single emotional group awareness tools might be thought to improve the co-regulation of emotional states by addressing the emotional challenge in the relational space of social interactions, which might heighten the group climate (Avry & Molinari, 2018). With respect to interaction effects, which have not been studied before in this systematic way, symmetrically supporting influences were assumed for cognitive and behavioral group awareness tools (Paper 3, Ollesch et al., 2021). Regarding cognitive and emotional group awareness tool combinations, the latter was expected to support the former (Paper 4, Ollesch et al., 2022). From this, the following research sub-questions are derived:

RQ2.1: What are the single and interaction (combined) effects of cognitive and behavioral group awareness tools?

RQ2.2: What are the single and interaction (combined) effects of cognitive and emotional group awareness tools?

It cannot be assumed that users always react identically to implicit guidance methods (Tchounikine, 2019). Therefore, the potential influence of various relevant personal characteristics was also investigated to predict even more precise group awareness tool interactions (Papers 2 – 4, Ollesch et al., 2020, 2021, 2022). Social comparison orientation was expected to influence all three types of group awareness tool effects (e.g., Neugebauer et al., 2016); need for cognition and need for cognitive closure, especially the cognitive group awareness tool effects (e.g., Heimbuch & Bodemer, 2019); and need for affect especially the emotional group awareness tool effects, with the last research attempt being entirely new to the field. This leads to the following research question regarding variables that potentially influence group awareness tool effects:

RQ3: How do personal characteristics influence such implicit guidance effects?

Answering these questions will help to advance state-of-the-art research on implicit guidance methods in educational social media environments, improve the potentials of such environments for learning, behavioral engagement, and social outcomes, and facilitate the

implementation of group awareness tools in this field (Papers 1–4, Ollesch et al., 2019, 2020, 2021, 2022). To conclude, the contribution of this thesis is twofold. On the one hand, it aims to extend the theoretical knowledge in the field of group awareness tools; on the other hand, it is intended to provide concrete inspiration for implicit guidance methods for the optimal design of existing and yet to be created learning environments. The studies in which these research questions are addressed and how they are structured are summarized below.

1.5 Summary of Included Subprojects

In total, five subprojects are integrated into this thesis, see Figure 3 for a summary of all the papers included and their respective research topics and methodological features. First, the established framework (Paper 1, Ollesch et al., 2019) is the starting point for new research directions in the group awareness field to improve the design of CSCL, including educational social media environments.

Figure 3

Overview of Subprojects

Framework (Paper 1)

Topic:
Theoretical understanding of group awareness support/interplay

Method:
Literature review for deriving future studies in CSCL/social media environments

Study 1 (Paper 2) → RQ1, RQ3

Topic:
Relevance of cognitive, behavioral, and emotional group awareness information

Method:
Choice-based conjoint analysis and questionnaires; $N = 104$

Study 2 (Paper 2) → RQ1

Topic:
Group awareness relevance and causes for decisions

Method:
Qualitative interviews; $N = 19$

Study 3 (Paper 3) → RQ2.1, RQ3

Topic:
Single and combined knowledge (cognitive) and participation (behavioral) awareness tools

Method:
2x2 between-subjects experiment with knowledge tests, eye-tracking, and questionnaires; $N = 158$ (main study); $N = 20$ (eye-tracking)

Study 4 (Paper 4) → RQ2.2, RQ3

Topic:
Single and combined knowledge (cognitive) and friendliness (emotional) awareness tools

Method:
2x2 between-subjects experiment with knowledge tests, sentiment analysis, and questionnaires; $N = 148$

Second, Studies 1 and 2 (Paper 2, Ollesch et al., 2020) investigated RQ1 (perceived relevance of group awareness information). Third, the core of this thesis consists of Studies 3 (Paper 3, Ollesch et al., 2021) and 4 (Paper 4, Ollesch et al., 2022), which help to answer RQ2 regarding the single and interaction (combined) effects of different types of group awareness support. RQ3, regarding personal characteristics, is considered in all the studies, except for Study 2.

1.5.1 Framework of Group Awareness Tools

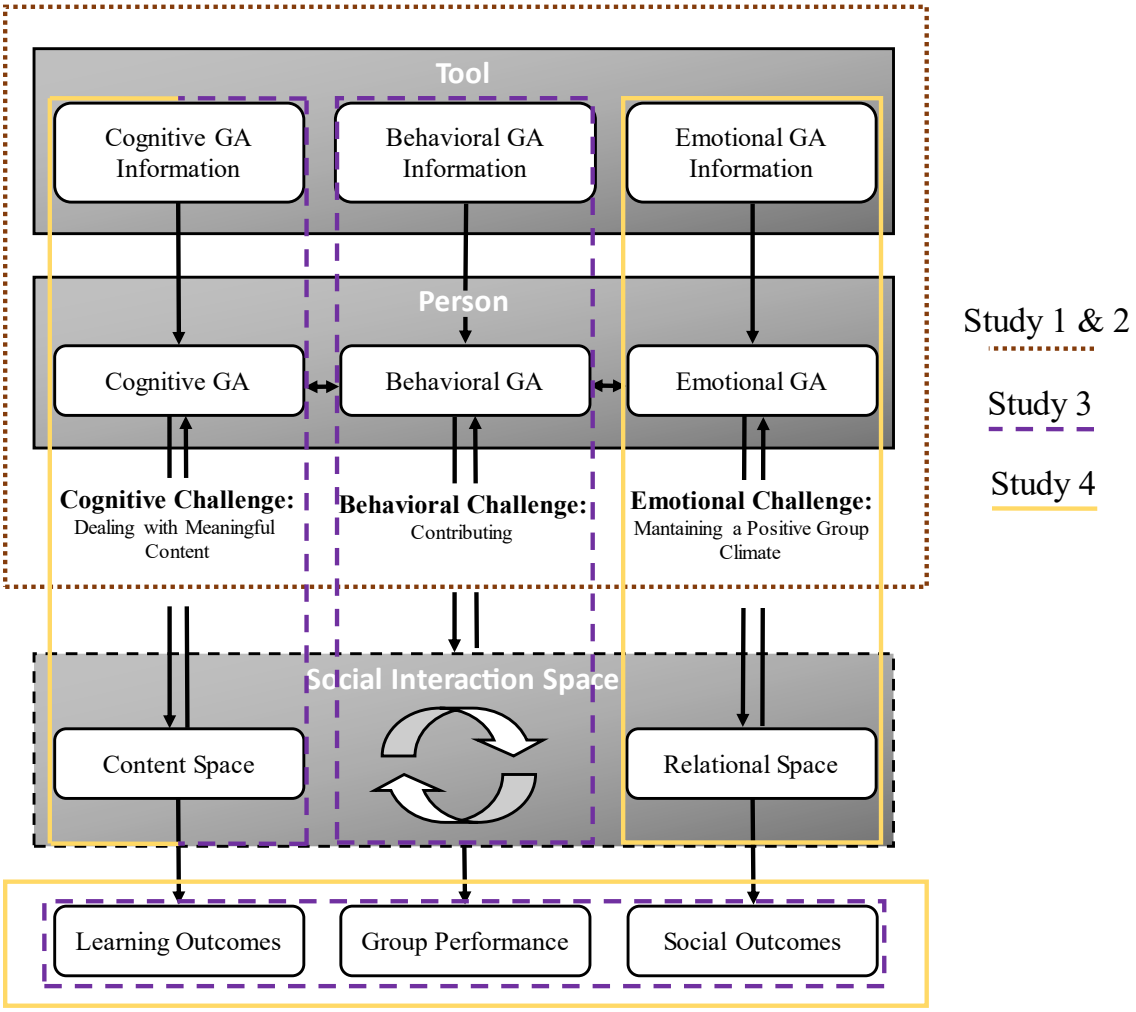
Original title: *Towards an integrated framework of group awareness support for collaborative learning in social media* (Paper 1)

In the first subproject, theoretical considerations and findings are reviewed that already exist in the group awareness field in different contexts. The framework was conducted in the form of a non-systematic literature review to evaluate prominent examples of previous group awareness research in CSCL and to assess their relevance to the educational social media context (see especially *5. An Integrated Framework of GAT Support* in Paper 1, Ollesch et al., 2019). This resulted in a new integrative and illustrative model of the potential interplay of cognitive, behavioral, and emotional group awareness information in educational social media environments, providing deeper insights into specific expected effects at the process and outcome levels (see Figure 4). In addition, this model serves as a basis for deriving future research questions to enable new knowledge gain and facilitate the future development of the framework (see *6. Future Implications* in Paper 1, Ollesch et al., 2019). The innovative aspect of the derived model is that it puts a strong focus on the person layer and does not only look at tool effects without considering the interaction with guidance preferences and influencing personal characteristics. Furthermore, a threefold division into cognitive, behavioral, and emotional group awareness information was introduced. A possible motivational attribute (as mentioned by Bodemer et al., 2018) was not integrated but assumed to be included in the cognitive (motivation to deal with meaningful content), behavioral (motivation to contribute), and emotional (motivation to maintain a positive group climate) challenges instead (for more details, see Paper 1, Ollesch et al., 2019). To date, there are several classifications of group awareness types. For example, Bodemer and Dehler (2011) proposed a three-way division of cognitive, behavioral, and social group awareness, whereas Janssen and Bodemer (2013) bifurcated group awareness into cognitive and social group awareness. Recently, Bodemer et al. (2018) and Buder et al. (2021) proposed a more sophisticated five-way division, with cognitive and social group awareness labels at the overall level but a more fine-grained division

at the sublevel that involves learning topic and metacognitive group awareness information (cognitive dimensions) as well as socio-behavioral, socio-emotional, and socio-motivational (social dimensions) group awareness information. Since there is not yet *the one* theory of group awareness tools and their interplay in educational social media environments, in this PhD project an integrated framework has been developed based on empirical and theoretical findings. The framework illuminates the single effects of cognitive, behavioral, and emotional group awareness tools as well as their interactions. Since group awareness tools in social media always have a social component, even at the cognitive level, the term "social" has been dropped. Furthermore, motivational group awareness information has not been included as a separate block in the framework (going back to the three-way division). It is, however, assumed that cognitive, behavioral, and emotional group awareness tools themselves have a motivational function (for more details, see Paper 1, Ollesch et al., 2019). In particular, the theoretical explanations in sections 1.1.2 to 1.2.4 present the content of this framework in more detail. In this framework, learning outcomes refer to outcomes related to the content space, considering task-related variables. Social outcomes refer to outcomes related to the relational space, considering task-unrelated variables. "Social" here does not refer to the group perspective but to individual feelings or activities within a group at the relational level. "Group performance," on the other hand, stands for outcomes on the group level related to both (content and relational) dimensions (see Figure 1). All outcomes can be cognitive, behavioral and emotional in nature. The framework enriches theoretical considerations about group awareness tools, from which implications for further research can be derived. The theoretical derivation of this cumulus is oriented to these considerations but with a stronger focus on theoretical grounding (see sections 1.1 to 1.3). Besides its theoretical contribution, the framework will guide future empirical studies. The studies of this thesis were planned based on the assumed effects of the framework and are illustrated in different line formats in Figure 4 before they are summarized in sections 1.5.2 to 1.5.5.

Figure 4

The Focus of the Four Studies



Note. Adapted from Paper 1, Ollesch et al., 2019, p. 127. Studies 1 and 2 are shown by dotted brown lines, Study 3 by dashed purple lines, and Study 4 by solid yellow lines. Some aspects overlap across studies.

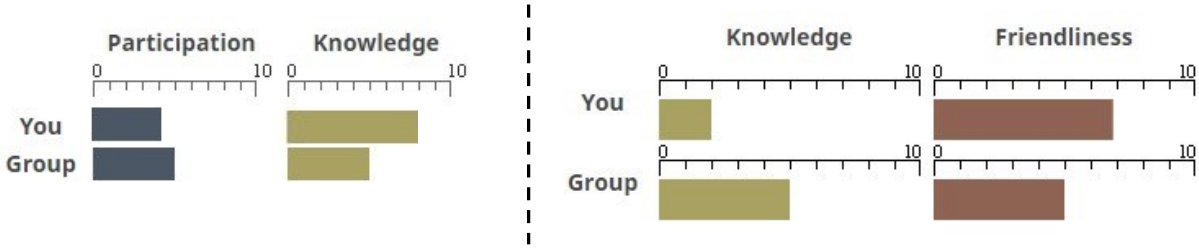
1.5.2 Overview of Empirical Studies

All the studies had a pseudo-collaborative (bogus) design, and participants were given a cover story in which they were part of an asynchronous collaborative interaction in a wiki setting. Whereas in Studies 1 and 2, it was a matter of selecting wiki articles or collaborators to work with, in Studies 3 and 4, the participants had the chance to write their own content in the form of article contributions and/or discussion contributions to the respective forum. Before presenting the individual studies in more detail, to facilitate understanding, a methodological overview of all studies is given that focuses on the group awareness information and dependent

variables used. In all studies, group awareness information was presented in the form of horizontal bars that are a common variant of presenting group attributes (e.g., Sangin et al., 2011). The presentation style was intentionally kept the same for all group awareness tool types across studies to account for display effects. Cognitive group awareness information was operationalized as feedback about group members' knowledge levels, behavioral group awareness information as feedback about participation levels, and emotional group awareness information as feedback about friendliness levels of the potential collaborators, labels that have already been used in the group awareness and CSCL context (see Figure 5; Bodemer, 2011; Cress & Kimmerle, 2008; Phielix et al., 2011). Matte colors were chosen, as these are not considered attention-drawing (Few, 2006). In Studies 1 and 2, the scaling and description of the group information were somewhat abstract, ranging from low to high (Paper 2, Ollesch et al., 2020, Figure 1, p. 1159). Participants were informed that knowledge stands for the average group knowledge in the learning environment about the respective topics measured via knowledge test assessment; participation stands for the average frequency of contributions, and friendliness stands for the average friendliness of the group members' discussions measured via a text recognition method. Group awareness information was provided at a bogus group level but not at the individual level in Studies 1 and 2.

Figure 5

Example Header Information from the Learning Environments



Note. Study 3 is on the left side; Study 4 is on the right side. Next to the respective discussion threads, group visualizations were also displayed at the subgroup level (Papers 3 and 4, Ollesch et al., 2021, 2022).[3]

In Studies 3 and 4, the participants were presented with similar group awareness bars; this time, an individual level was integrated. They received group means ("Group"; medium

[3] Note that the bar plots were enlarged for Study 4. Also, the position of the different types of group awareness information were randomized during each study.

expression) and their own adaptive individual ("You"; varying) values of each information type, both ranging from 0 to 10. Cognitive group awareness information (included in Studies 3 and 4) was operationalized as knowledge bars, based on a previously created and piloted 10-item single-choice pretest completed by all participants before the wiki editing started. Behavioral group awareness information (included in Study 3) was operationalized as participation bars based on the number of contributions in the discussion forum. Emotional group awareness information (included in Study 4) was operationalized as friendliness bars based on users' friendliness levels in discussion contributions, assessed via sentiment analysis, which is an implicit way of evaluating learners' emotional states while writing (Zucco et al., 2020; for more details on this method, see section 1.5.4). Excerpts from the group awareness bars at the header level are visualized in Figure 5. For the whole learning environments, see Paper 3, Ollesch et al., 2021, Figure 1, p. 236; and Paper 4, Ollesch et al., 2022, Figure 1, p. 5. Participants were provided with a wiki article page and an underlying discussion page. The editing phases were considered separately from each other during Studies 3 and 4, and only the discussion phase was enriched with group awareness bars. To avoid order effects, group awareness bars were horizontally randomized when presented in combination. For more information, see *Learning environment* in Paper 3 (Ollesch et al., 2021) and *2.3 Provided learning environment* in Paper 4 (Ollesch et al., 2022).

All studies were reviewed and approved by an ethics committee. Across studies, there were several dependent variables for which group awareness tool effects were investigated, some of which overlapped between studies, whereas others represented additions to the previous studies. For an overview of the main variables in all four studies, see Table 1. At the process level, variables related to selection behavior/relevance were recorded in all studies except Study 4 because by then, I had already obtained satisfactory knowledge in this regard. In Study 3, only the number of discussion posts in the created wiki environment was considered. In Study 4, this was expanded to include qualitative components of discussion contributions, such as correct argument count and balance. At the outcome level, the results of a knowledge test were examined in both Studies 3 and 4, as well as various quantitative and qualitative variables related to the resulting wiki article content such as argument count and balance, and further social and cognitive outcomes such as reported mental well-being (Lang & Bachinger, 2017) and mental effort (Paas, 1992). Several validated questionnaires were used in all the studies to capture the personal characteristics introduced. The personal characteristics in the focus of the studies are need for cognition (Epstein et al., 1996; Keller et al., 2000), need for cognitive closure (Schlink & Walther, 2007), social comparison orientation, the self-

improvement motive (Jonas & Huguet, 2008; Neugebauer, 2016; Ray et al., 2017), and need for affect (Maio & Esses, 2001); see Table 1.

Table 1

Main Variables Collected in Studies 1–4

Process level	Study	Outcome level	Study	Personal characteristics level	Study
Selection behavior/Relevance of group awareness attributes	1, 2, 3	Knowledge test performance	3, 4	Need for cognition/cognitive closure	1, 3, 4
Causes for relevance and identified problems	2	Article word count	3, 4	Social comparison orientation/ Motive of self-improvement	1, 3
Number of discussion posts	3, 4	Article argument count	3, 4	Need for affect	1, 4
Discussion word count	4	Article argument balance	3, 4		
Discussion argument count	4	Mental well-being	3, 4		
Discussion argument balance	4	Mental effort	3, 4		
Friendliness in discussions	4				

1.5.3 Studies 1 and 2: Relevance of Visualizing Specific Group Attributes

Original title: *How students weight different types of group awareness attributes in wiki articles: A mixed-methods approach* (Paper 2)

Studies 1 and 2 were designed to find out to what extent the informational group awareness three-way division (cognitive, behavioral, and emotional) presented within the theoretical framework confirms itself in the application and whether all three group awareness attributes are relevant when choosing groups to collaborate with (see RQ1), using different

methodological approaches (see the dotted brown lines in Figure 4). Both study designs were administered in a laboratory to avoid distractions and confounding influences. In addition, various personal characteristics were collected in Study 1 to increase the accuracy of personal-related predictions (see RQ3; need for cognition, need for affect, social comparison orientation/motive of self-improvement). Regarding the general procedure, Study 1 contained selection tasks with various group constellations involving groups with visualized low, medium, or high knowledge, participation, and friendliness expressions. No learning materials or knowledge tests were included. *Choice-based conjoint (CBC) analysis* was used to measure group awareness relevance, which offers the possibility of depicting decision situations that are close to reality since no rankings of the choices are formed, but discrete decisions are made for one of several alternatives (see *Method: Choice-based conjoint analysis* in Paper 2, Ollesch et al., 2020). The aim was to explain the decisions of individuals via the estimated evaluation of properties of the decision objects (Balderjahn et al., 2009). To determine the relevance or so-called importance values of the different types of group awareness information, 17 CBC tasks were implemented in which the participants had to choose one of four groups involved in wiki article creation. Two of the tasks were predefined by the used CBC software Sawtooth Software (https://sawtoothsoftware.com/), such that only 15 random tasks were included in the evaluation. From the decisions made, the relative importance of the individual properties and their utility values can be calculated (R. Johnson & Orme, 2003). In the case of Study 1, these were the three types of group awareness information knowledge, friendliness, and participation, which varied between low, medium, and high levels next to different article/group constellations that participants had to choose from. The aim was to find out the extent to which the information presented would be referred to in a learning environment. A repeated measures ANOVA was used to examine the difference in the group awareness information importance values and linear regression analysis to test for assumed influences of personal characteristics (for more details, see *Study 1* in Paper 2, Ollesch et al., 2020).

Study 2 adopted exemplary selection tasks out of Study 1, which was followed by a *qualitative, semi-structured interview* (see *Method: Qualitative interviews* in Paper 2, Ollesch et al., 2020). Open questions addressed causes for group decisions and potential problems resulting from visualized cognitive, behavioral, and emotional group deficits (see RQ1). As in Study 1, participants in the qualitative interviews had to choose specific online group constellations based on differently pronounced knowledge, participation, and friendliness bar levels in group scenarios. As an add-on to Study 1, the participants were asked for reasons for their decisions ("Which group constellations would you prefer to work with and which not?

What are the reasons for your decision?") as well as problems that could arise from a specific deficit in a group (low group knowledge, participation, or friendliness; "What difficulties, challenges, and conflicts might arise here?"). The evaluation was carried out using qualitative content analysis, as proposed by Mayring (2015). This method was chosen because it is widely used in the field of qualitative research. The main categories were formulated deductively, resulting in the categories "reasons for cognitive group awareness attribute relevance," "reasons for emotional group awareness attribute relevance," "reasons for behavioral group awareness attribute relevance," and potential "cognitive problems," "emotional problems," and "behavioral problems" based on group deficits in one of the group awareness attributes (for more details, see *Study 2* in Paper 2, Ollesch et al., 2020).

Innovative about Studies 1 and 2 was the consideration of the extent to which certain types of group awareness information are considered useful or relevant in collaborations, based on personal characteristics, using a multi (mixed)-methods approach, and taking a wiki-like environment as an example. Knowing and applying this information can have a decisive effect on whether such implicit guidance methods are accepted and utilized by the respective users (for more details, see Paper 2, Ollesch et al., 2020).

1.5.4 Studies 3 and 4: Knowledge, Participation, and Friendliness Awareness Tools

Original titles: *Improving learning and writing outcomes: Influence of cognitive and behavioral group awareness tools in wikis* (Paper 3)

Implicit guidance in educational online collaboration: Supporting highly qualitative and friendly knowledge exchange processes (Paper 4)

Studies 3 and 4 are laboratory experiments with guidance intervention to investigate single and interaction (combination) effects in educational online collaboration. Wiki learning environments and learning materials were created for both studies beforehand. In Study 3, the learning topic of *energy sources* was chosen, as it is controversial and includes strong arguments on both sides, making it suitable for argumentative knowledge construction. Study 4 was strongly oriented to Study 3 and considered the topic of *drive technologies*. A wiki-like environment was set up: an objective wiki article and a discussion page, including the pro and contra arguments of a bogus group regarding the respective topics. These studies aimed to investigate the actual interaction with group awareness tools systematically (single presentation and combination) in the content and relational spaces of CSCL environments (see RQ2). In a multi-stage experiment, the participants had the opportunity to write their own contributions to

an incomplete wiki article, as well as to exchange views about these topics and to learn with this content in a discussion forum.

As a first step, cognitive (knowledge) and behavioral (participation) group awareness information was chosen as the intervention (see RQ2.1 and the dashed purple lines in Figure 4). These have been considered most in previous empirical studies (e.g., Janssen et al., 2011; Sangin et al., 2011), but often separately or without examining single and combined effects in a systematic way (e.g., Phielix et al., 2011). Therefore, a systematic 2 × 2 between-subjects experiment was set up in which learners were provided with different levels of support (no support, single cognitive group awareness support, single behavioral group awareness support, and/or combination support) in a realistic learning environment. Subjects were assigned at random to the respective groups. The created learning materials, the 10-item knowledge pretest, and the 20-item knowledge posttest were piloted extensively (see *Methods* in Paper 3, Ollesch et al., 2021). It was expected inter alia that knowledge awareness information would lead to improved content selection behavior (preferring high knowledge threads with a learning goal and low knowledge threads with a supporting goal) and that participation awareness information would lead to a higher behavioral engagement (see Buder et al., 2015; Lin et al., 2019). Another hypothesis was that group awareness tool combinations are essential for unfolding the higher effects of group awareness support on cognitive ((knowledge test) learning outcomes) and behavioral (produced content quality) outcomes (see Galikyan & Admiraal, 2019). Social outcomes (mental well-being) were considered exploratory. Moreover, social comparison orientation and need for cognition were considered as potential relevant influencing variables (see RQ3). Also, it was of interest to observe, using *eye-tracking*, the participants' visual attention in the learning environment, which allows conclusions to be drawn about stimuli of interest (Alemdag & Cagiltay, 2018; E. B. Goldstein, 2008). The main aim was to see to what extent the group awareness tool visualizations would be considered or should be visually adapted and how this is linked to actual interaction behavior. Group awareness research is enriched with eye-tracking to gain a deeper understanding of how such tools are captured on a visual level. This can be used to better understand the interaction with group awareness information (for more details, see *Eye-tracking investigation* in Paper 3, Ollesch et al., 2021).

Study 4 followed directly from Study 3 to examine the single and interaction effects of cognitive (knowledge) and emotional (friendliness) group awareness information in a wiki-like context (see RQ2.2 and the solid yellow lines in Figure 4). A similar design to Study 3 was used, with adjustments to the type of group awareness information provided (no support, single

cognitive group awareness support, single emotional group awareness support, and/or combination support). Care was taken to make the group awareness bar scales somewhat larger and place them at greater distances from each other, as informed by the eye-tracking analysis in Study 3 (see *2. Methods* in Paper 4, Ollesch et al., 2022). In this study, the focus was on the expected effects of knowledge awareness tools on resulting (knowledge test) learning outcomes and content quality (see Heimbuch & Bodemer, 2017). A *sentiment analysis* algorithm was implemented to feed and adapt the individual friendliness bar, which is of enormous relevance in social media analytics and represents a systematic computer-based method to analyze sentiments toward an unstructured text (Stieglitz et al., 2018; Stieglitz & Dang-Xuan, 2013). The analysis is based on word features that may predict emotional states using a sentiment lexicon (Arguedas et al., 2015). Emoticons were also integrated into the algorithm used. Friendliness awareness information was expected to have a positive effect on the friendliness level in discussion posts and social outcomes like mental well-being within the collaborative interaction (see Eligio et al., 2012). Also, potentials for emotional group awareness support to enhance the effects of cognitive group awareness support (knowledge test learning outcomes and content quality) were assumed (see Arguedas et al., 2016, 2015). In terms of personal characteristics, need for affect and need for cognitive closure were considered (see RQ3). The use of sentiment analysis enriches group awareness research by providing a form of emotional assessment that goes beyond subjective evaluation and thus does not disrupt the flow of interaction (for more details, see *2.4 GA information on the individual level* in Paper 4, Ollesch et al., 2022).

In Studies 3 and 4, 2 × 2 ANOVAs were calculated, including the two considered main effects as well as their interaction effects (cognitive/behavioral or cognitive/emotional group awareness support). When conditions for parametric procedures were not met, bootstrapping or alternative (nonparametric) procedures were used. Therefore, in Study 3, for effects on the discussion thread selection, ordinal regression analyses were applied. In the case of significant interaction effects, in Study 3, a more cautious approach was taken with post hoc simple effect analyses, whereas in Study 4, contrast assumptions were set up, and contrast analyses were calculated. For influences of personal characteristics, moderation analyses were applied.

The innovative features of the two studies are the systematic approaches taken, supported by various data collection methods, which allows specific guidance effects to be considered on different levels. In particular, the automatic (implicit) detection of friendly interaction patterns and feedback as emotional group awareness information is a new aspect

that can enhance social behavior. For more details, see Papers 3 and 4, Ollesch et al. (2021, 2022).

1.5.5 Main Results of Empirical Studies

The following summary of the integrated results of Studies 1 to 4 is structured according to the research questions (see section 1.4). Detailed results and specific research questions can be found in the respective papers; see *Results and discussion* for Studies 1 and 2 separately in Paper 2 (Ollesch et al., 2020) and *Results* in Papers 3 (Ollesch et al., 2021) and 4 (Ollesch et al., 2022).

Addressing Research Question 1. RQ1 deals with the user relevance of cognitive, behavioral, and emotional group (awareness) attributes in educational social media environments. Therefore, for RQ1, the main variables considered are the selection behavior/relevance of group awareness attributes, the causes of relevance, and identified problems with a group awareness deficit (process level); see Table 1. The importance values from the CBC analysis in Study 1 support the assumption that all three types of group awareness information knowledge (cognitive group awareness information), participation (behavioral group awareness information), and friendliness (emotional group awareness information) are relevant to users, with equally high procedural importance values (29.83% to 35.93%, see Study 1 *Results and discussion* in Paper 2, Ollesch et al., 2020). This is in line with the three-way division of the proposed framework (Paper 1, Ollesch et al., 2019). Moreover, the attribute friendliness is descriptively more relevant than participation and knowledge and significantly different from knowledge. The qualitative interviews from Study 2 also support the relevance of all types of group awareness information, especially emotional group awareness information. Eight participants out of 19 chose friendliness as the most relevant group (awareness) attribute, which seems to have the most impact on reported subsequent problems (example "cause" statement: "This can lead to other people showing rage when you don't know something," see Study 2 *Results and discussion* in Paper 2, Ollesch et al., 2020, p. 1162). The results of Studies 1 and 2 underline, that the three group awareness attributes are wished for and might guide selection behavior in the social media context. This was followed by two systematic 2 × 2 between-subjects experiments including those attributes (Studies 3 and 4) to answer RQ2 (2.1 and 2.2).

Addressing Research Question 2.1. RQ2.1 deals with the single and interaction (combined) effects of cognitive and behavioral group awareness tools on various processes and

outcomes in educational social media environments. For RQ2.1, the main variables under consideration are selection behavior, the number of discussion posts (process level), knowledge test performance, article word count, article argument count, article argument balance, mental well-being, and mental effort (outcome level); see Table 1. In Study 3, the ordinal regression results clarify that cognitive group awareness information, in particular, has positive effects on improved selection behavior, with highly knowledgeable collaborators being preferred in relation to the goal of learning new content and low knowledgeable learners being preferred in relation to the goal of supporting others, instead of medium knowledgeable learners (see *Impact on selection (hypotheses 1 and 2)* in Paper 3, Ollesch et al., 2021). A 2 × 2 ANOVA shows that behavioral group awareness information leads to significantly higher behavioral engagement in terms of the number of discussion posts (see *Impact on number of discussion posts (hypotheses 3 and 4)* in Paper 3, Ollesch et al., 2021). Moreover, users who are supported by both types of group awareness bars produce qualitatively higher content than the single support conditions, as shown with post hoc simple effect analyses following a significant interaction effect. This result is related to a higher word count as well as to the number and balance of correct pro and contra arguments in the resulting wiki article, confirming one of the main hypotheses of this study *(*see *Interaction effects on article quality (hypothesis 6)* in Paper 3, Ollesch et al., 2021). Cognitive group awareness information also shows positive effects on the number of discussion posts; however, more frequently, the more knowledgeable individuals perceive themselves in the community. No learning outcomes regarding the knowledge posttest participation can be illustrated, either from single or combined group awareness support, as shown by a 2 × 2 ANOVA *(*see *Interaction effects on learning (hypothesis 5)* in Paper 3, Ollesch et al., 2021). This contradicts one of the guiding hypotheses. Exploratively, it is shown that the combination of the two types of awareness leads to lower mental well-being than one type of group awareness support, with mental effort at the same level across conditions (2 × 2 ANOVA; see *Exploratory analyses* in Paper 3, Ollesch et al., 2021). Finally, the eye-tracking observations highlight potentials for an adapted group awareness tool design (see *Eye-tracking results* in Paper 3, Ollesch et al., 2021), which is why the guidance visualization scales were slightly enlarged for Study 4.

Addressing Research Question 2.2. RQ2.2 deals with the single and interaction (combined) effects of cognitive and emotional group awareness tools on various processes and outcomes in educational social media environments. For RQ2.2, the main considered variables are the number of discussion posts, discussion argument count, discussion argument balance,

friendliness in discussions (process level), knowledge test performance, article word count, article argument count, article argument balance, mental well-being, and mental effort (outcome level); see Table 1. As the selection process had already been investigated in Studies 1–3, only further interaction behavior with the learning environment based on cognitive and emotional group awareness information was evaluated for Study 4 (Paper 4, Ollesch et al., 2022). In Study 4, emotional group awareness support leads to friendlier discussion exchanges based on the applied friendliness algorithm but also in comparison to SentiStrength (http://sentistrength.wlv.ac.uk/) and qualitative assessment as validation check. This supports one of the main hypotheses and is not the case for the single cognitive group awareness tool condition or the interaction of both, as shown by a 2 × 2 ANOVA with subsequent contrast analyses (see *4.2 Single emotional GA tool effects and interaction (combination) effects* in Paper 4, Ollesch et al., 2022). Moreover, an exploratory post hoc mediation analysis highlights that those friendly interactions are a full mediator variable for the effect of emotional group awareness support on increased mental well-being (see *4.4 Further exploratory calculations* in Paper 4, Ollesch et al., 2022). Besides, according to a 2 × 2 ANOVA with subsequent contrast analyses, only single cognitive group awareness support has a positive effect on content quality variables, both at the discussion and the article levels (argument count and argument balance). However, the combination with emotional group awareness support does not reveal to be additionally helpful, as is in the case of cognitive and behavioral group awareness tool combinations (see Study 3), which is why one of the main hypotheses is rejected (see *4.1 Single cognitive GA tool effects and interaction (combination) effects* in Paper 4, Ollesch et al., 2022). In general, most interaction effects of the 2 × 2 ANOVAs are not significant, except for the reported mental effort, which is slightly higher for the no support condition, descending followed by the combination, emotional, and cognitive group awareness tool conditions. It is moreover exploratively illustrated that both single emotional and cognitive group awareness information has positive effects on behavioral engagement, such as the number of contributions and written word count in the discussion forum (see *4.4 Further exploratory calculations* in Paper 4, Ollesch et al., 2022).

Addressing Research Question 3. RQ3 deals with personal characteristics influencing group awareness tool effects. For RQ3, the main variables under consideration are need for cognition/cognitive closure, social comparison orientation/the motive of self-improvement, and need for affect (personal characteristics level); see Table 1. Several linear regressions (Study 1) and moderation analyses (Studies 3 and 4) were performed to test for potential

influences of the personal variables on group awareness support types. Study 1 shows that social comparison orientation has a positive linear influence on the relevance or importance value of visualized group knowledge compared to the amount of one's own knowledge when choosing collaboration partners. However, it cannot be confirmed that the motive of self-improvement leads to the selection of better learning partners. In addition, need for affect has a positive linear influence on the relevance of friendliness, whereas need for cognition has no linear influence on the subjective relevance of knowledge (see Study 1 *Results and discussion* in Paper 2, Ollesch et al., 2020). In Study 2, no hypotheses regarding personal characteristics were set up. Furthermore, in Study 3, no moderating effects of personal characteristics on selection and interaction behavior are found, even though several influences were assumed, such as need for cognition and social comparison orientation (see *Impact on selection (hypotheses 1 and 2)* and *Impact on number of discussion posts (hypotheses 3 and 4)* in Paper 3, Ollesch et al., 2021). Since the previous studies did not find any moderating effects related to need for cognition, and only weak effects for social comparison orientation, in Study 4, only need for affect and need for cognitive closure were evaluated as potential moderator variables. Whereas need for cognitive closure has no moderating effect on the impact of the knowledge awareness tool on cognitive process and outcome variables, a moderating effect of need for affect on the impact of the friendliness awareness tool on emotional processes was found. Learners who report a higher need for affect also write more emotional or friendlier contributions in the learning environment (see *4.3 Moderating effects* in Paper 4, Ollesch et al., 2022).

1.6 Discussion

Even if the group awareness tools previously developed show promise, it is still very important not only to develop new tools but also to examine them for their systematic effects (Bodemer et al., 2018; Buder, 2011). The effectiveness of such tools for learning and collaborating in social settings is often evaluated at the overall tool level, with a focus on outcomes instead of underlying processes. Taking a differentiated view and adopting experimental approaches, this PhD project aims to identify and distinguish the underlying functions of different (single and combined) group awareness tools and to identify the personal characteristics that influence such functions. By helping to understand how and for whom such tool support works in educational social media environments, it makes an important and original contribution to this research field. The five subprojects included in the cumulus of this thesis aim to answer the overall research question of what the specific single and interaction

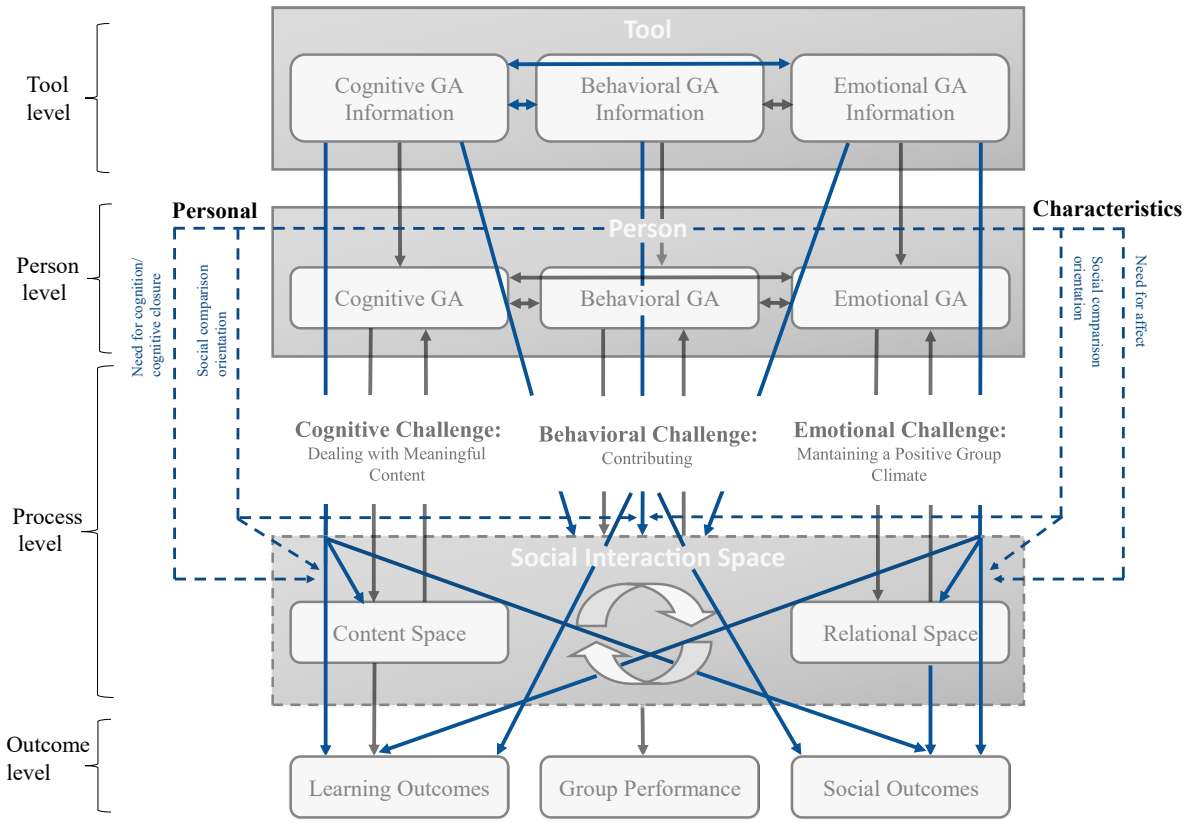
(combination) effects of group awareness tools are and what role personal group awareness relevance and characteristics play in these mechanisms (see the introduction in section 1). The systematic experimental approach of this thesis makes it possible to study different group awareness tool effects in a comparable way. Although Subproject 1 already made a theoretical contribution (Paper 1, Ollesch et al., 2019), the model established there is expanded in this section by integrating the results of Studies 1 to 4 and by deriving their theoretical and practical implications. By doing so, this cumulus provides a better understanding of implicit guidance and more specific group awareness tool effects in an educational social media application context.

Before the results of the studies are discussed, Figure 6 shows the adapted framework, which illustrates exactly which relationships/findings are illuminated in the thesis (Studies 1–4). The blue lines represent (new) relationships that have been investigated, while the **black** lines represent relationships that have not yet been investigated in depth in this thesis and in the literature but are intended for future studies (see inter alia section 1.6.4).

Even though the original framework in Paper 1 (Ollesch et al., 2019) assumes that the actual tool effects are mediated via personal group awareness (see the **black** lines in the person layer in Figure 6), this was not considered in this thesis because of the many other facets involved. Instead, the direct effects of three types of group awareness tools were investigated: the single effects of cognitive, behavioral, and emotional group awareness information on social interaction in general, the content space, and the relational space (see the blue lines in the process layer in Figure 6), as well as learning outcomes and social outcomes (see the blue lines in the outcome layer in Figure 6). No effects on group performance of real groups were measured, as only individual contributions to bogus group works were considered instead of real group interdependencies (see the **black** line in the outcome layer in Figure 6). The assumptions at the single effect level are not fundamentally new, but they are substantial in relation to the social media application context and the respectively applied methodology in this thesis. Moreover, this cumulus extends existing empirical findings with conceptual assumptions of group awareness tool interactions, focusing on the interaction between cognitive and behavioral as well as cognitive and emotional group awareness information (see the blue lines starting from the tool layer in Figure 6, taking the same dependent variables as respective single tool effects). Besides, various personal characteristics are considered, some of which are completely new additions to the field of group awareness tools (regarding need for affect) or have been adopted from previous work (regarding need for cognition/cognitive closure and social comparison orientation).

Figure 6

Breakdown of Examination Foci at the Tool, Person, Process, and Outcome Levels



Note. Adapted from Paper 1, Ollesch et al., 2019, p. 127. Blue = investigated relationships in the focus of this thesis.

In what follows, the theoretical and practical implications of the subprojects will be discussed in an integrated way. Detailed discussions can be found in the respective papers: *Future Implications* in Paper 1 (Ollesch et al., 2019), *Overall discussion* in Paper 2 (Ollesch et al., 2020), *Discussion* in Paper 3 (Ollesch et al., 2021), and *5. Discussion* in Paper 4 (Ollesch et al., 2022).

