All for one and one for all – How are students’ affective states and group-level emotion regulation interconnected in collaborative learning?

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ABSTRACT

This study explored the interplay between students’ group-level emotion regulation behavior and affective conditions and products of regulation (emotional valence, activation, participation). The participants were 12-year-old students (N = 31, 10 groups) performing a collaborative science task. Conditions, emotion regulation behavior, and products of regulation were captured from video and electrodermal activity data. Results reveal that affective conditions were related to students’ regulatory behavior. Students were more likely to initiate regulation when they indicated a personal need to restore affective grounds. Moreover, regulation was activated to restore participation by targeting regulation to non-participating students. While regulation did not always change conditions for collaboration, the results indicate that it was more influential for students who either initiated or were targets for regulation.

1. Introduction

Years of research have addressed the emotional effects of different aspects of students’ learning (Loderer et al., 2018; Pekrun, 2016), some also covering situational variation in affective states and social learning contexts (Goetz et al., 2016; Ketonen et al., 2017; Moeller et al., 2020). Research findings indicate that positive task-related emotions can enhance students’ engagement, motivation, and interest, and as well as their use of flexible, creative, and deep learning strategies. Negative emotions often have the opposite effects (Pekrun et al., 2002). However, negative emotions, such as anxiety, can also result in high motivation, for example to avoid failing a test (Pekrun & Stephens, 2010). The ways in which emotions affect learning and academic achievement are highly situational and task-specific. Hence, connections cannot be made without understanding the process whereby emotions manifest and are regulated during learning (Boekaerts & Pekrun, 2016; Järvenoja et al., 2020).

In collaborative learning, emotional processes become more complex as each group member’s affective states contribute to the group’s socio-emotional atmosphere and to the whole learning process (Lobczowski, 2020). In collaborative contexts, positive emotions have been linked positively to group interactions, collaboration, and conceptual understanding, while negative emotions have been linked to disengagement and social loafing (i.e., the tendency to reduce effort when working in a group compared with working alone; Linnenbrink-Garcia et al., 2011; Pietarinen et al., 2018). Less research, however, has focused on unraveling the mechanisms through which these negative or positive outcomes in collaborative learning processes take place, though such research would be critical for finding ways to explore emotional processes during collaborative learning and how emotions are jointly regulated to

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maintain favorable socio-emotional conditions throughout the learning process (Baker et al., 2013).

Learning theorists have recognized the interplay between cognitive and emotional group processes in discussions of the social nature of regulation (Bakhtiar et al., 2018; Lobczowski, 2020; Hadwin et al., 2018), arguing that students’ affective states can act as conditions that necessitate regulation for successful learning to continue (Bakhtiar et al., 2018; Winné & Hadwin, 1998). Until now, empirical evidence showing the connection between individual students’ affective conditions and activated group-level emotion regulation in context is still scarce (Mänty et al., 2020). Instead, the majority of studies have adopted either individual or group-level approach. This study aims to fill this gap by exploring how individual students’ situational affective states and participation in collaborative task execution fluctuate in relation to students’ group-level emotion regulation behavior during a collaborative learning process.

To capture the process whereby group members’ affective states and regulation build up conditions for collaboration (Lobczowski, 2020), this study utilizes multichannel process data, which enable an in-depth examination of the situational conditions present before and after emotion regulation (Järvenoja et al., 2020). First, video data observations are used to capture observable emotional responses, such as bodily expressions and verbal interactions, that serve as indicators of students’ situational emotional valence (Linnenbrink-Garcia et al., 2011; Porayska-Pomsta et al., 2013). To connect these emotional responses to group processes, video data observations are used to track students’ participation in collaborative task execution as well as students’ behavior in group-level emotion regulation situations (Isohätälä et al., 2017). Second, to gain more profound and continuous information on students’ situational affective states, the students’ emotional activation dimension is captured through sympathetic arousal, measured with electrodermal activity (EDA) (Palumbo et al., 2017). By capturing these situational conditions via different data channels and connecting them to group-level regulation, this study advances recent research by providing versatile information on multi-layered learning processes (Azvedo & Gašević, 2019; Sharma & Giannakos, 2020).

