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Collaborative writing regulation: a comparative case study of co-regulation and socially shared regulation in higher education

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Abstract
Active learning and project-based learning are well-established instructional practices in higher education: abundant evidence shows their effectiveness in student development and learning. Especially in STEM, these practices often entail group work and collaborative writing. Therefore, the framework of Social Regulation of Learning (SoRL)—including socially shared regulation of learning (SSRL) and co-regulation of learning (CoRL)—is useful for exploring how students regulate their writing processes in group work. Yet, studies of the social-regulation dynamics required for effective collaborative writing have rarely explored them. This comparative case study examines episodes of CoRL and SSRL, their relationship, and their influence on the process of collaborative thesis writing over time for two groups of BSc students in STEM. Over six months, we collected data through text histories, which included multiple drafts and repeated interviews with students, their supervisors, and their academic writing tutors. Through rich data, we trace the two groups' writing regulation trajectories and identify CoRL and SSRL episodes that were crucial in their writing process. Instances of CoRL were experienced by both groups and were initiated either by a group member or one of the supervisors. However, not all these instances of CoRL resulted in the establishment of successful SSRL of writing: shared goals, strategies, and metacognition about the developing text. When CoRL did not progress into SSRL, the collaborative dimension of writing failed, which had consequences on learning and students' motivation over time. We conclude with theoretical and pedagogical implications about explicitly teaching writing regulation to students in HE collaborative contexts.

Keywords Project-based learning · STEM writing · Collaborative learning · Collaborative writing · Writing regulation · Case studies

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Introduction

Instructional practices in higher education have increasingly embraced active learning, as student-centered approaches have been proven to be effective in terms of students' achievement and learning (Kozanitis & Nenciovici, 2022; Freeman et al., 2014; Hofer et al., 2018). In engineering education, active learning often takes the form of project-based learning and group work, as this type of collaborative approach is considered relevant for future employment situations and crucial for student development (Hernandez-Diaz et al., 2024). While the literature supporting the effectiveness of this approach is abundant in terms of how problem-oriented, collaborative project work offers the potential for "doing knowledge work" (Acton, 2022), a crucial element of collaborative, project-based work has been so far rather overlooked: writing. Most of the active, problem- or project-based instructional practices currently adopted in STEM ask students to collaboratively co-author a text.

While collaborative writing is often used as an academic learning task (Storch, 2011), in engineering education, it is not uncommon for courses to require students to collaborate on a semester-long project where they simultaneously learn about the technical field, about doing research, and how to work with others (Acton, 2022; Chen et al., 2021; Sukackė et al., 2022; Wallin et al., 2017). It is, therefore, crucial that students working in groups develop effective collaborative writing strategies since writing is both the means and the output of learning in this type of instructional practice. However, group work does not necessarily equal collaborative learning (Summers & Volet, 2010), and this distinction may also be true when considering collaborative writing. While individual students' ability to develop strategic learning behaviors has received attention (e.g. Cervin-Ellqvist et al., 2020), the regulation of learning processes involved in collaborative writing has been less explored. The Social Regulation of Learning (SoRL) framework is therefore useful for examining collaborative writing situations such as project-based learning in groups.

Around a decade ago, Hadwin, Järvelä, and colleagues proposed a re-conceptualization of the regulation of learning that explicitly addresses its social dimensions, especially in collaborative work (Hadwin & Järvela, 2011; Järvelä et al., 2010; Järvenoja & Järvelä, 2009). While the terminology has shifted over time, there is a general consensus that the SoRL framework ties together self-regulation of learning (SRL), co-regulation of learning (CoRL), and socially shared regulation of learning (SSRL) (Hadwin & Oshige, 2011; Hadwin et al., 2018). This framework has enabled studies capturing learning in collaborative situations, and has generated considerable research especially in combination with digital learning and computer-supported learning environments (cf. Järvelä & Bannert, 2021; Miller & Hadwin, 2015) but, to the best of our knowledge, no study has focused on the writing dimension of collaborative work through this framework.

This study was conducted at a leading technical university where project-based and problem-oriented approaches are integral to the curriculum, emphasizing active learning pedagogies and collaborative projects to prepare students for industry expectations. This context provides an authentic backdrop for examining SoRL while highlighting the challenges posed by diverse student experiences in collaborative academic writing. Using the SoRL framework, we investigate authentic, collaborative writing processes through two cases—groups of engineering students collaboratively writing their bachelor's thesis.

Our study addresses three critical areas in the research on SoRL: authenticity, temporality, and data richness (Hadwin, 2021). In terms of authenticity, we respond to the limited studies applying the SoRL framework in real-world contexts. Authenticity ties closely to temporality, emphasizing the need to explore how social regulation

of learning evolves over time and across regulatory stages. Finally, we emphasize the importance of data richness, using ethnographic methods to examine the nature, focus, timeline, and frequency of CoRL and SSRL episodes. These approaches allow us to trace unique collaborative writing trajectories and identify key factors influencing their differential successes. By doing so, the study provides novel insights into the interplay of regulation processes in active learning environments and addresses a significant gap in the international higher education literature, which often overlooks writing as a core component of project-based learning.

Theoretical framework: SSRL and CoRL

SSRL refers to a group's deliberate, strategic, and *metacognitive* effort in regulation phases: task understanding, goal setting and planning, task enactment, and reflection and adaptation (Hadwin et al., 2018). SSRL involves *negotiation*: it entails a discussion and an alignment of goals and strategies in the processes of planning, monitoring, and evaluating, particularly important in longitudinal tasks such as thesis writing (Bandura, 1982). SSRL, therefore, occurs fundamentally at the metacognitive level (Järvelä & Rosé, 2023) and requires metacognitive interaction (Haataja et al., 2022), i.e., social interaction that is focused on the thinking and decision-making required in collaborative learning and writing. As posed by Kuhn (2015, p. 4), this "socially mediated metacognitive talk about thinking may be a key factor in conferring any benefit the collaboration activity provides."

CoRL refers to the regulation of learning that occurs when a specific agent—such as a group member, instructor, or external party—introduces a suggestion, strategy, or perspective that shapes the regulation processes of an individual or a group (Hadwin et al., 2018). Unlike SSRL, which emerges through shared and negotiated regulation among all group members, CoRL often involves one-sided input that requires the group to decide how to act upon it. The interaction can either scaffold learning (e.g., prompting deeper engagement or reflection) or constrain it if the group fails to critically evaluate and integrate the input.