1.6.1 Theoretical Implications

An integrative theoretical approach to the use of group awareness tools in educational social media environments has been proposed within the framework of Paper 1 (Ollesch et al., 2019), which highlights relationships that were derived from theoretical assumptions and empirical research on which future theoretical and empirical approaches can build. In fact, the studies of this thesis (Studies 1–4) reveal strong positive effects of single group awareness tool usage on variables at the process level of the framework. At the outcome level, particularly in

relation to group awareness tool interaction effects, as well as at the person level, the results were mixed across the studies. For illustration purposes, the respective findings are highlighted in Figures 7–10 and justified in Tables 2–7. A green line means that the results are not entirely new to the community but that they confirm previous research. A red line highlights the results of this thesis that contradict previous empirical investigations. A blue line means that this thesis has found evidence about the assumed relationships that are new to the field and that should be expanded and validated in future studies. The symbol + indicates significant positive linear relationships between two nodes, – indicates significant negative linear relationships, and ⊘ indicates that no significant effects between the linked nodes were found.

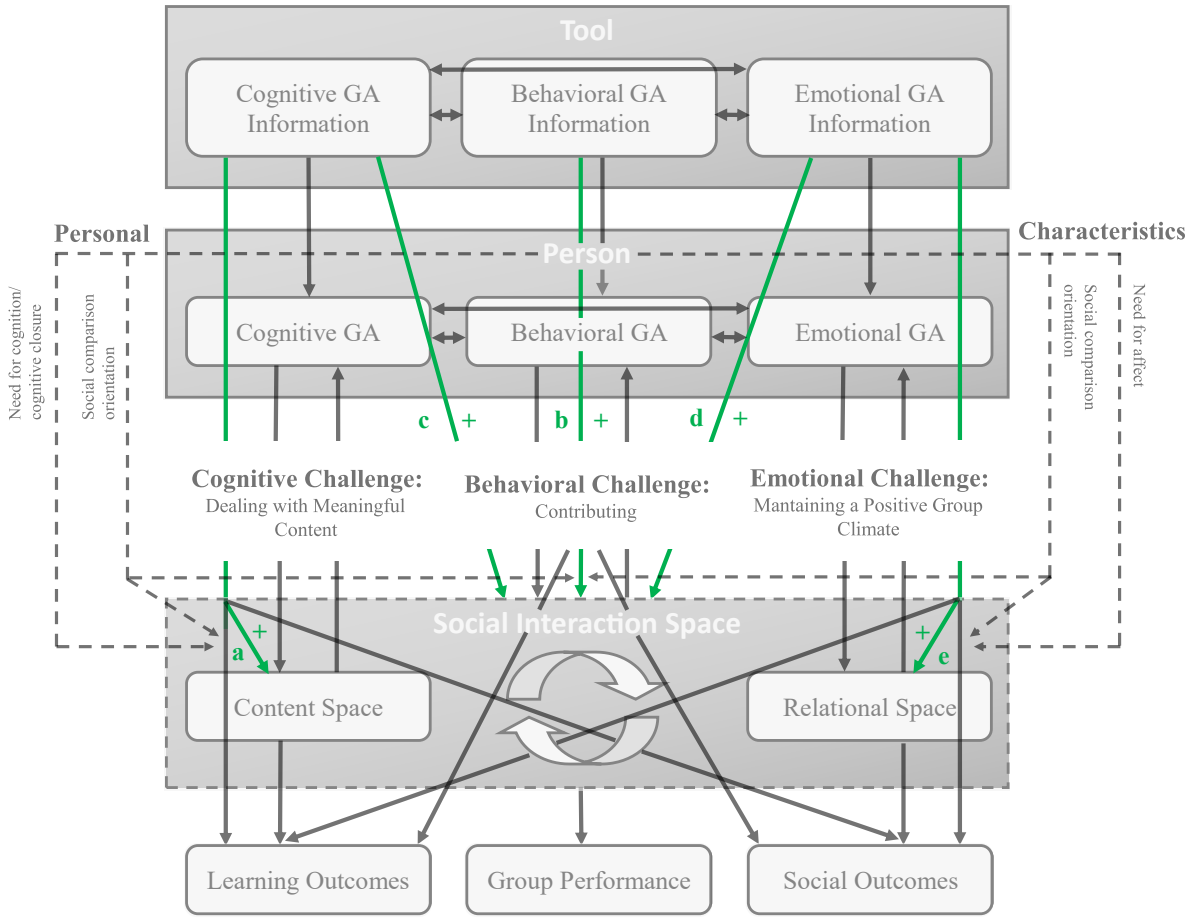
Single Group Awareness Tool Effects at the Process Level. In terms of single effects at the process level (see Figure 7 and Table 2), the expected effects of cognitive group awareness information on the cognitive challenge and content space interactions, emotional group awareness information on the emotional challenge and relational space interactions, and behavioral group awareness information on the behavioral challenge in the social interaction space in general, are confirmed (Papers 2–4, Ollesch et al., 2020, 2021, 2022).

Positive effects of single cognitive group awareness information on selection and writing processes in the content space have already been empirically revealed in both small-group and larger (social media) group learning contexts (Dehler et al., 2011; Heimbuch & Bodemer, 2017; Zhang et al., 2016). Therefore, the cognitive group awareness findings of this thesis regarding content space effects are in line with previous research (see **a+** in Figure 7 and Table 2). Moreover, they are in line with the theoretical considerations of the co-evolution framework, which assumes that the concept of cognitive conflict (Piaget, 1977) can be applied to a social media (wiki) context (Cress & Kimmerle, 2008). Socio-cognitive or content-related conflicts, and especially their resolution by weighing different statements or opinions, are essential for deep learning processes, where one incorporates other cognitive perspectives into one's own repertoire (Näykki et al., 2014). Even if, according to Piaget (1977), success in resolving such conflicts depends on the experience of the individual and should target appropriate cognitive structures, socio-cognitive conflicts are widely regarded as having a promoting effect on the acquisition of knowledge (Doise & Mugny, 1984; D. W. Johnson et al., 2000). Indicators for such processes triggered via single cognitive group awareness support are the preference for contrasting levels of knowledge in wiki discussion threads in Study 3 (Paper 3, Ollesch et al., 2021) and, on the other hand, wiki contributions containing more balanced arguments in the produced content in Study 4, which implies a stronger integration

of various conflicting group perspectives (Paper 4, Ollesch et al., 2022). Wiki infrastructures can facilitate the emergence and resolution of socio-cognitive conflicts when there is the motivation to do so since cognitive development is likely to take place if one perceives a discrepancy between one's own and the wiki information (Cress & Kimmerle, 2008). The results found in this cumulus back up the assumption that internal and external assimilation processes occur with single cognitive group awareness support since it can be assumed that most of the specific knowledge discussed in the discussion forum did not exist in the cognitive systems of the respective participants before and was therefore added to the own cognitive system (internal assimilation). Moreover, it should be noted that only a few restructuring attempts of the article can be found in Studies 3 (Ollesch et al., 2021) and 4 (Ollesch et al., 2022). Instead, mainly contents from the discussion forums were quantitatively added to the respective wiki articles, which corresponds to processes of external assimilation rather than accommodation.

Figure 7

Highlighted Single Group Awareness Tool Effects (Process Level)



Note. Adapted from Paper 1, Ollesch et al., 2019, p. 127. Green = confirms previous research.

Table 2

Findings on Single Group Awareness Tool Effects (Process Level)

Edge	Main findings
a+	Single cognitive group awareness information leads to an improved selection behavior (regarding knowledge level of content creators) and to a higher discussion content quality (in terms of discussion word count, argument count, and argument balance) (Papers 2–4, Ollesch et al., 2020, 2021, 2022)
b+	Single behavioral group awareness information leads to a higher number of contributions produced in the learning environment (Paper 3, Ollesch et al., 2021)
c+	More knowledgeable users write more contributions with single cognitive group awareness information (Paper 3, Ollesch et al., 2021)
d+	Users write more and more extensive contributions with single emotional group awareness information (Paper 4, Ollesch et al., 2022)
e+	Single emotional group awareness information leads to a friendlier climate in social interaction with a bogus group (Paper 4, Ollesch et al., 2022)

Furthermore, empirical studies with a smaller group context have already indicated that single behavioral group awareness information can increase behavioral engagement in the social interaction space (Kimmerle & Cress, 2008; Janssen et al., 2011). Study 3 (Paper 3, Ollesch et al., 2021) successfully extends the theoretical concept of descriptive norms to a bogus social media (wiki) group scenario with potentially unlimited users and illustrates that this concept also plays a crucial role in the number of contributions in an educational social media environment (see **b+** in Figure 7 and Table 2). Moreover, this thesis provides exploratory support for the idea that both single cognitive (Dehler et al., 2011) and single emotional (Avry et al., 2020) group awareness tools have the potential to address the behavioral challenge and increase behavioral engagement, thereby confirming previous findings (see **c+** and **d+** in Figure 7 and Table 2). Therefore, when using single cognitive or emotional group awareness support, one might tick off two goals or challenges at the same time. These results are not surprising, as cognitive group awareness information is known to facilitate selection (Schnaubert & Bodemer, 2019) and, therefore, to lower the hurdle for new contributions. In addition, increased positive emotional exchange, triggered via single emotional group awareness support, can help to create a productive learning environment (Boekaerts, 2011).

From a methodological point of view, what is particularly noteworthy about this cumulus approach is the automatic and dynamic presentation of emotional group awareness information in the form of friendliness awareness bars in textual social interaction patterns (Paper 4, Ollesch et al., 2022), in comparison to the self-reported sharing of feelings (Avry & Molinari, 2018; Eglio et al., 2012; Molinari et al., 2013) or manual coding of sentiments (Zheng & Huang, 2016). Phielix et al. (2011) followed a similar approach, but with a subjective (explicit) collection of friendliness parameters and without looking at the specific emotional effects on a textual level. The possibility of automatically (implicitly) detecting emotional interaction patterns with the help of sentiment analyses represents an important extension for implementing such guidance methods without interrupting users' interaction (Arguedas et al., 2015). The results show that textual exchanges in a wiki environment may indeed trigger emotional contagion processes (see e+ in Figure 7 and Table 2). Although emotions and emotional contagion processes were not measured explicitly during the discussion phase, the adaptation of emotional writing styles and the accompanying higher reported mental well-being of users suggest that these assumptions are true. When using Facebook as an example, textual messages may act as a sufficient channel for transferring emotional states, with similar textual emotional reactions and higher well-being (Kramer et al., 2014). This thesis highlights that these results also seem to apply to an educational social media context such as wikis, which makes a real (learning) community emerge and should not be neglected in future research. Furthermore, although Study 4 did not involve extremely malevolent socio-emotional conflicts and there is a need for non-bogus studies to investigate real emotional threats, the learning environment in this study was still intended to trigger socio-emotional conflicts by highlighting different levels of friendliness (Paper 4, Ollesch et al., 2022). Therefore, the results of this thesis extend the assumptions of the co-evolution model of Cress & Kimmerle (2008); not only does socio-cognitive knowledge seem to grow in collaborative wiki scenarios (i.e., knowledge on the topic content being exchanged – internalized and externalized – though the cognitive and social systems), but there is also an exchange of socio-emotional knowledge (i.e., internalization and externalization of knowledge on the socio-emotional norms and behavior between the cognitive and social systems). I, therefore, suggest not only that exchange and growth of the individual and the group take place on a socio-cognitive level, as stated by Cress and Kimmerle (2008), but also that (dis)equilibration might take place on a socio-emotional level, for example, triggered by different friendliness levels among group members that conflict with their own socio-emotional standards for collaboration. This may be promoted using wiki discussion pages enriched with single emotional group awareness information, as shown in

Paper 4 (Ollesch et al., 2022). Sweet and Michaelsen (2007) also assume the importance of such a socio-emotional learning process, especially at the beginning of group work. When equilibration in this regard is reached, socio-cognitive conflicts are more likely in focus (Sweet & Michaelsen, 2007).

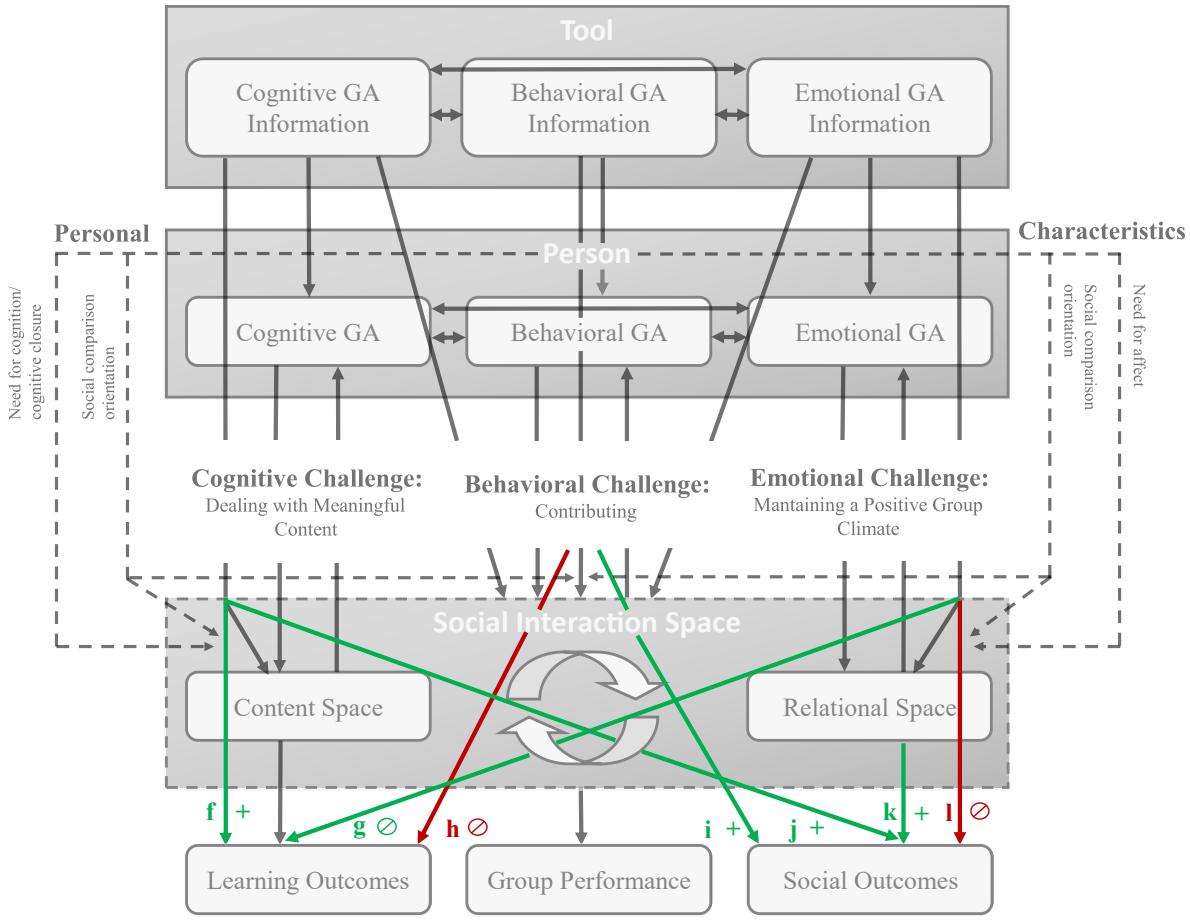
However, in addition to the positive findings of this thesis, single emotional group awareness tools highlighting socio-emotional conflicts, especially when they are strong, might also lead to avoidance behavior, which in turn can have a negative effect on the resolution of important socio-cognitive conflicts (Näykki et al., 2014). Therefore, the theoretical implications drawn here should be regarded with caution. More research is needed to investigate more in-depth the different degrees of conflict and the similarities and differences between conflict types (socio-cognitive versus socio-emotional) when interacting with group awareness tools. It is important to determine under which circumstances and to what extent the visualization of socio-emotional conflict situations has positive or even negative effects on the expansion of cognitive structures in the short and long term, and to what extent concepts like assimilation and accommodation play a role in socio-emotional development in comparison to socio-cognitive development. These issues fall outside the scope of this thesis. Even if there are parallels between socio-cognitive and socio-emotional conflicts (e.g., both are triggered by a social context; Darnon et al., 2007), it should be emphasized that the resolution of socio-cognitive conflicts might be more natural or more likely to occur than socio-emotional conflicts in joint learning situations, since a successful solution to a task requires the weighing of different perspectives, especially in the joint creation of a textual product (see Cress & Kimmerle, 2008; Heimbuch et al., 2018).

Single Group Awareness Tool Effects at the Outcome Level. Regarding the outcome level of single group awareness tool effects (see Figure 8 and Table 3), the findings are mixed. There are no learning outcomes with single cognitive group awareness support based on a knowledge test assessment, although this is not uncommon in group awareness research (Bodemer et al., 2018). There are, nevertheless, promising learning effects on the textual level. Furthermore, single emotional or behavioral group awareness support cannot achieve enhanced learning outcomes, measured either via a knowledge test or in textual form (Papers 3 and 4, Ollesch et al., 2021, 2022). Because of the lack of research in this regard, such a finding that goes beyond simple correlative relationships between single emotional group awareness information and learning outcomes would not necessarily be expected (Arguedas et al., 2016; see **g**⊘ in Figure 8). However, single behavioral group awareness implementations have

previously shown an increase in knowledge at the textual level, which contradicts the findings of this thesis (Liu et al., 2018; see **h**⊘ in Figure 8). This thesis moreover illustrates that there are enhanced social outcomes (regarding mental well-being) with single cognitive or behavioral group awareness support (Paper 3, Ollesch et al., 2021). This is in line with research on social outcomes and group awareness tools that visualize such behavioral and emotional aspects in a small-group context, even though precise conclusions are difficult to draw due to the used full-tool approach (Phielix et al., 2011; see **i+**/**j+** in Figure 8 and Table 3).

Figure 8

Highlighted Single Group Awareness Tool Effects (Outcome Level)



Note. Adapted from Paper 1, Ollesch et al., 2019, p. 127. Green = confirms previous research, red = contradicts previous research.

Table 3

Findings on Single Group Awareness Tool Effects (Outcome Level)

Edge	Main findings
f+	Single cognitive group awareness information leads to higher textual learning outcomes (Paper 4, Ollesch et al., 2022)
g⊘/h⊘	No effects of single emotional or behavioral group awareness tools on learning outcomes (Paper 3, Ollesch et al., 2021)
i+/j+	Single behavioral and cognitive group awareness tools are associated with higher social outcomes (mental well-being) of participants (Paper 3, Ollesch et al., 2021)
k+	Single emotional group awareness information leads to higher social outcomes (mental well-being) when resulting interaction patterns are friendly; however, there is no direct effect (**l**⊘) (Paper 4, Ollesch et al., 2022)

Moreover, when friendliness awareness support results in a positive adjustment in the way users interact with each other on a social level, this mediates the effect of single emotional group awareness support on mental well-being (Paper 4, Ollesch et al., 2022). Relationships between emotional co-regulation and social outcomes have already been noted by Molinari et al. (2013); see **k+** in Figure 8 and Table 3. Therefore, it is recommended that future studies control for (friendly) interaction patterns transmitted through group awareness tools when considering effects on social outcomes like mental well-being. Direct effects of emotional group awareness tools on social outcomes like positive affect might occur (e.g., Eligio et al., 2012) but are not always guaranteed, as shown in Study 4 (Paper 4, Ollesch et al., 2022; see **l** ⊘ in Figure 8 and Table 3).

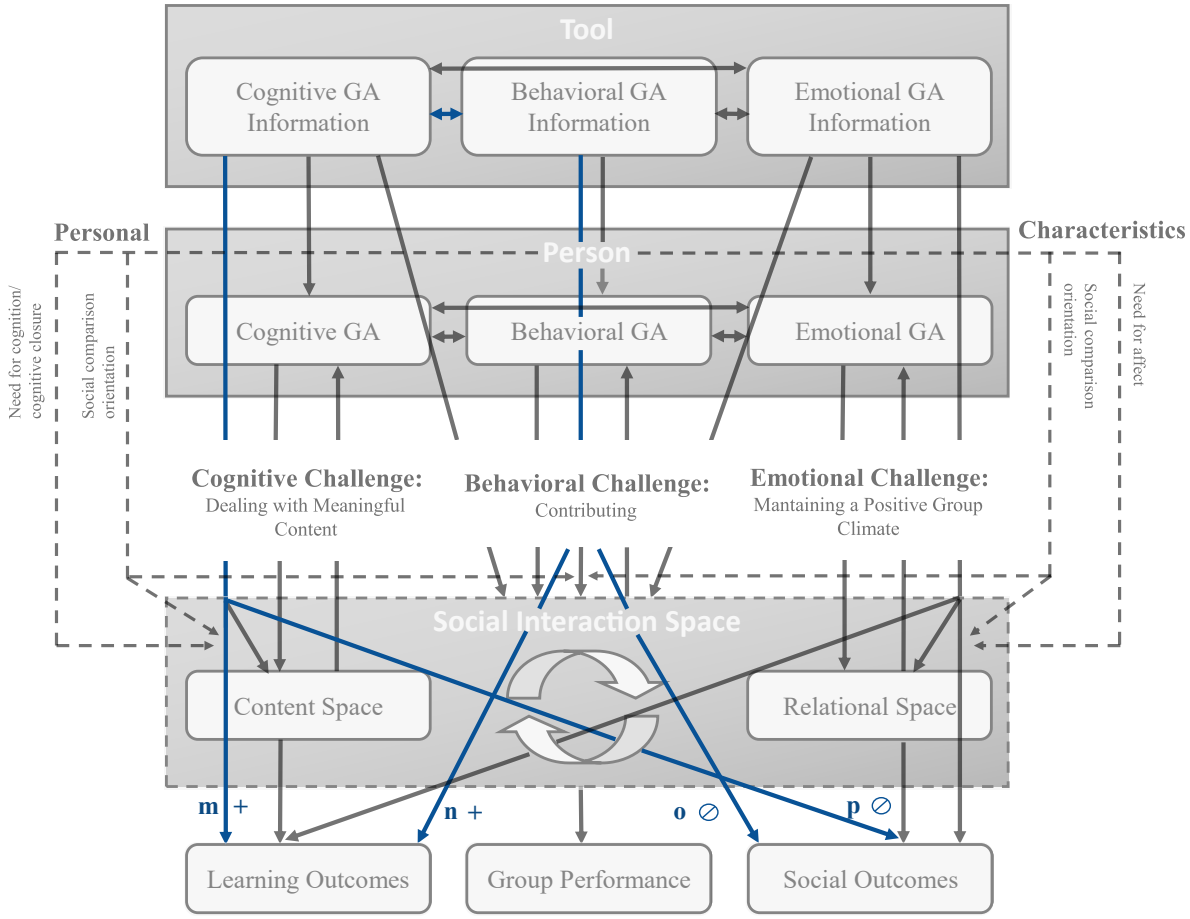
Cognitive and Behavioral Group Awareness Tool Combination Effects. Although the single group awareness tool effects are very promising, it is important to consider their potential interaction effects. The systematic investigation of the interplay of cognitive/behavioral and cognitive/emotional group awareness information is a new addition to research in the field of group awareness tools. This section deals with cognitive and behavioral group awareness interactions (see Figure 9 and Table 4). Positive symmetrical interaction effects of cognitive and behavioral group awareness information as an addition for the other type can be illustrated in terms of the resulting wiki article quality (textual learning outcome) (see **m+**/**n+** in Figure 9 and Table 4), albeit with no effects (even lower at the

descriptive level) on mental well-being expressions (social outcome) compared to single group awareness information (see o⊘/p⊘ in Figure 9 and Table 4). Also, the measured mental effort does not differ between single and combination support. Thus, an increased learning-impeding cognitive load can be excluded (Janssen & Kirschner, 2020; Kirschner et al., 2018).

The results regarding textual learning outcomes are in line with socio-constructivist assumptions, which regard active participation in social and interdependent discourse as a basic prerequisite for learning (Scardamalia & Bereiter, 2006; Vygotsky, 1978). This illustrates that not only are cognitive and behavioral processes interrelated in collaborative learning, but also cognitive and behavioral group awareness tool effects are closely intertwined in such settings.

Figure 9

Highlighted Cognitive and Behavioral Group Awareness Tool Interaction (Combined) Effects



Note. Adapted from Paper 1, Ollesch et al., 2019, p. 127. Blue = new findings.

Table 4

Findings on Cognitive and Behavioral Group Awareness Tool Interaction (Combined) Effects

Edge	Main findings
m+/n+	Behavioral group awareness information heightens the effect of cognitive group awareness information on textual learning outcomes (article word count, argument count, argument balance) and vice versa (Paper 3, Ollesch et al., 2021)
o∅/p∅	No significant effects of combined group awareness tools on mental well-being with lower values on a descriptive level than single group awareness tools (Paper 3, Ollesch et al., 2021)

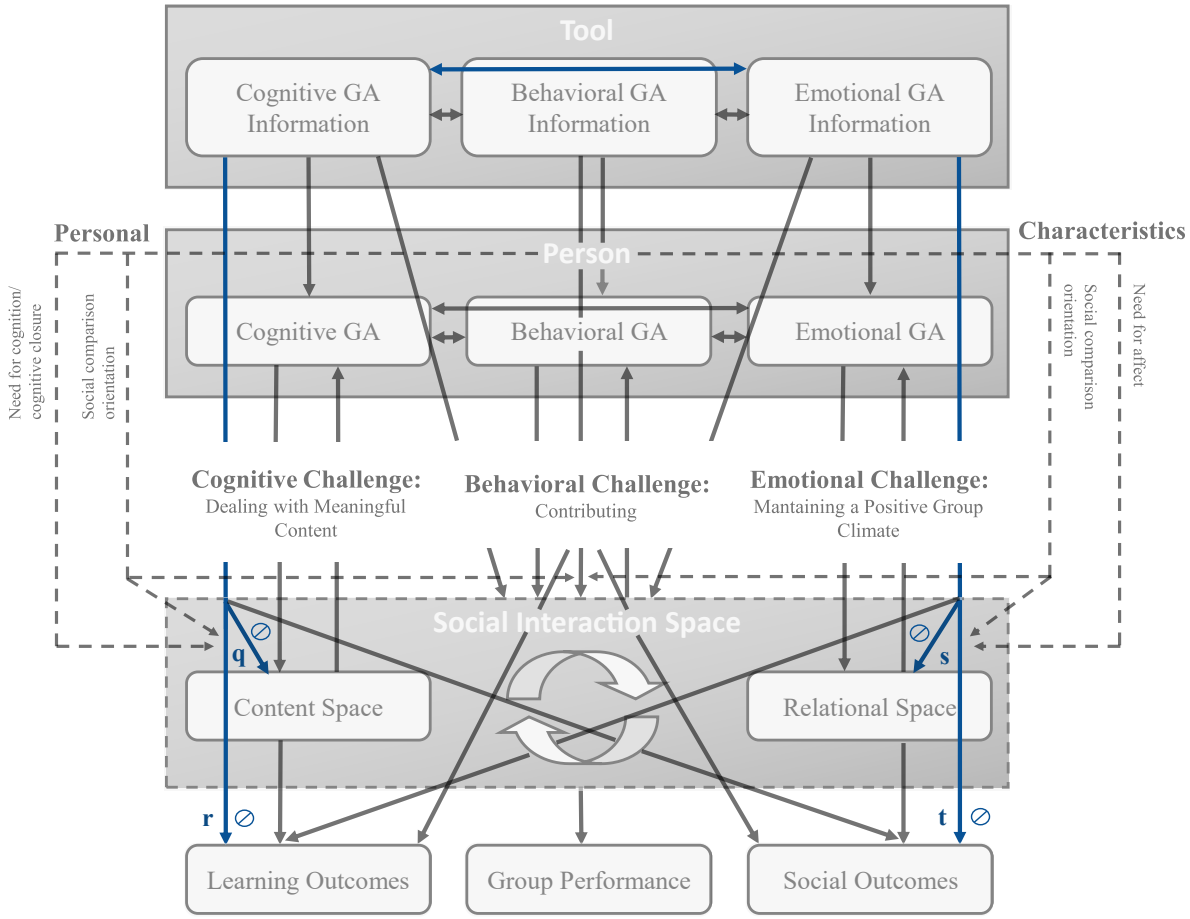
Cognitive and behavioral group awareness tool combinations can therefore be helpful in facilitating desired processes in the context of knowledge building processes (Scardamalia & Bereiter, 2006; Vygotsky, 1978). These findings are not intended to question the promising results for single cognitive and behavioral group awareness tools. However, single cognitive and behavioral guidance methods might interact positively in collaborative writing settings, meaning that a joint use would be beneficial for obtaining or expanding knowledge by structuring social interaction in a qualitative (cognitive) and quantitative (behavioral) way (Paper 3, Ollesch et al., 2021).

Cognitive and Emotional Group Awareness Tool Combination Effects. Considering the elaboration of cognitive and behavioral group awareness tool interactions, this section deals with cognitive and emotional group awareness tool interactions (see Figure 10 and Table 5). Study 4 (Paper 4, Ollesch et al., 2022) shows that both content and relational spaces play a role in educational social media environments, enriched with group awareness tools (see the sections on single tool effects; Janssen & Bodemer, 2013; Kirschner & Erkens, 2013), which is in line with the dual space assumption of Barron (2003). However, it cannot be established in any direction that emotional and cognitive group awareness tools, as well as the resulting cognitive and emotional processes, are positively dependent on or interact with each other. Textual reactions (sentiments) to emotional group awareness tools do not influence cognitive processes and outcomes for cognitive group awareness tools when applied simultaneously, an assumption that was made based on various cognitive-affective theories (Moreno, 2006; Pekrun, 2006). This indicates that text-based cognitive and emotional group awareness information is more likely to unfold the full, very promising, power separately in

educational social media environments (see q⊘/r⊘ in Figure 10 and Table 5). Reverse effects of cognitive group awareness information on emotional group awareness information, which were considered exploratively in Study 4 (Ollesch et al., 2022), are also not confirmed here (see s⊘/t⊘ in Figure 10 and Table 5). Since there are no empirical studies to date that focus on systematic investigations of cognitive and emotional group awareness tool interactions, and because the referenced cognitive-affective theories are very complex, it is difficult to make precise statements about theoretical implications without further investigations. Even if the emotional group awareness support in Study 4 (Paper 4, Ollesch et al., 2022) may very well have achieved the desired positive emotional effects, positive emotions associated with induced friendly writing might also claim cognitive resources, according to Meinhardt and Pekrun (2003).

Figure 10

Highlighted Cognitive and Emotional Group Awareness Tool Interaction (Combined) Effects



Note. Adapted from Paper 1, Ollesch et al., 2019, p. 127. Blue = new findings.

Table 5

Findings on Cognitive and Emotional Group Awareness Tool Interaction (Combined) Effects

Edge	Main findings
q∅/r∅	Emotional group awareness information does not heighten the effects of cognitive group awareness information on cognitive discussion processes and textual learning outcomes (Paper 4, Ollesch et al., 2022)
s∅/t∅	Cognitive group awareness information does not heighten the effects of emotional group awareness information on emotional discussion processes and social outcomes (mental well-being) (Paper 4, Ollesch et al., 2022)

The lack of results regarding the interaction effects of cognitive and emotional group awareness tools should not be understood as a general rejection of the assumption of a connection between cognitive and emotional processes in the group awareness tool context. However, it illustrates that these do not always have to function at the same time and that both constructs can positively influence cognitions, behavior, and emotions when considered successively. Moreover, the control-value theory (Pekrun, 2006) postulates that even if cognitions and emotions often positively accompany each other in an integrated way in academic activities, they can also occur separately. Especially in the context of socio-cognitive and socio-emotional conflicts, it may even make sense to resolve them one after the other, as there might not be enough resources for their joint resolution (Darnon et al., 2007). For example, when an individual's competence is questioned, the focus might be more on protecting self-competence and less on rethinking the topic under discussion and integrating different perspectives. Accordingly, the presence of socio-emotional conflicts leads individuals to regulate more relationally and less cognitively, which potentially leads to an absence of any positive effect on learning in the short term (Darnon et al., 2007). Moreover, this suggests that emotional group awareness support might be especially relevant at the beginning of a collaborative act, whereas cognitive support will come to the fore during the collaboration. Thus, resolving socio-emotional conflicts is necessary for successfully addressing socio-cognitive conflicts, which is something that combined group awareness support should promote. Additionally, if the information on emotional aspects has already been internalized or seems redundant for an individual, this could also mean an increased cognitive load (see Janssen & Kirschner, 2020). Indeed, Study 4 reveals that subjective mental effort is slightly increased at a descriptive level for the combination condition compared to the single support

conditions. Although these effects are very small, they could be an indicator of why the desired interaction effects do not occur with combined group awareness support. It would, therefore, be conceivable to consider personalized (adaptable/adaptive) learning systems that would enable learners/systems to set up the learning process according to their current needs (cognitive and/or emotional; Wang & Mu, 2017). Regarding cognitive and emotional group awareness tool combinations, initial support through emotional guidance methods could be considered until the social norms within the group have formed, especially if it is a longer collaboration involving the same people. Support could then move on to cognitive guidance methods, with emotional support provided only in "emergencies." In the case of adaptive systems, the need for high complexity should be considered, as availability of internal collaboration scripts needs to be ensured, and changes in learners' cognitive and metacognitive states should be detected and correctly interpreted by the system (Wang & Mu, 2017). Further (long-term) studies are needed to underpin these assumptions.

Even though emotional group awareness tools and their associated emotional processes do not have any direct effects on cognitive group awareness tool effects and their associated cognitive processes (Paper 4, Ollesch et al., 2022), it nevertheless makes sense to add a socio-emotional perspective in such learning situations. This is because emotional states triggered via emotional group awareness tools can have an impact on the general behavioral intensity of using such platforms (see Järvelä et al., 2016, 2019), which pave the way for socio-cognitive and socio-emotional conflicts more likely to be solved. Also, in the context of this cumulus, emotional group awareness tools could generally contribute to higher behavioral engagement (Paper 4, Ollesch et al., 2022), which can affect, at least indirectly, more active cognitive learning processes and is thus in line with the assumptions of the control-value theory (Pekrun, 2006) and the CATLM (Moreno, 2006). Since no subjective (explicit) feelings were measured during the interaction phase, no precise statement can be made about effects in other contexts besides textual effects. It is also possible that the supporting effects of the emotional group awareness tool in relation to the cognitive group awareness tool are stronger in the case of real emotional grievances or disputes, which did not occur in Study 4 due to the bogus setting (Paper 4, Ollesch et al., 2022). Real disputes should therefore be the focus of future research. According to Pekrun (2006), subjective control and the value of the activity are important regarding the effect of emotions on learning. Since these factors were not surveyed in the present dissertation, no definitive statements can be made about them. It is conceivable, for example, that some persons perceived a high level of control because the group awareness information was adapted in accordance with their own activities. However, it is also possible

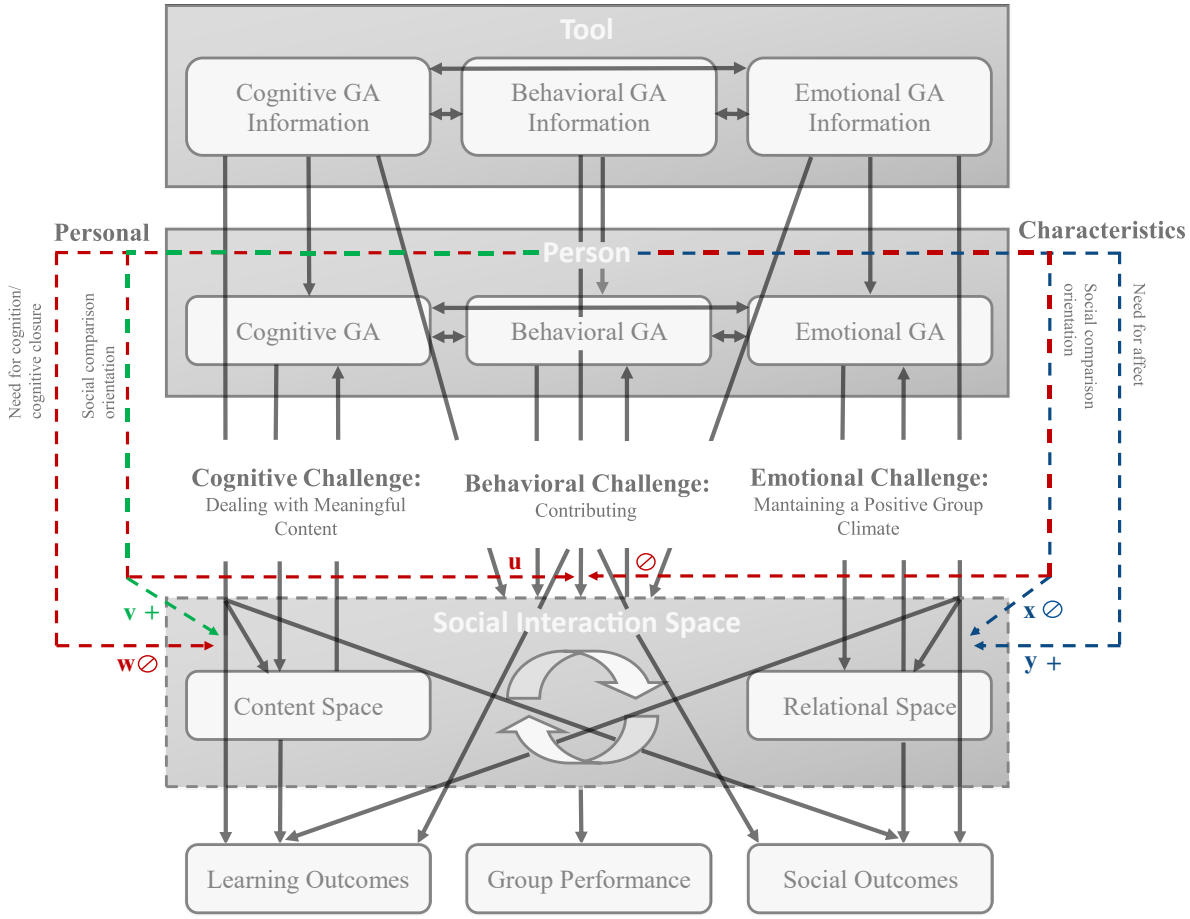
that these were perceived as discrepant to the individual's own perception and therefore did not achieve the desired effects, which might be another reason for the absence of interaction effects for emotional and cognitive group awareness tool combinations. Similarly, the value component is unclear because even if the studies suggest some relevance for the participants, there was no real performance situation. These considerations emphasize the need for more realistic settings in real performance situations that measure subjective (explicit) feelings, as well as control and value, over time (Pekrun, 2006).

Influence of Personal Characteristics. The relationship between the tool layer and the person layer is partially confirmed (see Figure 11 and Table 6), implying the involvement of underlying personal influences. On the one hand, group awareness information is weighted differently depending on subjective preferences, which underlines the relevance of presenting group awareness tool combinations to fulfilling users' individual guidance needs (Paper 2, Ollesch et al., 2020). On the other hand, personal influencing characteristics are not consistent across studies (Papers 2 to 4, Ollesch et al., 2020, 2021, 2022). There is no influencing impact of social comparison orientation on behavioral group awareness tool effects, something that was previously found (Kimmerle & Cress, 2009; see **u**⊘ in Figure 11 and Table 6). Also, cognitive group awareness support is not influenced by need for cognitive closure, which was already shown by Heimbuch and Bodemer (2019); see **w**⊘ in Figure 11 and Table 6. An explanation for these missing results could be that comparison to an ideal that appears unattainable can be demotivating (Lockwood & Kunda, 1997), which might have been the case in the bogus settings without real interaction partners. Moreover, the consideration of social comparison seems to be relevant at the selection level with cognitive but not emotional group awareness tools, which is in line with research on cognitive group awareness tools (Neugebauer et al., 2016; see **v+** in Figure 11 and Table 6) and a new addition for emotional group awareness tools (Paper 2, Ollesch et al., 2020; see **x**⊘ in Figure 11 and Table 6). Besides, need for affect, which was newly considered regarding emotional group awareness tools, confirms its value in interaction with emotional group awareness support (Papers 2 and 4, Ollesch et al., 2020, 2022; see **y+** in Figure 11 and Table 6). It can therefore be stated that even if not all personal characteristics of this thesis are confirmed as influencing, it is nevertheless well worth investigating differential influences in further research to gain more precise insights into the effects of various group awareness tool mechanisms. The consideration of a person layer is important, as it is not enough to assume that a group awareness tool type, like emotional group awareness support, has an equally strong effect on every person per se; it is also necessary to

consider, for example, that important emotional co-regulation processes (Avry & Molinari, 2018) are more likely to be triggered in persons who have a high need for affect. Indeed, emotional group awareness tools seem to be more effective for persons with a high need for affect, as illustrated in Paper 4 (Ollesch et al., 2022).

Figure 11

Highlighted Influence of Personal Characteristics



Note. Adapted from Paper 1, Ollesch et al., 2019, p. 127. Blue = new findings, green = confirms previous research, red = contradicts previous research.