1.1. Affect in collaborative learning

While affective states, including emotions, are situation-specific responses to meaningful events in one’s environment (Rosenberg, 1998), these responses are based on multifaceted psychological processes, including affective, cognitive, physiological, motivational, social, and expressive components (Pekrun, 2016; Russell & Barrett, 1999). As such, when emotions are experienced, students’ responses can be evident, such as verbal statements or facial expressions, but they can also manifest as changes in physiology (e.g., sympathetic arousal) that remain invisible to other group members (Boekaerts & Pekrun, 2016). In group learning situations, a stimulus event can evoke different kinds of emotional expressions and behaviors (Lobczowski, 2020). These individual reactions are also meaningful on a group level since they shape the group’s affective state and socio-emotional atmosphere (Bakhtiar et al., 2018). Earlier research has evidenced that students’ emotions can foster processes beneficial for collaborative learning, such as high-level cognitive processes (Järvelä et al., 2016; Rogat & Adams-Wiggins, 2015); however, if not successfully regulated, emotions can lead to socio-emotional challenges and have detrimental effects on collaboration (Baker et al., 2013).

Recent studies have sought to link individual emotional experiences or appraisals to the context of collaborative learning (e.g., Linnenbrink-Garcia et al., 2011; Pietarinen et al., 2020). For example, Zschocke et al. (2016) studied individual group work appraisals and emotions arising in the group work context, finding that appraisals of the cognitive benefits of group work were a significant predictor of positive activating emotions. Linnenbrink-Garcia et al. (2011) found that emotions can also be fostered by social aspects of group work, such as positive socio-emotional interactions. Experiences of negative emotions, in turn, can stem from negative socio-emotional interactions (Mänty et al., 2020) and lead to off-task behavior and abandonment of joint learning activities (Näykki et al., 2014). However, in group learning contexts emotional effects on learning are not so simplistic. Positive activating emotions expressed by, for example, joking with other group members about non-task related issues are important for constructing a positive socio-emotional atmosphere and creating a sense of togetherness (Järvenoja & Järvelä, 2013). However, they can also lead to prolonged social loafing or reduce cognitive recourses directed to the purpose of the task (Linnenbrink-Garcia et al., 2011; Pekrun et al., 2002; Tomas et al., 2016). Collaborative learning situations are emotionally very complex; for successful collaboration, group members need to address situational emotional issues as they emerge (Baker et al., 2013).

1.2. Emotion regulation in collaborative learning

When a favorable affective state for learning is jeopardized, students can engage in emotion regulation, attempting to influence their emotional experiences and expressions of emotions (Gross, 1998). In learning situations, emotion regulation can focus either directly on emotions and emotional expressions, or on the cause of the emotions (Harley et al., 2019). When the target of emotion regulation moves from the individual’s own emotions to the group’s socio-emotional processes, regulation is directed toward the group level (Järvenoja et al., 2015). Group members can support each other to maintain or restore affective states beneficial for learning (co-regulation), or they can work together to strengthen the socio-emotional atmosphere and overcome the emotional challenges they face (socially shared regulation, see Hadwin et al., 2018).

Previous studies have indicated that students’ active and joint participation in task activities is an important foundation for successful collaboration and the emergence of group-level regulation (Isohätälä et al., 2017; Volet et al., 2009). While group-level regulation is built up in interaction among group members, group members can enact different roles in the regulatory activities. An important aspect of emotion regulation is to understand and recognize one’s own and others’ emotions and emotional expressions, and furthermore, when an emotional challenge is recognized, to be able to initiate appropriate individual and group-level regulation to ensure motivated learning (Boekaerts, 2011; Järvenoja et al., 2015). After group-level emotion regulation is initiated by a group
member, others can shape the course of regulation by contributing, adding new elements into the regulatory discussion (Hadwin et al., 2018). Furthermore, especially when the need for regulation rises from an individual group member’s emotional challenges, co-regulatory activities can be particularly targeted at the student to prompt self-regulation of emotions (Bakhtiar & Hadwin, 2020). These actions are all executed through interaction, which serves as a main channel for group-level emotion regulation (Hadwin et al., 2018).