Collaborative learning, therefore, requires a shared regulation where CoRL and SSRL interplay. This interplay poses specific challenges to research on SSRL and CoRL. According to Järvelä et al. (2019), key methodological challenges comprise three aspects: i) capturing the cyclical nature of regulation and how it affects learning, ii) capturing how the different aspects of regulation interact together, and iii) understanding the sociocultural aspect of regulation, where the learning environment and the role of the network other than the group members themselves are investigated.

Another challenge comes from the need to trace the complex interplay of individual and group regulatory processes sequentially over time (Järvelä et al., 2016; Lajoie et al., 2015). This temporal dimension is crucial to understanding the effects that CoRL has on a group's regulation of learning since CoRL can have both a facilitative and a negative influence on SSRL (Grau & Whitebread, 2012). Related to this, research has also shown that different types of interaction in group work may stimulate either CoRL or SSRL, with potential consequences for the establishment of collaboration (Järvenoja et al., 2020; Ucan & Webb, 2015).

In collaborative engineering learning environments such as the one we study, the relationship between CoRL and SSRL is of particular interest since the outcome of project work is not an individual product but a shared text. While the social dimension of

individual writing regulation has been captured in research on academic writing, showing the connection between self-regulation of learning (SRL) and CoRL (Negretti & Mežek, 2019; Sala-Bubaré et al., 2021), in collaborative writing, the interaction initiated by CoRL and how it may lead to SSRL—the collective uptake described by Hadwin et al., (2018)—warrants scrutiny. For example, Nguyen et al. (2021) underscore the importance of understanding the connection between group-level regulation and student efficacy to enhance learning experiences. Using quantitative discourse analysis methods, namely epistemic network analysis (ENA) and process mining, the authors examined student discourse. The findings suggest that teams with more social exchange demonstrated dynamic collaboration patterns, engaging more in shared regulation of planning, progress monitoring, and task understanding. Successful groups typically initiate their regulatory activities with execution and conclude with monitoring, while less successful groups tend to depend solely on execution. The potentially intriguing connection between CoRL and SSRL emerges also from other studies. Li et al. (2021) examined the impact of social regulation strategies on the learning engagement and outcomes of 95 college students learning English as a foreign language (EFL) in wiki-supported literature circles. SSRL was a significant predictor of student engagement, while CoRL predicted learning outcomes, which were measured by a language test at the end of the course. This means that when students regulate their learning as a group, their involvement and participation in the learning process increase.

In SSRL, the importance of successful social dialogues has been stressed. For example, Chen et al. (2023) explored how small-group discussions with 5th graders can enhance critical thinking, reading comprehension, and argumentation in educational settings. By analyzing 4070 speaking turns in 60 group discussions using exponential random graph models, the study found a connection between the types of social dialogues speakers used and their cognitive dialogue patterns. It revealed that receiving certain types of social dialogue did not consistently lead to advanced cognitive processing among peers: receiving social support from peers in group discussions does not necessarily lead to more advanced cognitive dialogues. This echoes Kuhn's (2015) emphasis on socially mediated metacognitive talk as a prerequisite for collaborative learning, and Mercer et al. (1999) concept of "cumulative talk," i.e., interactions that are less productive because students only build upon peers' ideas without critical analysis or deepening understanding, resulting in a shared but unexamined agreement. The research summarized thus far raises the question of how the relationship between CoRL and SSRL impacts on learning. In response, we explore the dynamics of collaborative writing using a rich dataset, as advocated by Hadwin (2021). Our research question is:

RQ: How can the differential learning pathways be understood through the dynamics of SSRL and CoRL?

Methods

Research context

The BSc thesis project at the Technical University, spanning six months from January to June, engaged groups of three to six students formed based on their interest in specific projects for which they meet the eligibility criteria (Eriksson et al., 2021). Each student group was tasked with a broad thesis theme to allow flexibility in narrowing down specific

topics based on their interests, such as exploring the impact of tourism on transportation systems. This approach enabled students to decide on the methodological and theoretical frameworks most suitable for their chosen topic. Students had the autonomy to determine their group meeting frequency and medium (online or in person). All collaborative writing and document management were facilitated through Overleaf, a platform that supports simultaneous document editing and provides a comprehensive editing history.

In terms of supervision, each group was assigned two supervisors: an academic supervisor (AS) and an industry supervisor (IS). These supervisors varied in their levels of support to the students. Additionally, support was extended through an English for academic purposes (EAP) tutor, who conducted two tutoring sessions focused on improving the student's academic writing skills.

The project did not have interim deadlines, allowing students to manage their time and project milestones at their discretion. All groups were expected to produce a thesis that met predefined product outcome expectations, with all participants emerging from the same three-year BSc program at the university and sharing similar levels of experience and background. In recognition of their participation, students received detailed feedback on their drafts, further aiding their developmental process throughout the project.

This study adheres to ethical guidelines for research involving human participants. All participants provided informed consent before data collection, ensuring they understood the purpose of the study, their voluntary participation, and their right to withdraw at any time without consequence. Data confidentiality and anonymity were strictly maintained, with any identifying information removed or anonymized.

Comparative case selection

The selection process for this comparative case study followed a purposive sampling approach to ensure the inclusion of cases that offered meaningful contrasts in regulatory processes. The initial survey distributed to 60 BSc students provided baseline data about their prior collaborative writing experiences, group preferences, and expectations for the thesis process. Based on survey responses, we identified five potential groups displaying varying degrees of engagement and prior experience.

To further refine our selection, we conducted individual interviews with members of these groups to gain deeper insights into their collaborative dynamics and perceptions of group roles. These interviews allowed us to link individual perspectives to group-level dynamics and to assess variations in regulatory practices. For example, we examined indicators such as the alignment (or misalignment) of individual goals within the group, members' descriptions of decision-making processes, and the perceived role of external guidance in shaping their collaboration.

Unique and informative variations were assessed by comparing these indicators across groups. For instance, some groups displayed a high degree of alignment in goals and strategies, while others reported significant divergence in task understanding and contribution levels. Such contrasts were critical in selecting the final two cases (Negretti & Khuder, 2024), as they provided an opportunity to explore the relationship between CoRL and SSRL in different regulatory contexts.

Ultimately, group A was chosen as an extreme case representing a lack of shared regulation, with members displaying varying levels of engagement and reliance on external guidance. In contrast, group B exemplified strong alignment and collaborative regulation, providing a rich comparative framework to examine differential learning trajectories.