Table 6

Findings on Influential Personal Characteristics

Edge	Main findings
u⊘	No linear/moderation effect of social comparison orientation on behavioral group awareness tool effects (Papers 2 and 3, Ollesch et al., 2020, 2021)
v+	Linear effect of social comparison orientation on cognitive group awareness tool effects (Paper 2, Ollesch et al., 2020)
w⊘	No linear/moderation effect of need for cognition/cognitive closure on cognitive group awareness tool effects (Papers 2–4, Ollesch et al., 2020, 2021, 2022)
x⊘	No linear effect of social comparison orientation on emotional group awareness tool effects (Paper 2, Ollesch et al., 2020)
y+	Linear/moderation effect of need for affect on emotional group awareness tool effects (Papers 2 and 4, Ollesch et al., 2020, 2022)

In addition, further personal characteristics not included in this thesis should be considered to obtain greater insights. A personal characteristic that is likely to be relevant in the field of group awareness tools is the conflict behavior of individuals. Conflict avoidance is a method of responding to a conflict that avoids direct confrontation (e.g., changing the subject, postponing discussions, or simply not bringing up an issue) (S. B. Goldstein, 1999). However, to work together on collaborative projects, a certain level of socio-cognitive and socio-emotional conflict tolerance is required. This is because, in every team collaboration, at some point, there will be conflicts, and conflict avoiders are most likely to have difficulties in such situations or might avoid them altogether (S. B. Goldstein, 1999). Such conflict states can be further heightened by the cognitive or emotional displays of these individuals, and their avoidance of conflict might be detrimental for cooperation attempts and team problem-solving (see S. B. Goldstein, 1999). The concept of curiosity could also play a role. Berlyne (1954) divided curiosity into perceptual curiosity (curiosity that leads to increased sensory perception) and epistemic curiosity (the need to learn more and to fill gaps with knowledge). Epistemic curiosity describes basic dispositions to strive for knowledge and information (Litman & Spielberger, 2003). This could be especially relevant for the effects of cognitive group awareness information, as it may lead to a more intensive occupation with cognitive group awareness tools to close knowledge gaps based on presented individual and group knowledge (see Litman et al., 2005). Furthermore, it can be assumed that there is a difference between

performance and mastery goals in the handling of learning situations (Senko, 2019). Performance-oriented individuals are interested in demonstrating high performance. It follows that they are more interested overall in how their performance looks to the outside world. Accordingly, they are more likely to seek out learning circumstances in which success is easier to achieve (Spinath et al., 2012). This could also mean that they are more likely to engage with individuals who have less knowledge purely to look better and enhance their participation awareness count without explaining demanding factual contexts in a simple way for weaker members of the group. In contrast, individuals with mastery goals make a greater effort to achieve an acceptable level of learning. Individuals who are engaged in such deep-thinking situations are particularly motivated to learn (Rheinberg et al., 2001), probably focusing on content with high knowledge information and investing serious time in editing and explaining tasks and/or content.

Overall Impact. In terms of the overall theoretical impact of this thesis, the wide chain of findings in this work strengthens the field of group awareness, computer-supported collaborative learning, and educational psychology, but other familiar fields also benefit. For example, the presentation and management of knowledge are relevant in computer science when designing personalized learning, as smart learning environments should provide awareness mechanisms (Chatti, 2012; Chatti & Muslim, 2019). Moreover, even if they are not always labeled as "group awareness," emotional awareness mechanisms play an enormous role in the chat representation domain, including approaches that use bio-signals to increase context awareness in messages (Buschek et al., 2018), such as HeartChat, which employs color-coding based on users' heart rates (Hassib et al., 2017), or GamIM, which uses emotional bubbles to increase positive interaction (Pong et al., 2014). Such approaches could also be used in educational social media environments. However, they involve a great deal of collection effort, and text-based approaches, such as those proposed in this thesis, are a relatively simple alternative. Moreover, a concept related to group awareness support that benefits from this work is digital nudging (Weinmann et al., 2016). This is seen as a method of guiding behavior without forcing a specific action to achieve the most positive outcome possible for the decision-maker. This is helpful in disaster communication (Mirbabaie et al., 2020) but is transferrable to the learning context to "nudge" the learning decisions of individuals. Furthermore, the topic of this thesis is relevant to findings concerning gamification and leaderboards, which can be motivating for competitive students but might also be perceived as demotivating for those whose poor performance is mapped (Domínguez et al., 2013). This consideration emphasizes the need to examine the potential negative effects of group awareness tools. In particular, when

very low levels of individual knowledge or extremely low or high levels of group participation are displayed, individuals might be demotivated or inhibited and thus unwilling to act in an intended way.

Finally, here is a summary of the main theoretical implications of the findings of this thesis:

(1) This thesis provides a better understanding of different group awareness tools in educational social media environments, from which other research fields can also benefit.

To better understand the specific effects of group awareness tools and to increase the potential of educational social media environments, it is important to adopt systematic empirical approaches that go beyond examining full tool versus no tool approaches. By taking interaction (combination) effects into account, previous theoretical assumptions are fundamentally extended, and thus an important theoretical research contribution is made.

(2) All three types of group awareness information appear to be relevant to persons.

In general, the subjective relevance of such guidance methods should be considered when researching group awareness tools, as it can have an influence on their intentions to use. Based on the reported relevance of friendliness awareness information, emotional group awareness support needs to be considered even more in research on educational online collaboration.

(3) The influences of personal characteristics are illustrated regarding social comparison orientation (slight influence) and need for affect (more stable influence).

The social comparison orientation seems to play a higher role in the selection or the relevance of (cognitive and emotional) group awareness information than subsequent interaction behavior. Furthermore, especially when the individual need for affect is high, the consideration of emotional group awareness tools might enhance the learning experience of the users. This illustrates that a person layer should be included in theoretical considerations on group awareness tools when examining implicit guidance methods, as this can help to better understand why certain effects occur, do not occur, or occur more strongly in certain individuals.

(4) The single group awareness tool effects occur mainly at the process level, that is, at the point where they are implemented.

Effects of group awareness tools were mostly found in the discussion forum in the cases of the studies considered in this thesis. Transfer effects on the outcome level are more difficult to find and more likely on a textual level, which is also related to the fact that support was mainly provided at this (textual) level. Single cognitive group awareness information leads to improved content selection behavior and quality of content produced; single behavioral group awareness information leads to a higher number of contributions; single emotional group awareness information leads to a friendlier (group) climate. Some effects are also not as straightforward as originally assumed in the framework. Thus, not only does single behavioral group awareness support lead to more behavioral engagement, but also single emotional and cognitive group awareness support triggers contribution quantity.

(5) Results regarding the interaction (combined) effects of cognitive, behavioral, and emotional group awareness information are mixed.

The mixed interaction (combined) effects of different types of group awareness information suggest that group awareness tool effects are sometimes more likely to unfold separately. Cognitive and behavioral guidance methods may harmonize better than cognitive and emotional guidance methods, leading to enhanced effects on textual learning outcomes (quality of content produced). This means that previous assumptions about the positive effects of individual cognitive and behavioral group awareness tools can be extended with the insight that their combination is especially promising for such contexts. Of course, other application contexts and behavioral and emotional group awareness tool combinations should be considered in future studies to corroborate these results.

(6) Regarding the underlying theoretical mechanisms, this thesis enriches existing concepts and models.

The results provide evidence for the promotion of socio-cognitive conflicts through cognitive group awareness support, as contrasting knowledge states are preferred with learning and supporting goals, and the resulting articles contain more balanced arguments (pro and contra perspectives). In terms of behavioral group awareness tools, the concept of descriptive norms can be transferred to the wiki or social media context. What is particularly valuable about the findings is that social behavior, or friendliness levels in discussions, can have an impact on the emotional regulation and responses of individuals. Textual emotional expressions (sentiments) can be transmitted or created through friendly interactions via emotional group awareness tools that might trigger

emotional contagion processes at a textual level. This might lead to a co-evolution not only of knowledge about socio-cognitive learning content but also of socio-emotional norms and behavior of the individual and the group. However, the extent to which assumptions of socio-cognitive assimilation and accommodation also exactly take place on a socio-emotional conflict level needs to be examined more closely.

1.6.2 Practical Implications

As a first practical implication of the found results, it can be stated that social media environments such as wikis are suitable for educational online or blended contexts, as they offer many opportunities for collaboration and learning. To enhance such opportunities, group awareness information should be implemented in newly set-up or already existing environments such as wikis, online forums, databases, or blogs (i.e., collaborative environments that focus on textual exchange). The experimental studies of this cumulus indicate that such an approach could be especially profitable for large-scale and informal learning or collaboration settings. However, given the bogus nature of the integrated studies, smaller-scale settings could also benefit. In particular, university structures that enable remote teaching could make use of group awareness tools to support students in self-regulated and socially integrated learning (Schlusche et al., 2019). Likewise, school contexts in which group projects are to be worked on partially from home should benefit. For companies, a move toward the use of collaborative (social media) environments or platforms already implemented internally, enriched with group awareness tools, is equally promising. Promoting meaningful exchange among employees for the purposes of collaboration and further training has enormous potential for the development of the staff concerned. In this context, group awareness tools might reflect employees' knowledge (competencies), behavioral engagement (commitment), and social behavior (norms), thus making joint work more pleasant and efficient. Further company-specific influencing variables could be considered in this regard, including hierarchies and company philosophies.

The appropriate group awareness design to facilitate and improve decision-making and interaction patterns of users depends on the specific goals and target group. Bar charts and automated collection methods (knowledge tests, contribution counters, and sentiment analysis) are confirmed to be very helpful in shaping cognitions, behavior, and emotions. Moreover, questionnaires to assess personal characteristics and/or the subjective relevance should be used before the intervention. This could be significant for the acceptance of the group awareness

tools (Ghadirian et al., 2016). In terms of emotional support, which can affect mental well-being (Paper 4, Ollesch et al., 2022), preferences in relation to long-term usage intention should be considered (see Järvelä et al., 2019). Moreover, assessing need for affect, for example, before designing and implementing supportive tools, could be decisive for the willingness to use these tools. At the same time, potential unintentional effects of such preferences should be considered. If preferences or aversions in relation to certain types of information obscure other information that is more important in the specific learning or collaborating context, responsible parties should intervene.

To enhance the single and combined effects of group awareness tools, explanations or external scaffolding might be considered, especially given the complexity of cognitive group awareness support. Some users may lack internal collaboration scripts to use such group awareness information as profitably as possible on the relevant platform, meaning that they need additional support from external collaboration scripts (Schnaubert et al., 2020). For example, the chronological processing order of the learning materials and the approximate time required for task processing can be specified. Tsovaltzi et al. (2017) showed that the combination of implicit (group awareness tool) and explicit guidance methods (collaboration script) is beneficial for individual and collaborative learning activities. To avoid the risk of over-scripting in this regard, the task could be formulated according to the backward fading principle (Wang & Mu, 2017). On this approach, the initial period of group awareness tool deployment would include external scripts with detailed instructions for action. After a certain familiarization period, there would be few to no external scripts (also called flexible scripting). By then, it is assumed that learners will have internalized an internal script about the correct approach, which they can apply without explicit guidance methods (Wang & Mu, 2017). Moreover, to enhance the interaction (combined) effects of group awareness tools, a personalized implementation of guidance methods (using learning analytics methods) would be helpful in increasing interaction effects without overwhelming users with information (Buder et al., 2021; Chatti & Muslim, 2019). This would be especially applicable for emotional and cognitive guidance methods, as they seem to (slightly) increase mental effort when provided in combination (Paper 4, Ollesch et al., 2022).

The implementation of group awareness tools can include various collection methods (Bodemer et al., 2018; Buder et al., 2021), but the choice of the same automatic (implicit) collection methods for all the studies in this thesis made the implementation as uniform as possible. The automatic collection, transformation, and presentation offer advantages in educational social media environments, because the results may be less biased than subjective

(explicit) collections (Buder, 2011; Erkens, Bodemer, & Hoppe, 2016). Therefore, if the technological prerequisites are given, it is preferable to use these procedures. If the prerequisites are not given, depending on the context, knowledge could also be measured subjectively instead of using a knowledge test assessment (Erkens, Schlottbom, & Bodemer, 2016). Likewise, quantitative behavioral patterns do not need to be recorded in a system-driven manner as in Studies 3 and 4 but can be collected via the responses of the individuals by themselves (Phielix et al., 2011). Regarding the collection of emotional group awareness information, subjective captures of feelings are a simple alternative (Eligio et al., 2012), although automatic text classification methods such as sentiment analysis are very promising for feeding emotional group awareness tools (Arguedas et al., 2015; 2016). This method should be taken up and adapted to include more contextual features like ironic elements, which were missing from the method used here (Paper 4, Ollesch et al., 2022).

It can be concluded overall that the use of group awareness tools is beneficial for social media environments and their application in (educational) collaborative contexts. Which types of tools are used depends on the aims of the designers, facilitators, and teachers. When it comes to increasing the quality of resulting learning products, the use of single cognitive group awareness tools or combinations of cognitive and behavioral group awareness tools is especially recommended. This could increase the opportunities for beneficial socio-cognitive conflicts to occur and be resolved (Paper 3, Ollesch et al., 2021). Single behavioral group awareness tools (single cognitive and emotional group awareness tools under specific circumstances) show strong effects in terms of increased user contributions (Papers 3 and 4, Ollesch et al., 2021, 2022). This illustrates that setting descriptive norms in the form of participation awareness bars can be beneficial for large-scale learning management systems. If the main aim is to improve the social behavior of a group, single emotional group awareness tools are the first choice. This could prevent negative emotional contagion processes from co-collaborators that might impact the mental well-being of the whole group (Paper 4, Ollesch et al., 2022).

In summary, drawing on the insights provided in this thesis, the following recommendations for practical implementation can be made.

(1) The implementation of implicit guidance in the form of different types of group awareness tools is recommended in educational online collaboration.

Group awareness tool feedback in educational online collaboration (especially in social media environments) is beneficial. The application is not intended for a specific context, as various contexts can benefit, including higher education, schools, and workplaces.

Although the focus in this thesis is on larger environments, given the bogus nature of the studies, small groups with a focus on textual discussion exchange and content creation may also benefit from most of the results. Scaling down these findings might be easier than scaling up the findings of previous studies.

(2) The individual user relevance of group awareness attributes should be surveyed before implementation to provide users with the types of information they prefer or should use.

For example, in a group tutoring setting, CBC analysis could be used to identify user preferences, but it is conceivable that simple Likert scales could assess the user relevance of cognitive, behavioral, and emotional group awareness attributes. The tutor can, of course, also specify which group awareness tool focus (cognitive, behavioral, or emotional, as well as combinations) is desired and should be implemented in the respective learning or collaborative environment.

(3) To enhance the focus on learning-promoting (meaningful) content, use single cognitive awareness information.

For example, if the task is to create a shared wiki for a university course, knowledge tests could be used to capture and display the competencies of the respective participants in the form of bar visualizations. This would provide better guidance regarding the selection of high-quality content with a learning goal and low-quality content with a supporting goal.

(4) To enhance behavioral engagement (number of contributions), use single participation awareness information.

When implementing single behavioral group awareness support, it is necessary to ensure that not only group averages but also the individual's own contribution is visible. For example, if a joint work project report needs to be created for a client, participation bars could track the number of contributions of the individual group members and the group. This information could be played back to them to enhance their willingness to participate in team efforts. Single knowledge and friendliness awareness information could also be useful, as it may as well trigger behavioral engagement.

(5) To enhance social behavior (group climate) in interactions, use single friendliness awareness information.

Single friendliness awareness bars can achieve impressive results regarding social behavior or the emotional quality of discussion posts through sentiment analysis. Therefore, sentiment analysis is an approach that should be further developed for real-

life applications. This method is particularly recommended for large-scale environments, as it requires relatively high amounts of data (Kurian et al., 2015). In the context of remote working or studying, exchange possibilities should enable regulation of socio-emotional interactions, as negative interactions may have an impact on the working atmosphere. Regarding the effectiveness of this type of emotional feedback, it is advisable to ask in advance about the subjective need for affect to assess the extent to which this method is to be accepted by the intended users.

(6) To enhance the quality of textual learning outcomes, use single knowledge awareness information and the combination with participation awareness information.

Contributions to a wiki article are of higher quality with single cognitive and combined cognitive and behavioral group awareness support, which supports their use in similar settings (i.e., where joint textual artifacts are to be created). As higher mental well-being of the users in a single presentation is to be expected, a personalized use could be tried out as a compromise. Precisely because cognitive processes can be very complex, a script explaining the aims (e.g., choosing high-quality content or complementary content) and task consequences of cognitive group awareness information would be appropriate as an introduction into group awareness tool handling. It is, nevertheless, important to find the right level of guidance for each learner. Whereas for one person, behavioral group awareness support is unnecessary and experienced as an additional burden, for another person, it may not even be sufficient and should be topped up with additional explanations. The amount of guidance offered could be decided by both the responsible teachers or staff facilitators and by the users themselves, depending on how self-regulated their actions are (e.g., students versus employees).

In what follows, a concrete example of an already implemented application case including group awareness tools is provided. Based on the promising effects found in the laboratory settings of this thesis, group awareness tool combinations have already been implemented in practice (Ollesch, Kohlmann, et al., 2021): A web application for students called *uniMatchUp!* was developed and evaluated, funded by the Federal Ministry of Education and Research. The aim of the application is to support academic and social exchange among students considering the difficulty in making personal contact at university, especially in the COVID-19 era. Various functions were implemented, including a public forum, a private exchange function, and a learning group search (Ollesch, Kohlmann, et al., 2021). Based on the framework used in Paper 1 (Ollesch et al., 2019), cognitive, emotional, and behavioral

group awareness information was implemented, albeit operationalized differently than in this thesis based on pre-queries and internal conversations with further stakeholders. In addition to the opportunity to examine the subjective relevance of the group awareness tool three-way division, it was expected that *uniMatchUp!* would help students to improve learning outcomes (academic success) and social outcomes (social connectedness) within the study cohort (Algharaibeh, 2020; Paper 1, Ollesch et al., 2019; Schlusche et al., 2019; Wilcox et al., 2005). This project is ongoing, but the initial results indicate a high intended use of the three main functions of *uniMatchUp!* as well as the overall interface. Students who used the application more intensively in the first pilot phase reported a higher subjective group awareness level, which is in turn positively associated with resulting social connectedness, although not with academic success (subjective assessments in each case; for more details, see Ollesch, Kohlmann, et al., 2021). This illustrates the opportunities that group awareness information creates in practice, especially on a social level. Moreover, cognitive group awareness information was ranked higher than behavioral group awareness information, with emotional group awareness information being the least relevant in student matching according to the participants. This contrasts with the results found in Paper 2 (Ollesch et al., 2020), in which emotional group awareness information was considered most relevant for wiki collaboration. This underlines the need to consider the context for the group awareness information and to survey its relevance before actual usage.

1.6.3 Statement of Limitations

The specific limitations of the studies are addressed in detail in the respective papers (*Overall discussion* in Paper 2, Ollesch et al., 2020; *Addressing limitations* in Paper 3, Ollesch et al., 2021; and *5.3 Addressing limitations* in Paper 4, Ollesch et al., 2022). Therefore, only congruent limitations are addressed briefly in this section. These include the fact that laboratory settings were chosen for all studies. This approach helped to reveal the effects in a very controlled way; thus, although it is open to criticism in terms of external validity, it strengthened the internal validity of the results (Anderson & Bushman, 1997). The results can be further validated by using such support visualizations in more realistic or field settings, including transactive interaction patterns, which provide real and successive user questions and responses.

Moreover, for the experimental designs (Studies 3 and 4, Ollesch et al., 2021, 2022), the sample sizes are at the lower end of the ranges calculated using power analysis (see Figure

3 for details). Also, the mean age is low (ranging from 21.26 to 22.89) in all the studies since the participants were mainly German students from the first semesters of the study program Applied Cognitive and Media Sciences. Most of the participants were women (ranging from 61.54% to 73.42%), which reflects the dominance of this gender in the study program of the main target group. Therefore, there is the need to cover a broader target group since the present samples are female-dominated. Bigger and more diverse samples might allow narrowly missed results to become significant and reveal gender differences, which is especially relevant for emotional group awareness support (Avry & Molinari, 2018).

In pursuit of greater objectivity, automatic (implicit) collection methods of group awareness attributes were used for all experiments (Sangin et al., 2011). This incurs the risk that persons do not understand their compositions and do not know exactly how to deal with this information. Computer-based labeling of friendliness patterns could also lead to reactance effects (see Ehrenbrink et al., 2016), which is why it is important to conduct studies that compare subjective (explicit) and automatic (implicit) methods in terms of their effectiveness (Buder, 2011).

Moreover, the wiki context was chosen in all cases to give the learners a concrete scenario. Wikis are a cluster of social media environments that enable collaborative writing and discussion. Wiki-specific features were removed or adapted in all studies (e.g., no hypertext markup language, implementation of a classical discussion forum rather than an unstructured talk page) so that the results can be transferred to other remote group contexts in which computer-mediated exchange is involved (for example, discussion forums with the creation of a joint product or text). However, specific types of social media environments such as social networking sites (e.g., Facebook), which are more “social” than wiki-like, might contain more distractive elements and might therefore be accompanied by divergent or additional support needs (see Smith, 2016). Research on group awareness tools on social networking sites already exists, with positive effects on interpersonal relationships as well as enhanced knowledge and argumentative skills (e.g., Dado & Bodemer, 2018; Puhl et al., 2015). Furthermore, a distinction must be made between asynchronous communication (e.g., wikis, forums) and synchronous communication (e.g., chats, video conferences). The latter is not the focus of the present work and may have its own specific requirements (Jeong & Hmelo-Silver, 2016).

A theoretical limitation of the framework set up in Paper 1 is that it is somewhat simplistic and straightforward in its original version (Ollesch et al., 2019). Also, although the importance of personal group awareness is elaborated, it was not tested in the studies of this

thesis. However, elaborations on the adapted model as well as future research claims can be found in sections 1.6.1 and 1.6.4. Finally, the unaddressed issue of emotional and behavioral group awareness tools is a limitation of the research approach as a whole, owing to the complexity of the other study designs. Considerations on this shortcoming are discussed in the following section.

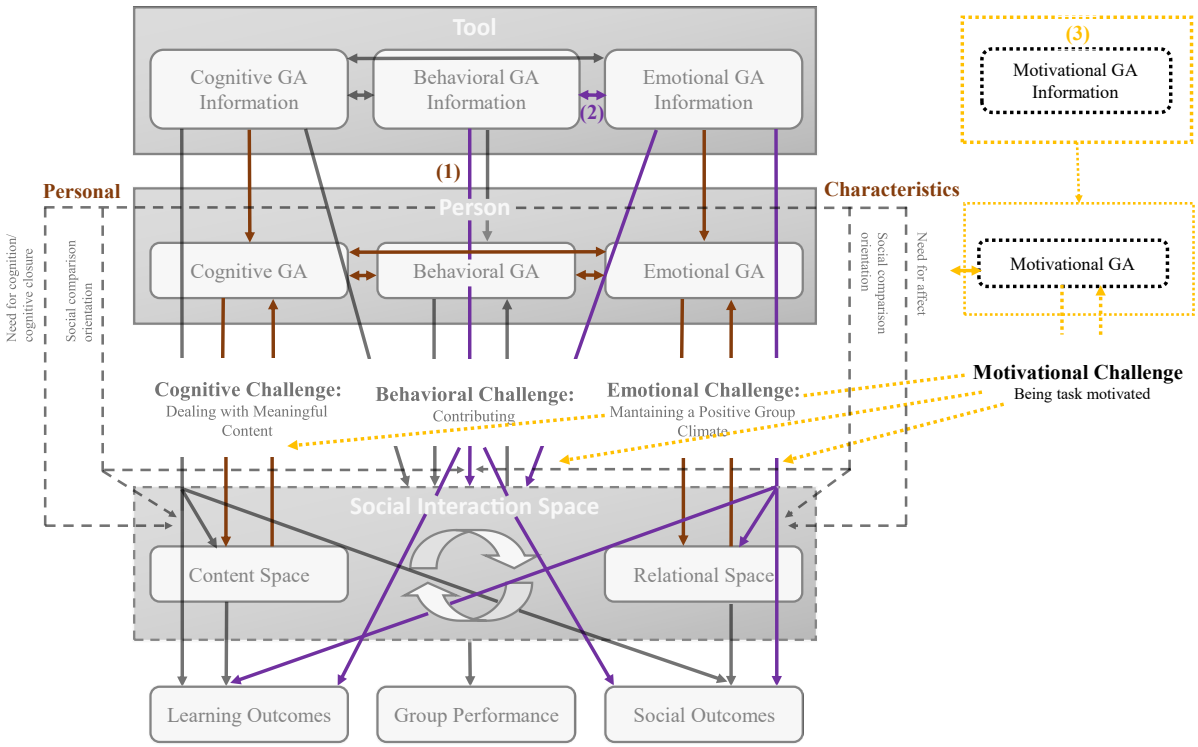
1.6.4 Outlook on Future Research Directions

This section presents three basic future research directions: (1) a focus on the person layer, (2) a focus on further interaction effects, and (3) a focus on potential motivational (group awareness tool) effects. Further future research directions are recommended in the respective papers (*Overall discussion* in Paper 2, Ollesch et al., 2020; *Discussion* in Paper 3, Ollesch et al., 2021; and *5.4 Implications for future studies and designing educational social media environments* in Paper 4, Ollesch et al., 2022).

In addition to exploring further non-university application contexts such as high school and workplace, future studies should look more closely at the person layer of the proposed framework (Paper 1, Ollesch et al., 2019; see Figure 12, (1), brown lines). Mediatory relationships between tools and subjective group awareness (included in the person layer) were not investigated in the main studies (Papers 3 and 4, Ollesch et al., 2021, 2022). Precisely because the effects at the outcome level (both single and combined) are less evident than the effects on the process level, it is particularly important to take a closer look at the person layer in the interaction with guidance methods. This includes subjective group awareness as a mediator variable for tool effects (Bodemer et al., 2018) and requires consideration of other personal variables that may explain the amplification or absence of support effects, especially since the eye-tracking results from Study 3 indicate that the focus does not always turn out as intended. Besides the newly introduced personal variables in the theoretical implications (see section 1.6.1), it can also be assumed that the main variables investigated in this thesis contribute in a more selective way in field studies, especially in relation to social comparison orientation in real interaction settings and group members. These possibilities need to be explored in future studies.

Figure 12

Ideas for Future Studies



Note. Adapted from Paper 1, Ollesch et al., 2019, p. 127.

In addition to personal characteristics, there should also be a stronger focus on further potential interaction effects, both positive and negative, as group means were always set at medium levels in the main Studies 3 and 4. In particular, the interaction between emotional (friendliness) and behavioral (participation) group awareness information has not been considered in the context of this thesis (see Figure 12, (2), purple lines). It is therefore not possible to make an all-encompassing statement about group awareness tool interaction effects. It can be argued that, without social interaction, no emotional outcomes such as group cohesiveness can arise per se (see Kirschner et al., 2015), which suggests that behavioral and emotional concepts are inherently linked. Positive relationships between users can, moreover, be beneficial for the intention to use a learning platform (Luo et al., 2018). When emotions are shared through emotional group awareness tools, for example, this can have a positive effect on the number of communicative exchanges (Avry & Molinari, 2018); negative emotions might stimulate exactly the opposite effects (Lescano & Costaguta, 2018). Conversely, it is conceivable that behavioral group awareness tools that present a lack of interaction might have a negative impact on emotions, leading inter alia to frustration, whereas awareness of equal workload might trigger positive emotions (see Hernández-Sellés et al., 2019; M. Li, 2014).

Future studies should focus on these issues to enhance the framework's insights. In addition, subjective (explicit) collection methods of different group awareness information should be compared systematically with respect to interaction effects as well as group awareness tool operationalizations other than knowledge (e.g., opinions), participation (e.g., network structures), and friendliness (e.g., actual feelings), which were selected in the context of this thesis.

The last research direction I would like to highlight is a deeper investigation of potential motivational challenges during collaborative learning (see Figure 12, (3), yellow lines) that may arise because of the different goals, interests, priorities, and expectations of individual group members towards the activities or task in the group, which is seen as an essential component for successful collaborative learning (Järvelä et al., 2008, 2010; Järvelä & Renninger, 2014). Group awareness tools are one way of increasing motivation in CSCL scenarios (Bodemer et al., 2018). It has already been established that motivational group awareness tools can effectively increase motivation to learn in collaborative learning scenarios (Zumbach et al., 2006). However, results regarding motivational awareness support are mixed, and Schoor et al. (2014), for example, could not demonstrate any effect of motivational assessments on motivational outcomes. In the first subproject in this thesis, it is suggested that the sole presentation of motivation may be insufficiently specific (Paper 1, Ollesch et al., 2019). Moreover, it is postulated that more specific motivational challenges during collaboration are addressed through cognitive, behavioral, and emotional group awareness information, which means that all types of awareness information have a specific motivational effect (Paper 1, Ollesch et al., 2019). A future research approach would be to juxtapose the opposing perspectives. This would help to empirically reinforce the integrated framework concerning motivational assumptions, making it possible to investigate whether the isolated presentation of motivational group awareness information promotes motivation to learn at a deeper level and whether the effect of motivational group awareness information is influenced by combining it with other types of group awareness information. Particular attention could be paid to motivational factors that increase or decrease cognitive engagement (Pintrich, 2003). The (additional) support provided by behavioral group awareness information is another promising research topic, as it addresses unbalanced participation during collaboration, which is seen as particularly inhibiting to motivation (Bakhtiar & Hadwin, 2020). Given the complexity of the other three awareness variables focused on in the studies of this thesis, this issue has not been explored here but will be marked for future studies. A closer look at motivational concepts might be especially relevant for remote CSCL settings because people

may perform computer-mediated actions to present themselves in a better light without actually having the motivation to do the activities (see Walther & Whitty, 2021). Regarding friendliness, inter alia, there may be discrepancies between externalized and felt emotional states to enhance social acceptance. Future studies addressing this topic will help to determine the extent to which motivational support should be designed in learning environments and in the proposed framework (Paper 1, Ollesch et al., 2019): that is, as a "hidden" variable in the three types of group awareness information (originally stated in the framework; see Paper 1, Ollesch et al., 2019), or as a separate building block (opposing option, "being task motivated"; see Figure 12, (3), yellow lines; Bodemer et al., 2018).

1.6.5 Conclusion

This thesis makes both theoretical and methodological contributions, considering the interplay of different types of group awareness information for guiding educational online collaboration. By setting up an illustrative and integrative framework, it enables the systemic consideration of group awareness tools in various learning and collaborating contexts. Furthermore, through the four experimental studies conducted, the empirical gain transfers previous group awareness research to social media contexts, thereby extending the systematic work that has been done in recent years. This fundamental extension is manifested in considering interaction (combination) effects of cognitive and behavioral and cognitive and emotional group awareness tool mechanisms, which provides further insights into the effects of single and combined group awareness tools. Regarding the overall research question stated in the introduction (see section 1), implicit guidance methods in the form of group awareness tools can be extremely helpful in enhancing cognitive, behavioral, and emotional effects on various processes and outcomes in educational online collaboration. Feedback in the form of knowledge bar presentations has positive effects on selection behavior regarding learning content and on the quality of content produced by triggering socio-cognitive conflicts. Feedback in the form of participation bar presentations has positive effects on behavioral engagement by setting descriptive norms, and feedback in the form of friendliness bar presentations has positive effects on social behavior in communicative exchanges by triggering emotional contagion processes. The latter should be highlighted, as this is a new approach for collecting and presenting emotional states in online collaboration. This approach is desired by the potential target group and capable of affecting the reported mental well-being of individuals and possibly the longer-term intensity of using the respective platforms. This furthermore

highlights the importance of considering socio-emotional processes in educational settings, which has so far often been limited to socio-cognitive processes. A variety of different methods were used in the four empirical studies to achieve the expected insights and to measure group awareness in ways that will inspire future research and applications. These range from the implementation of knowledge tests, through participation counters, to dynamic sentiment analyses in discussion forums.

The inclusion of personal characteristics also seems to be relevant for educational online collaboration, as need for affect and social comparison orientation can have an influence on the effectiveness of such implicit guidance methods. On the one hand, the results regarding group awareness tool combinations confirm the importance of cognitive and behavioral group awareness tools and the underlying processes in educational social media environments, which is in line with socio-constructivist theories. On the other hand, it reveals that emotional group awareness tools and processes, even if they are beneficial in a single presentation, are not necessarily profitable when presented simultaneously with cognitive group awareness tools. The number of guidance methods provided should therefore be considered carefully, as combinations of group awareness tools may have a positive impact on the quality of content produced, but not necessarily on social outcomes such as the mental well-being of individuals within a collaborative interaction. One reason for this limitation may be the higher processing overhead. Since the interaction of different types of group awareness information achieves mixed results, it is even more important to consider a personalized approach in the use of group awareness support.

Finally, the proposed framework is not intended to be a final product but rather an ongoing reference for future research in the field of group awareness tools that provides a better understanding of such guidance methods in social media and other contexts. It is suitable for deriving new research questions and hypotheses, and it also provides a basis for the development and implementation of tools and implicit guidance methods to improve educational online collaboration.

2. Paper 1: Towards an Integrated Framework of Group Awareness Support for Collaborative Learning in Social Media[4]

Ollesch, L., Heimbuch, S., & Bodemer, D. (2019). Towards an integrated framework of group awareness support for collaborative learning in social media. In M. Chang, H.-J. So, L.-H. Wong, F.-Y. Yu, & J. L. Shih (Eds.), *Proceedings of the 27th International Conference on Computers in Education* (pp. 121–130). Asia-Pacific Society for Computers in Education. Corrigendum in DuEPublico2: https://doi.org/10.17185/duepublico/74884

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Corrigendum to: Chang, M. et al. (Eds.) (2019). Proceedings of the 27th International Conference on Computers in Education. Taiwan: Asia-Pacific Society for Computers in Education

Towards an Integrated Framework of Group Awareness Support for Collaborative Learning in Social Media

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Abstract: In computer-supported collaborative learning, group awareness tools have been shown to be helpful regarding learning processes and outcomes. Previous research has focused on the support via cognitive and behavioural group awareness information, largely neglecting emotional group awareness information and often investigating these three aspects separately. To support large social media groups such as wiki communities, integrating different types of group awareness (GA) information may yield benefits, since these communities encounter several challenges. Although jointly presenting different GA information is assumed to be advantageous for collaborative learning, GA interaction effects including personality traits are still largely unexplored. In order to close this research gap, an integrated framework is proposed, which enables the systematic empirical investigation of (interaction) effects of different types of GA information on behavioural, cognitive, and emotional challenges in computer-supported collaborative learning, with a focus on wikis.

Keywords: Computer-supported collaborative learning, group awareness, social media, wikis

1. Introduction

Humans are inherently social creatures, even in contexts that appear to be primarily related to individual learning. Thus, research has highlighted the central role of social factors in achieving academic success (Wilcox, Winn, & Fyvie-Gauld, 2005). The increasing digital networking and importance of online social media in all areas of life, including individual and collaborative learning, entails new challenges for learners. Over almost 30 years of history, computer-supported collaborative learning (CSCL) has contributed significant research and innovative tools for facilitating learning processes (e.g., Miller & Hadwin, 2015). There seems to be a consensus that CSCL offers wide-ranging potentials for increasing the effectiveness and efficiency of learning and teaching processes, regardless of participants' time zone and location. Results range from positive effects on individual learning, through facilitating dyadic and small group collaboration up to more effective designs of collaborative tasks for large groups in massive open online courses (e.g., Jung & Lee, 2018). In CSCL research, social interaction is not solely observed as a method; Dillenbourg, Järvelä, and Fischer (2009) define it as the essence of cognition and as "the heart of CSCL" (p. 8). One example of widely used CSCL platforms are wikis. These are social media platforms with few social affordances to enable collaboration and therefore social interaction at virtually any point in time and between anyone (Chen, Jang, & Chen, 2015). Although such platforms offer new possibilities, they are also associated with difficulties, as computer-supported collaboration is not inherently advantageous. Learners must cope with further cognitive and social tasks beyond the requirements of individual learning by using digital media (Zheng, Niiya, & Warschauer, 2015), which are caused by the setting itself and the interaction of the learning material with the collaborative setting. To support learners coping with diverse requirements of learning with digital media, tools were designed and experimentally tested that combine established methods of support for individual learning processes. Such *Group Awareness Tools* (GATs) collect, transform, and present information about the learning partners (Bodemer, Janssen, & Schnaubert, 2018). In the following sections we provide an overview of the potentials of state-of-the-art CSCL research, as well as of some important challenges faced by learners in this field. Building upon existing CSCL and GAT frameworks, our objective is to introduce an integrated theoretical framework for

GATs, which can serve as a basis for future studies on the interplay of different types of GA information. Moreover, it intends to guide teachers and instructional designers in the reflective design of formal and informal learning environments that consider behavioural, cognitive and emotional aspects of social learning.

2. Potentials of Collaborative Learning and CSCL

Collaborative learning offers opportunities for elaborated learning processes and critical thinking (Johnson, Johnson, & Smith, 2000), such as a larger and broader knowledge base in groups. Every learner has a different amount of prior knowledge and different perspectives (Bell, 2004) that can benefit collaborative activities. During such activities it is possible to exchange heterogeneous knowledge, opinions and hypotheses, which offers a chance to recognise misconceptions in one's own thinking and to harmonise distributions of diverging knowledge. Furthermore, collaborative learning can also help to recapitulate knowledge through mutual explanation (Webb, 1991). In addition to increasing chances of collaborative learning, CSCL environments can further enhance the effectiveness and efficiency of learning processes. The continuous availability of learning materials and a relatively low threshold for collaborating without the need for face-to-face meetings can be highly advantageous (Walther & Bunz, 2005). As one example for a CSCL environment, wikis enable users to create socially shared artefacts as well as to share their knowledge on two rather distinct levels that relate to each other (e.g., Choy & Ng, 2007), in forms of firstly the article as a collaboratively created product and secondly corresponding talk pages for discussing article-related topics. Compared to other knowledge construction platforms evaluated in educational contexts, wikis enable users to perform in a way that influences the whole environment (e.g., Kimmerle, Moskaliuk, Oeberst, & Cress, 2015), which creates fertile ground for the multi-level occurrence of controversies and socio-cognitive conflicts (Bell, 2004). Controversies can be constructive when based on the exchange of contrasting viewpoints on a specific topic, which provides opportunities to trigger learning processes and foster higher learning outcomes (Johnson et al., 2000). Moreover, they might induce socio-cognitive conflicts within learners as well as between learners and wikis as social systems. This can be beneficial by triggering equilibration processes of accommodation and assimilation of new knowledge artefacts into one’s individual cognitive systems (Piaget, 1977). The combination of computer support and collaborative learning not only promotes these potentials but also poses challenges for learners.

3. Challenges in Collaborative Learning and CSCL

Effective learning processes and outcomes are not automatically produced by enabling computer-supported collaboration. Aspects of both computer support and collaboration, and especially in combination, bring their own challenges to learners (Zheng, Niiya, & Warschauer, 2015). Based on the current state of research, we identified three main challenges which serve as an indication of dominant challenges in CSCL and rather refer to large social media learning communities such as wikis. Addressing these challenges is essential to the success of CSCL.

3.1 Behavioural Challenge: Contributing

The lack of behavioural motivation is often considered to be one of the greatest difficulties in online communities. However, the willingness to share knowledge is a prerequisite to CSCL’s success. The motivation to contribute or participate is not always present, especially in large social media groups where free riding and social loafing represent more common risks in collaboration (see Kimmerle & Cress, 2008). Following a series of wiki studies conducted at our lab, we found that many undergraduate students participate in joint collaborative knowledge construction and learning activities on wiki talk pages when instructed to do so, offering potentials for elevated wiki quality and improved learning processes. Otherwise, collaborators tend to show cooperative behaviours instead of engaging in valuable social interactions (Heimbuch, Ollesch, & Bodemer, 2018). This could be because

individuals' contributions to wiki discussions are not necessarily visible, which highlights the high value of increasing participatory motivation in the social interaction space for successful wiki learning.

3.2 Cognitive Challenge: Dealing with Meaningful Content

Meaningful interactions between wiki collaborators are important in addition to CSCL settings' behavioural requirements, and difficulties achieving meaningful collaboration may occur without required motivation or skills among group members. Such difficulties can be rooted in the lack of understanding others' contributions that can manifest a cognitive challenge to learners. These problems arise when group members fail to pay sufficient attention to individual contributions as well as when such contributions are not sufficiently discussed (Näykki, Järvelä, Kirschner, & Järvenoja, 2014). Although this challenge applies to all CSCL domains, it is obvious that contributions conducive to cognitive learning are especially less simple to identify in larger communities which feature copious content. This can occur due to information overload, an unavoidable reality of larger online discussion forums growing to include hundreds to thousands of contributions (Buder, Schwind, Rudat, & Bodemer, 2015), or wiki talk pages that often lack salience of the aforementioned controversies at first glance (Heimbuch & Bodemer, 2017). Due to the limitations of working memory capacities, this lack means that those meaningful contributions are simply not perceived and therefore not read (see Bagherian & Thorngate, 2000). These processes of collaborative knowledge construction can be difficult and challenging by causing frustration during the learning process (Capdeferro & Romero, 2012), which emphasises the necessity to highlight cognitively relevant contributions and thus facilitate knowledge acquisition.

3.3 Emotional Challenge: Maintaining a Positive Group Climate

The motivation and skillsets to maintain a positive group climate represent another essential aspect that is often neglected in the context of designing and evaluating CSCL settings. Group formation is viewed as a prerequisite to successful collaborative learning (Kirschner & Erkens, 2013) since relational issues can strongly influence interaction, task engagement, and learning (Näykki et al., 2014). If negatively balanced emotions or negatively connotated utterances occur during conflicts, group members become less motivated to solve their assigned tasks and tend to demonstrate inferior performances (Ayoko, Callan, & Härtel, 2008). Therefore, CSCL environments should be designed to be more "sociable" for their users (Kreijns, Kirschner, & Vermeulen, 2013). This emotional challenge is also inherently relevant for wikis, such as on Wikipedia where so-called "edit wars" are likely to occur and difficult to solve when many users with contradicting viewpoints attempt to work on the same knowledge artefacts (Yasseri, Sumi, Rung, Kornai, & Kertész, 2012). This underlines the necessity to support wiki users in solving such socio-emotional issues to help a group of individuals transform into a team.

4. Supporting Learning Processes in CSCL

The many degrees of freedom offered by CSCL lead to users perceiving a high degree of autonomy, which positively influence the individual learning motivation. Nevertheless, this freedom demands a high degree of self-regulation to overcome the aforementioned challenges (see Järvelä & Hadwin, 2013). Moreover, without further support this freedom offers only minimal structure and risks learners experiencing themselves as less competent, which in turn can negatively impact the learning motivation (Rienties et al., 2012). It is thus desirable to structure collaborative learning processes to promote the experience of competence. CSCL research offers different means of support that vary regarding their degree of coercion. For example, collaboration scripts can improve the effectiveness of collaborative learning by providing explicit guidance concerning the manner in which people should form groups, interact with each other and solve group tasks (Kollar, Fischer, & Hesse, 2006). However, this entails an often-discussed risk of overscripting. An alternative regards implicit structuring which provides less coercive guidance and is intended to enable desirable behaviour through visual context stimuli in order to achieve more effective collaboration (Janssen & Bodemer, 2013). Identifying the more effective guidance approach represents a heatedly discussed topic in the CSCL community (Wise & Schwarz, 2017). This controversy will not be discussed in this study due to a lack of universal consensus as well

as because this article focuses on GAT support, but instead we define Group Awareness and different types of GATs.