1.3. Studying conditions and products of group-level emotion regulation

Interaction, through which group members’ share their regulatory actions, can be viewed through the conditions-operational-products-standards-conditions (COPES) architecture of regulated learning (Winne & Hadwin, 1998). Within COPES, emotions are considered internal conditions that influence how students engage in learning. However, emotions as conditions are not viewed as static; instead, they are constantly modified through the different operations students implement during the learning process. That is, when affective conditions are shaped by operations, they turn into affects products that, in turn, become the conditions for the continuing learning activities (Bakhtiar et al., 2018; Winne & Hadwin, 1998). In group learning, the role of emotions as conditions and products becomes multi-layered; each student brings their own internal affective conditions into the learning situation. These conditions together influence the behaviors and interactions among the group members, including both group-level and individual-level regulation (Lobczowski, 2020). Regulation, in turn, serves as an operation, shaping once again each individual’s affective state and the group’s socio-emotional atmosphere (Bakhtiar et al., 2018).

Following the theorization of the COPES model, this study regards individual students’ affective states, including their valence and activation, as conditions and products of emotion regulation. Valence separates positive emotions from negative, and activation refers to the extent of physiological arousal caused by an emotion (Ben-Eliyahu & Linnenbrink-Garcia, 2013; Boekaerts & Pekrun, 2016). Valence and activation come together in the affective circumplex model (Russell & Barrett, 1999), which divides academic emotions into four groups: positive activating (e.g., enjoyment, hope, pride), negative activating (e.g., anger, anxiety, shame), positive deactivating (e.g., relief), and negative deactivating (e.g., hopelessness, boredom) emotions. Differentiating positive and negative emotions by the dimension of activation aids in understating the roles and functions of different affective states during the learning process (Linnenbrink-Garcia et al., 2016; Pekrun et al., 2011; Robinson et al., 2017).

To capture these two dimensions continuously and unobtrusively as the collaborative learning process unfolds, e.g., video data has been used to capture students’ observable emotional responses, such as bodily expressions and verbal interactions, which can serve as indicators of situational emotional valence (Linnenbrink-Garcia et al., 2011; Pietarinen et al., 2020; Porayska-Pomsta et al., 2013). Sympathetic arousal, in turn, has been used to capture the emotional activation dimension — that is, the activation of the sympathetic nervous system (SNS) responsible for fight or flight responses (Palumbo et al., 2017). Recent research has indicated that during learning situations, students often experience quite low levels of arousal (Harley et al., 2019; Malmberg et al., 2019; Pijeira-Díaz et al., 2018). However, high arousal in learning situations has been linked to both negative (Ahonen et al., 2018; Harley et al., 2019; Malmberg et al., 2019; Roos et al., 2020) and positive emotions (Törnänen et al., 2021), to learning challenges and regulated learning (Malmberg et al., 2019; Törnänen et al., 2021), and to both poor (Mason et al., 2018; Pizzie & Kraemer, 2018) and good performance (Harley et al., 2019; Pijeira-Díaz et al., 2018). In relation to emotion regulation, it has been suggested that based on the regulatory goal, both increases and decreases in sympathetic arousal can reflect emotion regulation processes and also cognitive efforts related to regulation (Kinner et al., 2017; Matejka et al., 2013; Pizzie & Kraemer, 2018).

This study utilizes the COPES architecture not only by considering affective conditions of valence and activation, but also by conceptualizing group-level regulation as an operation shaping students’ affective states and the course of collaborative learning. Research has indicated that in addition to emotional and motivational strategies, emotions are regulated through cognitive strategies that aim to move the focus from non-task-related emotions, whether negative or positive, back to task execution (Jarvenoja et al., 2019). As such, we argue that participation in collaboration also plays a role in how students engage in emotion regulation and that this needs to be taken into account to understand how regulation affects further conditions for collaboration (Isohätälä et al., 2017). To track possible changes in students’ participation and the ways in which these changes are related to students’ emotion regulation behavior, students’ participation in collaborative task execution can be captured continuously by utilizing video data observations.