According to Palinkas et al. (2015), strategies such as extreme case sampling are particularly suited for examining pronounced differences, which aligns with the study's objective to understand how contrasting group dynamics of co-regulation and socially shared regulation influence their learning pathways. Both groups consisted of five students with some degree of familiarity between them but had never worked on a collaborative project together before.

Data collection methods

To effectively trace the collaborative writing processes of BSc thesis groups, and trace the relationship between the text and the regulation of the collaborative writing process (Paavola & Hakkarainen, 2021), our study employed the text histories method (Lillis & Curry, 2010). This approach involves the systematic collection of textual drafts and concurrent interview data with all stakeholders involved in the writing process, including students, their AS, and EAP tutors.

Textual data collection

We collected two main types of textual data: i) students' written drafts: utilizing overleaf, a collaborative writing platform, allowed us to access and download multiple versions of students' texts, enabling us to trace changes and developments over time; ii) feedback documents: students shared the written feedback they received from both their AS and EAP tutors.

Talk-around-text interviews

All interviews conducted in this study were structured as talk-around-text sessions, lasting between 60 and 120 min, which involved detailed discussions centered on the drafts and feedback at various stages of the writing process. Table 1 below shows the schedule and focus of these interviews.

By aligning interviews with key phases of the thesis development, we ensured that each stage was captured in-depth, providing rich insights into the collaborative dynamics and individual contributions throughout the project.

Data analysis: coding scheme and writing episode segmentation

Interviews were transcribed verbatim and coded alongside written documents to provide a comprehensive understanding of each regulatory phase. To analyze the collaborative writing process across two groups, we employed a coding scheme based on Hadwin et al.'s (2018) model of self-regulated learning phases. These phases include:

1. Task perception: where learners develop an understanding of the assigned task.
2. Goal setting and planning: where learners define objectives and plan strategies.
3. Task enactment: where learners execute their plans and strategies toward the goals.
4. Adaptation: where learners make adjustments to their strategies, either in real time (small scale) or for future tasks (large scale).

Table 1 Overview of talk-around-text interview schedule

Interview number	Participants	Focus of interview	Timing in the writing process
1	Individual students	Discussing initial project scope, roles, and expectations for early drafts	January (beginning)
2	Groups	Reviewing initial drafts, discussing changes based on early feedback, clarifying roles	February (early stage)
3	Academic supervisors	Integrating academic feedback, discussing adjustments and their impacts on the drafts	March (mid-project)
4	EAP tutors	Feedback on drafts from an academic writing perspective, suggesting improvements	March (mid-project)
5	Groups	In-depth comparison of drafts, discussing substantive changes and feedback reflection	April (late stage)
6	Individual students	Final draft reflections, overall project outcomes, assessing goal achievement	June (end)
7	EAP tutor	Final draft reflections	June (end)
8	Academic supervisors	Final draft reflections	June (end)

In each phase, we focused on coding for decision-making processes, identifying whether decisions were made collectively (SSRL) or directed by one member or an external guide (CoRL). Our coding approach was both deductive, using predefined categories from the literature, and inductive, allowing emerging themes related to participants' satisfaction, engagement, and emotional responses to surface from the data.

These phases were sequenced in a writing episode according to their writing focus (e.g., citation, defining study focus, editing introduction). We have identified 17 episodes for group A and 19 episodes for group B (Appendix). Given the longitudinal nature of our study, involving BSc thesis writing over six months, we defined an "episode" as a sequence of events, activities, or interactions sharing the same focus of the writing aspect. This operational definition facilitated the examination of learning regulation without the impracticality of continuous recordings, which could miss significant temporal developments. This approach also explicitly accounted for the iterative nature of the regulatory processes. When groups returned to earlier phases, such as planning and goal-setting after initial task enactment, these iterations were documented as part of the ongoing regulatory trajectory, encased in an episode. This method acknowledges the dynamic and cyclical nature of collaborative learning, where groups may revisit and revise earlier strategies based on evolving task perceptions and outcomes. Our coding scheme and writing episode segmentation can be found in Tables 2 and 3 in the Appendix.

Data analysis trustworthiness

Data analysis trustworthiness is established through a defined set of criteria designed to ensure the research process is trustworthy: credibility, dependability, transferability, and confirmability (Lincoln & Guba, 1985). Credibility, indicating alignment with both researchers' and participants' perspectives, was attained through prolonged engagement with participants and data triangulation (methods and informant triangulation). The second criterion, dependability, involves ensuring the traceability of the research process so that another researcher reanalyzing the data would yield the same results. This was achieved through researcher triangulation with an external researcher conducting an inter-coder reliability check on 10% of the data from interviews and textual analysis. Transferability was ensured by including a detailed description of the data and our findings here, enabling those seeking to apply the findings in their context to assess the suitability of such transfer. Confirmability ensures confidence that the study's findings are not influenced by the researchers' bias but rather rooted in the participants' narratives: we provide extensive data from multiple interviews.

Findings

To examine the effects of different regulation dynamics in collaborative writing, we present two cases, group A and group B, which varied greatly in their SSRL and CoRL trajectories. We provide an overview of these trajectories followed by a more detailed account of selected trajectory episodes, divided into three chronological stages (January, March/April, and June) and illustrated with visualizations generated by Lucid.App, combining textual and interview data from various sources. Episodes were selected based on their potential to demonstrate the interrelation between Hadwin et al.'s (2018) phases and how these could lead to divergent trajectories between the groups. The selection of these episodes, rather than an exhaustive report of all instances, was guided by their representativeness and richness in demonstrating the pivotal regulatory phases and transitions.

Group A

Group A's writing regulation trajectories are characterized by variety in the use of CoRL episodes but with no actual establishment of SSRL. Due to various constraints and events, this group did not seem to establish the shared metacognitive plan necessary to achieve SSRL, which led to consequences in terms of perceived motivation for learning, engagement with the project, and affective responses. Throughout their writing journey, the students experienced CoRL episodes from various agents, including peers, AS, IS, and their EAP tutor. Group A's AS was a PhD student in her final year with three years of supervision experience at the time of the study; their IS was appointed by the collaborating company (referred to as XX hereafter).

Overview of group A's regulation trajectory

This section provides an overview of how group A's reliance on CoRL hindered the establishment of meaningful SSRL across various stages of their thesis development. This pattern persisted throughout key aspects of their work, including methodology design, data analysis, and the writing of sections such as the literature review, discussion, and final revisions.