Group Awareness (GA) can be loosely defined as any information about the group possessed by a learner, such as knowledge about activities, skills of group members, or social activities within the group (Janssen, Erkens, & Kirschner, 2011). Prevalent GA is often regarded as an important prerequisite to meaningful collaborations in CSCL but cannot be taken for granted (Bodemer et al., 2018). GATs can be used to complement individuals' GA by providing information about specific properties of group (members), e.g., regarding their participation, knowledge, or feelings. This information can be collected, transformed, and presented in different ways (Bodemer et al., 2018). Although GATs are expected to benefit through stimulating productive interaction activities (Miller & Hadwin, 2015), behavioural, cognitive, and emotional challenges are not addressed by one single GA component due to the significant complexity of social interactions. When thinking about social interaction, it can be differentiated between a content space and a relational space of collaboration (Slof, Erkens, Kirschner, Jaspers, & Janssen, 2010). The content space contains the problem to be solved and interactions in this space refer to the task itself. Learners discuss ideas as well as opinions and thus gain a deeper understanding of the task in order to solve it. The content space contains not only cognitive but also metacognitive activities such as resolution strategies for the task (Janssen & Bodemer, 2013). Interactions in the relational space are activities concerning the social dimension of collaborations (Slof et al., 2010), which are important for the functioning of cognitive activity exchanges in the content space. Here, group members create a collective understanding of the discussed concepts in the content space. To become successful collaborators, both task fulfilment (content space) and team functioning (relational space) are essential in order for randomly assigned group members to become effective team players (Fransen, Weinberger, & Kirschner, 2013). The effects of different types of GA information on the two spaces are further examined by providing examples in the following paragraphs (see Figure 1).

Behavioural GATs (in the community also labelled as activity/(socio-)behavioural GATs) address the behavioural challenge by presenting the collaborators' activities, and they thus serve as a source of motivation for providing contributions in the social interaction space in general (Lin, Tsai, Hsu, & Chang, 2019; Kimmerle & Cress, 2008; see Figure 1a). Behavioural GA information has promising potential to increase participation rates in terms of motivational processes. This can be achieved by visually juxtaposing individuals' contributions against the group's contributions or average participation (Kimmerle & Cress, 2008). The possibility of self-presentation is crucial here, however single applications of behavioural GATs do not necessarily lead to increased cognitive performance as measured by means of message and project quality (Lin et al., 2019). Although there are already initial wiki approaches, e.g., to supplement MediaWiki with participation monitoring tools (Popescu, Anca, & Udrištoiu, 2014), they need to be systematically evaluated.

Cognitive GATs (in the community also labelled as knowledge GATs) provide content-related information about group members, such as their knowledge or opinions. These tools are promising for tackling cognitive aspects of learning (Janssen & Bodemer, 2013) and mainly address the cognitive challenge by facilitating the navigation and selection of meaningful content. Moreover, the presentation of partner knowledge facilitates grounding and partner modelling in the content space of social interactions (Bodemer et al., 2018). There is additionally potential to reduce unnecessary extraneous cognitive load (Chandler & Sweller, 1991) induced by the collaborative learning setting. Taking large learning environments as an example, cognitive GA information in the form of visual markers help learners to focus on meaningful content on large wiki talk pages in order to identify relevant controversies (Heimbuch & Bodemer, 2017; see Figure 1b; *blue markers label controversies in general, green markers stand for solved, and red markers for unresolved controversies*) or high-quality contributions in online forums (Buder et al., 2015), which could also be applied to the visualisation of collaborators' expertise/knowledge level in future studies.

Emotional GATs (in the community also labelled as social/(socio-)emotional GATs) are helpful tools to facilitate joint emotion regulation in the relational space of social interactions, to enhance mutual transactivity, and to create a positive group climate by increasing group members' awareness of other members' feelings (Eligio, Ainsworth, & Crook, 2012; see Figure 1c). Educational psychology currently predominantly focuses on cognitive and behavioural support. Socio-emotional issues are treated with a much lower priority in instructional designs, and to our knowledge there is no empirically tested tool that deals with joint emotion regulation in the field of wikis. Such tools could help to identify unfriendly posts on wiki talk pages or highlight self-assessed emotional states of wiki group members to

alert the group to emotional grievances. These represent initial design impulses, and a deeper investigation into the effects of emotional GA information on the emotional challenge is necessary.

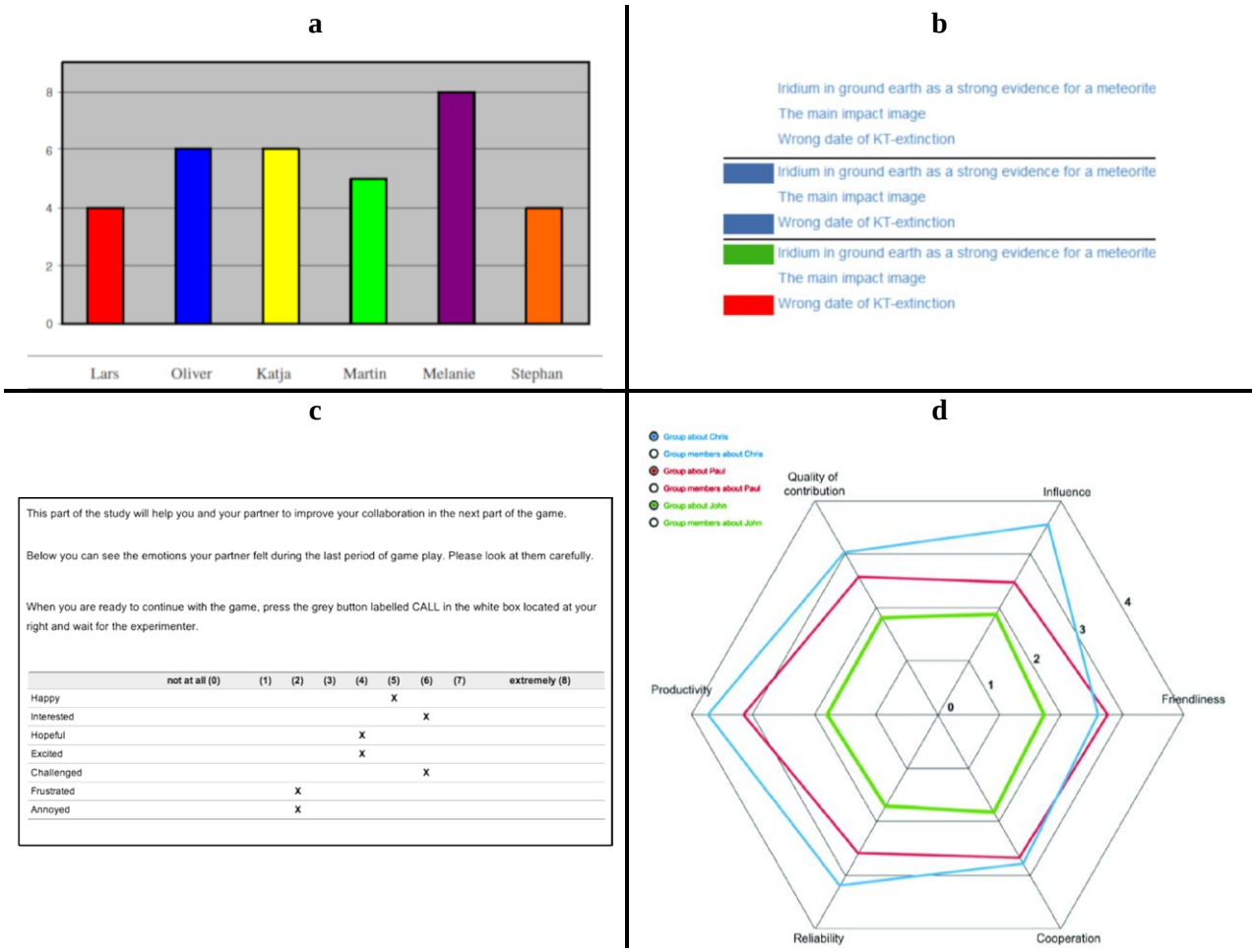

Figure 1. Examples of GAT support: a) Behavioural GAT: Kimmerle & Cress (2008); b) Cognitive GAT: Heimbuch and Bodemer (2017); c) Emotional GAT: Eligio et al. (2012); d) Combination of several tool aspects: Phielix, Prins, Kirschner, Erkens, and Jaspers (2011).

Lin, Mai, and Lai (2015) criticise that only a few studies examine the differences and overlaps between behavioural and emotional GA (social-context awareness) as well as cognitive GA (knowledge-context awareness) information. Their long-term study shows that while social-context awareness stimulates more quantitative peer interactions, knowledge-context awareness unexpectedly does not necessarily increase the quality of messages. They conclude that a combination of different types of GA information may be more effective. We agree that cognitive, behavioural, and emotional GA information may be required in order to achieve effective group performance (e.g., high wiki article quality). Consequently, GATs that provide more than one type of GA information are necessary such as the seldom exception of the RADAR tool (Phielix et al., 2011; see Figure 1d). It is one of the few GATs that reflect different aspects of collaboration and group functioning. This tool presents six self-assessed as well as peer-assessed group dimensions: influence, friendliness, cooperation, reliability, productivity, and quality of contribution. It could be shown that social performance such as group satisfaction is positively affected by communicating this information back to the group, however no effect on cognitive processes and learning outcomes could be observed (Phielix et al., 2011). Analogue to the GA information differentiation that we propose with this framework, influence and quality of contributions can be classified as cognitive GA information, friendliness and reliability as emotional GA information, and cooperation and productivity as behavioural GA information. Although the results of the RADAR tool are promising for GAT research, they have only been examined for smaller groups. In general, our literature review demonstrated that a significant portion of GAT research is not focused on social media communities like wikis and that research such as of Heimbuch and Bodemer (2017)

represents a rare exception. It is therefore important to investigate how larger social media communities can be supported with combined GA information as well as what types of group awareness information are most relevant in such settings. Moreover, the investigations regarding the RADAR tool only allow speculation about the reasons for the non-significant cognitive dependent variables and the different tool functions since the six dimensions have not been examined separately and systematically. Thus, a systematic investigation of different GA information is missing and necessary in GAT research.

5. An Integrated Framework of GAT Support

This section addresses existing conceptual considerations in the field of CSCL and GATs as well as how the proposed framework represents an extension. Kreijns, Kirschner, and Jochems (2003) presented a differentiated view of social and cognitive processes in CSCL, albeit without including GA but regarding the pitfalls in CSCL. The first discussed pitfall is to take social interaction for granted without stimulating it. In addition, the authors criticise the second pitfall or the fact that in many cases, instructors limit their actions to the content space of social interaction. Thus, it has been concluded that collaboration can only be successful if both cognitive and social processes are supported due to their mutual influence. An overview about how cognitive and social processes are stimulated or supported by means of GA information is provided by Bodemer and Dehler (2011). At that time, three types of GA had become distinguished: behavioural GA (e.g., Janssen et al., 2011), cognitive GA (e.g., Sangin, Molinari, Nüssli, & Dillenbourg, 2011), and social GA (e.g., Phielix et al., 2011). Based on an extensive literature review, another framework of GA support was set up in later years (Janssen & Bodemer, 2013). Considering the common use of terms in existing GA-related studies, the authors describe a division into only two GA components: cognitive (e.g., information about knowledge or opinions of group members) and social (e.g., information about participation or perceived friendliness of group members) GATs. Like Kreijns and colleagues (2013), they distinguish between two dimensions of social interaction, which are stimulated by different types of GATs. The framework presented by Janssen and Bodemer (2013) suggests that cognitive and social GA are prerequisites for the effectiveness of social interaction in the two spaces. Recently, Bodemer and colleagues (2018) analysed that a division into two types of GATs is still established at the first level in current research, whereas a more differentiated view on social GATs is supplied at the second level: a differentiation between tools collecting socio-behavioural information (such as information about the participation of group members), socio-emotional information (such as the perceived friendliness within a group), as well as socio-motivational information (such as the commitment of group members).

Regarding social media communities, we have identified a three-way division (see Section 4) based on the three challenges presented in Section 3. Accordingly, there is a need to more closely examine "social" GA information, since especially (socio-)emotional and (socio-)behavioural processes can achieve different effects but are often cumulated. Such a resumption of the three types of GA information is also suggested in a review by Ghadirian, Ayub, Silong, Bakar, and Hosseinzadeh (2016). The following section proposes an integrated framework, which could serve as a basis for new studies in the field of GAT research, especially regarding social media communities. This framework adopts a distinction between three types of GA information (Bodemer & Dehler, 2011) but replaces the term "social" with "emotional" since all types of GATs in the social media area contain a social component. Thus, the framework distinguishes cognitive, behavioural, and emotional GA information (see Figure 2). Despite the presence of promising separate findings on various GATs, this framework contributes by combining findings from different fields of GAT research considering a holistic and differentiated view regarding the effects of cognitive, behavioural, and emotional GA information on different challenges, learning, and social outcomes as well as group performance (see Figure 2). The illustrated framework clarifies that cognitive GA information entails mainly positive effects on interactions in the content space as well as on learning outcomes by addressing the cognitive challenge. Emotional GA information on the other hand mainly affects the emotional challenge of interactions in social interactions' relational space and, as a result, also entails positive effects on social outcomes. Furthermore, behavioural GA information heightens social interaction motivation in both spaces. The main message of this framework is that the interaction of all GA information may be crucial to consequent group performance. It should be noted that these considerations represent a beginning and need to be expanded or modified in the future, inter alia by highlighting interaction effects of different

GA functions, as the current framework only visualises linear effects. To our knowledge, there is no published study which systematically compares different types of GA information and their interaction effects in order to determine which (combination of) GA information is more fundamental than others in specific contexts (also see the review of Ghadirian et al., 2016). It is thus imperative to establish studies to investigate GA interaction effects in different contexts.

Kirschner and Erkens (2013) have already presented a framework to summarise the most prominent areas of CSCL research including GAT research. Despite parallels between our framework and that of Kirschner and Erkens, especially regarding the appeal to weigh emotional aspects (e.g., support of the well-being and satisfaction of group members) more strongly in CSCL settings, their issue is domain neutral. Our approach on the other hand focuses on the use of group awareness tools to support larger social media communities such as wikis. A further specific aspect of this framework is that it focuses not only on the objective information provided by a GAT but also on the influencing effect of "personal" GA, which is rarely considered in current research as most studies focus on the GA information collected by the tools rather than the actual GA. Already Bodemer and colleagues (2018) analysed that only few studies consider the actual GA as mediator variable or as manipulation check (e.g., Engelmann & Hesse, 2011; Sangin et al., 2011). Furthermore, no present study considers the subjective importance of GA information, which could help to predict whether specific tool information will be used as intended. A particular feature of the visualised framework is therefore the distinction between the information presented by the GAT and the actual person's GA, which depends on the individual's interaction with the GA information (see Figure 2). Especially when several GA information are combined, individuals may use some types of information more heavily than others during the collaboration. As an example, learners may not care about a learning community's knowledgeability level if there is a friendly group climate. It is also possible for individuals to draw their own conclusions based on presented GA information, and the visualisation of specific actions could thus be associated with much expertise (see Ogata & Yano, 2004), even if this might be a fallacy.

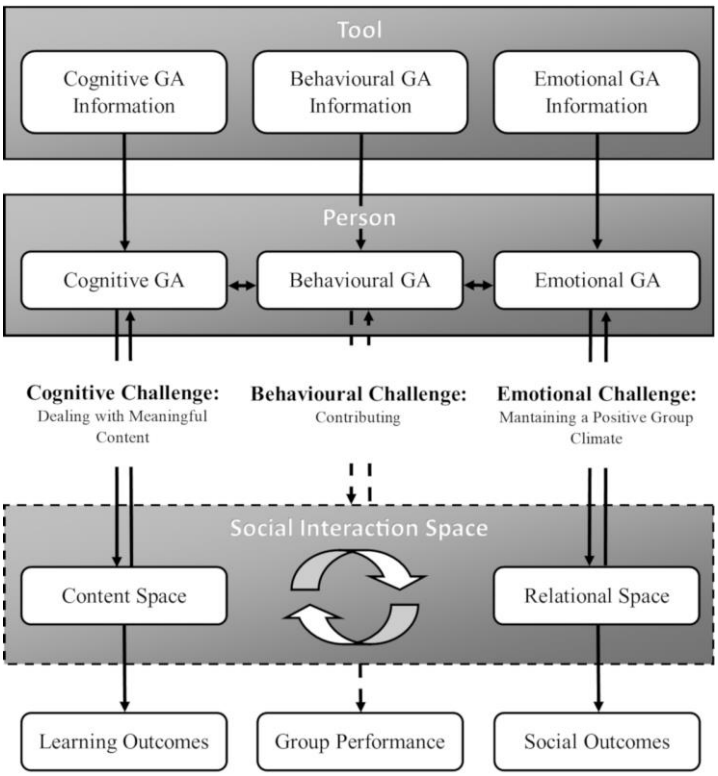

Figure 2. Framework for future studies regarding the interplay of GATs.

The effect of (socio-)motivational GATs (Bodemer et al., 2018) is not explicitly visualised in this framework. Motivational challenges are "related to different goals, priorities, and expectations within the group towards group activities" (Näykki et al., 2014, p. 2). Although different theories of motivation can be very relevant for understanding individual and collaborative learning processes, a complete discussion on this topic exceeds the scope of this article. Rather, we postulate that

motivational issues are addressed by each of the three types of GA information (see Sections 3 and 4). Behavioural GA information affects the general *motivation to contribute* (behavioural challenge), which requires no advanced abilities beyond basic writing and reading. Cognitive GA information addresses, besides the skill (as cognitive states may be difficult to detect in large social media settings) the *motivation to deal with meaningful content* (cognitive challenge). Finally, emotional GA information addresses, besides the skill (as emotional states may also be difficult to detect), the *motivation to maintain a positive group climate* (emotional challenge). In addition, studies have already empirically shown that the simple presentation of motivational states does not need to entail positive effects on outcomes such as increasing one's own motivation or knowledge (e.g., Schoor, Kownatzki, Narciss, & Körndle, 2014). This could be because a simple motivation presentation is highly unspecific, whereas cognitive, behavioural, and emotional GA information concern specific motivational effects.

6. Future Implications

With this framework we want to stress that even though there are already some enlightening and promising results for different types of GATs, it is time to develop a comprehensive full picture regarding their connections. There is a great imbalance in GAT research regarding the types of information provided. The clear focus lies on the support of cognitive GA (Ghadirian et al., 2016) followed by behavioural GATs, whereas the use of emotional GATs remains rather unexplored. To proceed, it is important to examine the positive and negative interaction effects of cognitive, behavioural, and emotional GA information on the respective challenges and outcomes. Although positive effects of cognitive GATs on learning outcomes can already be demonstrated in several contexts (Bodemer et al., 2018), it is likely that behavioural GA information has the potential to intensify these effects. This is based on the finding that explanations help to recapitulate previous knowledge (Webb, 1991). It is also possible that the presentation of cognitive group information leads to information being strategically withheld when learners perceive themselves as experts (Ray, Neugebauer, Sassenberg, Buder, & Hesse, 2013). Here, behavioural GA information could potentially enhance motivation for providing explanations in the social interaction space. However, the presentation of behavioural information could also entail negative effects on emotional challenges or the group climate if the tool visualises unequal participation (Strauß, Rummel, Stoyanova, & Krämer, 2018). There is a need for GATs that present different types of GA information in specific contexts. It is important to examine how this GA information support should look while considering cognitive variables such as mental effort, which could be affected by the interaction with tool information (see Janssen et al., 2011). In this paper, we have exemplarily referred to the area of wikis, however this framework is also transferable to other communities with the challenges being more applicable to larger learning platforms. Since many of the existing studies regarding GATs focus on smaller group collaborations (e.g., Kimmerle & Cress, 2008; Phielix et al., 2011), there is an urgent need in the field of CSCL and GATs to conduct additional research regarding social media platforms, because both students and faculties increasingly use social media in teaching and learning activities (Dabbagh & Kitsantas, 2012). Furthermore, it is important to consider the individual weighting of different GA information as well as the interaction with personality traits. A high tendency towards social comparisons could potentially strengthen behavioural GAT effects (Neugebauer, Ray, & Sassenberg, 2016), whereas need for cognition should influence the cognitive GAT effects. Moreover, a conflict avoidance tendency might affect the interaction with emotional GA information. These represent a few of many conceivable personality interactions that need to be addressed in future GA studies in order to advance this field of research. Laboratory as well as longitudinal field research (Wang, 2011) is needed to examine what kind of processes and outcomes are triggered by the single and combined visualization of GA information, how learners perceive and interact with the different tool information (e.g., by using eye-tracking or qualitative methods) and which role influencing personality variables play. Conducting such studies can help to design and apply adaptive GATs that consider the interplay of different types of GA information as well as support learners according to their specific personalities, which is considered one of the main challenges for future CSCL work (Wise & Schwarz, 2017). Nevertheless, it is not only a question of gaining new insights in the field of GATs, but also of inviting teachers, facilitators, and designers to consider this framework and future research regarding GA interaction effects in order to promote motivation and learning in formal and informal educational settings.

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Appendix 1 – Acknowledgements

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3. Paper 2: How Students Weight Different Types of Group Awareness Attributes in Wiki Articles: A Mixed-Methods Approach (Studies 1 and 2)[5]

Ollesch, L., Heimbuch, S., Krajewski, H., Weisenberger, C., & Bodemer, D. (2020). How students weight different types of group awareness attributes in wiki articles: A mixed-methods approach. In M. Gresalfi & I. S. Horn (Eds.), *The Interdisciplinarity of the Learning Sciences, 14th International Conference of the Learning Sciences* (Vol. 2, pp. 1157–1164). International Society of the Learning Sciences. https://repository.isls.org/handle/1/6309

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How Students Weight Different Types of Group Awareness Attributes in Wiki Articles: A Mixed-Methods Approach

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Abstract: Group awareness (GA) tools can visualize different types of group attributes. Studies often focus on the representation of one attribute, although social media environments such as wikis may benefit from GA combinations. In our studies, we examined the importance of cognitive (knowledge), behavioral (participation), and emotional (friendliness) GA information in wiki article selections, which allows initial predictions about how individuals deal with combined GA information. A quantitative analysis using choice-based conjoint analysis (N = 104) showed that the visualization of friendliness is weighted higher than participation in wiki groups. GA assessments are moreover slightly related to personal characteristics like the learning motivation, the tendency towards social comparisons, and the need for affect. The additional qualitative analysis (N = 19) revealed a higher effect of visualized emotional deficits on perceived group problems than cognitive and behavioral deficits, underlining the need for a stronger investigation and support of emotional GA.

Keywords: Group awareness information, wikis, choice-based conjoint analysis, interviews

Background

In comparison to other knowledge construction platforms evaluated in educational contexts, social media environments like wikis offer much potential for the beneficial occurrence of controversies and socio-cognitive conflicts (Kimmerle, Moskaliuk, Oeberst, & Cress, 2015). However, collaborative learning through social media is also associated with challenges (Kirschner & Erkens, 2013). These involve the lack of participation motivation due to responsibility diffusion in large groups ("behavioral challenge"), the inability to deal with cognitively relevant content due to information overload ("cognitive challenge"), and the lack of group feelings due to missing emotional cues ("emotional challenge"). All of these challenges may hinder effective group performances or even lead to people not participating in collaboration processes at all. This highlights the need for specific support measures (Ollesch, Heimbuch, & Bodemer, 2019). To support social media or wiki communities in addressing the aforementioned challenges and make more people engage in wiki article editing, the use of so-called *Group Awareness Tools* (GATs) is very promising. Those tools provide information about specific properties of group members, e.g., regarding their participation, knowledge, or feelings (Janssen & Bodemer, 2013) and therefore enhance the person's existing GA. GA information can be collected in different ways (from objective to subjective measures) and is very commonly visualized as bar chart (e. g., Kimmerle & Cress, 2008). So far, the visualization of cognitive (very common: knowledge bar chart based on knowledge test), behavioral (very common: participation bar chart based on amount of contributions), and emotional (so far rarely evaluated: friendliness bar chart based on sentiment analysis of contributions) *Group Awareness* (GA) information has mostly been investigated in isolation (cf., Janssen & Bodemer, 2013). Cognitive GATs have shown to facilitate the navigation and selection of meaningful content in wikis (thereby addressing the "cognitive challenge", Heimbuch & Bodemer, 2017). Moreover, behavioral GATs serve as a source of motivation for (equal) participation through the visualization of collaborators' activities (thereby addressing the "behavioral challenge", Kimmerle & Cress, 2008). Last but not least, emotional GATs, even though only systematically investigated in online contexts with smaller groups and not in social media contexts yet, facilitate the joint emotion regulation in the relational space of interactions (thereby addressing the "emotional challenge", Eligio, Ainsworth, & Crook, 2012).

Research questions and hypotheses

Based on the already existing separate but complementary findings, we strongly assume that the joint visualization of several GA attributes could be accompanied by advantages for group processes and outcomes, especially on larger learning platforms as the mentioned challenges cannot be addressed with one type of GA information alone (Ollesch et al., 2019). However, more research on GA combination effects needs to be done to reveal combined effects (Janssen & Bodemer, 2013). As a first step, taking widely used wiki platforms as an example, we aim to

investigate how cognitive, behavioral, and emotional GA information are weighted when selecting a wiki article or group as the decision for a wiki article includes the decision for a certain group constellation of editors. This serves as an important indicator of how people refer to GA information in its combined representation. This helps to test our assumption about the importance of all three attributes in the improvement of existing wiki designs. We focus on the group aspects knowledge, participation, and friendliness. The first two aspects are very common used GA attributes. Emotional or friendliness awareness has rarely been explored (cf., Eligio et al., 2012) but previous interviews with our students showed that it is a desirable attribute to visualize. Besides, when several types of GA information are externally presented, personal characteristics likely influence the subjective importance of GA attributes in wiki article or group decisions (Heimbuch & Bodemer, 2017). Here, we focus on the influence of the current learning motivation, the tendency towards social comparisons, the need for cognition, and the need for affect. Our research questions are as follows: *RQ1)* How important are cognitive (knowledge level), behavioral (participation level), and emotional (friendliness level) GA attributes in a collaborative wiki learning environment when choosing for wiki groups/wiki articles to be edited? *RQ2)* How do characteristics of learners influence the subjective importance or weighting of GA information in this selection process? To answer RQ1 and RQ2, students were asked to choose their preferred wiki group from a set of hypothetical wiki articles with different levels of knowledge, participation, and friendliness awareness information (see Figure 1).

Learning motivation

One relevant characteristic is the *current learning motivation*, which is seen as a prerequisite for collaborative learning (Kirschner & Erkens, 2013). Individuals with high motivation are more likely to select learning partners with high competencies or knowledge than individuals with low motivation (French, 1956). Moreover, learners with high motivation are willing to contribute more to a wiki collaboration than people with low motivation (Ebner, Kickmeier-Rust, & Holzinger, 2008), which should also influence the decision for more active wiki groups to avoid frustrations (Capdeferro & Romero, 2012). Especially when people have high interest in successful task accomplishment and consider the task to be challenging, the amount of knowledge and participation will potentially be more important than the friendliness of group members' contributions. Therefore, this hypothesis is set up: *H1)* Learners with high learning motivation tend to decide for wiki articles visualizing *a)* high group knowledge and participation, whereas *b)* high group friendliness becomes less important.

Social comparison processes

In addition to the motivation of learners, the *tendency towards social comparisons* influences the learning partner choice (Neugebauer, Ray, & Sassenberg, 2016). GATs promote social comparisons by presenting information about the group, e.g., by making learners aware of the group members' knowledge. People with higher tendency towards social comparisons are more interested in information that allows comparisons and in using it in interaction with others (Neugebauer et al., 2016). Even if all GA attributes could trigger social comparison processes, it should be noted that when selecting a new wiki group or article, individuals do not yet have their own participation level or friendliness score, at most expectations, since those GA attributes are based on contributions after the selection process. However, knowledge is a GA attribute, which can be and is very often assessed in advance, e.g., via knowledge test (Janssen & Bodemer, 2013). For this reason, the social comparison effects should especially occur in the importance of knowledge when selecting a wiki article. Since both upward and downward comparisons are possible, it cannot be said per se that a higher amount of knowledge will be more important. But when the motive behind the comparison process is self-improvement, this should lead to the choice for better learning partners (Ray, Neugebauer, & Sassenberg, 2017): *H2a)* Learners with high tendency towards social comparisons attach more importance on group knowledge than on group participation and friendliness when deciding for a wiki article. *b)* Moreover, when these learners score high in the motive self-improvement, they tend to decide for wiki articles with high group knowledge.

Need for cognition and affect

The construct *need for cognition* (NFC) is a personality trait that has become relevant in many fields of research. It is assumed that NFC influences decision-making behavior (Nair & Ramnarayan, 2000). Individuals with high NFC (rational-oriented cognitive styles) tend to process the information they receive in a decision-making scenario reflectively and rather prefer cognitive-demanding features (Carbonell & Brand, 2018), comparable with high group knowledge. Contrary to the NFC, the *need for affect* (NFA) is a personality variable that describes how individuals deal with emotion-triggering situations. It is defined as general motivation to approach or avoid such situations (Bartsch, Appel, & Storch, 2010). High NFA includes the desire to experience and understand the emotions of oneself and others (Bartsch et al., 2010), which also suggests that the amount of emotional GA information in the form of friendliness is weighted more heavily. On the basis of these findings, we hypothesize

the following: *H3a)* Learners with high NFC tend to decide for wiki articles visualizing high group knowledge, whereas *b)* learners with high NFA tend to decide for wiki articles visualizing high group friendliness.

Experimental studies

This paper is a first step in investigating the importance of different GA information in collaborative wiki learning. Choice-based conjoint analysis (study 1) is applied to determine how people value different types of GA information based on personal characteristics (answering RQ1, RQ2, H1 to H3). As ad-on for RQ1, qualitative interviews (study 2) are applied. Our main aims are to help researchers and practitioners getting a big picture of GA combination influences on (wiki) decision-making and help them to select the appropriate support measures.

Study 1

Method: Choice-based conjoint analysis

A sample of N = 104 participants (64 females, students of the University Duisburg-Essen) with a mean age of M = 21.26 (SD = 2.52) took part in laboratory study 1. To determine the relative importance values of the GA attributes in wiki article selections, we employed choice-based conjoint (CBC) tasks. CBC analysis provides the opportunity to model realistic decision-making situations. Participants make discrete decisions for one of several alternatives which differ in the qualities or levels of different attributes. After that, the relative importance of these attributes and the estimated utility value of their levels can be calculated by means of Hierarchical Bayesian analyses using Sawtooth Software. Every CBC task consisted of four articles with the three GA attributes knowledge, participation, and friendliness (randomized arrangement of bar charts) and three levels per attribute (low, medium, and high), see Figure 1. Higher relative attribute importance values do not necessarily mean that a higher attribute level (e.g., higher knowledge) is preferred, but that changes in the levels have a higher effect on the selection preferences. Therefore, CBC also provides the utility values of the attribute levels, here low, medium, and high, from which the relative importance values of the GA attributes are composed (highest level−lowest level of the same GA attribute divided by total range across all attributes). Subjects were provided with a wiki scenario in which they should imagine that they have to work together with other people on a wiki article. The whole wiki article as well as individual contributions would be evaluated and also serve as test preparation on the hypothetical topic. The respondents should imagine that the respective wiki articles involve different group constellations each as well as topics about which they have an assessed medium knowledge, so neither particularly much nor particularly little knowledge to allow upwards and downwards comparisons. Prior to testing, subjects were informed about the meaning of the GA attributes, e.g., the high quality of knowledge in article 1 meant that the wiki group members are extraordinarily knowledgeable about the topic. The visualization of the participation presented the mean frequency of contributions, whereas friendliness presented the friendliness level of the group members' contributions in the wiki. The subjects should imagine that, based on their group preferences, actual groups would subsequently be formed that fit together particularly well. Subjects were then confronted with 17 of those successive CBC tasks, always visualizing different levels of the three attributes.

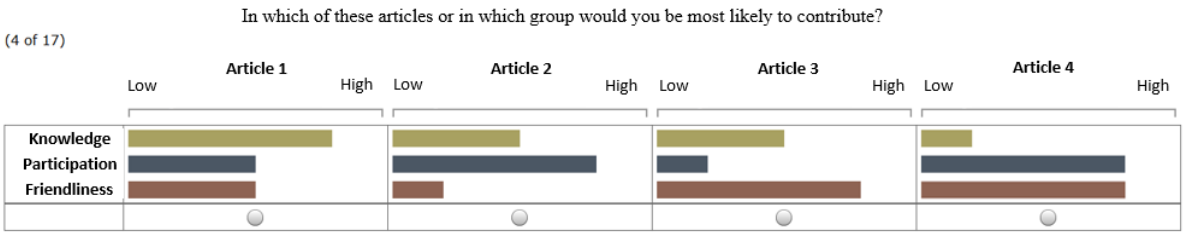

Figure 1. An excerpt of the CBC paradigm.

To assess the current learning motivation, the Questionnaire on Current Motivation by Rheinberg, Vollmeyer, and Burns (2001) (QCM, 18 items answered on a 7-point Likert scale) was completed by the participants right after the provided scenario. The factors challenge (α = .63, 4 items) and interest (α = .81, 5 items) were used for calculations because they become particularly relevant in self-regulated learning (Rheinberg et al., 2001). The tendency towards social comparison was surveyed by the validated German translation of the Iowa-Netherlands Comparison Orientation Measure (COM, Jonas & Huguet, 2008) (α = .80, 11 items answered on a 7-point Likert scale). Moreover, the social comparison motive self-improvement was surveyed by the Strategic Social Comparison Motives Measure (SSCMM, Ray et al., 2017) (α = .79, 4 items answered on a 5-point Likert scale). To measure the NFC, the NFC subscale of the Rational-Experiential Inventory by Keller,

Bohner, and Erb (2000) (α = .90, 14 items answered on a 7-point Likert scale) was used. The NFA was measured with the NFA measure by Appel, Gnambs, and Maio (2012) (α = .84, 10 items answered on a 7-point Likert scale).

Results and discussion

The following applies to all calculations: Extreme values were filtered out if they were at least three interquartile distances away from the upper or lower quartile. To answer RQ1, the mean relative importance values of the GA attributes knowledge, participation, and friendliness were considered, for descriptive values see Figure 2. These results show that in general all three attributes seem to be important in wiki decision-making based on the similar descriptive values of the relative importance values. This goes in line with theoretical assumptions by Ollesch and colleagues (2019) as well as Janssen and Bodemer (2013) and stresses the potential for providing combined GAT designs in order to fulfil different learners' needs. Despite similar values, a repeated-measure analysis of variance showed significant differences in the importance of the different types of GA information ($F(1.86, 191.63) = 3.39$, $p = .039$, $\eta^2 = .03$). The following post-hoc analysis revealed significant differences between the importance of friendliness and participation ($p_{tukey} = .033$), but there were no significant differences between friendliness and knowledge ($p_{tukey} = .764$) as well as knowledge and participation ($p_{tukey} = .164$). The GA information friendliness proved to be significantly more important than participation, which means that visualized differences of the GA attribute friendliness had a greater impact on the decision probability for wiki groups or wiki articles to be edited. This is interesting as emotional GA information is under-represented in current research in comparison to cognitive and behavioral GA information (Ghadirian, Ayub, Silong, Bakar, & Hosseinzadeh, 2016), even though individuals seem to care about this type of information (slightly on a descriptive basis) the most.

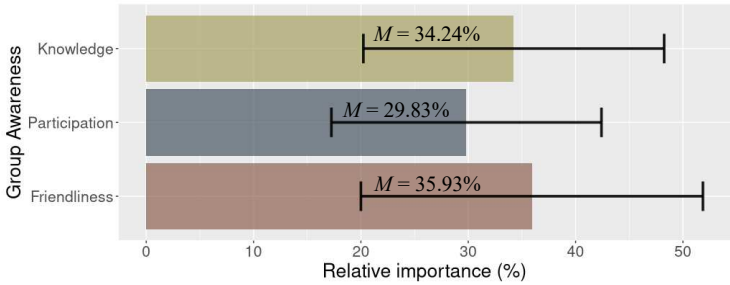

Figure 2. Relative importance values of the GA attributes. Whiskers represent standard deviations.

The descriptive values for the utility values of the (zero-centered and interval-scaled) GA attribute levels show that in all cases high levels were more preferred in comparison to low levels: low knowledge $M = -52.64$ ($SD = 32.42$), medium knowledge $M = 22.94$ ($SD = 14.33$), and high knowledge $M = 28.84$ ($SD = 34.17$); low participation $M = -50.22$ ($SD = 25.76$), medium participation $M = 16.91$ ($SD = 11.27\%$), and high participation $M = 34.12$ ($SD = 18.06$); low friendliness $M = -63.65$ ($SD = 29.37$), medium friendliness $M = 21.23$ ($SD = 13.67$), and high friendliness $M = 42.43$ ($SD = 21.32$). Except of H2a, which refers to the general relative importance values of the GA attributes (see Figure 2), all hypotheses address the preferences for high levels of the respective GA information. Therefore, in the first step, simple linear regressions were performed with the scores of the relative importance values of the GA attributes as criterion. In the second step, the scores for the preferences of the high levels of the respective GA attributes were examined in the same way to see if the direction of the effects were hypothesis-confirming. Predictors were the personal characteristics of H1 to H3.

Hypotheses 1: With respect to H1a, we found significant positive relationships between the QCM dimension challenge and the relative importance of knowledge ($F(1, 102) = 12.38$, $p = .001$, $\beta = .33$, $\omega^2 = .10$). Moreover, students who found the task from the scenario challenging preferred to collaborate with wiki groups that have a high level of knowledge when editing wiki articles ($F(1, 101) = 4.44$, $p = .038$, $\beta = .21$, $\omega^2 = .03$), supporting H1a. For the QCM dimension interest, however, neither the relationship with the relative importance of knowledge ($F(1, 102) = 1.56$, $p = .214$, $\beta = .12$, $\omega^2 = .01$) nor with high knowledge articles ($F(1, 100) = 1.38$, $p = .244$, $\beta = .12$, $\omega^2 = .004$) turned out to be significant, which does not support H1a. We also found no significant relationships between the QCM dimension challenge and the relative importance of participation ($F(1, 102) = 0.06$, $p = .814$, $\beta = -.02$, $\omega^2 = -.01$) as well as high participation articles ($F(1, 100) = 0.90$, $p = .346$, $\beta = .09$, $\omega^2 = -.001$). Students with high interest did not weight participation in general ($F(1, 102) = 0.67$, $p = .416$, $\beta = -.08$, $\omega^2 = -.003$) and more concrete also not high participation articles higher ($F(1, 100) = 0.19$, $p = .667$, $\beta = .04$, $\omega^2 = -.01$), which does not support H1a. With respect to H1b, we found significant negative relationships between the QCM dimension challenge and the relative importance of friendliness ($F(1, 102) = 8.08$, $p = .005$, $\beta = -.27$, $\omega^2 = -.06$). Students who found the task from the scenario challenging tended to avoid wiki groups that

have a high level of friendliness when editing articles ($F(1, 102) = 6.91$, $p = .010$, $\beta = -.25$, $\omega^2 = .05$), supporting H1b. For the QCM dimension interest, however, neither the relationship with the relative importance of friendliness ($F(1, 102) = 0.20$, $p = .654$, $\beta = -.04$, $\omega^2 = -.01$) nor with articles visualizing very friendly contributions of other group members ($F(1, 102) = 0.39$; $p = .533$; $\beta = -.06$; $\omega^2 = -.01$) turned out to be significant, which does not support H1b. To sum up, the expected relationships could be shown between the QCM dimension challenge and knowledge as well as friendliness but not for the QCM dimension interest. Regarding the GA attribute participation, no significant relationships could be shown at all. H1 is only partially supported.

Hypotheses 2: With respect to H2a, students with higher tendency towards social comparisons showed a significant stronger weighting of the GA attribute knowledge ($F(1, 101) = 4.85$, $p = .030$, $\beta = .21$, $\omega^2 = .04$), which supports H2a. Even though effect sizes illustrate the right direction, H2b is not securely supported as the motive self-improvement was not significantly related to the preference for high knowledge wiki articles ($F(1, 98) = 1.59$, $p = .211$, $\beta = .13$, $\omega^2 = .01$). Moreover, the relative importance values of participation ($F(1, 101) = 1.30$, $p = .257$, $\beta = -.11$, $\omega^2 = .003$) and friendliness ($F(1, 101) = 1.02$, $p = .315$, $\beta = -.10$, $\omega^2 < .001$) were not significantly related with the tendency towards social comparisons in this setting and therefore weaker than the relationship with knowledge, which supports H2a.