Group A consistently adopted a receptive approach to external advice, drawing heavily from their BSc AS, IS, and examples of previous theses. However, they failed to engage in collaborative discussions to evaluate or adapt this guidance. For instance, in their goal setting and planning, the group initially proposed using quantitative methods and designing questionnaires. However, the IS recommended conducting interviews instead. David, one of the group members, persuaded the group to adopt this suggestion without deliberation or consensus-building (task adaptation). This lack of shared metacognitive planning affected later stages in task enactment, such as data analysis, where the students had no clear strategy for handling qualitative data. Instead, they relied on replicating methods from previous theses. Consequently, their individual approaches to reliability checks were inconsistent, and a discrepancy was noted multiple times in their final thesis.

Similar patterns emerged during the writing process (task enactment). Decisions about content inclusion, such as in the literature review and discussion sections, were often made unilaterally or based on external suggestions. When questioned about specific deletions in the text, group members often shifted responsibility, with one stating, "It wasn't my section—it must have been someone else." This lack of ownership over authorial decisions highlights the absence of shared regulation and collaborative engagement.

During revisions, the group divided tasks among members without collectively discussing feedback (task enactment). Their approach was characterized by comments such as, "I am responsible for this part, so it makes sense that I do what the supervisor suggested." As a result, revisions were executed as isolated efforts rather than as part of a cohesive, collaborative process.

The general trajectory of regulation in group A can be summarized as follows:

Information Received → Students Accept It (from BSc AS, IS, and previous theses) → Implementation Without Discussion.

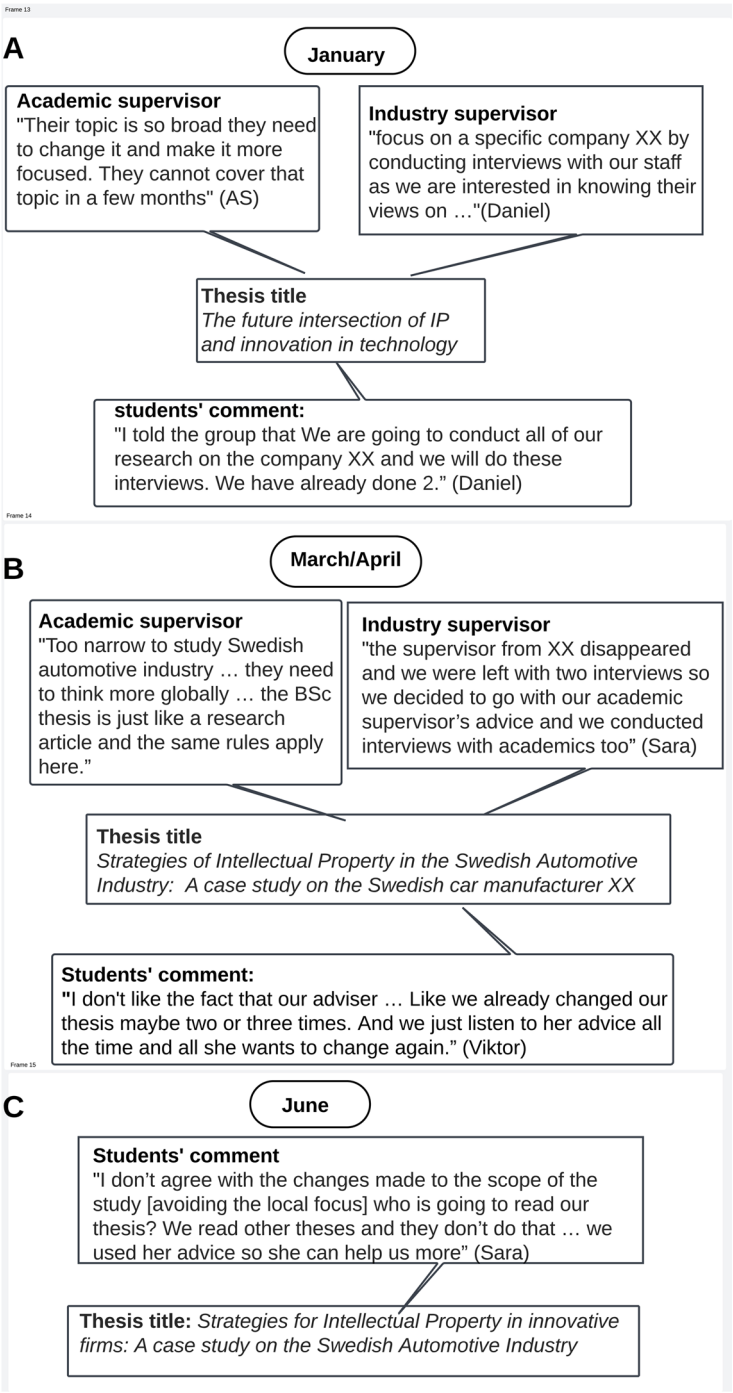

Fig. 1 Group A's task perception and planning in defining study focus for January (**A**), March/April (**B**), and June (**C**)

To illustrate how these regulatory patterns unfolded throughout group A's thesis development, we present selected episodes in greater detail. These episodes highlight key moments in the group's collaborative writing process and demonstrate how their reliance on external guidance shaped their regulation of learning and writing.

Episode 1: defining study focus

At the outset of the writing process, group A undertook two key phases: task perceptions and goal setting and planning (phases 1 and 2 as defined by Hadwin et al., 2018). Initially, both academic and industry supervisors interacted with the group, offering guidance on the project's focus, as illustrated in Fig. 1A below. It was at this point that Daniel, one of the students, established the group's objective. The group members concurred with his decision and adhered to the industry supervisor's recommendation to focus on interviewing their staff members about their perspectives on intellectual property rights, as shown in Fig. 1A. Daniel's decision to follow the industry supervisor's advice stemmed from their first meeting, where she expressed confidence in him, saying, "I trust you to do the job. I believe in you."

After the industry supervisor "disappeared," the students, following Daniel's advice, decided to set a new goal. They chose to follow their academic supervisor's suggestion to broaden their initially narrow focus. Not all group members found this new direction appealing, as illustrated in Fig. 1B below.

Once again, following Daniel's guidance, group A accepted the advice from their academic supervisor and ended up interviewing employees from other companies. Even though the students worked hard to meet the academic supervisor's expectations, they were rather dissatisfied with the final product, as Fig. 1C below shows.

Episode 1 reveals that the group's writing goal was never collaboratively discussed among the members. Instead, the goal was set based on the perceived benefits of supervisor assistance rather than a shared interest or a metacognitive understanding of the goal. This episode highlights a failure in collaborative regulation of learning (CoRL), which did not facilitate shared goal setting but instead led the group to relinquish their agency. As circumstances and advice shifted, subsequent attempts at CoRL did not result in joint discussions or agreements on goals, leading to dissatisfaction among most group members.

Episode 2: Writing and editing the introduction

The second episode aligns with phase 3, task enactment, focusing on revisions to the introduction of group A's thesis. This involved writing metatext to organize the introduction, a strategy derived from analyzing previous theses to understand common structural elements. Initially, the students strategically planned their text by examining previous theses, which informed their approach to writing the introduction section, as depicted in Fig. 2A.

When the EAP tutor advised group A to delete the metatext section, this recommendation appeared to challenge their initial planning strategy. Despite this, the group once again accepted this external guidance without further discussion or negotiation on the revisions. Figure 2B illustrates how the students accepted the tutor's comment; in explaining their changes, they primarily reiterated the EAP tutor's advice.

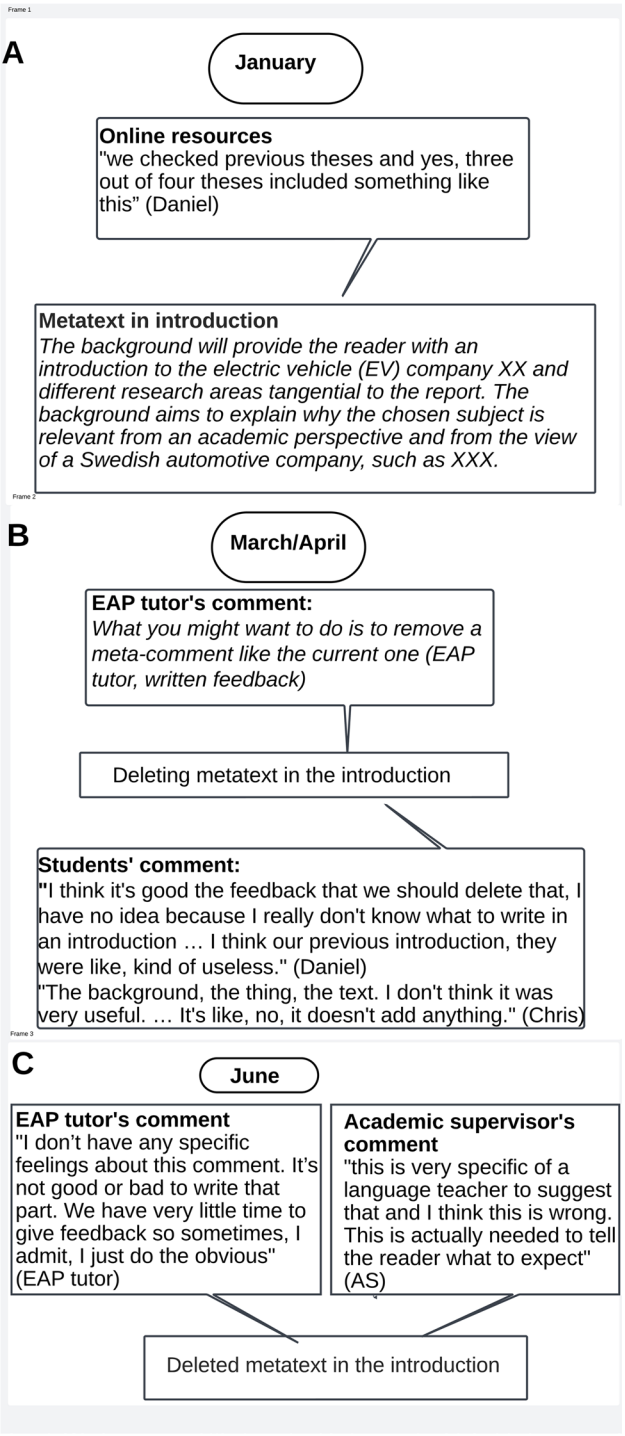

Fig. 2 Group A's task enactment in writing and editing the introduction for January (**A**), March/April (**B**), and June (**C**)

Contrary to the students' belief that the section must be deleted, the EAP tutor had not given much thought to his comment. Additionally, the academic supervisor was dissatisfied with both the comment and the students' response to it, as illustrated in Fig. 2C.

This episode highlights yet another instance where external CoRL failed to positively influence group A's writing regulation. Although their planning strategy was effective, the students lacked confidence in it, leading them to abandon their plan. Consequently, they missed the opportunity to develop shared metacognition and once again relinquished their agency.

In summary, the regulation of writing within group A was predominantly characterized by CoRL, although there were moments of SSRL, especially during the shared planning stages. Despite these instances, the overall effectiveness of their collaborative writing regulation process was limited. While the group met their performance goal, evidenced by a good grade, the predominance of CoRL over robust SSRL processes hindered their development of shared goals and cohesive task enactment strategies. This imbalance often resulted in negative affective outcomes and a sense of lost agency among the members, impacting their metacognitive engagement with the task. As Sara pointed out, despite the good grade, it held no emotional significance or value for meaningful learning. This underscores the complexity of regulatory processes in collaborative learning environments, where the quality and extent of engagement in different modes of regulation can significantly affect both the experience and trajectory of learning.

Group B

Group B's collaborative writing trajectory was marked by a variety of CoRL and SSRL episodes. This group consisted of five male students with a strong pre-existing friendship. Similar to group A, group B was overseen by an academic supervisor appointed by the university, who brought to the role a well-established reputation in their field, numerous publications, and over two decades of supervisory experience. They also had guidance from an industry supervisor.

Overview of group B's regulation trajectory

In this section, we provide an overview of how group B regulated the different aspects of writing their project thesis. The students consistently acted in a collective and collaborative manner, ensuring weekly meetings to discuss all aspects of their work. Even when tasks involved specialized skills, such as data analysis conducted by Hans, who was the only one with the relevant programming knowledge, the students held meetings specifically to update the group (task enactment). This allowed Hans to explain how the data were analyzed and ensured that everyone understood and felt ownership of the process. The group even made efforts to learn basic programming concepts to integrate Hans's recommendations into their work, emphasizing the sentiment: "It is important that whatever goes into the report is from all of us. At the end of the day, we are all responsible for this text." (Andreas).