Hypotheses 3: With respect to H3a, even though expected descriptive trends were given, already no significant relationships could be shown between the NFC and the relative importance of knowledge ($F(1, 102) = 0.28$, $p = .595$, $\beta = -.05$, $\omega^2 = -.01$) as well as high knowledge articles ($F(1, 101) = 1.76$, $p = .187$, $\beta = .13$, $\omega^2 = .01$). H3a is therefore not securely supported. Missing significant results regarding the NFC (H3b) could be explained by the use of a scenario instead of a real collaboration situation. Thus, for the students with high NFC, it may not have been salient enough whether they would benefit from articles with high knowledgeable group members. We originally expected that high knowledge would imply that cognitive activity has to be put into group discussions, which is in line with high NFC. However, people with high NFC also tend to be less affected by cognitively demanding problems, like a low group knowledge level, than people with lower NFC (Cacioppo, Petty, Feinstein, & Jarvis, 1996). This may have led to the fact that the influence of the NFC on the GA attribute knowledge was not as great as expected, because it could not only be satisfied in group constellations with high knowledge. However, the analysis revealed that the NFA has a significant effect on the relative importance of friendliness ($F(1, 102) = 4.17$, $p = .044$, $\beta = .20$, $\omega^2 = .03$) and that students with high NFA tended to prefer articles with visualized high friendliness ($F(1, 102) = 6.40$, $p = .013$, $\beta = .24$, $\omega^2 = .05$). H3b is supported.

Although it has to be noted that in all cases the explained variances were rather low, these results give first impressions about how individuals with different personal characteristics would deal with combined GA information in real collaborations, assuming that importance is an indicator of increased interaction. People with high NFA might ignore cognitive and behavioral GA information in a wiki learning environment because they rather care about the regulation of emotional aspects. More potential influencing variables need to be identified in future studies. Before we discuss our results in more detail, an additional qualitative approach is introduced in the following. This approach serves to examine the motives behind this decision-making as well as perceived problems of learners when a GAT indicates a deficit in one of those three GA attributes.

Study 2

Method: Qualitative interviews

After the termination of study 1, a supplementary qualitative study was conducted amongst 19 students (*s01* to *s19*) who had not participated in study 1 with a mean age of $M = 21.74$ ($SD = 3.48$); seven were male and 12 were female. The aim of this study was to support the quantitative study and find out why certain decisions were made in Study 1. The face-to-face interviews were transcribed and analyzed using the software MAXQDA 2018. The participants were introduced to the scenario in the same way as in study 1, in which an intermediate knowledge level was specified. In contrast to study 1, regarding their most important GA attribute, the interviewees were also asked whether their assessment would change if they had a different level of knowledge (high or low knowledge). Moreover, they were asked to talk about the problems they see in wiki articles visualizing one GA deficit (cognitive, behavioral, or emotional deficit) to delve deeper into potential causes for preferences. Article 4 in Figure 1 visualizes the shown cognitive or knowledge deficit (knowledge low but rest high) among the potential wiki group members. Two analogous article constellations with emotional (friendliness) and behavioral (participation) GA deficits were provided, three in total. Based on the interview data, we (two coders, $\kappa = .90$) categorized the named problems associated with a deficit in one of the GA information as follows: A cognitive problem was characterized by a participant's *contribution that is not part of the topic* or is of *poor quality, missing solutions of socio-cognitive conflicts, slow cognitive progression,* and *missing cognitive outputs*. *Low well-being*, *interpersonal conflicts*, *feeling of stress* or *frustration*, *low tolerance of mistakes/knowledge gaps*, and *low*

acceptance of other opinions were classified as components of emotional problems. Behavioral problems were understood as *low participation motivation, unequal workload, slow work pace,* and *missing behavioral outputs*.

Results and discussion

Concerning to RQ1, eight interviewees each chose friendliness and participation as their most important attribute, while only three interviewees chose knowledge. Individuals who preferred friendliness mostly stated as a reason that it was important for effective group cooperation and outcome to get along well within the group. Individuals who preferred participation stated as a reason that motivation to contribute was important to get the chance for a good outcome. Individuals who preferred knowledge stated as a reason that the average knowledge in the group is the basis for processes and outcomes and that you cannot move forward without an adequate level of knowledge among the group members. Of the 19 respondents, six said their importance assessment would change with a different knowledge level. Five of those had previously chosen friendliness as their most important attribute, one had previously chosen participation. Except for one person, all students indicated that they would rather prefer the GA attribute knowledge for changing knowledge levels. An exemplary statement is provided in the following, given by a subject with a self-improvement motive: "With a low level of knowledge, *knowledge is most important to me because I have the hope that I will then learn more*. Then I would be willing to accept smaller losses in friendliness. If my knowledge is high, then friendliness is more important to me than knowledge" (s11).

To sum up, similar to study 1, study 2 highlighted the importance of the GA attribute friendliness. However, the qualitative interviews showed that knowledge seems to be less important than participation, which is not compliant with the descriptive values from the CBC analysis but in our opinion less meaningful due to the small sample size. It could also be shown that the importance of the knowledge is very dependent on knowledge levels since some interviewees would rather pay attention to knowledge if they had a low level of knowledge. Nevertheless, with medium knowledge, there was a preference for friendliness and participation information, which is also underlined by the number of assessed problems based on different group deficits. Table 1 shows the frequencies and example statements for problems mentioned for cognitive, emotional, and behavioral deficits.

Table 1: The perceived impact of cognitive, emotional, and behavioral group deficits on different problems

N = 19	Cognitive problems	Emotional problems	Behavioral problems	Problems each deficit
Cognitive deficit	17 (89.47%) "One problem could be that the quality of the finished product does not correspond to what the task was." (s18, *poor quality*)	4 (21.05%) "If there is someone who has higher knowledge than the low group average, interpersonal conflicts can arise because this person can reveal that the input of others contains bad information." (s17, *interpersonal conflicts*)	6 (31.58%) "If you don't know that much, you may only progress slowly in fulfilling your tasks." (s14, *slow work pace*)	27
Emotional deficit	14 (73.68%) "Unresolved disagreements could arise based on the low level of knowledge, in which both parties permanently stick to their opinions." (s04, *missing solution of socio-cognitive conflicts*)	19 (100%) "This can lead to other people showing rage when you don't know something." (s19, *low tolerance of mistakes/knowledge gaps*)	7 (36.84%) "The division of labor will be unequal." (s10, *unequal workload*)	40
Behavioral deficit	14 (73.68%) "You'll probably have to wait until you get an answer when you ask a question. That will be difficult." (s11, *slow cognitive progressing*)	9 (47.37%) "Since difficulties and conflicts can arise, they can distract from the actual work, so that there is a lack of time, this can lead to everything becoming very stressful in the end." (s13, *stress*)	15 (78.95%) "This has a negative effect on your own participation motivation. (s07, *low participation motivation*)	38

According to interviewees a visualized emotional deficit in a group has the largest effect on different problem types (40 mentioned problems). This underlines the results of study 1 as well as current research, which

suggests that relational issues significantly influence interaction, task engagement, and learning (e.g., Näykki, Järvelä, Kirschner, & Järvenoja, 2014), highlighting the need for a stronger support of emotional GA.

Overall discussion

Even though wikis offer many learning potentials (Kimmerle et al., 2015), these are not fully exploited. We assumed that the support through combined GA information could be useful as different types of GA information tackle different challenges (Ollesch et al., 2019). Therefore, it is important to understand how people deal with GA combinations and whether all three GA attributes are actually used for wiki decisions. We have addressed this goal in two studies to investigate the perceived importance of knowledge, participation, and friendliness awareness information for guiding students' wiki article decisions. This was an important first step as they are often considered separately in CSCL environments (Janssen & Bodemer, 2013). Moreover, with study 1, we contributed to understand how users' characteristics influence the way decisions are made.

Regarding RQ1, all types of information seem to be relevant, which highlights the need for a holistic perspective in the development of GATs to improve the design of already existing wikis and similar platforms. Our study results support the assumption that it makes sense to visualize more types of GA information if the preferences of users have not been captured beforehand by the respective researchers, instructional designers, or teachers. This would help to facilitate navigation in wiki or similar learning communities as GA combinations could offer every learner or student to choose the "right group". A person focusing on knowledge might use this attribute to be more efficient in his or her tasks and a person who thinks friendliness is important can choose a group that stresses him the least. Common denominator of both studies was the importance of emotional GA information in the form of friendliness. These results suggest that especially emotional processes should be supported even more in wiki or other social media environments as some students care a lot about this information. However, it has to be investigated how this emotional GA support should exactly look like as current emotional GA research focuses on smaller groups (e.g., Eligio et al., 2012) and a friendliness bar chart (e.g., based on sentiment analysis of contributions) is just one possible operationalization. Regarding RQ2, the first indication for interpersonal differences in study 1 were the high standard deviations of the relative importance values and attribute levels. Further, linear regression analysis revealed slight relationships of all personal variables and the relative importance values of the GA attributes as well as their high levels, except of NFC and the motive for self-improvement. Even if the influence of the motive self-improvement (H2b) was not statistically verified in study 1, the qualitative interviews could show that a small amount of personal knowledge triggers self-improvement motives, leading to the preference for high knowledgeable groups (e.g., statement of s11), which goes in line with literature (Ray et al., 2017). The learning motivation (factor challenge), the tendency towards social comparisons, and the NFA seem to be relevant to distinguish different types of preferences. These findings about personal influences could be used for developing adaptive GA visualizations fitting to personal characteristics. e.g., a person with high NFA might be more motivated by having the option to choose articles with high friendliness.

Even if the results are promising, providing GA can also lead to the "rich-get-richer" principle, e.g., when those topics which were indicated as friendly get more and more people for collaboration, whereas those topics with a lower friendliness level people will not pay attention to. Concrete task instructions could counteract this but more studies that relate GA information and decision-making need to be conducted in order to better understand this phenomenon as well as the dangers of "filter bubbles" when providing personalized GA information. Moreover, the present scenario has exemplary addressed the wiki context and students. Nevertheless, these results are not only specific to wikis and are therefore transferable to other CSCL contexts. Future studies should consider different types of (wiki) users with real and varying knowledge levels as well as different learning topics as those aspects can significantly determine whether someone will contribute something or not. We are already conducting systematic studies that go beyond the importance of different GA attributes and examine the interaction effects of different types of GA information (e.g., two-factor between design with knowledge and participation as well as knowledge and friendliness) on real learning processes.

Based on these studies, providing wiki communities with GA combinations could help to reduce information diversity and provide users with better tools to make easier decisions for wiki articles, leading to the facilitation of their usage in teaching scenarios and to more people participating in wiki writing processes. New GA applications could on the one hand focus on providing GA information individuals put importance on or would like to have visualized, e.g., friendliness, which would improve user experience. On the other hand, they could also ensure that potentially distracting information is not visualized to draw attention to GA information relevant to the task completion, e.g., knowledge. With this mixed-methods approach, we clarify that it is time to bring the often separate GAT findings together as each type of GA information seems to have a value for different types of learners or students. Friendliness awareness should be considered and explored more closely in future design attempts for new support measures as it is not yet clear which kind of emotional support is most helpful

for certain contexts. However, we believe, that not only designers of online learning environments could benefit from these findings. Knowing about students' importance weightings and providing personalized GA can be helpful for teachers in the support of traditional learning to create matching groups dependent on the teaching objectives (e.g., based on similar or heterogeneous preferences) and maintain a pleasant learning atmosphere.

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4. Paper 3: Improving Learning and Writing Outcomes: Influence of Cognitive and Behavioral Group Awareness Tools in Wikis (Study 3)[6]

Ollesch, L., Heimbuch, S., & Bodemer, D. (2021). Improving learning and writing outcomes: Influence of cognitive and behavioral group awareness tools in wikis. *International Journal of Computer-Supported Collaborative Learning*, *16*(2), 225–259.
https://doi.org/10.1007/s11412-021-09346-6

Intern. J. Comput.-Support. Collab. Learn (2021) 16:225–259
https://doi.org/10.1007/s11412-021-09346-6

Improving learning and writing outcomes: Influence of cognitive and behavioral group awareness tools in wikis

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Received: 6 August 2020 / Accepted: 17 May 2021 / Published online: 16 July 2021

Abstract

Group awareness (GA) tools can facilitate learning processes and outcomes by visualizing different social attributes, such as cognitive and behavioral information about group members. To assist learning and writing in social media, combining various types of awareness information may foster learning processes due to challenges, which are difficult to address by one type of GA information alone. The systematic investigation of GA tool combinations is largely unexplored with GA information often being examined separately or intermixed. To reveal both positive and negative (interaction) effects of providing different types of GA information, we conducted a 2×2 between-subjects experiment with $N = 158$ participants. Learners were provided with a wiki learning environment and, except for the control condition, different types of GA tools involving cognitive (knowledge bars) and/or behavioral (participation bars) GA information. GA tool effects were considered at wiki selection, discussion, and article levels. Eye-tracking was used for investigating the attentional effect of the GA visualizations. The results show that both types of GA information have effects on individuals' selection preference, more strongly with the goal to learn new content than to support other wiki collaborators, which were introduced as within goal scenarios. Also, participants provided with behavioral GA support were more engaged in wiki contributions. However, only the combination of cognitive and behavioral GA information, rather than their separate visualization, had a positive effect on resulting article quality. This highlights the need for a holistic perspective when developing GA tools to improve wiki processes and outcomes.

Keywords Computer support · Group awareness · Wikis · Eye-tracking

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Introduction

Wikis can support collaborative learning and writing in many ways. They enable users to work with each other on joint knowledge artifacts without time and place constraints (Chen et al., 2015). Furthermore, their usage involves both valuable cognitive and behavioral processes. Since wiki articles are often created collaboratively, a large knowledge base is depicted. Therefore, wiki content can itself serve as an extensive learning database. Although the potential for using wikis in learning scenarios is enormous, not every wiki has a primary learning focus. It is also possible to obtain wiki information solely for a specific problem or task. Moreover, it is necessary to encourage wiki users to actively produce content. This is not only important for collection purposes but can also have positive effects on cognitive processes, especially when change intentions are discussed in detail in the underlying wiki discussion forum (Heimbuch et al., 2018). Nevertheless, using such platforms also poses challenges (Hadwin et al., 2018), such as the facilitation of selecting meaningful content that is conducive to learning (cognitive challenge) and the stimulation of active content production/contributions (behavioral challenge). To overcome such challenges, we consider *group awareness tools* (GATs), which collect, transform, and present information about group members (Bodemer et al., 2018). GATs can provide learners with different types of *group awareness* (GA) information, with cognitive and behavioral GATs precisely addressing the two challenges mentioned above. Although there are already some promising findings for both types of GA information in relation to different learning processes and outcomes (e.g., Janssen et al., 2011; Sangin et al., 2011), the types are often examined separately or in combination without disentangling their specific functions (Bodemer et al., 2018; Janssen et al., 2011). Only few studies have investigated the differences and overlaps between different types of GA information as well as the effectiveness of GAT combinations (e.g., Lin et al., 2015). We aim to shed light on their interplay in a systematic way to better support learning processes in wikis and similar computer-supported collaborative learning (CSCL) platforms.

By using an experimental 2 × 2 between-subjects study and taking wiki environments as an example, this paper considers the linkage of cognitive and behavioral GA information and how the combination of both can be used to enhance single GAT outcomes. Additionally, we illuminate attention processes on a descriptive level by using eye-tracking to measure the extent of visual attraction of the designed GA support functions and other elements of the wiki environment. Our findings will help to better understand GA support and involved processes in CSCL for improving the instructional design of existing technologies.

Potentials of wiki-based CSCL

One essential characteristic of social media platforms, such as wikis, is that they promote user-generated content and social interaction among their users (Dabner, 2012). The popularity of such participatory technologies can be explained by using socio-constructivist approaches, which assume that individuals learn best when they have constructed knowledge through social interaction (Cole, 2009), something that is particularly promoted by wikis. This construction of knowledge is possible on the wiki article page as well as on the underlying discussion page. Thus, wikis offer considerable potential for valuable processes,

both behavioral (content creation) and cognitive (individual learning/collaborative knowledge construction), to occur (Daspit & D'Souza, 2012).

Content creation is possible on several levels in wikis. Learners can create articles collaboratively, and they can interact with each other on the underlying discussion pages (Reinhardt, 2019). At the article level, writing can be seen as a distinctive set of monitored thinking processes, orchestrated by the user and based on self-generated goals. These include the planning, translating, and reviewing of texts (Flower & Hayes, 1981), which is considered a fundamental method to support learning growth (Tynjälä et al., 2001). At the discussion level, writing offers the opportunity to exchange views on what has been written and to clarify disagreements, making it possible for content-related controversies to occur. Such controversies are based on the exchange of different points of view on a specific topic. These might induce beneficial socio-cognitive conflicts between learners' cognitive structures and the social system or wiki, leading to meaningful cognitive reorganization, restructuring, and consensus-finding processes (Bell, 2004).

According to Piaget (1977), defending or balancing different opinions is relevant because disequilibrium or cognitive conflicts have positive effects on learning growth. Although this theory was originally intended to describe individual learning processes, Piaget's assumptions can also be applied to social interactions and collaborative knowledge construction within a wiki (Cress & Kimmerle, 2008). If wiki users encounter information that contrasts to their original assumptions, such a beneficial state of conflict can be triggered. Individual learning then takes place through internal assimilation or accommodation processes – more specifically, knowledge is transferred from the wiki into the user's cognitive system by purely adding new information or changing existing knowledge. However, the user can also resolve this conflict status by external assimilation and accommodation processes. External assimilation refers to the simple addition of new information to the wiki, whereas external accommodation describes activities of rearranging entire wiki sections. Both internalization and externalization of wiki information leads to a *co-evolution* of the cognitive (individual learning) and social (collaborative knowledge construction) systems (Cress & Kimmerle, 2008). This highlights that beneficial cognitive and behavioral processes are closely intertwined in wiki-based learning.

Challenges of wiki-based CSCL

Even if wikis have huge potential for learners, this has not always been fully exploited. In the following subsections, we introduce the cognitive and behavioral challenges that learners face in their wiki's intersubjective space.

Cognitive challenge

Although social interaction is conducive to learning, not all types of interaction have the same beneficial effects (Heimbuch & Bodemer, 2017). Therefore, the drive to select or focus on "relevant" and content-related discussions is important. Social interaction needs to be meaningful and highly qualitative, in the sense of wiki actors dealing with content that can lead to the aforementioned beneficial socio-cognitive conflicts (Ollesch et al., 2019). This could be content about which of the user has less knowledge than other collaborators or has a different point of view. Dealing with meaningful content can lead to relevant internalization or externalization processes, which is not always the case due to the huge

amount of information offered by social media (Buder et al., 2015). It has already been shown that discussions in this context are frequently not deeply elaborated, instead simply skimming "over the surface" (Zhang & Zhang, 2010). Most wiki discussion pages (e.g., in MediaWiki) are empty pages lacking any pre-structure (Heimbuch & Bodemer, 2017), which makes it difficult to dive deeply into existing discussions without further structuring. This indicates that it makes sense to highlight cognitively relevant contributions to support the information search and navigation in discussion forums. Although selection processes can be described as a kind of behavioral process, the cognitive challenge is primarily concerned with decision-making prior to the actual action.

Behavioral challenge

In addition to meeting the cognitive challenge, all collaborators should be willing to actively engage or interact with each other in task fulfillment and communication processes (Ollesch et al., 2019). In wikis, the behavioral challenge involves both contributing to filling the article with content and creating this content collaboratively and with adequate discussion. For this purpose, the discussion forum is suitable for exchanging opinions on the article topic before actual editing (Heimbuch et al., 2018). However, there is not always the willingness to exchange opinions in such environments (Kimmerle & Cress, 2008; Kreijns et al., 2013). One reason is that the individual contributions in wikis are not directly visible, because the version history as well as the discussion page are hidden behind the actual article. As soon as individuals work toward a common goal and their individual performance becomes anonymous or not openly visible to all, their participation quantity is often reduced (Kimmerle & Cress, 2008), which can lead to social loafing and free riding (see Janssen et al., 2007). Moreover, social exchange arguably poses a social dilemma because it takes time and effort for individuals to share their knowledge, and they do not immediately benefit from this action. However, if no one contributes, the whole group is more likely to suffer (Cress & Kimmerle, 2007). This shows that it is important to overcome the behavioral challenge at both the article and discussion page levels. Our study focuses on supporting the exchange in wiki discussion forums before article editing. It has already been shown that social interaction before actual article editing can be beneficial for both behavioral and cognitive outcomes (Heimbuch et al., 2018), leading to articles with fewer mistakes and enhanced learning potentials.

Group awareness support

To stimulate social interactions in general (addressing the behavioral challenge) and in a meaningful way (addressing the cognitive challenge), wikis and similar platforms depend on some degree of support (Kreijns et al., 2013; Stahl & Hakkarainen, 2020). Here, we consider GATs as one solution to overcome the challenges mentioned above. These were highlighted by Rosé et al. (2019) as a helpful scaffolding method for collaborative learning. GA information is known to provide implicit guidance, which assists and improves self-regulated collaborative learning without giving explicit instructions regarding what to do (Miller & Hadwin, 2015). GA includes the knowledge about other group members' knowledge, opinions, activities, or feelings. While this information is often highly inferable by learners in face-to-face situations, it is often not salient enough in computer-mediated learning scenarios (Wendt & Rockinson-Szapkiw, 2015), which highlights the need to

support GA technically. With the help of GATs, the perception of GA can be supported. GATs provide learners with information they can use to form a group, to participate in effective collaborative learning procedures (Bodemer et al., 2018), to monitor their learning and collaboration behavior, and to change this behavior if necessary (Butler & Winne, 1995). GATs differ in the GA information they contain (Phielix et al., 2011). In the following, we discuss the effects of cognitive and behavioral GA information on cognitive and behavioral processes as well as on individual and collaborative outcomes.

Cognitive GA information: different levels of knowledge

Cognitive GATs are tools that provide learners with awareness information about the knowledge, interest, or opinions of group members and help to focus on what content is meaningful, thereby mainly stimulating qualitative cognitive processes (addressing the cognitive challenge; Bodemer et al., 2018; Lin et al., 2015). They allow an individual's knowledge or opinions to be compared with those of other group members, thus promoting better grounding and partner modeling processes (Bodemer, 2011; Sangin et al., 2011). Especially regarding knowledge, it has been shown that the expertise of others is often over- or underestimated without any kind of support and that there is a need to support learners in the construction of accurate partner models (Dehler et al., 2011). An example of a cognitive GAT is the *knowledge awareness tool* of Sangin et al. (2011), which provides learning partners with information about each other's knowledge differences (in the form of bar charts) based on a pretest score. It has been shown that this tool allows for a better assessment of the learning partners' knowledge (Sangin et al., 2011).

Selection preference based on learning and supporting goals. Studies in the social media field have already shown that the provision of cognitive GA information in the form of rating visualizations can facilitate navigation in large online forums and help to find high-quality contributions for learning purposes (e.g., Buder et al., 2015). Moreover, learners who are provided with controversy awareness markers in wikis direct their attention toward the selection of unresolved controversies for supporting purposes, leading to the potential for socio-cognitive conflicts to occur (Heimbuch & Bodemer, 2017). Although there can be a variety of intentions for actions in wiki learning environments, we count the aforementioned learning and supporting purposes as the main goals that drive learners in such environments. Even though not yet examined in the social media context and for knowledge awareness, we assume that there are also positive effects on discussion thread selections in wiki environments when GATs visualize different levels of involved user knowledge. When the main *goal is to learn new content*, learners potentially select wiki discussion threads that visualize a *high level of group knowledge* rather than a *medium* or *low level*, because of the higher chance for finding helpful contributions. However, when the main *goal is to support other collaborators*, they potentially tend to select wiki threads that visualize *low group knowledge* among the participants rather than a *medium* or *high level*.

Engagement in behavioral contributions. Cognitive GA information stimulates not only cognitive processes but also behavioral processes like the formulation of messages (Krauss & Fussell, 1991). On the one hand, there is the possibility of explaining and discussing information that is not known by the learning partner. On the other hand, there is the chance of closing knowledge gaps with the help of experts (Dehler et al., 2011). It has been shown that the visualization of partner deficits can motivate learners to contribute more in

terms of explanations (addressing the behavioral challenge; Dehler et al., 2011), whereas experts may also strategically withhold information (Ray et al., 2013). Therefore, cognitive GA information can trigger calculated supporting behavior, although this has yet to be confirmed across different contexts.

Outcome variables. According to Bodemer et al. (2018), cognitive GATs show positive effects on both internalization and externalization tasks as outcome variables. These range from objective measures, such as individual knowledge gains (e.g., Gijlers & de Jong, 2009) and collaborative wiki article quality (Heimbuch et al., 2018), to subjective measures like partner knowledge assessment (e.g., Sangin et al., 2011). However, desirable effects on outcome variables cannot be shown across all studies in this field, especially in relation to the findings on learning outcomes (Bodemer et al., 2018).

Behavioral GA information: different levels of participation

Even if wiki participants perceive that an action is expected, there are often no clear standards of what this effort should look like. Behavioral GATs provide such awareness information by visualizing the activities of the group and its members (Kimmerle & Cress, 2008), e.g., the number of contributions to online discussions (Bodemer et al., 2018). When group members are aware of one another's productivity rates during learning, they are able to assess how much content is desirable, which mainly stimulates quantitative behavioral processes (addressing the behavioral challenge; Lin et al., 2015). This is even the case when people get bogus feedback (given information without real persons involved) about teammates' high or low contribution rates (Cress & Kimmerle, 2007). A prominent example of a behavioral GAT is Janssen et al.'s (2011) *participation tool*, which represents each group member as a circle whose size and distance from a group center varies. The larger the circle, the more has been contributed. Results show that learners who used the tool for a longer period were more involved in the discussions and the work on the group project.

Selection preference based on learning and supporting goals. Although there is still little research on how the visualization of behavioral GA information influences selection decisions (addressing the cognitive challenge; Ollesch et al., 2019), analogous to cognitive GA information, it might be concluded that when the main *goal is to learn new content*, learners potentially select wiki threads that visualize a *high level of group participation* rather than a *medium* or *low level* due to a potential higher amount of available learning material. However, when the main *goal is to support other collaborators*, they rather select wiki threads visualizing *low group participation* rather than a *medium* or *low level* due to the lack of available contributions regarding a specific learning topic.

Engagement in behavioral contributions. Being mutually aware of contribution rates stimulates feedback and motivational processes because learners want to avoid negative social evaluations by the group (Janssen et al., 2011). In particular, descriptive social norms play a crucial role in the effectiveness of behavioral GA information on contribution engagement because they motivate actions by specifying what most people do in a particular situation (Reno et al., 1993). It is assumed that actual participation is determined by such norms and that people adapt their behavior by observing others (Ajzen, 2015), an assumption that can be transferred to the observation of behavioral GAT information about other people. Crucial to the effectiveness of behavioral GA information in

information-exchange situations is not only the knowledge about others' behaviors but also the identifiability of one's own effort, because all people have a need to present themselves in a certain way (e.g., as a very productive person; Heo et al., 2019; Kimmerle & Cress, 2008). According to Cress and Kimmerle (2007), the self is especially strategically presented in online CSCL settings, as people have more control than in offline settings. People use the technological characteristics of such environments with the goal of managing the impressions they give to other people (Walther, 2007, as cited in Kimmerle & Cress, 2008). This highlights that cognitive processes are also involved in the effects of behavioral GA information.

Outcome variables. According to Bodemer et al. (2018), behavioral GATs have mixed results. Behavioral GATs mostly (not exclusively) show positive effects on externalization outcomes, which range from objective measures, such as the quality of collaborative writing products (e.g., Liu et al., 2018), to subjective productivity assessments (e.g., Phielix et al., 2011). However, results on the quality of collaborative group performances are not consistent across studies (e.g., Janssen et al., 2011; Lin et al., 2019). In addition, internalization outcomes, such as learning performance, are often not explicitly addressed in most papers on behavioral GA support or rarely present (Bodemer et al., 2018).

Personal characteristics influencing GAT effects

Although GA support has been proven to be beneficial, it is important to focus not only on the objective information given by a tool because learners may act differently, even with identical technology support (Tchounikine, 2019). Personal characteristics are currently rarely considered in the GAT context and could provide the basis for personalized GA support approaches. It may be that individuals, depending on their personal characteristics, use one type of information more heavily than the other type during the collaboration. Here, we introduce possible influencing variables, since it cannot be assumed that different GATs have the same effect on all types of learners.

One potential influence on the processing of both types of GA information is social comparison, which helps individuals to compare their own opinions and abilities with those of others in order to maintain an adequate and stable self-image (Festinger, 1954). Once learners work collaboratively on a task, they can become aware of the skills and activities of their learning partners. This promotes processes of social comparison and helps them to gain information about themselves and their own performance (Neugebauer et al., 2016). GATs can further foster this by visualizing awareness information about others (Bodemer et al., 2018), such as their knowledge level (cognitive GA information) or participation amount (behavioral GA information). However, social comparison is not used by everyone to the same extent, with some relying more on it than others. Gibbons and Buunk (1999) termed this predisposition *social comparison orientation*. People with a higher tendency toward social comparison are more interested in information that allows comparison with interaction partners, enhancing GAT effects (Kimmerle & Cress, 2009; Neugebauer et al., 2016; Ollesch et al., 2020).

Besides the tendency toward social comparisons, the construct *need for cognition* (NFC) is a potentially relevant personality trait affecting information processing in wiki environments, especially with regard to cognitive GA information. One prerequisite for effective cognitive GA support is that learners need to be willing to engage in valuable cognitive processing activities, as described by the NFC (Cacioppo & Petty, 1982). NFC

is considered a stable individual difference in people's tendency to engage in and enjoy effortful cognitive activity (Cacioppo et al., 1996). Cohen et al. (1955) defined the NFC construct as "a need to structure relevant situations in meaningful, integrated ways. It is a need to understand and make reasonable the experiential world" (p. 291). It can thus be assumed that NFC determines the perception of a learning environment and the setting of learning goals. Cognitive GA information helps people with different amounts of NFC to distinguish between content with different cognitive requirements. Based on this, learners with a high NFC can elaborate presented GA information and wiki content more thoroughly, whereas learners with low NFC might avoid effortful thinking. It can be assumed that people with low NFC try to avoid cognitively demanding tasks, whereas people with high NFC consistently engage in and enjoy cognitively challenging activities (Petty et al., 2009) or deep learning activities in general (Cazan & Indreica, 2014). However, both selecting wiki discussion threads involving people with high knowledge and low knowledge could be considered challenging, so the direction of these effects is not clear here. On the one hand, choosing threads with GA information visualizing high group knowledge means that more cognitive effort is needed for potentially highly qualitative group discussions, which is in line with high NFC (Ollesch et al., 2020). On the other hand, people with high NFC should not be inhibited by content that implies cognitively challenging issues and therefore potentially prefer threads with GA information that visualizes a lower group knowledge level in comparison to people with lower NFC (see Cacioppo et al., 1996).

Potential interplay of cognitive and behavioral GATs

Both cognitive and behavioral GATs have shown promising results on both cognitive and behavioral processes and outcomes in isolation. However, the separate provision of these types of GA information does not always lead to an improvement regarding cognitive (e.g., learning performance) and behavioral outcomes (e.g., wiki article quality), even though these are crucial dependent variables when it comes to measuring the success of GAT support in CSCL settings. A possible explanation for this is that both types of information are more likely to unfold their full effect when combined. Single GA indicators may not be able to address all the challenges that learners face in high-level CSCL settings to the fullest extent. While behavioral GA information mainly has the potential to heighten social interaction in general (addressing the behavioral challenge and quantitative behavioral processes), cognitive GA information has predominantly positive effects on content-related decisions and interactions (addressing the cognitive challenge and qualitative cognitive processes), which we concretize in the following.

Behavioral GA information could be beneficial for strengthening the effects of cognitive GA information because it is known to trigger intensified social interaction, which cannot be taken for granted but is seen as a fundamental prerequisite to knowledge construction by socio-constructivist approaches (Bento & Schuster, 2003; Scardamalia & Bereiter, 1994). For high-order thinking skills, active participation or externalization of knowledge is indispensable (Daspit & D'Souza, 2012; Galikyan & Admiraal, 2019). It has already been shown empirically that collaborative writing processes, including active interaction patterns, generate higher-quality texts, can have a positive effect on learning performances (Liou & Lee, 2011; Liu et al., 2018), and help to develop better writing and language skills (Oh, 2014; Storch, 2011). The importance of such behavioral processes in knowledge construction illustrates the potential for using behavioral GA information to trigger behavioral engagement as a supplement to cognitive GA information.

Although behavioral processes in general can stimulate cognitive processes, simple participation does not automatically guarantee the emergence of valuable and highly qualitative cognition as assumed by Piaget (1977) or by the co-evolution model (Cress & Kimmerle, 2008). Rather, interaction frequently refers only to emotional instead of cognitive exchange (Garrison et al., 2000). However, group collaboration requires both behavioral and deep cognitive engagement. Instructional design should therefore also strengthen valuable cognitive processes, such as by using cognitive GA information (Daspit & D'Souza, 2012; Ma et al., 2020). This is very promising because specific individual and group knowledge levels, highlighted by cognitive GA information, might influence the direction of social interaction and help to steer goal setting for wiki writing processes in a certain desirable direction (see Dehler et al., 2011). This might involve discussions with interaction partners who have a higher level of knowledge that is challenging but still within the user's zone of proximal development (see Vygotsky, 1978). The importance of cognitive processes in content and discourse orientation illustrates the potential for using cognitive GA information to trigger cognitive engagement as a supplement for behavioral GA information.

Each form of GA information potentially benefits from the interaction with the other one, since the previously outlined learning processes are essential but cannot be triggered equally by single behavioral or cognitive GA information. Therefore, in studies without or with only slight GAT effects, providing one type of GA information might not have been enough to make learners aware of how much and what kind of content is desirable. We argue that even in studies where such effects have been shown, these could potentially have been enhanced by GAT combinations. We assume that cognitive and behavioral GA information could complement each other positively when presented simultaneously to fulfill the aforementioned wiki potentials and enhance expected outcomes. This is in line with the research of Phielix et al. (2011), who considered and examined the effects of combined GA information, but using a full-tool versus no-tool examination strategy as well as a small group context. For the next step of understanding the behavioral and cognitive functions of GATs and of empowering wiki-based CSCL with GATs, it is essential to systematically disassemble and compare separate and combined effects of cognitive and behavioral GA information. This will help to identify positive, as well as potentially negative, (interaction) effects (see also the review by Ghadirian et al., 2016). Accordingly, hypotheses based on the previous theoretical considerations are derived and presented in the next section.

Hypotheses

Hypothesized single effects of GATs on selection decision (cognitive challenge)

With regard to the cognitive challenge and earlier empirical results, cognitive GA information and especially group knowledge awareness leads to improved topic selection in different contexts (e.g., Dehler et al., 2011; Heimbuch & Bodemer, 2017). We also expect that different levels of group participation influence wiki selection, depending on the individual's intentions. Above, we defined two selection goals that should be considered as the main drivers for actions in a wiki learning environment: the *goal to learn new content* and the *goal to support other collaborators*. Based on these two selection goals, we assume that people with GA support are more focused on selecting threads with a clearer need for

action – involving high and low group knowledge and participation levels – rather than medium levels. The following hypotheses are proposed:

H1.1: With the goal to learn new content, individuals who are supported by cognitive GA information select wiki threads presenting high group knowledge, whereas with the goal to support other collaborators, wiki threads with low group knowledge are preferred.
H1.2: With the goal to learn new content, individuals who are supported by behavioral GA information select wiki threads presenting high group participation, whereas with the goal to support other collaborators, wiki threads with low group participation are preferred.

As outlined in the section on personality influences, a high NFC can potentially be satisfied in group constellations involving both very high and low group knowledge (see Cazan & Indreica, 2014; Cacioppo et al., 1996). Therefore, for H2, we focus on potential moderation effects related to high and low group knowledge awareness presentations, this time without distinguishing between specific selection goals. We derived the following two-sided hypothesis on the influence of NFC on the effects of cognitive GA information:

H2: The effect of cognitive GA information on the individuals' selection of wiki threads presenting (a) high and (b) low group knowledge levels is moderated by NFC.

Hypothesized single effects of GATs on contributing (behavioral challenge)

With regard to the behavioral challenge that has not yet been examined in the social media or wiki context, research suggests that information about the participation amount of other wiki users leads to an alignment of discussion contributions when these are salient on the individual and group level (e.g., Kimmerle & Cress, 2008). We also assume certain effects of cognitive GA information on behavioral engagement, depending on the individual's self-perception as more knowledgeable, which can be beneficial (Dehler et al., 2011) but potentially also non-beneficial (Ray et al., 2013) for behavioural outcomes, leading to the following hypotheses:

H3.1: Individuals who are supported by behavioral GA information match their own number of written discussion contributions to a presented behavioral group mean in comparison to individuals without behavioral GA support.
H3.2: With cognitive GA support, there is a correlation between the individual's presented knowledge and the individual's number of written discussion contributions.

Moreover, it has already been shown that a high need to engage in social comparison can enhance GAT effects on behavioral engagement of learners (Kimmerle & Cress, 2009; Neugebauer et al., 2016). Therefore, we propose:

H4: The effects of (a) cognitive GA information and (b) behavioral GA information on the individual's number of discussion contributions are reinforced by the tendency toward social comparison.

Hypothesized interaction effects of GATs on learning and wiki article quality

As stated above, behavioral and cognitive processes can support each other in collaborative learning settings, which suggests that the interaction of behavioral and cognitive GA guidance, potentially triggering the same processes, should be crucial for increasing learning outcomes and wiki group products, in comparison to providing only one type of support. This goes beyond the simple addition of cognitive and behavioral GA information. We are mainly interested in the interaction effects of both types of information, since our assumption is that they unfold their effects disproportionately or fully if they are presented in combination:

H5: Individuals who are supported by cognitive and behavioral GA information achieve a better learning performance about the wiki topic than individuals who are supported by only one type of GA information.
H6: Individuals who are supported by cognitive and behavioral GA information achieve a higher wiki article quality than individuals who are supported by only one type of GA information.

Exploratory investigations

This section explains the variables collected in the exploratory investigations. Regarding H5 and H6, it could be argued that the joint processing of cognitive and behavioral GA information may be mentally exhausting (see Janssen et al., 2011) and thus cancels out the assumed positive interaction effects of GAT combinations in H5 and H6, especially when they contain subjectively unnecessary information (Janssen & Kirschner, 2020). However, we assume that the positive interaction effects clearly outweigh the potential negative interaction effects based on the presented empirical and theoretical relevance of cognitive and behavioral GA information. To check this, we controlled for the cognitive variable *mental effort* to exclude this as a confounding variable. Moreover, despite focusing mainly on cognitive and behavioral outcomes in this research, we are also interested in whether cognitive and behavioral GAT combinations have a potential positive interaction effect on emotional outcomes, such as the *well-being* of the group, because emotions are part of cognitive and behavioral processes and relevant for intended technology use (Polo et al., 2016).

Methods

Research design

We used a 2 × 2 (cognitive GA information: present vs. absent; behavioral GA information: present vs. absent) factorial between-subjects design to test the hypotheses. There were four experimental conditions: a group without GA support; two groups with either cognitive or behavioral GA support; and a group receiving both. The study was approved by the ethics committee.

Participants

$N = 158$ German participants (116 females, rest males; M age $= 22.89$, $SD = 4.90$, 17–59 years) took part in the study, which lasted 1 to 1.5 h. Most participants (93%) were students in study programs unrelated to the topic, with the rest being in employment. Some participants were randomly assigned to the control condition ($n = 38$), others were assigned to the cognitive ($n = 41$) and behavioral GA ($n = 41$) conditions, while the rest were assigned to the combination condition ($n = 38$).

Learning environment

Learners were provided with a self-designed wiki environment. We initiated an objective work-in-progress wiki article on energy sources. Participants were also provided with a wiki discussion forum, including additional arguments for and against different types of energy (e.g., solar energy, wind energy, etc.), given by a bogus group. In each thread of the discussion forum, two bogus collaborators were involved: one person in favor of the respective energy form and another person against the respective energy form. GA information was presented as horizontal bars in the discussion forum in the header (individual and whole group level) as well as next to the 12 discussion threads (subgroup level). Figure 1 shows the wiki discussion forum for the combination condition, which was provided with cognitive GA information (yellow knowledge bars) and behavioral GA information

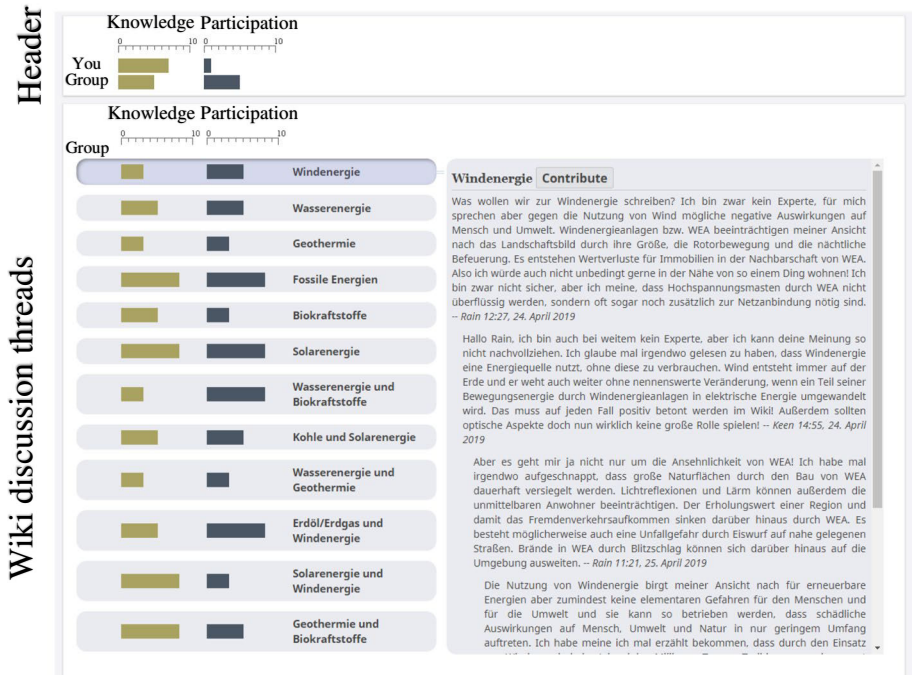

Fig. 1 Extract from the discussion forum with *individual* and *whole group* GAT levels in the header and *subgroup* GAT levels next to the discussion threads (partially translated in English)

(blue participation bars). To eliminate sequence effects, the order of individual and group knowledge/participation bars was horizontally randomized across participants. We used "standard colors", which are not especially eye-catching (Few, 2006). The wiki article contained no GA visualizations.