This shared sense of responsibility extended to all sections of their thesis, particularly the discussion and literature review. The students demonstrated full awareness of and engagement with the decisions made in each section. For instance, when asked about a specific revision (e.g., regarding the inclusion of key arguments in the literature review),

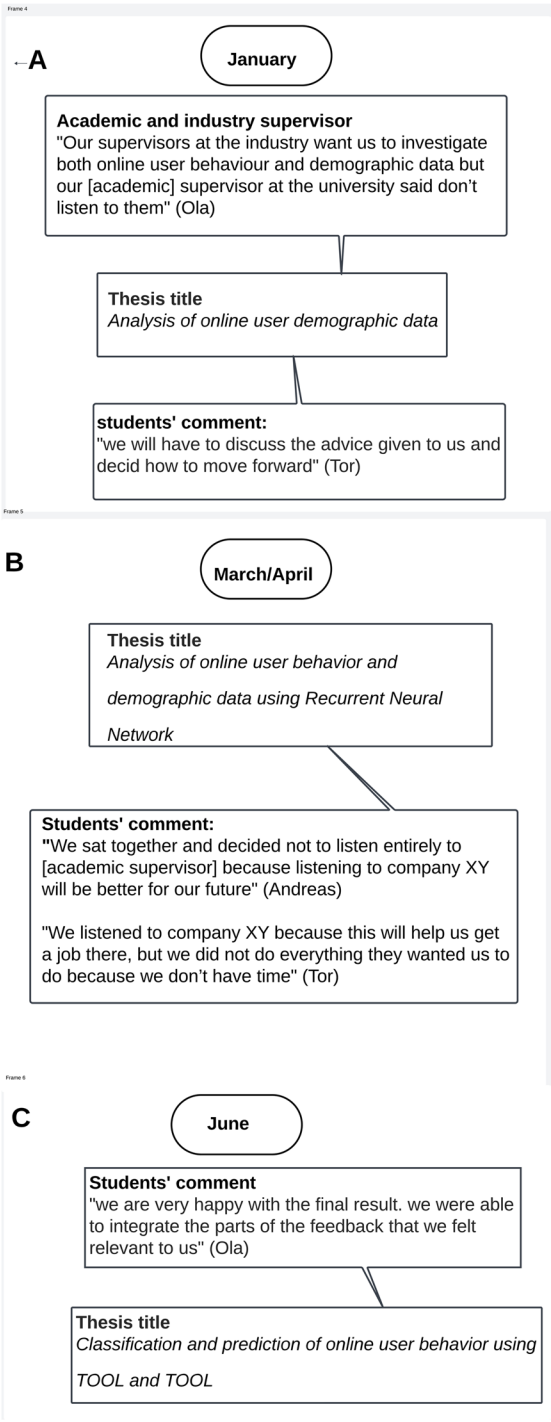

Fig. 3 Group B's task perception and planning in defining study focus for January (**A**), March/April (**B**), and June (**C**)

several group members confidently explained their rationale, underscoring their collaborative regulation processes.

Even in moments of disagreement or when tackling unfamiliar challenges, the group consistently engaged in collective problem-solving. They reported that their discussions often facilitated creative solutions and deeper understanding, further reinforcing their commitment to shared responsibility and collaborative success. For example, when implementing feedback, the group noted that when they received ambiguous feedback from their supervisor, they first discussed their differing interpretations together (task adaptation). They deliberated on potential solutions, considering their implications for the project, before seeking clarification and advice from their academic supervisor.

The overall regulatory trajectory for group B can be summarized as follows:

Information Received → Group Discussion → Shared Decisions and Implementation (via SSRL).

To provide a deeper understanding of how group B's collaborative approach manifested throughout their thesis development, the following section details selected episodes. These episodes exemplify the group's ability to transform external feedback and challenges into shared regulatory processes, highlighting their effective use of SSRL.

Episode 3: defining study focus

Episode 3 aligns with the task perception and goal setting and planning stages as described by Hadwin et al. (2018). During this phase, group B received conflicting feedback from their supervisors. The industrial supervisor suggested expanding the project, while the academic supervisor, referring to time constraints, deemed this expansion unrealistic. This divergence in advice is illustrated in Fig. 3A below.

Figure 3B below illustrates how group B engaged in a thorough discussion and collectively decided to follow the industry supervisor's feedback while also considering the academic supervisor's concerns about feasibility. This balanced approach led to a study focus that was perceived as both achievable and satisfactory by the group and their supervisors.

The continuous discussions that the students in group B engaged in during the writing process of their BSc thesis led to a satisfactory written product. This product successfully met the students' objectives, as illustrated in Fig. 3C below.

In this episode, external CoRL from the supervisors was transformed into SSRL as the students collectively discussed and adapted the advice to align with their own goals and interests. Through this process, they achieved a shared understanding of the task requirements and successfully negotiated both the feedback and their own objectives.

Episode 4: revising the introduction and the literature review

Episode 4 demonstrates task enactment and adaptation (phases 3 and 4, according to Hadwin et al., 2018), highlighting changes to the thesis structure, specifically within the introduction and theory sections. In their initial draft, the group included sections on "problem

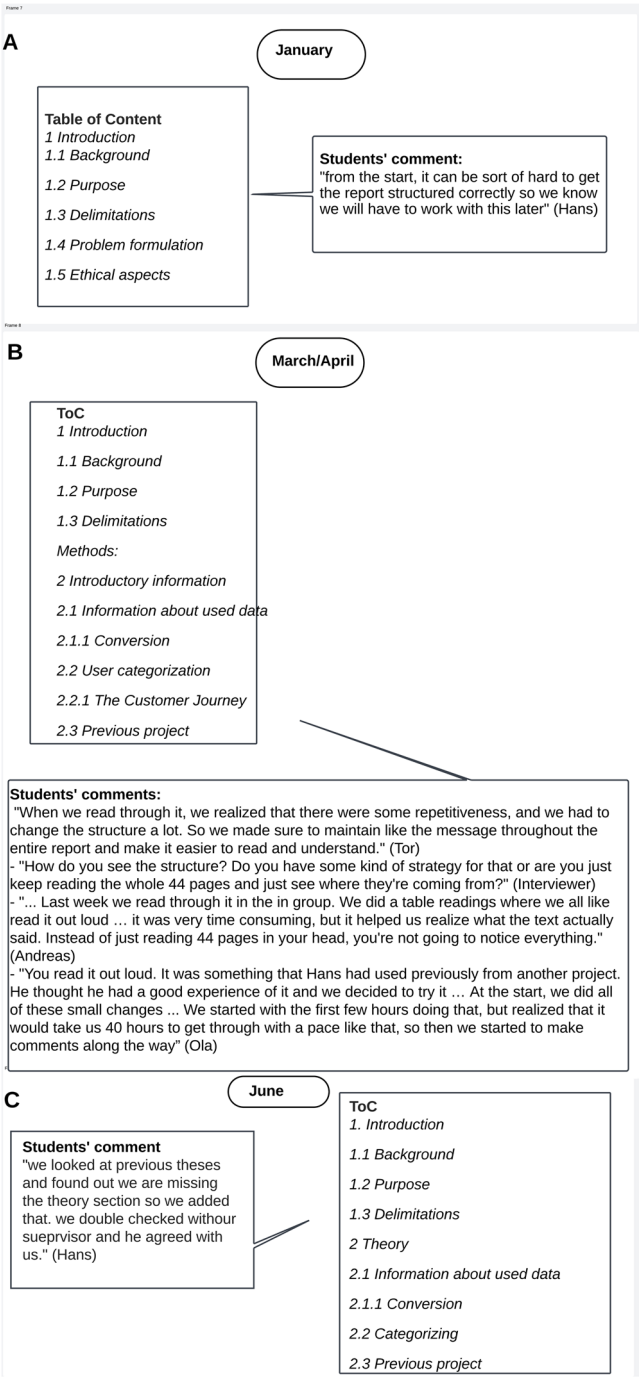

Fig. 4 Group B's task enactment and adaptation in revising the introduction and the literature review for January (**A**), March/April (**B**), and June (**C**)

formation" and "ethical aspects." As shown by the interview data in Fig. 4A, group B recognized the need to revise their table of contents (ToC).

The students subsequently revised their thesis outline to include two introductory sections, repositioned "problem formulation" under "previous projects," and relocated "ethical aspects" to the methods section. In interviews, the group described their revision strategy as conducting "a table reading": they would gather, read aloud, list necessary changes, and then implement them. As illustrated in Fig. 4B, this strategy originated from CoRL but was negotiated through SSRL. It was initially suggested by a group member who had found it effective in a previous project. However, upon finding it time consuming, the group adapted the strategy to better fit their timeline.

The final written product was the result of carefully negotiated processes and strategies. In contrast to group A, group B first discussed issues among themselves before seeking advice from their academic supervisor. This approach, which emphasizes collaborative decision-making, is illustrated in Fig. 4C.

Episode 4 showcases a collaborative writing regulation process, where objectives and strategies are developed through engagement in SSRL. The group adapted their strategy, achieving a shared metacognitive understanding of the text's purpose and the optimal structure to communicate it effectively.

In summary, these two episodes clearly demonstrate that all members of group B shared goals, made decisions together, and consistently regulated their writing process through SSRL. This collaborative approach not only fostered a sense of motivation and positive affect but also led them to take pride in producing research that is academically valid and industry relevant.

Discussion

This study explores how the dynamics of SSRL and CoRL explain divergent learning trajectories across the four phases of SoRL (Hadwin et al., 2018) in two extreme cases of collaborative BSc thesis writing. Our findings indicate considerable variation in learning pathways between the two groups of students. Both groups relied on external CoRL in goal setting and planning, but in group A, this led to internal CoRL (by Daniel) and no SSRL, while in group B, goals and plans were socially regulated among all members (SSRL). Task enactment and adaptation were guided via CoRL for group A, while in group B, CoRL fostered SSRL. In group A, the failure to transition from CoRL to SSRL led to negative emotions and a loss of learning opportunities. This shift impacted their sense of agency and perceived task value. Conversely, in group B, where CoRL evolved into SSRL, students displayed an enhanced understanding of their and their peers' interests and goals, fostering a more effective learning environment.

In exploring the dynamics of SSRL and CoRL in collaborative writing, it seems crucial to consider the role of the writing drafts themselves, not merely as products of collaboration but as central mediators of the regulatory processes. Following the framework suggested by Paavola and Hakkarainen (2021), the drafts serve as trialogic agents that guide and shape the inquiry in often unpredictable ways. In both groups, the evolving drafts influenced the direction and intensity of regulatory actions. For instance, in group A, where SSRL was notably less prominent, the writing drafts frequently served as focal points for CoRL, directing subsequent actions without fostering a genuine shared understanding or engagement. This lack of engagement with the draft as a shared object

of regulation contributed to the group's conceptual stagnation, where joint authorship did little to develop ideas or deepen understanding. Conversely, in group B, the writing drafts acted as catalysts for deeper SSRL, prompting discussions that not only refined the drafts but also enhanced the group's collective metacognitive grasp of the ongoing writing process. The iterative revisions and discussions around these drafts facilitated a richer, more connected understanding, demonstrating how the material embodiment of the group's efforts—i.e., the draft—can play a dynamic role in fostering effective collaborative learning. This interaction underscores the need to recognize the draft not just as a byproduct of collaborative effort but as a pivotal component of the regulatory landscape, dynamically influencing the group's regulatory trajectories and learning pathways.

The findings highlight the impact of conflicting feedback on students' collaborative regulation processes. While it may seem intuitive to suggest that supervisors align their guidance, such uniformity could undermine the authenticity of feedback. In real-world contexts, students often face conflicting perspectives and must learn to navigate them effectively. Rather than avoiding conflicting advice, the focus should be on equipping students with the skills to critically evaluate and synthesize diverse inputs. Group B demonstrated how discussing and negotiating feedback as a team fostered SSRL and enabled them to integrate differing perspectives into their work. Supervisors can support this by encouraging students to reflect on feedback, deliberate as a group, and create a synthesis of the advice received. Iterative processes, where students justify their decisions and seek further clarification, can further strengthen these skills. By framing conflicts as opportunities for growth and modeling effective negotiation strategies, supervisors can help students build resilience and adaptability—skills critical for navigating collaborative professional environments.

Our findings also underscore the role of shared metacognition (Summers & Volet, 2010) in collaborative writing regulation. In group A, the lack of shared metacognitive practices altered the learning trajectory and diminished agency, as evidenced by their shift from mastery to performance goals. Conversely, group B engaged in interactions that focused explicitly on establishing co-constructed, shared understandings in all phases of regulation. This finding connects to Ucan and Webb (2015), showing that certain types of interactions, like seeking consensus and resolving contradictory views, are conducive to SSRL and the establishment of shared metacognition, a pre-requisite for collaborative learning (cf. Haataja et al., 2022; Kuhn, 2015).