Presentation of cognitive and behavioral GA information on individual level

Concerning individual level awareness information, the participants' individual GA information was presented in the header. This "You"-row was initially without an entry but was measured and adjusted accurately during the course of the study, leading to naturally occurring differences between participants.

The individual knowledge bar was adjusted after taking part in a knowledge pretest. In order to make the pretest neither too difficult nor too easy, a pilot study was conducted in advance, which comprised $N = 55$ participants (37 females, 16 males, 2 diverse; M age = 28.42, $SD = 8.40$, 20–62 years). The aim was to select suitable items of medium difficulty from a predefined set of 25 single-choice items on energy sources with four answer options each. Most participants (55%) were students, the others were in employment. As criteria for the item selection, the items should result in a score of ≈ 5 and should cover a wide range of the energy topics. This resulted in 10 items for which 10 points could be achieved, with a mean test score of $M = 5.29$ ($SD = 1.57$). Hence, there was a 10-step knowledge scale. Those items were mainly fact-based – that is, they asked for facts, such as "What is the efficiency of hydropower?". An example for an adjusted individual knowledge bar with a final score of 7 points (= 7 correct answers) can be seen in the header's "You"-row in Fig. 1.

The individual participation counter was adapted dynamically during the collaboration. It went up by one every time a new discussion contribution was written. An example for an adjusted individual participation bar after one discussion contribution can be seen in the header's "You"-row in Fig. 1.

Presentation of cognitive and behavioral GA information on group level

Even if the participants were not informed about it, the different levels of cognitive and behavioral GA information at whole and subgroup level were experimentally varied before the experiment started. For reasons of complexity, a distinction was only made between discussion threads visualizing low (counter on 2), medium (counter on 5), and high (counter on 8) subgroup average knowledge and/or participation. Concerning group level awareness information, the knowledge bar in the header next to "Group" represented the average overall group knowledge of the whole group involved in the wiki environment/discussion forum, based on the total score of the aforementioned knowledge pretest. The participation bar in the header next to "Group" represented the average group contribution frequency of the whole group in the discussion forum in an aggregated form. Below, next to the respective discussion threads, the same visualizations were shown in a non-aggregated form. These GA visualizations referred to subgroups of the whole group and indicated the extent of participation and knowledge of the respective group members involved in threads like "Windenergie" (wind energy), in this case with low subgroup knowledge and medium subgroup participation (see Fig. 1).

Regarding the different levels of knowledge, discussion threads differed in terms of the bogus contributors' own expertise assessment and the number of sources they used. In threads with low subgroup knowledge (small knowledge bar), collaborators were novices and did not use any sources (e.g., "[…] I am not an expert, but for me, the potential negative effects on people and the environment speak against the use of wind energy. […]"). In threads visualizing medium subgroup knowledge (medium knowledge bar), collaborators were very well-read or interested in the area and used only one source each (e.g., […] "I have read quite a bit on the subject of biofuels. According to Source x, biofuels have so far proven to be very inefficient and also represent for only about 10 percent of mankind an important source of energy. […]"). In threads with high subgroup knowledge (large knowledge bar), both collaborators indicated that they worked in a relevant area of the energy industry and used two sources each (e.g., […] I work for a large energy company and think we should emphasize the good availability of silicon. It is the preferred material for crystalline solar cells according to Source a. According to Source b, the earth's crust consists of about 25.8 percent silicon […]"). None of the threads contained false or irrelevant information. Participants were told that this knowledge variation at the group level was based on the total score of the 10-items pretest, which they also took part in before the wiki collaboration.

Regarding the different levels of participation, discussion threads differed in terms of the number of contributions by the bogus collaborators. There were threads with low average subgroup participation (2 discussion contributions), medium average subgroup participation (5 discussion contributions), and high average subgroup participation (8 discussion contributions). In order to keep the visualization of knowledge and participation GA information equal, a scale of 0-10 was chosen here as well. Participants were informed that the group member who contributed most had made 10 contributions (which was actually possible, derived from pilot testing).

Editing phases

The editing consisted of three phases, which all participants went through, regardless of the respective assigned condition. GAT effects were examined systematically at selection, discussion, and article levels (see Fig. 2). In the *selection phase*, participants were provided with the discussion forum (see Fig. 1). Only the wiki topics and the GA information were visible, depending on the different conditions. The actual discussion content was not yet revealed. For participants in the cognitive GAT condition, their individual knowledge bar

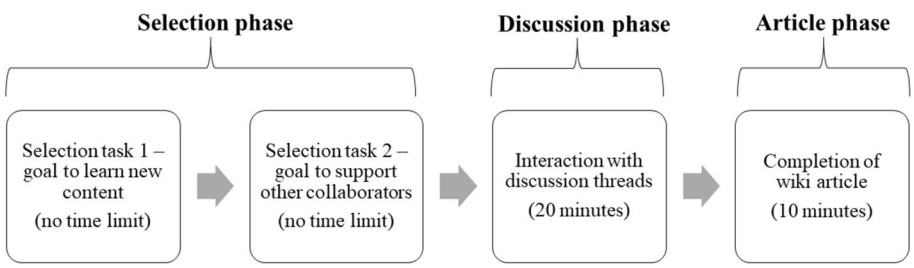

Fig. 2 Procedure of the editing phases for all participants (within steps)

was adjusted in this phase based on the pretest. As assessment of the participants' intention behind specific thread selections (see H1.1 and H1.2) was difficult later in the study, the selection tendencies were examined in detail during the selection phase. This phase consisted of two selection tasks (STs), queried in succession, in which selection tendencies were systematically examined for learning and supporting goals. All participants were asked to choose the three preferred threads (out of 12) they would most likely select based on the two subsequent scenarios. In ST1, they were asked to engage in using the wiki discussion forum with the goal to learn new content. In ST2, they were asked to engage in using the discussion forum with the goal to support other collaborators in solving their controversies.

The second 20-min *discussion phase* was about interacting with the discussion page. In this phase, participants were free only to read the content and learn from it or to write their own contributions to the discussion forum to solve bogus collaborators' controversies. They were not instructed to support others or share their knowledge. Discussion contributions were restricted to contain a word count of 30–100 words in order to be sent. For participants in the behavioral GA condition, their individual participation bar was updated in this phase. In the last 10-min phase, the wiki article should be supplemented with arguments from the discussion forum. This *article phase* contained only the wiki article rather than any kind of GA information. Kimmerle et al. (2017) recently identified different stages of collaborative activities during text development, starting with individual knowledge sharing, leading to a mutual restructuring phase, and finally the expression of a shared opinion. Since our work is primarily concerned with the contribution that the individual makes to the group and no actual reaction occurs, our research can be located in the knowledge-sharing phase.

Measures

To answer H1.1 and H1.2 (concerning selection preferences), we measured the proportion of selected threads presenting high, medium, and low group knowledge, as well as presenting high, medium, and low group participation, relative to the total number of threads in both STs (goal to learn new content and goal to support other collaborators). This resulted in 12 variables (six variables each ST).

To measure NFC (H2a and H2b), the NFC subscale of the German Rational-Experiential Inventory (Epstein et al., 1996) by Keller et al. (2000) was used ($\alpha = 0.87$; 14 items measured on a seven-point Likert scale, ranging from 1 = "completely incorrect" to 7 = "completely true"). An example item is: "I would rather solve a task that requires intelligence, is difficult and significant than a task that is somehow important but does not require much thought." Two mean values for thread preferences were determined from STs 1 (goal to learn new content) and 2 (goal to support other collaborators): one for the selection preference of high group knowledge, the other for the selection preference of low group knowledge across both STs.

To answer H3.1 and H3.2 (concerning the number of discussion posts), the number of total discussion contributions was counted.

The tendency toward social comparison (H4a und H4b, concerning personal influences) was surveyed with the German version of the Iowa-Netherlands Comparison Orientation Measure (COM; Jonas & Huguet, 2008) ($\alpha = 0.84$; 11 items answered on a seven-point Likert scale, ranging from -3 = "I don't agree at all" to 3 = "I totally agree"). An example item is: "I always pay a lot of attention to how I do things compared to others."

To answer H5 (concerning learning-related variables), we used a posttest consisting of 24 single-choice items: 10 fact-based items were identical to the pretest, to which we added 14 argument-based items. The latter were mainly related to pro and contra arguments regarding different energy types, derived from the discussion forum, such as "What are the arguments against using biofuels?". A total sum score was calculated for the whole posttest with the number of correctly answered questions and the learning gain for the 10 identical fact-based items of the pretest and posttest.

To answer H6 (concerning article quality), we analyzed the word count, the argument count, and the balance of new pro and contra arguments in the article. Since the task was to add new content from the discussion forum to the article, it was assumed that more content or a higher article productivity also implied higher quality. Arguments were considered as new if they contained new and correct information not yet included in the article, such as "An argument against the use of water for energy production is that it would involve interfering with nature, such as by constructing reservoirs, which would affect humans and animals.". Eight overall categories were defined as being analogous to the respective topics contained in the text: fossil energy, nuclear energy, renewable energy, wind energy, hydro energy, solar energy, biofuels, and geothermal energy. The following subcategories were created for each topic: *contra argument*, *pro argument*, and *additional information*. The latter was almost never the case, as it was the participants' task to complement the article with pro and contra arguments from the discussion forum. One coder encoded all records, and 10% of records were initially counter-encoded by a second coder with an almost perfect interrater reliability of Cohen's $\kappa = 0.83$. After a discussion among the researchers, the rest were further finalized by the first coder. To calculate the argument balance, two categories were created. Code 1 was assigned when there was at least one pro and one contra argument for a topic; otherwise, a code of 0 was assigned. The sum score of all codes was then divided by all thread topics contained in the article to evaluate whether people wrote balanced articles on average.

Mental effort was measured with a German translation of Paas's (1992) one-item scale ("In solving or studying the preceding problem I invested"; 1 = "very, very low mental effort" to 9 = "very, very high mental effort"). Well-being was measured with the German version of Lang and Bachinger's (2017) Well-being scale ($\alpha = 0.89$; 14 items answered on a five-point Likert scale, ranging from 1 = "none of the time" to 5 = "all the time"). An example item is: "I've been feeling good about myself." The scores for COM, NFC, and well-being were calculated from the corresponding questions in the questionnaire. In the case of mental effort, we calculated an overall mean score from three measuring points ($\alpha = 0.76$).

Procedure

Before the study began, participants received information about it and signed a consent form. During the study, participants were provided with a scenario about working together with other people on a wiki article on energy sources, which would be evaluated and also serve as a test preparation. Participants who were in the different GA conditions additionally received an explanation of the function of the knowledge and/or participation bars, but without being explicitly told how to deal with such GA information. The main procedure was as follows:

(1) After an initial five-minute wiki article reading phase, (2) all participants completed the aforementioned 10-items pretest. (3) Then, the actual editing commenced, consisting of the three phases (see Fig. 2). (3.1) In the selection phase, all participants went through the

two STs (with a goal to learn new content and a goal to support other collaborators). For participants supported with cognitive GA information (cognitive GA and combination conditions), their individual knowledge bar was adjusted at this point based on the score they achieved. (3.2) In the discussion phase, some participants (behavioral GA and combination conditions) were provided with an adaptive individual participation bar. In this phase, there was no specific focus on whether cognitive (reading) or behavioral activities (contributing) were preferred. (3.3) In the article phase, the wiki article on energy sources was edited. Mental effort (Paas, 1992) was measured directly after each editing phase. After the editing phases, all respondents filled out the well-being scale (Lang & Bachinger, 2017), the posttest, the COM (Jonas & Huguet, 2008), and the NFC scale (Keller et al., 2000), before being debriefed.

Eye-tracking investigation

We were interested in the participants' visual attention on different elements in our learning environment, because this provides an insight into participants' consideration of our GA visualizations and further underlying attentional processes. Visual attention is understood as the process of selecting and concentrating on stimuli of interest, and hence the processing of characteristics to which attention is paid more deeply (Goldstein, 2008). This is relevant as people never perceive the whole scene or learning environment; rather, only a fraction of the available visual information is processed. The actual processing of visual information only takes place when there is a persistent fixation – in other words, when the gaze remains in a certain position for a quarter or half a second. Saccades represent the eye movements or "jumps" between fixations (Manhartsberger & Zellhofer, 2005). Since humans have only a limited processing capacity, attention processes are directed to subjectively important aspects, something we wanted to disclose for our setting.

To investigate the impact of cognitive and behavioral GA visualizations on visual attention, a further $N=20$ participants (11 females, M age $=22.45$, $SD=3.59$, 18–30 years) were recruited (five participants for each condition). The number was small because of the limited eye-tracking equipment. Moreover, via visual observations, we found that participants' behavior was inhibited by the eye-tracking procedure. They received further eye-tracking-related instructions, which potentially interfered with their natural interaction behavior. The distribution of attention in the learning environment was recorded and examined via Tobii Pro Spectrum. Participants were positioned at a distance of about 70 cm from the screen and were instructed to move as little as possible during editing. To increase recording accuracy, eye movements were calibrated with a nine-point calibration technique before the editing phases. The aim of this was to adjust the eye tracker to the participants' eyes. Lighting conditions were kept as similar as possible for each participant.

Results

For H1.1 and H1.2, we used ordinal regression analyses because of the ordinal selection variables. For H2a/H2b and H4a/H4b, we used the PROCESS macro v3.4 for SPSS to run moderation analyses. Extreme outliers (three interquartile distances away from the upper/lower quartile) were removed in all regression-based procedures. We mainly calculated 2×2 ANOVAs (H5, H6, and exploratory calculations on mental effort and well-being) to check for significant *interaction terms* (involving the factors *cognitive GA* and *behavioral*

GA information). For H3.1, we were particularly interested in the *behavioral GA* information effects. In most cases, a normal distribution was not given for the dependent variables of the ANOVAs (Shapiro–Wilk test; $p < 0.05$), and bootstrapping (10,000 samples) was applied. To test H3.2, a bivariate correlation was applied. A significance level of $\alpha = 0.05$ was defined for all procedures. Tests for directional hypotheses were one-sided.

Impact on selection (hypotheses 1 and 2)

In H1.1 and H1.2, we assumed that the availability of GA information has an impact on the preference of threads visualizing different levels of GA information, depending on the selection goal (variables derived from ST1 and ST2). To check if there was a difference between persons with respective cognitive or behavioral GA support and those without GA support, we calculated ordinal regression analyses with the factors *cognitive* or *behavioral GA information* (single factor models). To test the hypotheses, we report the following selection effects: cognitive GAT effects on the selection of high/medium/low group knowledge wiki threads in comparison to no cognitive GA support (H1.1), and behavioral GAT effects on the selection of high/medium/low group participation wiki threads in comparison to no behavioral GA support (H1.2). In total, we conducted 12 regression analyses (support conditions were used as a baseline here), because there were two STs (goal to learn new content and goal to support other collaborators) and six dependent variables. The $\chi 2$ tests for the whole model fits of all regression analyses (step 1) are reported in Table 1.

In the following (step 2), we provide only the parameter estimates (*b*) for ordinal regression analyses showing a significant $\chi 2$ test (see Table 1) to determine the direction of effects. In H1.1, we assumed that the selection frequency of wiki threads presenting different group knowledge levels is influenced by the provision of cognitive GA information. Ordinal regression analysis shows that when the goal was to learn new content (ST1), learners supported with cognitive GA information were more likely to select threads

Table 1 $\chi 2$ tests related to differences in selection preference of threads involving low, medium, and high group knowledge (k.) and participation (p.)

		$\chi 2$	*df*	*p*	R^2	*M (SD)%*	*M (SD)%*
Cognitive GA information						Present	Absent
Low k.	*1*	14.07	1	< 0.001	0.11	19.83 (22.34)	31.25 (15.57)
	2	2.74	1	0.098	0.02	41.35 (35.09)	30.05 (20.44)
Medium k.	*1*	15.54	1	< 0.001	0.12	14.77 (19.79)	28.17 (21.56)
	2	7.56	1	0.006	0.06	28.24 (22.14)	37.09 (20.74)
High k.	*1*	29.04	1	< 0.001	0.19	65.40 (30.40)	39.81 (23.50)
	2	1.04	1	0.308	0.01	29.54 (29.23)	32.41 (22.36)
Behavioral GA information						Present	Absent
Low p.	*1*	5.35	1	0.021	0.04	16.88 (23.79)	25.32 (25.72)
	2	0.06	1	0.812	< 0.001	31.22 (37.49)	26.16 (21.79)
Medium p.	*1*	1.48	1	0.224	0.01	31.05 (23.78)	35.19 (21.59)
	2	12.95	1	< 0.001	0.09	24.47 (25.99)	37.55 (21.59)
High p.	*1*	6.49	1	0.011	0.05	51.48 (30.57)	39.91 (19.21)
	2	1.60	1	0.205	0.01	44.30 (34.89)	36.29 (21.48)

The first line of each cell represents ST1 (goal to learn new content), the second line represents ST2 (goal to support other collaborators)

with GA visualizing high group knowledge (Wald's $\chi2(1)=26.56$, $p<0.001$, $b=1.71$, $Exp(B)=5.54$) and less likely to select threads with GA information visualizing low group knowledge (Wald's $\chi2(1)=13.13$, $p<0.001$, $b=-1.29$, $Exp(B)=0.28$) in comparison to learners without cognitive GA support. They were also less likely to choose threads with medium group knowledge in comparison to participants without cognitive GA support (Wald's $\chi2(1)=14.75$, $p<0.001$, $b=-1.28$, $Exp(B)=0.28$). However, when the goal was to support other collaborators (ST2), the provision of cognitive GA information did not make a significant difference regarding the selection of threads with GA visualizing high group knowledge or with GA information visualizing low group knowledge in comparison to learners without cognitive GA support (see Table 1). On the other hand, there was a significant effect on the number of selected threads with GA visualizing medium group knowledge. Here, participants with GA support were less likely to choose threads with medium group knowledge in comparison to participants without cognitive GA support (Wald's $\chi2(1)=7.20$, $p=0.007$, $b=-0.96$, $Exp(B)=0.38$). In summary, it can be stated that the provision of cognitive GA information had an effect on selection (clearer in ST1, goal to learn new content). Participants with cognitive GA support were more focused on "relevant" or high GAT levels with a learning goal (ST1), as stated in H1.1.

In H1.2, we assumed that the selection frequency of wiki threads with different group participation levels is influenced by the provision of behavioral GA information. Ordinal regression analysis shows that when the goal was to learn new content (ST1), the provision of behavioral GA information made a significant difference regarding the selection of threads with GA visualizing high group participation, in favor of the behavioral GA support condition (Wald's $\chi2(1)=6.34$, $p=0.012$, $b=0.81$, $Exp(B)=2.24$), as well as threads with GA information visualizing low group participation, here in favor of the control condition (Wald's $\chi2(1)=5.26$, $p=0.022$, $b=-0.71$, $Exp(B)=0.49$). However, there was no effect on threads with GA visualizing medium group participation (see Table 1). When the goal was to support other collaborators (ST2), the provision of behavioral GA information made a significant difference regarding the preference of medium group participation threads, in favor of the control condition (Wald's $\chi2(1)=12.40$, $p<0.001$, $b=-1.10$, $Exp(B)=0.33$). There were no significant differences regarding low and high group participation threads (see Table 1). Although the provision of behavioral GA information did not produce such clear effects as the provision of cognitive GA information, there were interesting effects, partially supporting H1.2.

To better understand the influence of NFC on selected threads visualizing high (H2a) and low (H2b) group knowledge, two moderator analyses were conducted. In our moderator analysis, NFC represented the moderator, cognitive GA information was the predictor, and (a) selection preference of high group knowledge threads and (b) selection preference of low group knowledge threads were the respective criteria for the two analyses. The calculations revealed no significant interaction effects for NFC and the cognitive GA factor on selection preference of high group knowledge threads ($\beta=-0.01$, $t(141)=-0.09$, $p=0.930$) and low group knowledge threads ($\beta=0.06$, $t(145)=0.78$, $p=0.433$), thus refuting H2a and H2b.

Impact on number of discussion posts (hypotheses 3 and 4)

Concerning H3.1, a 2×2 ANOVA shows the expected positive main effect for the factor behavioral GA information ($F(1, 154)=64.50$, $p<0.001$, $\eta^2_p=0.30$; further single/interaction GAT effects were absent; see Table 6 in the Appendix). People with behavioral

GA support wrote approximately two more contributions to the discussion forum (without being instructed to do so) than people without behavioral GA support (no support: $M = 1.74$, $SD = 1.75$; behavioral GA: $M = 3.63$, $SD = 1.22$).

Concerning H3.2, we applied a two-sided bivariate correlation to examine if there was a relationship between the presented individual knowledge score and the number of written discussion posts. Because the focus here was on the effects of cognitive GA information, only people who received knowledge bars were included in the calculations. We found a small positive correlation ($r(79) = 0.25$, $p = 0.029$), supporting H3.2. Participants wrote more discussion posts when the cognitive GAT presented a higher individual knowledge score.

To better understand the influence of the tendency toward social comparison processes on the effect of the factors of cognitive GA information (H4a) and behavioral GA information (H4b) on the number of discussion contributions, we conducted two moderator analyses. In these moderator analyses, the tendency toward social comparison processes represented the moderator, the cognitive or behavioral GA information factors were the predictor, and the number of discussion contributions was the criterion. However, there was no significant interaction effect between cognitive GA support and tendency to comparison ($\beta = 0.03$, $t(153) = 0.33$, $p = 0.373$). Also, the interaction of behavioral GA support with tendency toward social comparison did not explain a significant proportion of the number of discussion contributions ($\beta = 0.07$, $t(153) = 1.02$, $p = 0.154$). H4a and H4b are not supported.

Interaction effects on learning (hypothesis 5)

Before we checked H5 or the interaction effects on learning outcomes, we examined whether there were differences in the first pretest score. The descriptive pretest scores (10 points for 10 correct answers) are as follows: no support – $M = 4.66$ ($SD = 1.84$); cognitive GA support – $M = 4.73$ ($SD = 1.61$); behavioral GA support – $M = 4.85$ ($SD = 1.74$); and combined support – $M = 5.16$ ($SD = 1.22$). A 2×2 ANOVA shows that the cognitive GA information factor ($F(1, 154) = 0.54$, $p = 0.465$, $\eta^2_p = 0.003$), the behavioral GA information factor ($F(1, 154) = 1.45$, $p = 0.230$, $\eta^2_p = 0.01$), and their interaction ($F(1, 154) = 0.20$, $p = 0.656$, $\eta^2_p = 0.001$) did not become significant; hence, potential effects of prior knowledge could be excluded.

For the main calculations of H5, we were interested in the interaction effects of cognitive and behavioral GA information regarding the learning performance variables. For descriptive values, see Table 2. Here, the means show that a slight superiority of combined GA support is recognized.

Although the descriptive values are always slightly in favor of the combination condition, neither the interaction effects for the whole posttest score ($F(1, 154) = 1.84$, $p = 0.178$, $\eta^2_p = 0.01$) nor the learning gain ($F(1, 154) = 0.02$, $p = 0.903$, $\eta^2_p < 0.001$) became significant. Further single GAT effects were also absent (see Table 6 in the Appendix).

Table 2 Descriptive statistics (M (SD)) of the learning variables

	No Support	Cognitive GA	Behavioral GA	Combination
Posttest score	13.05 (4.34)	12.88 (3.74)	13.17 (2.89)	14.50 (2.75)
Learning gain	0.95 (1.89)	1.24 (2.34)	1.17 (1.60)	1.40 (1.50)

A repeated-measure analysis shows that there was a general learning gain (improvement of fact-based items between pretest to posttest) across all conditions ($F(1, 157) = 65.00$, $p < 0.001$, $\eta^2_p = 0.29$) from $M = 4.85$ ($SD = 1.62$) points to $M = 6.04$ ($SD = 1.77$) points. The interaction with our created wiki environment thus generally led to an improvement in learning, even when it was independent of GA manipulation.

Interaction effects on article quality (hypothesis 6)

As assumed in H6, a 2×2 ANOVA reveals that there were positive interaction effects on (a) article word count ($F(1, 154) = 4.17$, $p = 0.043$, $\eta^2_p = 0.03$), (b) argument count ($F(1, 154) = 18.31$, $p < 0.001$, $\eta^2_p = 0.11$), and (c) argument balance ($F(1, 154) = 5.07$, $p = 0.026$, $\eta^2_p = 0.03$), however, the latter was low in all conditions (possible maximum value = 1). For interaction plots, see Fig. 3. Further single GAT effects (see Table 6 in the Appendix) are not interpreted because of the significant interaction terms.

To show that each form of GA information benefits when the other one is added, we calculated two post-hoc simple effect analyses for each dependent variable, using cognitive or behavioral GA information as a predictor. The results reveal the visual trends and show that the single presence of knowledge or participation awareness information did not make a significant difference on (a) word count, (b) argument count, and (c) argument balance, in comparison to the control condition. Only in combination are significant positive effects in evidence (see Table 3). Thus, H6 is supported.

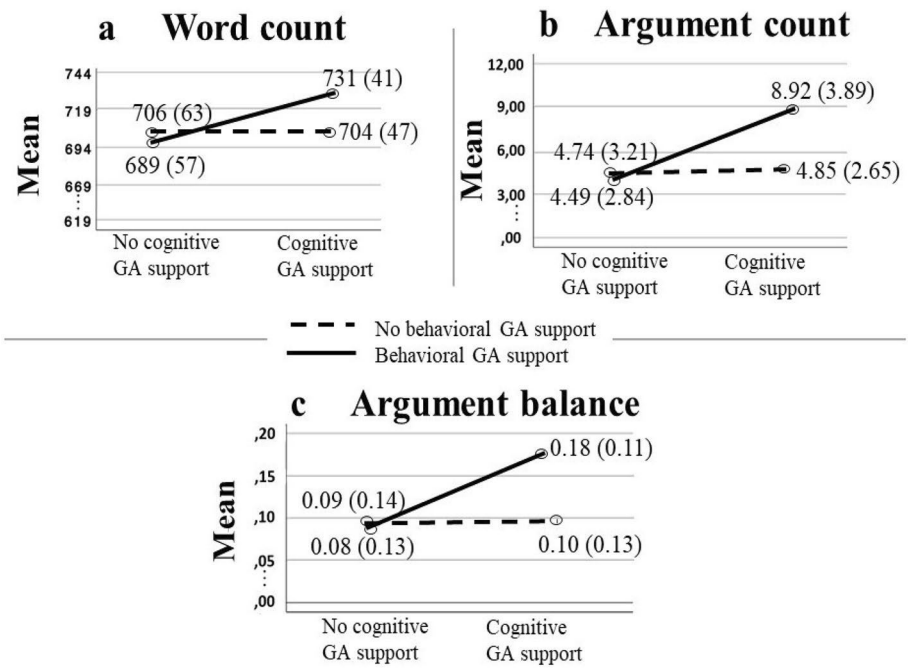

Fig. 3 Interaction plot (M (SD)) of article word count, argument count, and argument balance

Table 3 Post-hoc simple effect analyses for article quality

Dependent Variable	Predictor	Factor levels	*df*	*F*	*p*
Word count	Behavioral GA	No Cognitive GA	1, 154	0.42	0.519
		Cognitive GA	1, 154	5.02	0.027
	Cognitive GA	No Behavioral GA	1, 154	0.02	0.885
		Behavioral GA	1, 154	7.52	0.007
Argument count	Behavioral GA	No Cognitive GA	1, 154	0.12	0.727
		Cognitive GA	1, 154	32.51	< 0.001
	Cognitive GA	No Behavioral GA	1, 154	0.03	0.870
		Behavioral GA	1, 154	38.62	< 0.001
Argument balance	Behavioral GA	No Cognitive GA	1, 154	0.12	0.729
		Cognitive GA	1, 154	8.05	0.005
	Cognitive GA	No Behavioral GA	1, 154	0.04	0.847
		Behavioral GA	1, 154	11.40	0.001

Exploratory analyses

Due to the missing positive interaction effects for the learning variables, it can be assumed that an increased mental effort or decreased well-being played a role here (see "Exploratory investigations").

No significant interaction effect was found for the 2×2 ANOVA concerning the overall mental effort ($F(1, 154) = 0.79$, $p = 0.376$, $\eta^2_p = 0.01$). However, the 2×2 ANOVA relating to well-being revealed a significant interaction effect ($F(1, 154) = 5.87$, $p = 0.017$, $\eta^2_p = 0.04$); see Fig. 4. Further single GAT effects were absent for both dependent variables (see Table 6 in the Appendix).

Post-hoc simple effect analyses show that the single presence of cognitive or behavioral GA information made a significant positive difference on well-being. However, in

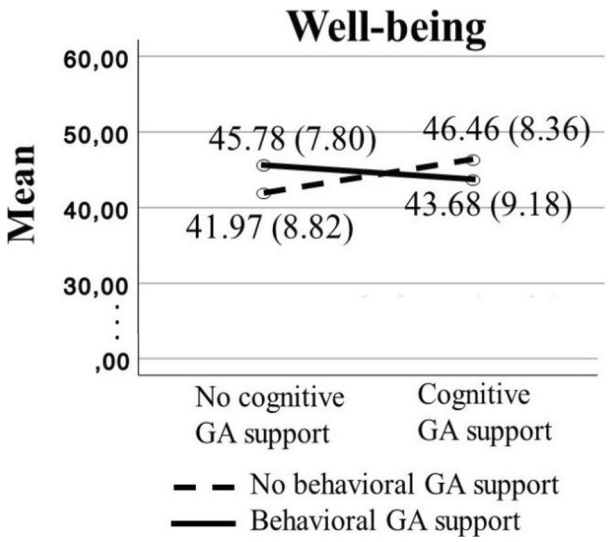

Fig. 4 Interaction plot (*M* (*SD*)) of well-being

Table 4 Post-hoc simple effect analyses for well-being

Dependent Variable	Predictor	Factor levels	*df*	*F*	*p*
Well-being	Behavioral GA	No Cognitive GA	1, 154	3.92	0.049
		Cognitive GA	1, 154	2.09	0.150
	Cognitive GA	No Behavioral GA	1, 154	5.45	0.021
		Behavioral GA	1, 154	1.19	0.227

combination these positive effects were not significant, neither with knowledge nor participation awareness information as a predictor (see Table 4).

Eye-tracking results

To examine visual attention in our wiki environment, we chose the relative duration time as a measurement metric, because none of the editing phases contained an automatic forwarding. After the respective time frames, participants were asked to go to the next page. They proceeded independently, so the absolute duration times were slightly different for each participant. To ascertain which elements attracted the most attention, the following areas of interests (AOIs) were defined for the selection phase (including both STs; goal to learn new content and goal to support other collaborators) and discussion phase: *topics*, *cognitive GA bars*, and *behavioral GA bars*. Header bars (individual and whole group level) and wiki thread bars (subgroup level) were included together; see Fig. 1 as a reference. The article phase was not considered as it contained no GA information. The folded *text field* in the discussion phase (see Fig. 1, right side) was also not defined as an AOI in the first step or for the duration time. Most of the focus on it was during the discussion phase, which was not included in the selection phase, and thus including it would have made the further duration times uninterpretable.

Table 5 Duration time on area of interests (in %)

	Topics		Knowledge bars		Participation bars	
	M	*SD*	*M*	*SD*	*M*	*SD*
Selection phase						
No Support	100.00	0.01	N/A	N/A	N/A	N/A
Cognitive GA	72.12	17.68	27.88	17.68	N/A	N/A
Behavioral GA	82.70	4.52	N/A	N/A	17.30	4.52
Combination	44.36	9.87	32.84	8.10	22.80	6.55
Discussion phase						
No Support	100.00	0.00	N/A	N/A	N/A	N/A
Cognitive GA	95.82	1.87	4.18	1.87	N/A	N/A
Behavioral GA	84.69	5.29	N/A	N/A	15.30	5.29
Combination	83.91	5.42	10.96	6.47	5.13	3.67

Due to rounding, the total is not always exactly 100%. N/A: No data available

Independently of all conditions and editing phases, the thread topics received the most attention out of the three defined AOIs (see Table 5). In the control condition, this was 100% because there was no GA support at all. Moreover, both types of GA information received considerably more attention in the selection phase, especially in combination, than in the discussion phase. Furthermore, (individual and group) knowledge bars received more attention than (individual and group) participation bars in the selection phase (see Table 5). In the discussion phase, participation bars got more attention than knowledge bars in separate GA support conditions, whereas it was the other way around in combination.

In order to derive further insights into attention processing, the share of the total saccade amount between all AOIs was considered (see Table 7 in the Appendix). This time, the *text field* was included as a further AOI. Saccade results indicated that there was more switching between the wiki thread topics and the text field (especially in the discussion phase), whereas GA information was given relatively little attention, thus supporting the results of the duration times. However, in the selection phase attention was more distributed with combined GA information, with more saccades between participation and knowledge bars.

Discussion

The aim of the reported study was to uncover potential individual effects of providing learners with cognitive and behavioral GA information, as well as investigating the interaction of both types of GA information in a wiki context.

Main results

The results of our study reveal that both cognitive (H1.1) and behavioral (H1.2) GA information have certain effects on selection. Especially with the goal to learn new content (ST1), threads involving much group knowledge as well as group participation are preferred when there is GA support. H1 is, therefore, partly supported. Related to the number of written discussion threads (H3.1), behavioral GA information leads to a stronger alignment of engagement. Moreover, people for whom the GAT displayed more individual knowledge were more motivated to support other people in resolving content-related conflicts (H3.2). H3 is, therefore, fully supported. With regard to the assumed effects of the influencing variables (H2a/b and H4a/b), no significant effects could be found. Therefore, H2 and H4 are not supported. With respect to the assumed positive interaction effects on learning performance (H5) of behavioral and cognitive GAT combinations, we were not able to show significant results. Thus, H5 is not supported. However, there were positive interaction effects for article productivity (word count, argument count) and argument balance (H6), which were our defined metrics for article quality. Participants from the combination condition scored best here. H6 is, therefore, fully supported.

Single effects on cognitive challenge

With regard to selection decisions or the cognitive challenge, both H1.1 and H1.2 are partially supported. When the intention was to use the wiki threads as a learning material (ST1), people with cognitive GA support preferred threads involving high levels of group knowledge. This is in line with the study of Dehler et al. (2011), who found that learners

are more likely to ask for explanations if their learning partners know more than they do. Selection effects of behavioral GA information have not been systematically investigated in prior studies, but our research shows that there were indeed behavioral GAT effects for ST1 (goal to learn new content) in favor of high group participation threads. These are not unexpected, because high participation or the availability of many contributions can mean that there is much content to learn. In terms of supporting others (ST2), however, the effects are not clear for either type of GA information. This may be due to the fact that we only presented GA information without any action recommendations to the learners. Thus, some participants might have associated low group knowledge with a need to support, whereas other participants saw high group knowledge as an incentive to engage in and support higher-quality discussions. Similarly, low group participation may indicate a need for support, but a high level of participation might also have signaled heated discussions or a high potential for conflicts, which increased the need for support. Since GA information only provides implicit incentives (Janssen & Bodemer, 2013), it can be interpreted in different ways. Therefore, it would be interesting to examine how participants behave when telling them the expected use of GA information, such as by enhancing GA usage with scripting (see Tsovaltzi et al., 2014). To sum up, our results show that cognitive GATs in wikis have the potential to overcome the cognitive challenge in wiki-based learning by helping to focus on meaningful content (Ollesch et al., 2019). Moreover, behavioral GA support can have some valuable effects here, which is a new insight.

For H2a/b, we had assumed that NFC would influence the effect of cognitive GA information on selected threads presenting high and low group knowledge. However, this was not statistically supported. Think-aloud protocols could be useful for gaining a more precise idea of what kind of threads are considered more cognitively strenuous and why.

Single effects on behavioral challenge

With regard to discussion contributions or the behavioral challenge, both H3.1 and H3.2 were supported. Participants who saw individual and group participation bars wrote two more discussion contributions in 20 min than those without these participation bars. This is a large difference considering the short time slot, and it aligns with the findings of Kimmerle and Cress (2008) and Janssen et al. (2011). Therefore, behavioral GA information can be shown to contribute to overcoming the behavioral challenge in wiki-based learning. With regard to cognitive GA information, it was not clear in advance what effect this would have on discussion engagement, especially for persons with high individual knowledge. We were able to show that people with more knowledge presented also wrote more supporting discussion posts, so cognitive GA information did indeed address the behavioral challenge in wikis. However, for those with less individual knowledge presented, the trend is more likely to go in the opposite direction.

For H4a/b, we assumed that the tendency toward social comparison processes would increase the GAT effects (Neugebauer et al., 2016). This tendency was not significant for the behavioral GA condition, possibly because the behavioral GAT effects were generally already strong (see H3.1) so that individual differences did not make a big difference. Furthermore, real or synchronous interactions instead of bogus interactions might have increased the effects for both types of GA information.

Interaction effects of cognitive and behavioral GA information

Regarding the interaction effects on the learning-related variables (whole posttest and learning gain), the results for H5 were not significantly supported. There was a general increase in learning related to fact-based items from the pretest to the posttest. This means that the interaction with the wiki content per se was beneficial. However, we originally assumed that the effects for behavioral and cognitive GA information combinations would be stronger than found in this study (Ollesch et al., 2019). We expected that cognitive GA information would help indicate unequal knowledge levels within the group and thus trigger beneficial socio-cognitive conflicts (Bell, 2004), and that behavioral GA information would help verbalize and internalize new content more deeply (Garrison et al., 2000; Webb, 1991). It is possible that a learning superiority was not that clear because of the time limit of 20 min in the discussion phase, leading to the content being dealt with rather superficially. Since the instructions for the discussion phase were open, it would have been interesting to expand the engagement time and define the learning purpose more clearly, thereby possibly identifying stronger learning differences between those conditions.

With respect to article quality, our findings clearly show a positive interaction effect or that, on average, significantly more new words and arguments were added when both types of GA information were provided, which supports H6. Blumenstock (2008) suggested quantitative metrics like word count as good predictors of highly qualitative wiki articles in comparison to other more complicated methods. Additionally, participants in the combination condition wrote on average more balanced wiki articles – that is, they inserted both pro and contra arguments regarding one topic into the whole article – which also supports H6. This finding should be looked at more deeply in the future; however, it provides an initial indication that participants in the combination condition not only added more words and arguments, but also argued in a more balanced way, even though balance scores were in general rather low. Future learning environments and research should take this into account in order to support learners in their balance of argumentation style.

To sum up, the results on word count, argument count, and argument balance demonstrate that cognitive and behavioral GA support can indeed improve the contribution to group outcomes or wiki article quality by triggering participation and providing awareness about cognitively relevant content. It makes sense, therefore, to look at both GA components together (see Janssen & Bodemer, 2013), because respective activities go hand in hand: Behavioral activities can contribute to increasing cognitive competencies and vice versa.

Exploratory findings and eye-tracking observations

We did not find any significant differences in mental effort, so the provision of two types of GA support did not have a negative impact on cognitive resources. However, the combination of cognitive and behavioral GA information did not have a positive effect on well-being for the group, which contrasted with the situation for the single support conditions. Although we did not focus on emotional processes and outcomes, these might be considered more in relation to long-term usage intentions because social media use is significantly driven by emotional needs and interpersonal support. Current research suggests giving greater weight to emotional regulation support in CSCL settings, both at individual and group level (Järvelä et al., 2016, 2019). Therefore, future research should integrate and investigate emotional cues in the form of awareness tools (see Slakmon & Schwarz, 2019).

Eye-tracking observations show that the content elements (topics and text field) received more attention (duration time and saccades) than the GA information, which means that GA bars were more likely to be seen as an add-on. We had expected that GA information would have a higher visual impact, which might have increased its effects. However, as higher duration time and saccades for the GA information were found in the selection phase than in the discussion phase (especially for GAT combinations), it is clear that the GA information is more likely to be drawn to the selection than to the actual engagement. As duration time was higher for cognitive GA information than for behavioral GA information in the combination condition for the selection and discussion phases, this might mean that cognitive GA information was more important to participants. However, this could also be a sign of higher complexity. The cognitive GA bars were possibly more difficult to elaborate on. Whereas the participation bars simply represented the number of contributions, in the case of knowledge bars participants may have needed more elaborations on necessary actions with little or high individual and group knowledge.

The eye-tracking sample was small, so it is difficult to say whether the results can be fully generalized. However, they provide initial indications of potential improvement. We plan to change the GA design in future studies to make it more prominent or to explicitly suggest threads with specific GAT constellations when it comes to, for example, supporting others and best practices are not known (see Rosé & Ferschke, 2016). Also, implicit real-time gaze feedback would be conceivable, which is known to facilitate coordination processes and learning gains in CSCL (Hayashi, 2020). In this study, we deliberately did not specify a concrete goal for GA usage. In the context of online communities, it is conceivable to give guidelines or tips on how to deal with GA information on a visual level. This could also be accompanied by a stronger consideration of GA information, which, according to our eye-tracking observations, seems to take a back seat. Eye-tracking was very helpful for assessing how attention-grabbing our GA design is, so we recommend ensuring that support measures are prominently placed in the focal point of a user's visual field to enlarge their effects. Moreover, adapting the learning environment accordingly is a priority (Wise & Schwarz, 2017). We believe that attention patterns could be used in the future to give adaptive (on-the-fly) feedback to students (Król & Król, 2019) when helpful support measures are not adequately considered.

Addressing limitations

Our study has some limitations. First, a wiki is a specific platform and not everyone has experience with handling wikis. However, advanced wiki-specific functionalities (markup language, etc.) were removed beforehand in order to simplify the handling as much as possible and to make the results generalizable.