The type of CoRL and SSRL sequences we identified in our groups illustrate how important it is to account for the uptake of a specific writing episode (Chen et al., 2023): not just what happens *within* the episode, but also what happens *after* the episode (Järvelä et al., 2019). The type of communication groups engage in seems crucial to this end: symmetrical communication (Grau & Whitebread, 2012)—as opposed to cumulative talk (Mercer et al., 1999). Our findings suggest that symmetrical communication, where all participants contribute to the discussion, needs to be fostered by both the co-regulator and the co-regulated. For example, group A's academic supervisor could have fostered a more symmetrical communication by inviting students to take part in the negotiation of feedback. Of course, group A could have been less agreeable to the supervisors' CoRL and engaged in more advanced cognitive processing (Chen et al., 2023). Thus, accounting for contextual conditions (such as power dynamics) seems essential to the study of collaborative learning in authentic settings (Hadwin, 2021; Vermunt, 2005).

Another relevant finding regards the difference in motivation and perceptions of positive engagement observed in the two groups. Although both groups scored a similar final grade for their thesis, their levels of satisfaction with their learning and its

processes differed considerably in light of their experiences of collaborative writing regulation. Connections between affect and regulation dynamics have been traced in other studies of group work in engineering education (Li et al., 2021; O'Connell et al., 2023), similarly suggesting that SSRL, leading to collaborative learning, requires both affective and metacognitive engagement. Our findings illustrate the dual role of motivation as recognized in SoRL: "(a) a *condition* that influences regulatory actions (e.g., a high level of motivation influencing choices for deeper study strategies), and (b) a *product* of regulatory actions (e.g., being more motivated after setting a clear goal)" (Bakhtiar & Hadwin, 2022, p.97). In our study, it was clear that motivational conditions and products emerged from positive and negative experiences and shaped the groups' regulation engagement. This underscores the importance of accounting for emotional and motivational regulation in the study of shared regulation (Hadwin et al., 2018; Järvelä et al., 2019).

In conclusion, our study contributes to the understanding of how SSRL and CoRL dynamics influence learning pathways in collaborative academic writing in STEM. We show that while CoRL is essential, its evolution and embeddedness into SSRL are critical for effective collaborative learning and the development of the agency. This has significant implications for how educators and supervisors set up complex collaborative writing tasks in academic settings: these need to provide opportunities for interactions that lead to shared metacognition, joint evaluation of the quality of their work (Tai et al., 2017), and, generally, the establishment of SSRL. Additionally, students need to be supported in the potentially tricky negotiation between misaligned or conflicting goals and expectations, especially when industrial partners are involved (Hernandez-Diaz et al., 2024).

Overall, our findings suggest that effective collaborative writing, just like collaborative learning, requires a socially shared effort to regulate learning for collaborative practices to fully reap the benefits of development and knowledge construction that an active, problem- and project-based education can offer (Acton, 2022; Balleisen et al., 2023), collaborative writing processes need to be accounted for, and regulation of learning (and writing) at the group level may require instructors' careful monitoring. Effective regulation of academic writing processes is a social phenomenon, but while individual writing may benefit from recurrent cycles of CoRL and SRL (Negretti & Mežek, 2019; Sala-Bubaré et al., 2021), at a group level, CoRL may misfire: a shared metacognitive space and affective engagement with the learning task are only achieved if the process entails cycles of SSRL.

Building on these findings, this study's longitudinal design provided valuable depth and insights into the dynamics of CoRL and SSRL in collaborative writing. However, its periodic data collection posed certain limitations. Some regulatory processes that occurred between scheduled interviews and data collection points may not have been captured. Employing real-time data collection methods, such as video recordings or live collaborative sessions, could enhance future research by providing a more comprehensive understanding of these dynamics. Despite these limitations, the quality assurance measures implemented in this study worked effectively overall. Triangulating textual and interview data ensured robust findings, while inter-coder reliability checks confirmed the consistency of our coding. Nevertheless, aligning insights from individual interviews with group-level analysis proved challenging, underscoring the complexity of studying collaborative processes. These challenges highlight the need for further methodological innovation to enhance the rigor and precision of future studies.

Appendix: coding scheme and data segmentation

Table 2 Coding scheme

Phase	Regulatory process	Indicators of engagement	Indicators of satisfaction
Task perception	Socially shared regulation OR co-regulation	Active involvement in discussion vs non-active involvement	Satisfaction with progress/ activity vs. frustration and/or dissatisfaction
Goal setting and planning	Socially shared regulation OR co-regulation	Active involvement in discussion vs non-active involvement	Satisfaction with progress/ activity vs. frustration and/or dissatisfaction
Task enactment	Socially shared regulation OR co-regulation	Active involvement in discussion vs non-active involvement	Satisfaction with progress/ activity vs. frustration and/or dissatisfaction
Adaptation	Socially shared regulation OR co-regulation	Active involvement in discussion vs non-active involvement	Satisfaction with progress/ activity vs. frustration and/or dissatisfaction

Table 3 Episode segmentation scheme

Segment focus	Description
Citation practices	Episodes where groups discuss and implement citation rules and integrate sources into their writing
Defining study focus	Episodes focused on defining or refining the main research question or hypothesis of the thesis
Editing introduction	Episodes involving the editing of the introductory section, including refining thesis statements and context
Methodology design	Discussions and decisions regarding the methods section, including data collection and analysis techniques
Results compilation	Episodes where groups compile, discuss, and interpret their findings
Discussion writing	Focused on crafting the discussion section, where implications, limitations, and conclusions are debated
Final revisions	Final editing phases, including proofreading and adjustments post-feedback
Literature review	Detailed discussions and writing of the literature review section, analyzing and linking prior research
Data analysis procedures	Deliberations on selecting and applying specific analytical tools and software
Handling feedback	How groups respond to and incorporate feedback from supervisors and peers

Author contribution Baraa Khuder contributed to conceptualizing the study, designed the methodology, conducted data collection and analysis, co-wrote the first draft, and carried out revisions. Raffaella Negretti contributed to conceptualizing the study, co-wrote the first draft, and provided contributions to the theoretical framework. Both authors reviewed, revised, and approved the final manuscript.

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Data Availability Due to the sensitive nature of the research and in order to protect the identities and safety of participants, the data underlying this study are not publicly available. Access to the data is restricted for security and ethical reasons.

Declarations

Ethics approval and consent to participate This study was conducted in accordance with ethical guidelines for research involving human participants. Informed consent was secured from all participants prior to their involvement in the study.To ensure anonymity, all names are pseudonyms and identifying details have been modified.

Competing interests The authors declare no competing interests.

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