The greatest limitation is most likely the laboratory design of the study, which focused more on internal validity and experimental control than on external validity. Laboratory settings have artificial features in comparison to real-world settings. For example, participants knew they were in an experiment, and the visualizations of the group's cognitive and behavioral variables were generated artificially rather than by real group data, which makes it easier to manipulate the independent variables but reduces external validity. The overall topic could not be chosen by the user, which is often a critical defining characteristic of wikis like Wikipedia. Moreover, the group's behavioral GA mean was initially always higher than the participants' individual behavioral GA bar. This allowed for positive effects rather than negative effects to occur. If this had been the other way round, opposite effects

are conceivable. According to Kimmerle and Cress (2009), this could be counteracted by using a different information presentation format. In our study, for example, a format that visualizes not only group means but also individual values of other people might have allowed for more accurate comparisons, even if group mean values were not necessarily high. Nevertheless, we believe that it is necessary to further investigate these results in more realistic settings and to investigate potential negative effects of low group means in subsequent work.

Despite these concerns, we believe that conducting our study in a laboratory setting was important because the complex mixture of uncontrolled factors in field studies can threaten their internal validity (Anderson & Bushman, 1997). The detailed and exact analysis of the isolated and pure effects of cognitive and behavioral GA information would not have been possible without this kind of manipulation (e.g., allowing for systematically different GAT levels). Field studies include confounding variables, for example introduced by possible cheating in knowledge tests or error variance due to fluctuations in technological conditions (Reips, 2000). Despite the highly controlled laboratory setting, it is worth noting that participants were not instructed to do anything specific in the discussion phase, such as sharing their knowledge; instead, they were free to read or write discussion posts, which particularly makes the behavioral results notable. Furthermore, real interaction over larger time spans might have even heightened the effects. Finally, the setting allowed us to examine the attentional impact of the GA information, which helps to optimize future design efforts.

Our laboratory study provides a basis for recognizing fundamental GA mechanisms that can be easily transferred to more realistic settings. This is supported by the fact that many properties of real wiki scenarios can be found in our laboratory study – for example, not knowing each other individually, selecting subtopics of interest, writing asynchronous discussions, and editing the wiki article – even if they were investigated in isolation in our research. In addition, the high number of different types of data collected in our study (from log-data to attentional metrics) also suggests an easy transfer to more realistic settings, since studies need to collect more diverse types of data to characterize a situation in all its complexity (Jeong et al., 2014). In environments such as Wikipedia, the editing phases are not divided in the way we divided them, but the design could be contextualized in a classroom setting, which is guided by a teacher outside the physical classroom who defines the overall topic and deliberately divides the collaboration into wiki discussion and editing phases. GATs may be helpful in such and similar learning situations to give real-time feedback about task progress, facilitating teacher orchestration (Martinez-Maldonado, 2019). One way of examining the effects in such contexts could be a randomized classroom quasi-experiment in which the experimental conditions are set up through online grouping (see Cho & Schunn, 2007).

Implications

Although most of our results show only small effect sizes, it can be stated that both cognitive and behavioral GA information have an effect on cognitive processes like selection decisions (cognitive challenge), as well as on behavioral processes like motivation to contribute in wiki-like environments (behavioral challenge). Thus, we believe it could be helpful to provide such GA information in real wiki learning or similar scenarios to make it easier for users to navigate the platform and plan certain actions.

In this paper, we have shown that cognitive GA information indeed addresses the cognitive challenge (Ollesch et al., 2019). Behavioral GA information also seems to offer direction to students. Furthermore, we have demonstrated that behavioral GA information, in particular, addresses the behavioral challenge (Kimmerle & Cress, 2008; Ollesch et al., 2019). Hence, this can be a very helpful support measure in wiki or similar scenarios when the goal is to get people to contribute.

In the case of cognitive GA information, effects regarding the behavioral challenge are not so straightforward. If the focus of a wiki learning activity is on contributing or supporting, less knowledgeable users may better overcome their inhibitions if the state of knowledge is not visualized. To avoid overwhelming participants with information in this study, we considered only the effects of GATs in the discussion forum. It would be interesting to look at the effects at the article level in further studies. Furthermore, we deliberately chose average GA values for the bogus group to give participants the possibility of outperforming or underperforming the group means. Therefore, it would be important to look at what the effects look like if GATs visualize group deficiencies or superiorities. Cognitive and behavioral GA information might have the opposite effect and should possibly even be faded out in order not to reduce the motivation of the participants. In addition, further user characteristics should be considered in follow-up studies, as the effects of NFC and the tendency toward social comparison could not be shown.

Finally, it can be stated that article quality can be increased by combining cognitive and behavioral GA information, which means that these GAT combinations could be evaluated in the field context. Based on the results on well-being, it has to be considered to what extent emotional processes or challenges in wikis can be further supported in the future, such as by asking for wiki users' subjective feelings or by using sentiment analysis of discussion posts to make people aware of potentially unfriendly comments. Sentiment analysis includes the automatic recognition of the tonality of text, such as a tweet, an online customer review, or a comment in a forum (Liu, 2012). Although this has not yet been applied to the wiki context, it might in the future be used to automatically extract the friendliness level of wiki contributions based on constellations of words used.

Conclusion

The results show that providing users with cognitive and behavioral GA information, both when separately applied and in combination, can have positive effects on cognitive as well as behavioral learning processes and outcomes in social media. This is highly relevant for the practical application and support of wikis and other CSCL platforms. However, the results also highlight that cognitive and behavioral GAT combinations do not necessarily have a positive effect on emotional outcomes like the well-being of learners. Maintaining a positive group climate is one of the big challenges in CSCL, which underlines the necessity of also considering emotional processes in learning contexts. Such investigations serve to discover the extent to which emotional GA needs to be supported in wikis or similar platforms to create a sense of community. In general, more laboratory and field studies that systematically investigate other types of GAT combinations (e.g., emotional and cognitive GA information) are therefore needed to uncover other interaction effects. Further, disentangling behavioral, cognitive, and emotional processes and outcomes on different levels (support measures, challenges) seems to be essential for understanding and using the full potential of GA support in social media contexts.

Acknowledgements This work was supported by the Deutsche Forschungsgemeinschaft (DFG) under Grant No. GRK 2167, Research Training Group "User-Centered Social Media". We would like to thank Maribell Steiner, Kirsten Wullenkord, and Leon Chamoun for their support in the qualitative analysis and the processing of the eye-tracking data.

Funding Open Access funding enabled and organized by Projekt DEAL.

Appendix

Table 6 Summary of all 2×2 ANOVAs

Dependent Variable	Factor	*df*	*F*	η^2_p	*p*
Discussion contributions	Cognitive GA	1, 154	1.29	0.01	0.258
	Behavioral GA	1, 154	64.50	0.30	< 0.001
	Interaction	1, 154	0.07	< 0.001	0.798
Posttest score	Cognitive GA	1, 154	1.08	0.01	0.300
	Behavioral GA	1, 154	2.46	0.02	0.119
	Interaction	1, 154	1.84	0.01	0.178
Learning gain	Cognitive GA	1, 154	0.77	0.01	0.382
	Behavioral GA	1, 154	0.40	0.003	0.530
	Interaction	1, 154	0.02	< 0.001	0.903
Word count	Cognitive GA	1, 154	3.37	0.02	0.068
	Behavioral GA	1, 154	1.27	0.01	0.262
	Interaction	1, 154	4.17	0.03	0.043
Argument count	Cognitive GA	1, 154	20.34	0.12	< 0.001
	Behavioral GA	1, 154	14.33	0.09	< 0.001
	Interaction	1, 154	18.31	0.11	< 0.001
Argument balance	Cognitive GA	1, 154	6.37	0.04	0.013
	Behavioral GA	1, 154	3.10	0.02	0.080
	Interaction	1, 154	5.07	0.03	0.026
Mental effort	Cognitive GA	1, 154	0.44	0.003	0.507
	Behavioral GA	1, 154	0.03	< 0.001	0.875
	Interaction	1, 154	0.79	0.01	0.376
Well-being	Cognitive GA	1, 154	0.78	0.01	0.380
	Behavioral GA	1, 154	0.14	0.001	0.706
	Interaction	1, 154	5.87	0.04	0.017

Table 7 Saccade metrics of the selection and discussion phase (% related to total number of saccades)

AOI Connections	No Support				Cognitive GA				Behavioral GA				Combination			
(Order not relevant)	Selection		Discussion		Selection		Discussion		Selection		Discussion		Selection		Discussion	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Topic/Topic	100.00	100.00	62.93	23.83	61.38	25.52	59.67	16.19	68.32	11.09	38.83	15.35	14.95	10.15	40.61	18.41
Topic/Participation bar	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	26.22	10.54	13.16	8.50	12.04	6.29	2.01	2.85
Topic/Knowledge bar	N/A	N/A	N/A	N/A	25.77	14.70	5.26	6.51	N/A	N/A	N/A	N/A	20.88	9.16	8.67	8.44
Participation bar/Participation bar	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5.46	3.62	2.00	4.47	7.85	7.18	0.00	0.00
Participation bar/Knowledge bar	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	35.46	13.99	5.38	6.15
Knowledge bar/Knowledge bar	N/A	N/A	N/A	N/A	12.84	15.05	0.00	0.00	N/A	N/A	N/A	N/A	8.82	3.87	2.34	3.46
Text/Topic	N/A	N/A	37.07	23.83	N/A	N/A	33.55	19.25	N/A	N/A	41.03	13.33	N/A	N/A	35.19	19.84
Text/Participation bar	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.98	4.04	N/A	N/A	1.57	2.15
Text/Knowledge bar	N/A	N/A	N/A	N/A	N/A	N/A	1.52	1.44	N/A	N/A	N/A	N/A	N/A	N/A	4.23	5.88

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5. Paper 4: Implicit Guidance in Educational Online Collaboration: Supporting Highly Qualitative and Friendly Knowledge Exchange Processes (Study 4)[7]

Ollesch, L., Venohr, O., & Bodemer, D. (2022). Implicit guidance in educational online collaboration: Supporting highly qualitative and friendly knowledge exchange processes. *Computers and Education Open*, *3*, Article 100064.
https://doi.org/10.1016/j.caeo.2021.100064

Computers and Education Open 3 (2022) 100064

Contents lists available at ScienceDirect

Computers and Education Open

journal homepage: www.sciencedirect.com/journal/computers-and-education-open

Implicit guidance in educational online collaboration: Supporting highly qualitative and friendly knowledge exchange processes

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ARTICLE INFO

Keywords:
Collaborative/cooperative learning
Distance education and online learning
Informal learning
Social media

ABSTRACT

Group awareness tools that implicitly guide users by presenting information about intangible cognitive (e.g., knowledge) and emotional (e.g., friendliness) group aspects have different effects in educational online collaboration. Prior research has focused on smaller group settings, with examining different tools separately or in combination without systematically disentangling their specific effects. Social media learning communities may particularly benefit from combining cognitive and emotional group awareness support, as emotional processes are closely related to cognitive processes in such settings. To systematically test this, we conducted a 2 × 2 between-subjects experiment ($N = 148$), in which participants were provided with a wiki-like environment and, except for the control condition, dynamic cognitive (based on knowledge tests) and/or emotional (based on sentiment analysis) group awareness information. As a theoretical implication, the results provide insights into the positive effects of single cognitive group awareness information on produced content quality by highlighting different knowledge levels. Single emotional group awareness information moreover positively affects the friendliness of exchange processes, which depends on the learners' need for affect. Neither single cognitive group awareness support nor the interaction with emotional group awareness support reveals direct positive effects on learning posttest performance. However, emotional group awareness tools have the potential to indirectly affect well-being and learning posttest performance, mediated via friendly interactions. As a practical implication, knowledge bar visualizations should be considered to improve outcome quality in social media collaboration. Besides, the use of dynamic sentiment analysis for assessing and visualizing different friendliness levels promotes discussions in a polite and respectful manner.

1. Introduction

Social media environments enable users to interact with both broad and narrow audiences in real-time or asynchronously, selectively present themselves and derive their individual values from the produced content and communication with others [15]. Due to their seemingly unlimited social interaction possibilities, it is not surprising that such environments are also becoming increasingly important for online collaboration in educational settings [58]. Especially wikis, well-known representatives of such environments, can enable benefits for collaborative knowledge exchange and writing processes in both formal and especially informal learning settings [22,109]. These are built as a community-driven platform allowing the collective sharing of factual information and the preservation of user-generated content [9,65]. In this way, social media platforms like wikis offer potentials for valuable learning processes to occur that are likely to arise from discrepancies between individual knowledge and collaboratively created knowledge [50]. Nevertheless, the usage of social media for education is also accompanied by challenges. These involve the facilitation of selecting meaningful content that is conducive to learning, which is particularly relevant in large online learning environments involving huge amounts of contributions. Also, the willingness and ability to maintain a positive group climate is important but challenging when a lot of collaborators come together, especially when social media platforms are unlimited to new users [71]. One way to potentially overcome those challenges and support knowledge exchange in such settings is the use of implicit guidance measures in the form of so-called *group awareness (GA) tools*, which implicitly guide users by highlighting various relevant group aspects in digital environments [13]. *Cognitive GA tools* help to facilitate learners' selection processes by drawing attention to meaningful

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https://doi.org/10.1016/j.caeo.2021.100064
Received 9 June 2021; Received in revised form 6 December 2021; Accepted 7 December 2021
Available online 9 December 2021

content, for example, in the form of visual markers in wiki environments, offering potentials for valuable cognitive processes to occur [35]. *Emotional GA tools,* in turn, help to create a positive group climate by increasing awareness of group members' emotions, for example, in the form of emotion interface buttons, offering potentials for valuable emotional processes to occur [69]. Prior research in the context of computer-supported collaborative learning (CSCL) has focused primarily on examining different types of GA tools separately or in combination without systematically disentangling their specific effects. Moreover, even though especially cognitive GA tools are a widely searched phenomenon, more GA tool research is needed that focuses on larger online group contexts like social media learning environments (e.g., wikis), as current literature is often examining small group settings (e.g., [82]). Illuminating the separate effects and the potential interplay of cognitive and emotional GA information more deeply makes sense in the social media context, since positive emotions like enjoyment and excitement can benefit learning processes and should be promoted in such settings [38,81]. Therefore, to better understand the use of GA tools as support measure for knowledge exchange in social media learning environments, we aim to, systematically and comparably, investigate single and combined effects of cognitive and emotional GA tools on several processes and outcomes in social media, taking a wiki-like environment as an example. In addition, the use of cognitive and emotional personal characteristics is investigated to predict even more precise GA tool interactions. In summary, the overall research question considers the effects of single and combined cognitive and emotional GA tools and how they can be used to improve educational online collaboration in social media learning environments. Answering this question will help to advance state-of-the-art research on GA tools in larger online group or, more specifically, social media contexts, to advantage the potentials of social media learning environments for knowledge exchange, and to optimize the practical use of GA tools in this field.

1.1. Potentials and challenges in social media learning environments

From a cognitive perspective, collaboration in social media environments is beneficial since such online settings bring together many people, offering the chance for high-level knowledge to be constructed through social exchange [19]. Various knowledge levels or emerging opinions can lead to advantageous socio-cognitive conflicts, i.e., conflicts between the individual's and group knowledge, that help to integrate new opinions and perspectives [98] and the recapitulation of what has already been learned through mutual explanations [51,101]. From an emotional perspective, collaboration in social media contexts can have a positive influence on student satisfaction and enjoyment [2]. When implemented as a supplement in formal learning contexts, it may also lead to a positive classroom atmosphere [1]. Learning on social media platforms moreover allows cross-cultural collaboration without or with only a few boundaries [100], potentially reinforcing feelings of cohesiveness and belonging to the community. For more introverted students, the use of social media platforms is known to be helpful for building up self-confidence [99].

Despite these potentials, there are also challenges. It is not always the case that people deal with meaningful content in such environments, i.e., content-related controversies or heterogeneous knowledge, that can trigger beneficial socio-cognitive conflicts [22]. Especially social media environments that serve the exchange of information often contain a high number of contributions, which makes it difficult to filter cognitively relevant contributions. However, for highly qualitative knowledge exchange, there is the need to select content that promotes deep learning processes [31], something that can be considered as a "cognitive challenge." In addition to finding contributions conducive to learning in a variety of information, it is also important to deal with such content in a way that is conducive to the group climate. This means to behave in a friendly manner towards each other, something that can be, analogous to the cognitive challenge, considered as an "emotional challenge" [74]. Moreover, even though social media use in educational settings may go along with positive effects on emotional variables as outlined above, their use might also result in lower well-being (see [28]). According to Kreijns, Kirschner, and Vermeulen [54], CSCL environments should therefore focus more on socio-emotional support because these emotional grievances can have a negative impact on learning outcomes [71].

1.2. Cognitive and emotional group awareness tools

To overcome the challenges and support both cognitively and emotionally appropriate interactions, the use of implicit guidance tools that provide awareness is promising in social media learning environments [106]. According to Gross, Stary, and Totter [34], GA can be defined "[…] as consciousness and information of various aspects of the group and its members" (p. 4). Thus, GA describes any information about the group that a learner possesses, such as knowledge about the abilities of group members, their behavior, or social states within the group [45]. The provision of GA via tools is necessary for CSCL environments from a psychological point of view to compensate for the lack of social presence [53], which causes the challenges users are facing. In the following, we introduce cognitive and emotional GA tools and their guidance effects for social media learning environments.

Cognitive GA tools mainly affect the cognitive challenge at the content exchange level by collecting and presenting content-related information about group members, for example, the individual and partner or group knowledge on a specific topic. By highlighting those aspects, cognitive GA tools help to facilitate partner or group modeling [13] and to filter meaningful contributions from a larger number of contributions, reducing information overload and enhancing the chance for socio-cognitive conflicts to occur on social media platforms (see [16, 22]). The collection of cognitive GA information ranges from self-assessed and subjective information [56] to automatic transformation of scores through test participation [88]. Sangin et al. [88], for example, could show a more accurate assessment of partner knowledge, which is very often under- or overestimated, when presenting individual and partner knowledge posttest scores as bar visualizations.

With a focus on social media environments, there are relevant empirical results to mention. Cognitive GA information, for example, in the form of quality rating visualizations, enhance the chance for identifying highly qualitative content in extensive online environments [110]. Moreover, when presented as knowledge awareness bars, cognitive GA information may trigger learning processes based on the contributions of more knowledgeable people in wiki environments [75]. By supporting these navigation mechanisms, cognitive GA tools could already show positive and context overarching effects on both cognitive process variables like resulting discussion or argument quality (e.g., [67]) and outcome variables like wiki article quality (e.g., [37]) and learning performance (e.g., [88]).

Emotional GA tools, on the other hand, mainly affect the emotional challenge at the relational exchange level by collecting and presenting socio-emotional information about group members, for example, the emotional state of collaborators [69]. In this way, they help to increase awareness of the emotional states of other group members. This may lead to mutual emotion regulation activities that are triggered by processes of social comparison (comparison with other emotional states; [7]) and emotional contagion processes (transferring the feelings of the sender to the receiver; [11]) – helping users to maintain or create a positive group climate [27]. Even though less often focused on than cognitive GA tools, emotional GA support already show positive effects on both emotional process variables like a better understanding and empathizing of other's emotions (e.g., [27]) as well as outcome variables like group cohesion (e.g., [62]) and group performance (e.g., [111]).

To our knowledge, existing emotional awareness solutions mostly

employ subjective questionnaires to collect such GA information [27, 69], whereas automatic techniques like emotion extraction from documents are rarely seen [86]. Especially in social media environments like wikis, automatic and affective text-based state recognition techniques like sentiment analysis might be a beneficial method for emotion mining on content level [39,104]. Besides visualizing individuals' subjective emotional states, this could enable the investigation of emotional GA information for highlighting (un)friendly contributions in discussion forums that could cause detrimental or beneficial emotions to arise [76].

The concept of friendliness plays an important role in groups as it can enhance group satisfaction and response rates [14,79]. According to Phielix et al. [82], friendliness means treating each other with respect. The term friendliness is fundamentally associated with polite manners by students [72]. Moreover, the concepts of politeness and friendliness are seen as similar concepts, which implies that persons with polite or respectful behavior are also considered as friendly [43,107]. In this research, when talking of friendliness in online discussions, we also see such construct inter alia expressed by the application of politeness rules (e.g., appreciations of other contributions, gratitude, praise, and greetings). Friendliness within the group has hardly been considered at all in (emotional) GA research so far, even though it is very promising. Phielix et al. [82] analyzed GA tools in which group members were asked to rate their own friendliness as well as the friendliness level of other group members. Feedback of such ratings had positive effects on socio-emotional outcomes, such as lower conflict levels and higher group satisfaction. However, such subjective assessment might also be biased and not honest [33]. According to Ghadirian et al. [33], even though automated computer-based content analysis of such states can be very costly, it is a way to measure the friendliness of written posts without disrupting users' interaction behavior. Therefore, it is the focus of the current study. Written (textual) content could already be proven as a sufficient channel for emotional contagion processes to occur, i.e., transferring positive and negative emotional states, leading to similar written emotional responses and effects on community mental well-being [52]. Mental well-being is an individual or collective state or process of experiencing oneself, others, and corresponding life circumstances as positive [103]. This concept includes a hedonic (positive affect; also considered as emotional well-being) and eudaimonic (positive functioning and satisfying relationships; also considered as social and psychological well-being) component [59]. The consideration of mental well-being in the area of learning communities makes a lot of sense since learning situations, inter alia in the university context, can be associated with negative mental well-being [21]. On the other hand, they might also have a positive impact on well-being when designed in the right way [30]. Socio-emotional support is therefore essential for positive effects on well-being to occur, which might be facilitated in the form of emotional GA tools (see [42]).

1.3. Potentials of emotional GA tools for enhancing cognitive GA tool effects

Even though both types of GA support are already promising in a single presentation, as we outlined above, their interaction could be particularly profitable in social media learning contexts. Especially emotional GA information may enhance beneficial cognitive GA tool effects on knowledge exchange based on the value of emotional processes for cognitive processes, which are often not in the focus of instructional interventions [57].

1.3.1. Value of emotional processes for cognitive processes

Collaboration can be considered as consisting of two spaces, the content space, which is related to the task itself, and the relational space, which is related to interpersonal relationships [10]. According to Pekrun [81], collaborative learning situations imply the influence of social emotions like sympathy or anger (part of the relational space) in learning and task exchange (part of the content space) with others. It is widely assumed that such emotional processes accompany cognitive and collaborative learning processes and outcomes or are even an inherent part of rational decision-making [26,32,84]. Positive emotions concerning the learning object are therefore considered essential for enhancing task focus and motivation [80], whereas negatively balanced emotions or expressions during a content-related or socio-cognitive conflict may lead to lower group achievements based on detrimental tensions [8,84]. One reason is that focusing on negative emotions towards one another makes people more resistant to others' ideas [94]. It is therefore assumed that positive emotions rather act as facilitators of collaborative learning, whereas negative emotions rather act as inhibitors in the learning context [61]. Therefore, besides supporting cognitive awareness processes, students should also be aware of their own and their co-learners emotional states, which would enable them to regulate those states while learning and collaborating with each other [81].

1.3.2. Chances of cognitive and emotional group awareness tool combinations

Emotional GA tools are promising to support the co-regulation of emotions at both individual and group levels, which may in this way also increase the perception of valuable socio-cognitive processes. However, there is a lack of investigating emotional GA tool effects on such processes [6]. Moreover, even if cognitive GA information may trigger beneficial socio-cognitive or task-related conflicts between the self and the social environment (see [50]), inter alia by highlighting knowledge differences between collaborators, collaborative discussions may also lead to destructive socio-emotional or relationship conflicts. These might interfere with on-task engagement and team performance when emotion regulation skills are not pronounced enough [25,47,71]. Emotional GA tools that provide incentives for positive instead of negative emotions to evolve could counteract these undesirable effects [7,27]. Also, Phielix et al. [82] noted that it is important in CSCL environments to create GA about not only socio-cognitive variables such as contribution quality but also socio-emotional variables such as friendliness, but they referred to smaller group sizes and did not consider single cognitive and emotional GA tool effects in their study. Therefore, their promising findings should be transferred to the social media area, systematically disentangling different GA tool effects.

Focusing specifically on social media contexts, it is worth investigating to what extent an emotional GA tool that visualizes and promotes the friendliness level of contributions in an argumentative discourse can potentially increase the impact of a cognitive GA tool that makes knowledge differences of collaborators/discussants more transparent. This is based on assumptions that respect and willingness to work with each other, also labeled as social affinity, is important to enhance the effectiveness of collaboration [49]. Also, Kwon et al. [57] illustrate that positive socio-emotional interactions such as encouraging other group members are essential for groups to be successful, whereas unfriendly reactions like rejecting or ignoring collaborative partners' contributions are key factors for the underperformance of teams [7]. From a linguistic perspective, the tonality of the argumentative exchange influences how the argumentative claim is put forward, which makes an awareness tool that recognizes emotional aspects in discussions even more important [64,84]. On the one side, when presented in combination, the additional usage of an emotional GA tool might be promising here in reducing unfriendly interactions in the relational space like aggressiveness in criticizing others' views. On the other side, it might promote friendly interactions and the establishing of politeness rules in the relational space, enhancing the potentials of cognitive GA tools to fully unfold in the content space (see [44,84]). In this way, we believe that the effects of cognitive GA information on cognitive process and outcome variables might be stronger in combination with emotional GA information than in a single presentation.

Regarding the opposite effects of cognitive processes on emotional processes and outcomes, something we do not focus on in this study, the

expectations are less clear. On the one side, cognitive GA tools might also be able to promote emotions (e.g., reducing sense of loneliness) in the relational space [67], albeit to a lesser extent than emotional GA tools. For example, learners' expertise might be beneficial for positive and harmonious relationships to develop [66], which is something a cognitive GA tool could deliver. On the other side, even though it could already be shown that single cognitive GA support with knowledge awareness bars has a positive impact on the mental well-being in a social media (wiki) setting, for combined GA tool implementations, this positive effect cannot be transferred [75]. Regarding the potentials of cognitive GA tools for enhancing emotional GA tool effects, we, therefore, choose an exploratory approach, see Section 1.5.

1.4. Personal characteristics

Despite assumed positive single and combined effects of cognitive and emotional GA support, it is important to consider personal influences when investigating the effects of GA tools in knowledge exchange scenarios, as it is very unlikely that they have the same effect on all types of users. In terms of cognitive and emotional GA information, certain cognitive and emotional needs exist that potentially interact with such kind of support.

In a study by Heimbuch and Bodemer [36], it was found that the effects of cognitive GA information on discussion contributions' quality depend on the individuals' *need for cognitive closure*. Need for cognitive closure is a personality and situational variable that is defined as the pursuit of a definite answer to a question or problem, rather than uncertainty and ambiguity [102]. A high need for cognitive closure leads to the attempt of eliminating socio-cognitive conflicts and making decisions quickly [24,89], whereas a low need for cognitive closure leads to a higher cognitive engagement and reflection of issues and new information or arguments [18]. In terms of learning performance, low levels of need for cognitive closure were found to be associated with deeper processing of learning content [29]. Although little research has been done on need for cognitive closure in GA research, it has already been shown that the need for cognitive closure influences the extent of willingness to engage in an epistemic change in general [87]. A high need for cognitive closure leads to people being less willing to integrate other opinions into their own cognitive structures and tend to show a higher confirmation bias [23], which might also have a negative impact on cognitive GA tool effects that highlight such cognitive differences between learners.

Furthermore, it has already been shown that *need for affect* positively influences the preference for collaboration groups in which emotional GA information visualizes friendliness about involved users [76]. Need for affect is defined as the general motivation to approach or avoid situations and activities that are emotional for themselves and others [68]. People with a high expression of need for affect are more likely to immerse themselves in emotional activities and events [12] and show a tendency to choose emotional media [68]. Thus, they are more focused on processing emotional messages than people with a low need for affect, who primarily pay attention to and engage with cognitive information [4]. Although the need for affect has been less studied in emotional GA support or educational psychology in general, studies on political attitudes and the health sector show that this variable can have an impact on the effectiveness of emotional messages in different domains [20,60]. The present study aims to fill a research gap by considering need for affect in educational discourse as a potential influencing variable for emotional GA tools.

1.5. Hypotheses and exploratory investigations

Based on the existing findings and theoretical considerations on GA support, several hypotheses are derived. First, we assume positive effects of cognitive GA information on cognitive process and outcome variables [67,88], which we do not expect for emotional GA information. More precisely, we have the following assumptions regarding textual quality and learning:

H1: Single cognitive GA support leads to a higher (a) quality of textual contributions to the respective learning environment and (b) resulting learning performance in comparison to no support and single emotional GA support.

Besides single GA tool effects, it is promising to investigate the potential interplay of combined cognitive and emotional GA tools on the in H1 mentioned variables, based on the dominant role of emotions in learning achievement and further cognitive processes and outcomes [6,71]. We consider emotional GA information, which potentially contributes to positive emotion regulation, as a beneficial supplement for cognitive GA tool effects here. This leads to the following assumption:

H2: The assumed effects of single cognitive GA information on the (a) quality of textual contributions and (b) learning performance are increased with simultaneous emotional GA support.

Also, we assume positive effects of emotional GA information on emotional process and outcome variables [7,27], which we do not expect for cognitive GA information. More precisely, we have the following assumption regarding textual friendliness and mental well-being:

H3: Single emotional GA support leads to a higher (a) friendliness in textual contributions to the respective learning environment and (b) reported mental well-being in comparison to no support and single cognitive GA support.

Regarding reverse cognitive GA tool effects as a supplement for emotional GA tool effects on the in H3 mentioned variables, we are not sure about the concrete effects. Therefore, another research question is derived:

RQ1: Can the assumed effects of single emotional GA information on (a) friendliness and (b) mental well-being be increased with simultaneous cognitive GA support?

Based on the findings and theoretical considerations related to the need for cognitive closure and cognitive variables [29] as well as the need for affect and emotional variables [4], we assume moderating effects of low need for cognitive closure on the cognitive GA tool effects and high need for affect on the emotional GA tool effects mentioned in the previous hypotheses. The following hypothesis is derived:

H4: The effects of (a) cognitive GA information are reinforced by a low need for cognitive closure, whereas the effects of (b) emotional GA information are reinforced by a high need for affect.

On an exploratory basis, we control for subjective mental effort as an influencing variable. Furthermore, several behavioral parameters like the number of textual contributions and written word count are considered in the learning environment to gain deeper insights into the behavioral effects of single and combined GA support.

2. Methods

2.1. Participants and study design

$N = 148$ German participants ($M_{age} = 22.71$ ($SD = 4.70$), 17–44 years) were recruited for the study (approx. 1.5 h) via university lectures or social networking sites. Those were mostly students (81.1%) of programs not related to the learning topic. The rest of the sample consisted of 15.5% employees, 2% self-employed, and 1.4% unemployed

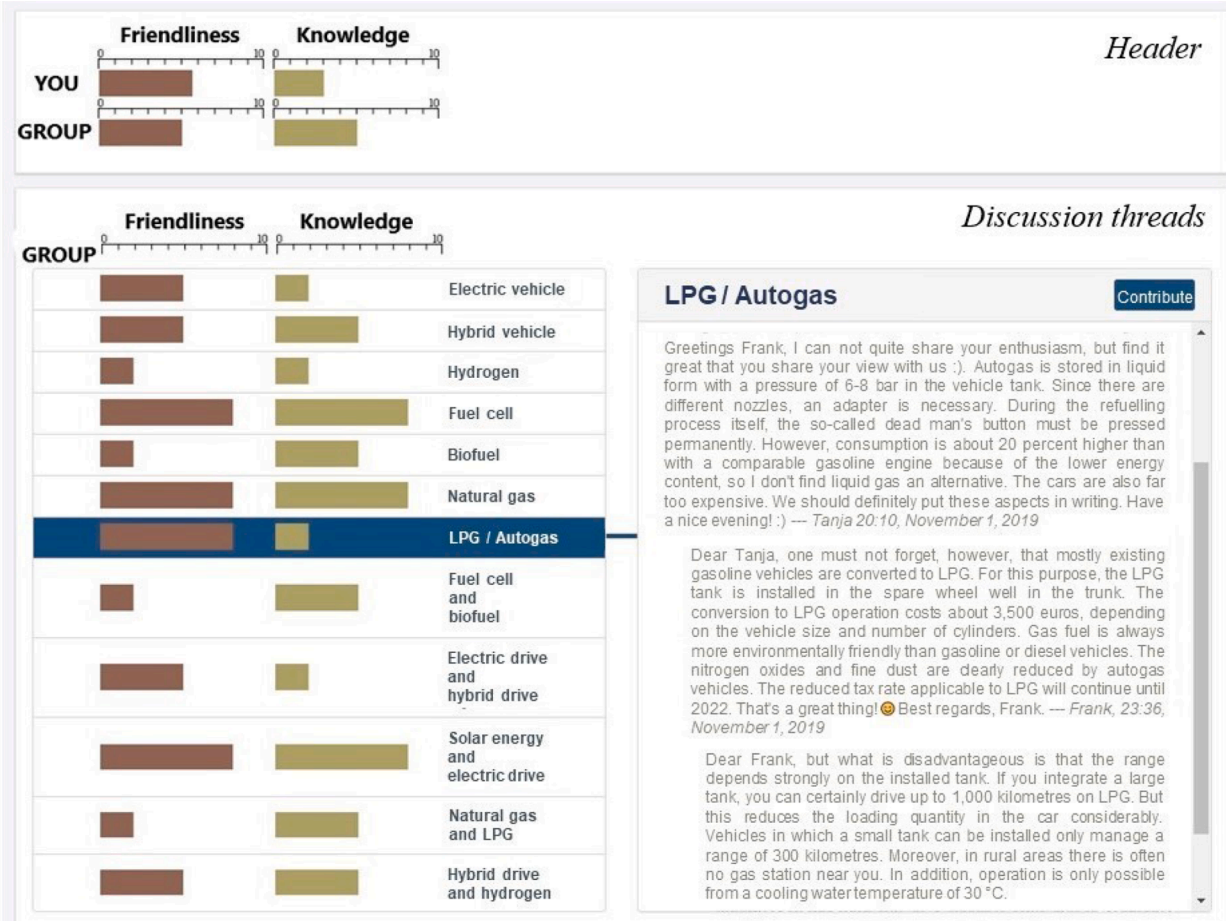

Fig. 1. Discussion page for the combination condition. The placement of cognitive (knowledge) and emotional (friendliness) GA information was horizontally randomized during the experiment.

participants. 106 participants were females, 41 males, and 1 diverse. The study consisted of four experimental groups (2 × 2 between-subject design): a control group without GA support, two groups with single cognitive or emotional GA support, and a group receiving a combination of both. Participants were randomly assigned, which resulted in four equal-sized groups of 37 participants.

2.2. Ethical considerations

All participants were informed in detail about the aim and purpose of the study. Afterward, they filled out an informed consent form. The data of the participants was recorded confidentially and anonymously in the questionnaire software LimeSurvey so that it was not possible to draw any conclusions about their identity. In addition, during the laboratory experiment, partition walls were used to reduce experimental ladder effects and to ensure as much privacy as possible. The learning topic and the discussions presented did not include any topics or content that could harm other people. The study ended with a detailed written and oral debriefing. It was approved by an ethics committee.

2.3. Provided learning environment

Participants were provided with a wiki-like environment: an objective article on drive technologies and a discussion page, including pro and contra arguments of a bogus group (given information without real persons involved), with two opposing discussants in each thread. As wikis lack social functionalities to provide sufficient GA, this was presented as horizontal GA bar charts on the discussion page according to the respective condition. Fig. 1 shows the discussion page of the combination condition (translated from German to English). The other conditions received successively fewer supportive visualizations. Cognitive GA information was operationalized as *knowledge* bars ranging from the lowest level of 0 to the highest level of 10. Emotional GA information was operationalized as *friendliness* bars also ranging from 0 to 10. The article page did not contain any GA support visualizations across all conditions. GA visualizations were differently provided at individual and group levels, which is explained in more detail in the following sections.

2.4. GA information on the individual level

The individual GA values ("You" row in the header; see Fig. 1) of the respective participants were implemented dynamically in the platform, based on real actions.

The participants' individual knowledge score was determined by a single-choice knowledge pretest. Here, every participant had to answer 10 items on the topic of "Alternative Fuel and Drive Technologies" before actual editing. One point was awarded for each correct answer, with 4 answer options each. The total score was then visualized on the discussion page on a scale from 0 to 10 in the form of a bar chart (score of 3 in Fig. 1).

The participants' individual friendliness score ("You" row in the header; see Fig. 1) in the written discussion contributions was determined by using a sentiment algorithm. Sentiment analysis is a systematic computer-based analysis that analyzes the emotions, moods, opinions, and attitudes of individuals toward an entity of unstructured

text [96]. This involves the analysis of linguistic or word features that may predict such states based on a sentiment lexicon/workbook, with a higher value usually indicating a more positive sentiment [5]. Emotions and sentiments are often used interchangeably; however, sentiments are assumed to be more stable and directed to a specific object [70] and represent the affective state of a person while writing [41]. Therefore, sentiment analysis is a suitable method to enable a form of emotional GA in a textual educational discourse. We implemented a dynamic sentiment algorithm, which means that when a discussion contribution was posted, the algorithm calculated the mean sentiment score of such discussion contribution in real-time and fed it back to the respective participant by changing the individual friendliness bar length (score of 5.5 in Fig. 1).

We used an existing JavaScript code on GitHub, enabling dynamic sentiment detection [93]. Also, we used a German translation and subset of the attached AFINN sentiment lexicon [73]. Both code and sentiment lexicon were adapted to fit the questionnaire environment and to contain German words associated with friendliness. We only included words with positive connotations (ranging from 1 to 5) and no words with negative connotations because the GA scale only visualized the positive dimension of friendliness (see Fig. 1), and we wanted to keep the runtime calculations in the browser as less complex as possible. However, both positive and negative dimensions were considered after the experiment; see Section 3.1 for more details. Also, we included an emoticon workbook as the text editor for discussion contributions only allowed the integration of strings. The individual friendliness adaptation was visualized on the discussion page on a scale from 0 to 10, analogous to cognitive GA information (see Fig. 1). The calculated friendliness scores were transformed before playing back to fit the 10-point scale and to present the mean values after each discussion contribution related to all the previous posted contributions. The whole code and codebook can be found in the attached source link [91]. The procedure is roughly summarized in the following.

To determine the friendliness score in a discussion contribution, all positive words and emoticons were identified by the implemented sentiment algorithm, and their sentiment scores were added up from the sentiment lexicon. This sentiment score was then divided by the respective word count of the written discussion contribution. Based on pilot testing, we found that the resulting sentiment or friendliness scores were too high for visualizing them on a 0 to 10 scale. Therefore, we additionally divided the results through 30, which was the minimum needed word count of a new post, to fit the range of the implemented friendliness scale. Values that were still too high were cut off at 10. If multiple discussion threads were commented on, then the algorithm calculated a mean score for all discussion posts. The requirement for the participants was at least one post in the discussion exchange forum to be able to determine the individual friendliness score.

2.5. GA information on group level

The header contained the bogus GA mean of the whole group ("Group"). Next to the respective discussion threads, the same visualizations were shown in a non-aggregated form (also "Group"). These GA visualizations referred to subgroups of the whole group and indicated the extent of knowledge and friendliness of the respective group members involved in threads like "electric vehicle." Both whole group and subgroup GA information were static and bogus, but participants were made to believe that these had arisen from real interactions. For reasons of complexity, a distinction was only made between discussion threads visualizing low (counter on 2), medium (counter on 5), and high (counter on 8) subgroup knowledge and friendliness bars.

In threads involving low subgroup knowledge, the created content involved participants who tended to be novices in the respective area and made rather vague statements. However, none of the threads contained misinformation:

> for example, *"[…] I don't know much about electric cars, but I once heard that electric cars are not that popular because they are supposed to have short ranges and long charging times. […]"*.

In threads involving medium subgroup knowledge, discussants were literate on the topic and used one source per discussant in their discussion contributions:

> for example, *"[…] I have also read quite a bit on the subject and find that the negative aspects outweigh the positive aspects of hybrid cars. In the paper by Source x, I read about these, which include the always high additional mass on board, limited cargo space, and of course, very high initial cost. […]"*.

In threads involving high subgroup knowledge, there were discussion participants who worked in the topic area and were, therefore, experts in the field. Moreover, they used two sources per discussant:

> for example, *"[…] I am an engineer at a well-known car company and involved in the development of fuel cell cars. Hydrogen as a fuel for fuel cell cars is available in unlimited supply, unlike mineral oil (Source x). Fuel cell vehicles are one of the environmentally friendly solutions because they emit only water as a waste product – according to Source y, this is a good prerequisite to becoming the car of the future. […]"*.

In threads involving low subgroup friendliness, the created content involved conversations which tended to be rather unfriendly but not offending:

> for example, "*[…] Your arguments are completely out of the air. So far, the cultivation of biofuels leads to monocultures and displaces ecologically valuable areas. […]*".

Threads with medium subgroup friendliness contained discussion posts written in a rather friendly style:

> for example, *"[…] Hybrids are simply a good compromise: You can drive locally emission-free as often as you want – of course only when the battery is charged. And when the battery is empty, and there is no charging possibility in sight, you just continue to drive conventionally. […]"*.

In threads involving high subgroup friendliness, the discussion contributions in the discussion threads were written in a very friendly manner. Additionally, emoticons and smileys were used to emphasize friendliness:

> for example, "*[…] Greetings Frank, I can't quite share your enthusiasm, but think it's great that you're sharing your perspective with us.* 😊 *[…]*".

3. Data collection and analysis

3.1. Instruments and questionnaires

To assess the cognitive quality of textual contributions to the wiki learning environment (answering H1a; H2a), one experimenter coded the *number of new and correct knowledge artifacts* in both the *article* and *discussion* page. Two categories were created per article and discussion topic: contra argument, pro argument, and additional information. Here, 10 percent of all article and discussion contributions were counter-coded to test the reliability of the coding scheme. The content for counter-coding was randomly selected. This resulted in a very pleasant interrater reliability of Cohen's $\kappa = .86$ (article) and $\kappa = .91$ (discussions). After a joint discussion of the results and clarification by both coders, the first coder continued with the rest of the contributions. If a single contribution contained at least one pro and one contra argument, a balance score of 1 was given; otherwise, a score of 0 was given. Subsequently, all scores (for article and discussion forum separately) were added together and divided by the number of article/discussion

contributions to calculate the *total balance scores* in the *article* and *discussion* forum. For answering H1b and H2b, a *knowledge posttest* consisting of 20 single-choice items was used to measure the learning performance, which involved the 10 items used in the pretest and further items derived uniformly distributed from the topics of the discussion forum with 4 answer options each.

The emotional quality or friendliness of textual contributions was only examined at the discussion level. To assess the overall *friendliness level* of discussion contributions (answering H3a, RQ1a), we calculated a mean friendliness score of the dynamic friendliness algorithm across all written discussion posts. In addition, to validate the used method, we subsequently examined all discussion posts with the established sentiment analysis tool SentiStrength [97], along with the validated German dictionary of Pirker [83], this time including both positive and negative word constellations ranging from −4 to +4. Besides, as a second attempt to validate the algorithm, all discussion contributions were manually and inductively coded into *1 = neutral*, when the comment contained no positive emotion or friendly energy (objective comment on content level); *2 = friendly*; when the comment contained some but not very strong positive energy (comment containing appreciation, gratitude, praise, empathy and/or emoticons); and *3 = extremely friendly* when the comment contained very strong positive emotion or friendly energy (comment containing very strong or a combination of appreciation, gratitude, praise, and emoticons). A randomly chosen 10 percent of all discussion contributions were counter-coded with an interrater reliability of Cohen's $\kappa = .93$, following the same procedure as for argument count. There were no contributions that could be considered unfriendly, which is why we did not focus on negative classification in the qualitative evaluation. Both the qualitative post coding and the analysis by SentiStrength correlated significantly positively with the friendliness algorithm we used; therefore, we believe that the results of the study can be considered trustworthy. More concrete, the validation check proved that there were positive small to medium correlations between the calculated mean friendliness score and the overall SentiStrength sentiment score ($r(145) = .29$, $p < .001$) as well as the qualitative friendliness assessment ($r(146) = .85$, $p < .001$), which reinforces the friendliness algorithm. For answering H3b and RQ1b, *mental well-being* was assessed by the German Warwick-Edinburgh Mental Well-Being Scale of Lang and Bachinger [59] that involves 14 items answered on a five-point Likert scale ($\alpha = .86$), ranging from 1 = "none of the time" to 5 = "all the time." This scale contains items measuring eudemonic and hedonic concepts as manifestations of mental well-being. However, a single-factor calculation is recommended by Lang and Bachinger [59]. Example items are: "I've been feeling good about myself." and "I've been feeling close to other people." Emotions quickly fluctuate over time, and thus, there might also be short-term changes in mental well-being [40]. Moreover, participants were told that the items on mental well-being referred to the previous discussion phase they participated in, not their general well-being.

For answering H4a, *need for cognitive closure* was assessed by the German 16-items need for cognitive closure scale of Schlink and Walther [90], answered from "do not agree at all" to "agree completely." "I do not like it when a person's statement is ambiguous." represents an example item from the scale ($\alpha = .80$). For answering H4b, the 10-item German *need for affect* questionnaire-short form (NAQ-S) by Maio and Esses [68] was used. Response options are presented on a seven-point Likert scale and range from "strongly disagree" to "strongly agree." "I believe that I need strong feelings on a regular basis" is an example item from the scale ($\alpha = .76$).

For exploratory investigations, the *number of discussion contributions* as well as *discussion word count* and *article word count* were derived from the log data. *Mental effort* was measured with a German translation of Paas's [77] one-item scale ("In solving or studying the preceding problem I invested," ranging from 1 = "very, very low mental effort" to 9 = "very, very high mental effort"). We calculated a mean score from three measuring points ($\alpha = .75$).

3.2. Experimental procedure

After completing the sociodemographic questionnaire, the participants were shown an incomplete article on the topic of "Alternative fuel and drive technologies," for which they had 3–5 min to read, independent of experimental groups. This was followed by a 20-min engagement phase with the discussion threads. An example is illustrated in Fig. 1 for the combination condition. In this phase, participants were free to choose which threads to read and disclose their own knowledge and opinions on, although writing at least one discussion contribution (30–100 words) was a requirement for the study. After that, the participants were allowed to edit the article (10 min) they had previously read to expand it with the gained knowledge from the discussion forum. The editing phase was followed by the completion of the well-being questionnaire. After that, the participants were given the 20-items knowledge posttest and the questionnaires to assess the need for cognitive closure and need for affect. Mental effort was measured three times: after the article reading, the discussion editing, and the article editing phase.

3.3. Statistical procedure

To calculate the results, several 2 × 2 ANOVAs were performed, which involved the factor "Cognitive GA information" (e.g., relevant for H1), the factor "Emotional GA information" (e.g., relevant for H3), and their "Interaction effect" (e.g., relevant for H2 and RQ1). Additionally, for H1, H2, H3, and RQ1, we performed contrast analyses to find nuanced differences regarding the predefined sub-comparisons. The contrast coefficients to weight the groups' means are in brackets in Section 4. H4 was tested by calculating two moderator analyses. In all regression/correlation-based calculations, extreme values (> 3.0*IQA) were identified via box plots and removed beforehand. Regarding all calculations concerning the mean friendliness score, one person (subject code 7) was excluded, who systematically tried out the friendliness algorithm. Directed hypotheses (H1, H2, H3, and H4) were tested one-sided for *t* distributions, further calculations (RQ1 and exploratory calculations) were tested two-sided with $\alpha = .05$. Analyses were performed in IBM SPSS Statistics 26, including the PROCESS macro for moderation and mediation analyses.

4. Results

4.1. Single cognitive GA tool effects and interaction (combination) effects

A 2 × 2 ANOVA revealed a significant main effect for cognitive GA information but not for emotional GA information on article argument count (see Table 4 in the Appendix). Contrast analysis proved that the argument count in the article was significantly higher in the group with single cognitive GA support (weight 1) than in the groups with no support (weight −0.5) and single emotional GA support (weight −0.5), with a mean difference of 1.38 ($SE = 0.81$); $t(50.80) = 1.70$, $p = .048$, $d = 3.66$. Similar 2 × 2 ANOVA results were found for cognitive GA information but not for emotional GA information on argument count in the discussion forum (see Table 4 in the Appendix). Moreover, contrast analyses revealed a mean difference of 2.30 ($SE = 0.71$) in favor of the single cognitive GA support condition (weight 1) compared to the groups with no support (weight −0.5) and single emotional GA support (weight −0.5); $t(49.51) = 3.23$, $p = .001$, $d = 3.28$. These results support H1a; see Fig. 2 for descriptive values.

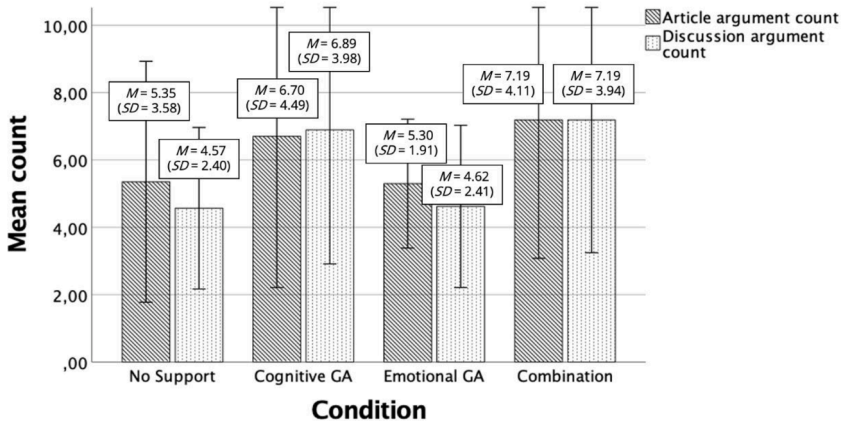

Fig. 2. Mean count of added arguments on the article and discussion pages, split by condition.

Besides the argument counts, a 2 × 2 ANOVA also revealed a significant main effect for cognitive GA information but not for emotional GA information on article argument balance (see Table 4 in the Appendix). However, contrast analysis could not confirm a significant difference between the single cognitive GA tool condition (weight 1) and the no support (weight −0,5) and single emotional GA (weight −0,5) conditions, with a mean difference of only 0.04 ($SE = 0.03$); $t(144) = 1.39$, $p = .084$, $d = 0.13$. Regarding argument balance in the discussion forum, there was a significant main effect for cognitive GA information but not for emotional GA information (see Table 4 in the Appendix). Also, contrast analysis revealed a difference between the single cognitive GA tool condition (weight 1) and the no support (weight −0,5) and single emotional GA (weight −0,5) conditions, with a mean difference of 0.20 ($SE = 0.08$); $t(144) = 2.64$, $p = .005$, $d = 0.38$; see Fig. 3 for descriptive values. These results partially support H1a.

Regarding learning performance in the knowledge posttest, there were no significant main effects for cognitive and emotional GA information (see Table 4 in the Appendix). Also, contrast analysis between

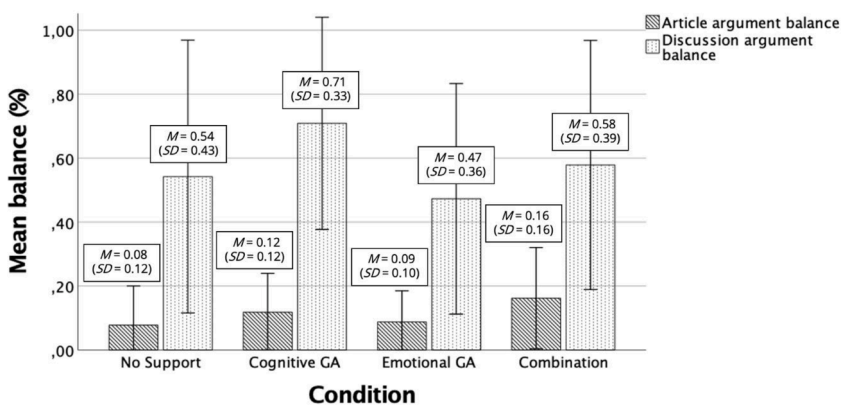

Fig. 3. Mean balance of added arguments on the article and discussion pages, split by condition.

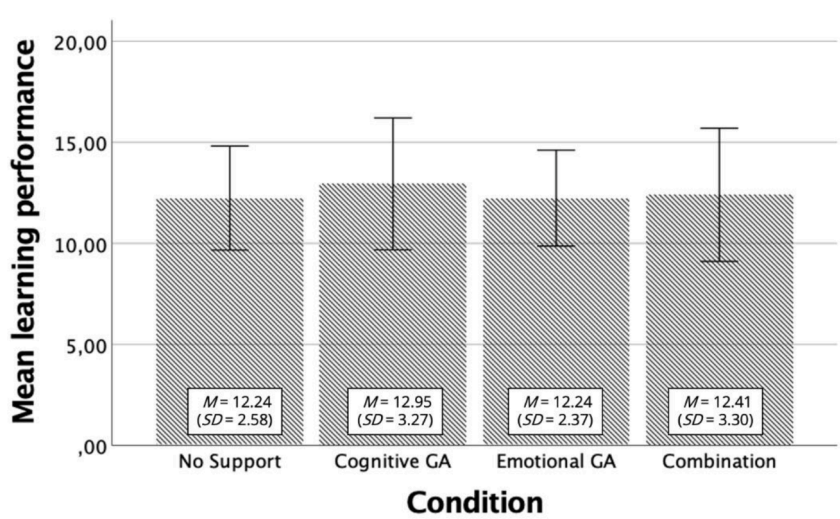

Fig. 4. Mean score in the posttest for learning performance, split by condition.

Table 1
Contrast analyses for investigating combination effects.

	Mean Difference	*SE*	*t*	*df*	*d*	*p*
Article argument count	0.49	1.00	0.49	71.44	3.66	.314
Discussion argument count	0.30	0.92	0.32	71.99	3.28	.374
Article argument balance	0.04	0.03	1.49	144	0.13	.069
Discussion argument balance	−0.13	0.09	−1.48	144	0.38	.071
Learning performance	−0.54	0.68	−0.80	144	2.91	.213

the single cognitive GA tool condition (weight 1) and the no support (weight −0,5) and single emotional GA (weight −0,5) conditions did not become significant with a mean difference of 0.70 ($SE = 0.59$); $t(144) = 1.20$, $p = .116$, $d = 2.91$, even though descriptive values are slightly in favor of the single cognitive GA tool condition. H1b is therefore not supported. All descriptive values can be found in Fig. 4.

Differences in prior knowledge, which could have led to these missing results, can be largely ruled out. There were no significant 2 × 2 ANOVA main or interaction effects for the 10-items pretest with no support $M = 4.54$ ($SD = 1.50$), cognitive GA support $M = 4.81$ ($SD = 1.51$), emotional GA support $M = 5.11$ ($SD = 1.49$), and combination support $M = 4.84$ ($SD = 1.71$); see Table 4 in the Appendix.

Regarding H2, there were also no significant interaction effects related to the relevant variables from H1 (see Table 4 in the Appendix). To examine H2 more specifically, we used contrast analysis to compare the combination condition (weight 1) only with the single cognitive GA tool condition (weight −1), to see if the difference is significant between those two types of support measures, which is not the case (see Table 1). Therefore, H2 cannot be supported, as single cognitive GA tool effects are not enhanced with simultaneous emotional GA support; for descriptive values; see Figs. 2 to 4.

4.2. Single emotional GA tool effects and interaction (combination) effects

Regarding H3, a 2 × 2 ANOVA revealed a significant main effect for emotional GA information but not for cognitive GA information on the mean friendliness score (see Table 4 in the Appendix). According to a

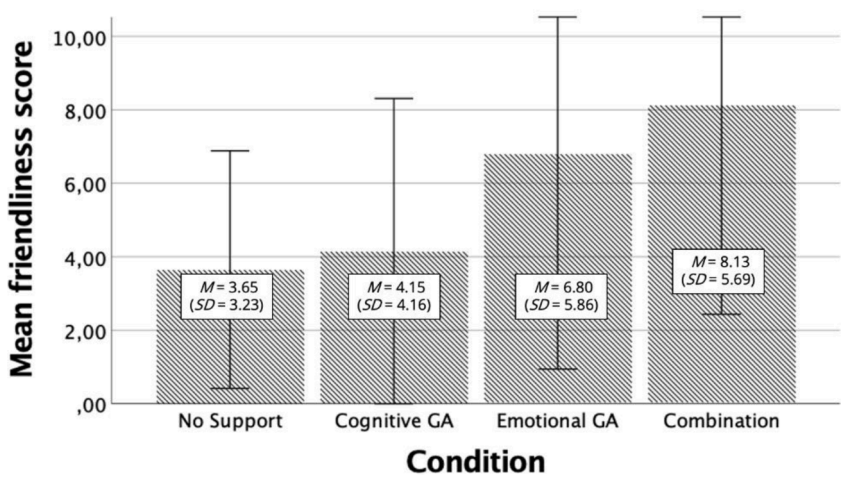

Fig. 5. Mean score measured via friendliness algorithm, split by condition.

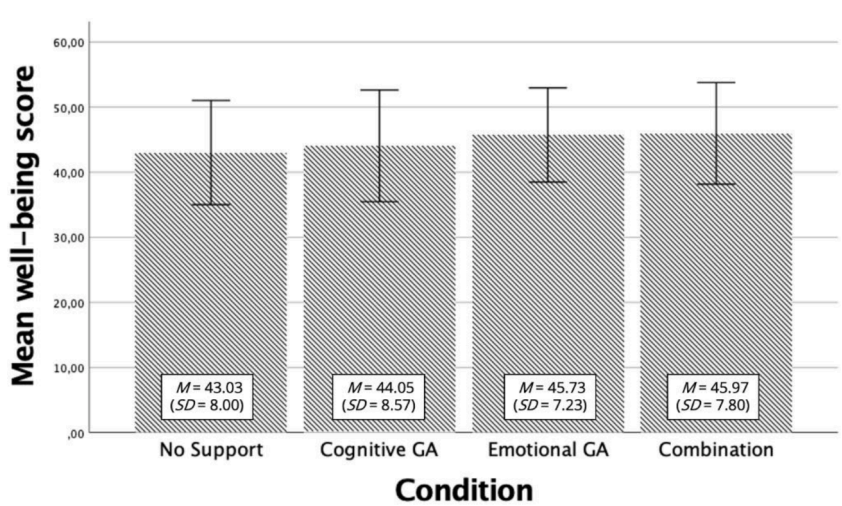

Fig. 6. Mean score of subjective well-being, split by condition.

conducted contrast analysis, the mean friendliness score was significantly higher in the group with single emotional GA support (weight 1) than in the groups with no support (weight −0.5) and single cognitive GA support (weight −0.5), with a mean difference of 2.90 ($SE = 1.07$); $t(49.16) = 2.71$, $p = .005$, $d = 4.85$; see Fig. 5 for descriptive values. This higher friendliness score or positive sentiment was mainly associated with appreciations of other contributions, friendly greetings, and the use of emoticons. H3a is therefore supported.

Regarding mental well-being, a 2 × 2 ANOVA did not show significant main effects for emotional and cognitive GA information (see Table 4 in the Appendix). Moreover, there was no significant difference between the single emotional GA support condition (weight 1) and the no support (weight −0.5) and single cognitive GA (weight −0.5) conditions in the contrast analysis, with a mean difference of 2.19 ($SE = 1.59$); $t(144) = 1.37$, $p = .086$, $d = 7.92$, even though descriptive values are slightly in favor of the single emotional GA tool condition. H3b is therefore not supported; see Fig. 6 for descriptive values.

Regarding RQ1, there were no significant interaction effects related to the relevant variables from H3 (see Table 4 in the Appendix). To examine RQ1 more specifically, analogous to H2, we compared the combination condition (weight 1) only with the single emotional GA tool condition (weight −1) to see if the difference is significant between those two types of support measures, which is not the case (see Table 2).

Table 2
Contrast analyses for investigating combination effects.

	Mean Difference	*SE*	*t*	*df*	*d*	*p*
Friendliness score	1.33	1.35	0.98	70.77	4.85	.329
Mental well-being	0.24	1.84	0.13	144	7.92	.895

Single emotional GA tool effects, therefore, do not differ from effects of simultaneous emotional and cognitive GA support related to emotional process and outcome variables.

4.3. Moderating effects

To examine the potential influence of need for cognitive closure on the effects of cognitive GA information, we tested for moderation effects of need for cognitive closure and the factor cognitive GA support on the variables examined in H1/H2. However, we found no significant interaction effects on argument count in the article ($\beta = -.003$, $t(142) = -0.46$, $p = .482$), argument count in the discussion forum ($\beta = .004$, $t(144) = 0.05$, $p = .481$), article balance ($\beta = .08$, $t(144) = 0.73$, $p = .232$), discussion balance ($\beta = -.03$, $t(144) = -0.30$, $p = .381$), and learning performance ($\beta = .09$, $t(144) = 1.09$, $p = .138$). H4a is therefore not supported.

To examine the potential influence of need for affect on the effects of emotional GA information, we tested for moderation effects of need for affect and the factor emotional GA support on the variables examined in H3/RQ1. The calculations revealed a significant interaction effect on mean friendliness score in discussion threads ($\beta = .16$, $t(142) = 2.09$, $p = .020$). Also, the simple slope analysis (see Fig. 7), revealed significant conditional effects for high ($\beta = .51$, $t(142) = 4.82$, $p < .001$), medium ($\beta = .38$, $t(142) = 4.94$, $p < .001$), and low ($\beta = .19$, $t(142) = 1.74$, $p = .043$) need for affect values.

The simple slopes in Fig. 7 show that a high need for affect can indeed enhance the effects of emotional GA information on the mean friendliness score, whereas there is no notable difference for individuals without emotional GA support. However, the interaction effect of emotional GA support and need for affect on reported mental well-being did not become significant ($\beta = -.04$, $t(144) = -0.48$, $p = .315$). Thus,

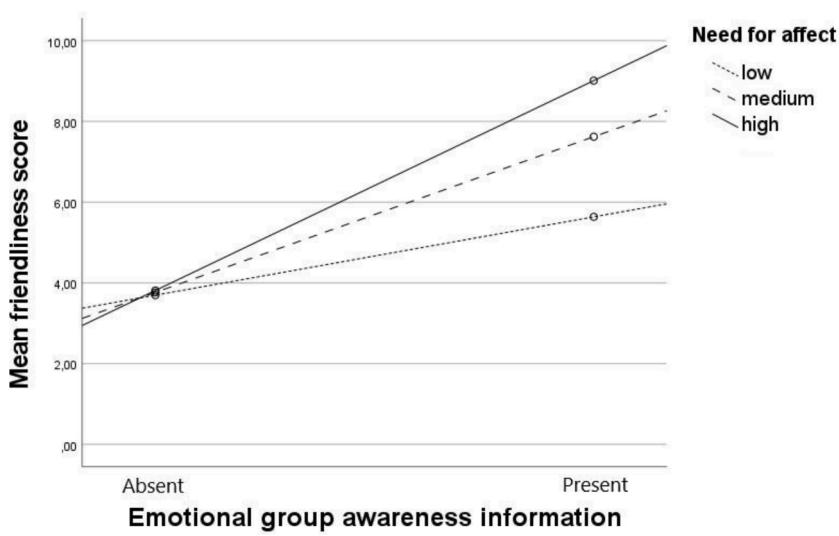

Fig. 7. Simple slopes of the moderating effect of need for affect.

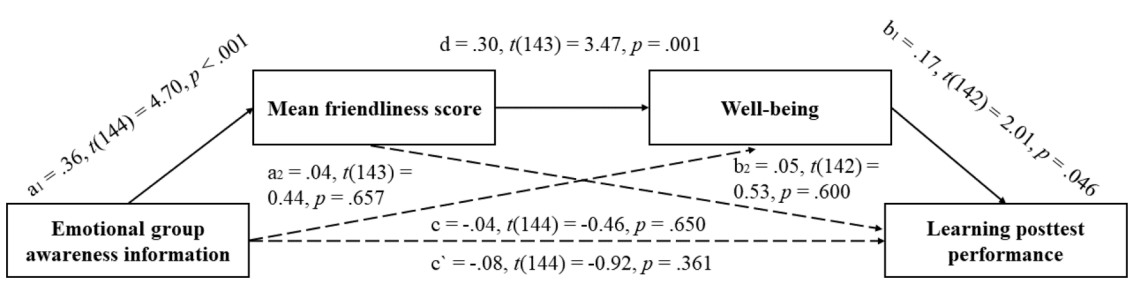

Fig. 8. Mediation model including standardized effect sizes.

Table 3
Descriptive statistics (*M* (*SD*)) of the exploratory variables.

	No Support	Cognitive GA	Emotional GA	Combination
Mental effort	5.81 (1.12)	5.32 (1.24)	5.38 (1.11)	5.74 (1.33)
Discussion contributions	2.08 (0.95)	2.30 (1.10)	2.51 (1.15)	3.05 (1.56)
Discussion word count	130 (66)	147 (77)	163 (80)	193 (79)
Article word count	688 (59)	716 (59)	713 (52)	720 (41)

H4b is only partially supported.

4.4. Further exploratory calculations

Even though we did not find significant direct effects of single emotional GA information or in combination with cognitive GA information on mental well-being and learning posttest performance, we decided to conduct a post-hoc sequential (serial) mediation analysis. This revealed that the relationship between the predictor emotional GA support and the criterion learning posttest performance is fully mediated by the mean discussion friendliness score and mental well-being score (indirect effect = .02, 95% CI[0.001, 0.05]), with a higher friendliness score leading to higher well-being and higher well-being leading to a higher learning posttest performance; see Fig. 8 for a summary of the results.

To gain more exploratory insights, we calculated further 2 × 2 ANOVAs without specifying concrete contrasts (see Table 3 for descriptive statistics): Regarding mental effort, the 2 × 2 ANOVA indicated a significant interaction effect (see Table 4 in the Appendix). However, post-hoc simple effect analyses show that there were no significant differences of the single cognitive GA support ($F(1, 144) = 3.02$, $p = .084$) or single emotional GA support ($F(1, 144) = 1.66$, $p = .200$) conditions compared to the combination of both. Besides, there were further main effects of emotional GA information on the number of discussion contributions and mean word count as well as of cognitive GA information on the number of written words in the article (see Table 4 in the Appendix), each in favor of the respective support conditions.

5. Discussion

The study investigated the single and interaction (combination) effects of cognitive and emotional GA support on valuable processes and outcomes to optimize knowledge exchange and social interaction in social media learning environments in terms of quality and friendliness, taking a wiki-like environment as an example. The results, as well as derivable implications, will be discussed in the following.

5.1. GA tool effects

Regarding cognitive GA support, the results show that single cognitive GA information in the form of individual and group knowledge bars has a positive influence on both the quality of contributions in a wiki discussion forum (argument count and argument balance) and article (argument count), supporting H1a. This is in line with previous findings [67] and illustrates that cognitive GA support can be crucial in improving the quality of written content in social media, which might be relevant for formal and informal learning contexts. Even though we did not find the expected results for argument balance in the article, it must be noted that article balance scores were in general rather low across all conditions, with no mean value that came close to the maximum achievable score of 1 (see Fig. 3). Furthermore, whereas discussions usually contain pro and contra arguments, wiki articles also tend to be more neutral in real settings, which may have prevented people from writing too controversially. Moreover, even though descriptive values are in most cases the highest for the combination conditions, it could not be shown that emotional GA information can significantly reinforce the effects of single cognitive GA information on the pre-defined cognitive variables (not supporting H2a/b), something we expected due to the dominant role of emotions in cognition and learning [26,32,81] as well as potentials of emotional GA tools for improving socio-cognitive processes [6,7]. These unexpected results could be explained by the fact that negative emotions like anger might have claimed cognitive resources [80]. Since some created discussion threads involved a lower level of friendliness, this may have hindered positive effects in the short term to occur because participants rather focused on emotional mediation instead of discussion exchange relevant for cognitive argumentation and learning growth [3]. Moreover, emotions are very complex in nature, and positive emotions with a deactivating function like relaxation might also have negative effects on effort and the use of learning strategies. Likewise, negative emotions with an activating function like tension might also have a positive effect on resulting learning motivation [81]. Since we measured only the written emotional expression, we cannot make concrete statements about the actual positive or negative emotions and its intensity felt during wiki engagement with rather friendly or unfriendly collaborators, which might play a role in exploiting the educational value of such platforms [84].

Regarding emotional GA support, single emotional GA information in the form of individual and group friendliness bars has a positive influence on interactions in the discussion forum, leading to friendlier discussion contributions, supporting H3a. That emotional GA tools can have a positive effect on emotional co-regulation could already be shown [27]. However, the effect of playing back some kind of emotional awareness information on writing styles in social media environments is a rather new and promising insight in the context of emotional GA tools. This makes clear that it is possible to measure the friendliness of written contributions and that playing this information back to the respective users helps to regulate the togetherness of collaboration. Especially in wiki environments, this is important because so-called “edit wars” are very likely to occur. These impair collaborative work [105] and might be avoided by the implementation of emotional GA information, as we outlined in this study. This offers further potentials, as Stieglitz and Dang-Xuan [96] were able to show that emotional messages in social media might also trigger greater cognitive engagement. Besides, emotional GA tool effects could not be reinforced with simultaneous cognitive GA support, something we wanted to look at exploratory. This negates RQ1. Therefore, if it is about regulating emotional processes and outcomes in a wiki or similar social media environments, it is sufficient to implement single emotional GA support.

Significant direct effects on outcome level could unfortunately hardly be determined for both cognitive (regarding learning performance) and emotional (regarding well-being) GA information, not supporting H1b and H3b. This is very likely due to only the discussion phase being enriched with GA visualizations, which heightened the potential to find effects on the process or discussion level instead of the outcome level. Regarding the missing direct effects of emotional GA information on well-being, we must admit that potential engagement with rather unfriendly threads, which were also provided in the learning environment, might have led to negative effects on well-being (see [108]). This is because mental well-being – both hedonic (including emotional aspects) and eudaimonic (including social and psychological aspects) dimensions – is known to be affected or harmed by negative socio-emotional interactions [42,55,59]. However, this forum design was intended as the bogus setting should be as real as possible and not biased in a positive direction. The mediation analysis shows a positive influence of emotional GA support via friendly interactions in the discussion forum on well-being in the group. This is in line with research (e.g., [62]) and highlights the potential of emotional GA support when achieving the expected positive effects on writing styles in wiki contributions. Regarding the missing single effects of cognitive GA information and combined effects with emotional GA information on learning

performance, this might be related to the fact that the experimental time was too short to yield any significant positive effects on learning performance. The interaction time of 20 min with the discussion forum was probably not enough for finding significant learning differences (see [85]). A longer interaction time would have potentially consolidated the knowledge and made the handling of the GA information more intuitive.

Particularly notable is the fact that single emotional GA support has a positive influence on knowledge test participation under certain circumstances, namely precisely when positive mental well-being is reported based on friendly interaction. Even if the effect sizes of the mediation model are small and there are no interaction effects between the two awareness forms, the results at least show the importance of emotional processes for cognitive ones. The used knowledge posttest was not piloted but its structure was strongly oriented towards the knowledge test that we already used in Ollesch et al. [75], which was piloted extensively and contained balanced topics across the whole forum. Also, care was taken to ensure that the experiment and test participation was conducted in a controlled environment. Furthermore, the mean values of the test scores reflect a medium level of difficulty with high standard deviations, which indicates a broad distribution of knowledge across participants so that an overly easy or difficult constellation of questions can be ruled out (see Fig. 4). Furthermore, the results regarding the produced content could very well show that people with single cognitive GA support added more new and correct arguments to the wiki article, which can be considered as a learning gain on a textual level and may have been more appropriate to measure learning performance than simple test participation since GA was also provided at contribution level.

5.2. Personal influences and exploratory findings

Regarding personal influences, we found an interaction effect of need for affect and emotional GA support, which strengthened the effect of the friendliness condition, supporting H4b but not H4a. Thus, it makes sense to control for personal variables like the need for affect in the context of emotional GA tools, for which little is known so far. However, more potential influencing variables need to be identified, especially in relation to cognitive GA tools, because no interaction effects could be found for the need for cognitive closure and cognitive GA support.

The exploratory findings show that cognitive and emotional GA information had a positive effect on quantitative behavioral outcomes such as the number of discussion contributions, discussion word count, and article word count, whereas this was not the case for the no support condition (see also Table 4). Even though this was not in the focus of the study, getting individuals to engage not only in a highly qualitative way (related to both cognitive and emotional engagement) but also in a highly quantitative way (related to behavioral engagement in knowledge exchange) is another major challenge in social media environments that should not be neglected ("behavioral challenge"; [74]). This is because active participation is considered crucial for learning growth in constructivist learning theory [19]. Last but not least, contrast analysis did not show significant differences in mental effort, which largely rules out increased effort in the use of GA tool combinations so that there is nothing to prevent implementation in this respect.

5.3. Addressing limitations

Even though the laboratory setting allowed for systematic consideration of process- and outcome-related variables in GA tool usage, such separation in discussion and article phases is unrealistic in CSCL environments. Especially in wikis, there is often a switch between the discussion and article page, which is why these results need to be tested for their applicability in more realistic contexts. The found effects might be enhanced in a longer field study, including real contact with other users also adapting their knowledge and friendliness level. Even though we chose wikis as the context, the results are still generalizable or transferable to similar learning environments: All CSCL or social media environments in which there is a common exchange/social interaction possibility of people, for example, in the form of an online discussion forum, and user-generated content, for example, in the form of an article or created group product, can benefit by such GA visualizations.

We did not measure the actual emotions felt during the wiki interaction, which is why we cannot fully exclude the effects of mimicry regarding writing styles. However, the results on well-being measured after the wiki interaction, mediated by friendly interaction patterns, show an emotional adjustment (see Fig. 6). In the future, it should be considered to what extent longer interaction phases might have a stronger and stable influence on changes in mental well-being. Also, well-being should not only be collected after the respective treatment but also before to detect actual changes, which would make the results more meaningful.

Moreover, even though sentiment analysis can only give a rough indication about the tone of posts, and even though it can be used for emotion detection, a clear classification into friendly and unfriendly posts is not possible. The discussion content was analyzed at a word level, without including the context; therefore, the results on friendliness or the sentiment score need to be interpreted cautiously as the number of contributed words might have distorted these. Sentiment analysis usually rather works for larger datasets to find tendencies and is also known as opinion mining, which is not equivalent to emotion mining [63,78]. Therefore, also a very friendly contra opinion could contain negative connotations and vice versa, thereby distorting the results. Also, we needed to adapt the results of the sentiment algorithm to match the 10-level friendliness visualization in the learning environment as equivalent to the 10-level knowledge visualization. In addition, the sentiment algorithm did not include negations or proverbs, and no spelling and character corrections have been considered, which is the case in well-known tools such as SentiStrength [97]. The used dictionary did not represent a large vocabulary and offers potentials for improvements. We do not claim that this was technically the best-practice method, and the approach still needs to be optimized, especially regarding the final GA visualization. However, we did not aim to present a ready-made method with this study, but we wanted to illustrate that playing back some form of emotional feedback can lead to an adaptation of friendliness in writing and that it makes sense to look at how to optimize this to build and validate automatic classifiers enabling the analysis of sentiments or socio-emotional conflicts.

5.4. Implications for future studies and designing social media learning environments

The presented study offers several implications for future studies. Only the discussion forum was provided with GA information. A balanced argumentation style may have also led to a higher quality of written content in the wiki article (see [48]). Therefore, it makes sense to also enrich the article level with GA in future studies and be more transparent to students about what makes a highly qualitative writing product. Also, such studies should record actual felt emotions during the learning interaction to underline the exact correlations between sentiments and these. Of course, in future studies, it also makes sense to examine to what extent such emotional awareness algorithms we presented might also prevent people from interacting with others and sharing their knowledge, as fear of social disapproval might play a role and people tend to protect their self-presentation as much as possible [86]. Moreover, we had a very high number of female participants, and gender differences in emotional processes are very likely [92,108]. Therefore, studies could be conducted that include a more balanced sample, considering various social learning contexts. Long-term field studies are conceivable here to enhance the possibility of finding real learning outcomes and differences. As the study shows that cognitive and emotional GA tools can trigger behavioral engagement, studies investigating behavioral GA information in combination with cognitive

and/or emotional GA information are recommended to further explore these possibilities.

The study offers several implications for pedagogical interventions. Cognitive development should be promoted by enabling socio-cognitive conflicts to be resolved in terms of assimilation and accommodation processes. Didactic materials should be linked to the learner's current cognitive stage here, and wiki platforms represent a suitable medium for enabling such meaningful knowledge exchange processes [22]. Emotional states also need to be considered even in textual exchanges via social media platforms, as this can affect learners' friendliness level and, based on this, also subjective mental well-being and learning outcomes. This, in turn, might be an indicator for a higher usage probability of social media learning environments in the long term [46,75]. Therefore, ensuring a positive group climate within the respective collaboration can positively influence the acceptance of such platforms for educational purposes. Cognitive and emotional GA tools can be helpful in achieving and enhancing these pedagogical goals; however, more likely separately than integrated, as the study results show. Especially informal and large-scale learning settings, very likely lacking awareness about others, should benefit from these measures, but they can also enrich formal learning, especially in blended formats. The study offers concrete implications for the practical use of GA tools in social media learning environments. Since we have found many positive effects of cognitive and emotional GA tools, it is recommended to implement such GA visualization in practice to enhance cognitive but also emotional quality, especially in group discussions, and in this way enhance the sociality of a social media learning environment. When the aim is to make users aware of the knowledge level of co-collaborators that are known to trigger socio-cognitive conflicts, regular knowledge quizzes could be helpful to collect this information and feed it back to the users. Bar charts are one option to present GA information; further presentation types like numerical scores are conceivable here. In this way, knowledge awareness could help to positively affect the cognitive challenge and thus increase the quality of textual contributions, as we could show in the study. Also, such knowledge vaults could help to better assess oneself and take appropriate actions in a social media or wiki environment for individual improvements. Moreover, when it comes to ensuring positive and peaceful interactions, the use of algorithms that measure friendliness based on written text could be implemented here, addressing the emotional challenge. This would help to test how friendly one's writing style is and adapt it, which might also avoid negative emotional contagion effects for the rest of the group. This is especially true when students have a high need for affect. A survey of this variable prior to the intervention is therefore recommended adjusting to the preferences of the learners and, if necessary, to bring less affective persons to a stronger consideration of emotional support tools with specific instructions (e.g., by encouraging them to address reasons for socio-emotional conflicts). Of course, at this point, it is also important to find out about the acceptance of such emotional awareness methods in pedagogical settings, as non-acceptance can have an impact on their observance [33]. To really get people to interact with GA tools, the respective teachers or facilitator could explain the specific objectives of such implicit guidance measures to increase their effects.

Both cognitive and emotional GA visualizations could be easily implemented in existing environments, but also blended approaches are possible to support school and university teaching with technologies and applications presenting such GA information. It would be advisable to educate students about the value of these GA incentives to further increase their motivation to use them (see [95]). When the technical capacities of the methods used here (e.g., sentiment analysis) are not given, less sophistic procedures such as the subjective assessment of knowledge, socio-emotional conflicts, or sentiments could be used instead, which have already proven their value [56,61]. Also, cognitive and emotional GA combinations could be increasingly used in learning practices. Such approaches could also be designed adaptive to systematically display and hide relevant information depending on how learners respond to it. Personalization is seen as a key element for learning environments to be successful [17], which potentially also increases possible combination effects on cognitive and emotional processes and outcomes.

6. Conclusion

The paper advances the field from a theoretical and methodological perspective. A novel theoretical contribution of the paper is that it provides a better understanding of the various effects of individual and combined GA support in social media learning environments systematically, something that should be tackled more intensively in research to increase the potentials of effectively using such educational technology. Regarding the overall research question, we could illustrate that single cognitive and emotional GA information has positive effects on various interaction patterns and user-generated content in wiki-like environments, even though the results should be transferred to further social media contexts. The effects are different in knowledge exchange scenarios for cognitive GA information (enhancing content quality of discussions and writing products) and emotional GA information (enhancing friendliness (politeness) patterns and, building on it, well-being), which is why their use depends on the context or the respective goal of the teacher or designer. Even if no positive interaction/combination effects were found, joint use may also make sense and should be tested to achieve desirable changes in educational settings, considering personal differences like need for affect. A novel methodological contribution compared with current research is the use of on-the-fly sentiment analysis as an approach to present the friendliness level in online collaboration. This might be promising to automatically assess the social behavior in large forums that needs to be further explored instead of using self-reports or retrospective methods. Nevertheless, the results also underline that single cognitive or combined GA support does not necessarily have a direct positive effect on learning outcomes in terms of knowledge posttest participation. On the other hand, emotional GA support has the potential to enhance such learning outcomes if positive effects are achieved on an emotional level (related to friendliness and mental well-being), something that is a completely new insight. This illustrates that the interconnections at the tool level and at the level of the underlying cognitive and affective processes are complex. Designing specific tools that promote social media learning requires consideration of these linkages and underlying functions.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We thank Maribell Steiner, Kirsten Wullenkord, and Leon Chamoun for their support during the whole process. Funding: This work was supported by the Deutsche Forschungsgemeinschaft (DFG) under Grant No. GRK 2167, Research Training Group "User-Centered Social Media".

Appendix

Table 4

Table 4
Summary of all calculated 2 × 2 ANOVAs.

	Dependent Variable	Factor	*df*	*F*	η^2_p	*p*
H1/H2	Article argument count	Cognitive GA	1, 144	7.28	.05	.008
		Emotional GA	1, 144	0.13	.001	.720
		Interaction	1, 144	0.20	.001	.654
H1/H2	Discussion argument count	Cognitive GA	1, 144	20.63	.13	< .001
		Emotional GA	1, 144	0.11	.001	.745
		Interaction	1, 144	0.05	< .001	.822
H1/H2	Article argument balance	Cognitive GA	1, 144	7.60	.05	.007
		Emotional GA	1, 144	1.68	.01	.197
		Interaction	1, 144	0.66	.01	.419
H1/H2	Discussion argument balance	Cognitive GA	1, 144	4.78	.03	.030
		Emotional GA	1, 144	2.57	.02	.111
		Interaction	1, 144	0.24	.002	.625
H1/H2	Learning performance (posttest)	Cognitive GA	1, 144	0.82	.01	.367
		Emotional GA	1, 144	0.32	.002	.573
		Interaction	1, 144	0.32	.002	.573
Exploratory	Prior knowledge (pretest)	Cognitive GA	1, 144	< 0.001	< .001	> .999
		Emotional GA	1, 144	1.36	.01	.246
		Interaction	1, 144	1.12	.01	.292
H3/RQ1	Friendliness score	Cognitive GA	1, 143	1.30	.01	.256
		Emotional GA	1, 143	19.82	.12	< .001
		Interaction	1, 143	0.27	.002	.603
H3/RQ1	Mental well-being	Cognitive GA	1, 144	0.24	.002	.626
		Emotional GA	1, 144	3.15	.02	.078
		Interaction	1, 144	0.09	.001	.764
Exploratory	Mental effort	Cognitive GA	1, 144	0.10	.001	.750
		Emotional GA	1, 144	0.002	< .001	.964
		Interaction	1, 144	4.58	.03	.034
Exploratory	Discussion contributions	Cognitive GA	1, 144	3.61	.02	.060
		Emotional GA	1, 144	8.90	.06	.003
		Interaction	1, 144	0.66	.01	.417
Exploratory	Discussion word count	Cognitive GA	1, 144	3.52	.02	.063
		Emotional GA	1, 144	9.97	.07	.002
		Interaction	1, 144	0.25	.002	.615
Exploratory	Article word count	Cognitive GA	1, 144	4.04	.03	.046
		Emotional GA	1, 144	2.54	.02	.113
		Interaction	1, 144	1.46	.01	.230

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