1.4. Aims and research questions

The aim of this study is to explore the interplay between students’ group-level emotion regulation behavior during collaborative learning, and the conditions and products of this regulation, namely emotional valence and activation, and participation in collaborative task execution. The research questions are as follows:

1. Which combinations of affective states and participation do students have as conditions for group-level emotion regulation?
2. How are students’ conditions related to their group-level emotion regulation behavior?
3. What kinds of sequential patterns can be found between conditions, emotion regulation behavior, and products of regulation during a collaborative learning process?
2. Material and methods

2.1. Participants and task

This study utilizes data from 31 volunteer sixth-grade primary school students (12–13 years old, 17 females) from Finland, who composed 10 groups of 3–4 members. These students comprised 77% of the entire data corpus (three groups were left out due to poor-quality EDA data). The students came from three classrooms and the data collection was conducted as a part of their environmental studies. That is, one environmental studies class was held in a classroom-like learning and research space (LeaForum, University of Oulu), where one class of students worked at a time. Thus, the students knew each other and had prior experiences of collaborating. The students were assigned to groups heterogeneously based on gender and interest in science. Interest was measured using the Task Interest Inventory (Cleary, 2006).

Both the topic of the task (heat energy) and a collaborative way of working derived from the Finnish curriculum of basic education (Finnish National Agency for Education, 2016). During data collection, the groups performed a collaborative task: designing and constructing a model of an energy-efficient house powered by solar energy. Before the task, some basic information about heat energy was presented. The pedagogical structure of the collaborative task followed four phases: (1) becoming an expert (15 min), (2) brainstorming (10 min), (3) sketching (20 min), and (4) building (60 min). Each phase was timed in order to follow a normal classroom activity where time for task performance is normally limited. The passing of time was visible so that the groups could organize their work according to the time limits. In phase 1, each group member studied an individual subtopic (the heat capacity of different materials, heat conduction, and heat convection). Thus, expertise was divided among the group members, and they needed to collaborate to be able to perform the next phases. In phase 2, the group members were instructed to form a shared list of facts they would need to consider when designing the house. In phase 3, each group made a sketch of its house, which made clear how and with which materials (e.g., cardboard, tape, aluminum foil, cotton wool, and Styrofoam) the house would be built. In phase 4, the group members collaboratively constructed a scale model of the house.

2.2. Data collection

Phases 2–4 of the collaborative task were recorded with the MORE observation system, which collects data simultaneously using three 360° cameras and individual microphones for each participant (for technical information, see Keskinarkaus et al., 2016). Altogether, observational data included 16 h of video (session mean duration 95 min).

Students’ sympathetic arousal was tracked using EDA, which is related to the function of sweat glands, and is the sole measure of sympathetic arousal (Braithwaite et al., 2013; Dawson et al., 2007). EDA produces temporal online process data with high granularity. EDA measurement is divided into phasic short-term skin conductance response (SCR) and tonic skin conductance level (SCL) (Boucsein, 2012). SCR peaks are strongly related to emotional responses caused by an external stimulus and more reactive to variations in experimental conditions than SCL (Christopoulos et al., 2016; Dawson et al., 2007). However, EDA values can also rise without a specific external stimulus, and those fluctuations are called non-specific (NS)-SCRs (Dawson et al., 2007). In situations with continuous stimuli, such as during a learning activity, the frequency of NS-SCRs can be used as an indicator of current arousal state (Braithwaite et al., 2013). In this study, EDA was recorded using Empatica E4 wristbands (Empatica Inc., Cambridge, MA, USA) (Garbarino et al., 2015), which were placed on the non-dominant hand of each student. Empatica E4 measures EDA with two silver-coated electrodes and a sampling rate of 4 Hz. The recorded EDA data were analyzed in combination with the video data, so the duration of each student’s EDA recording used for the analysis was equal to the recorded video of the group in question.

2.3. Analysis

The analysis included four phases. First, group level emotion regulation in socio-emotional interactions was located from the video

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Fig. 1. The analysis procedure detecting the conditions, emotion regulation behavior, and products of regulation from video and EDA data.
data. Second, students’ regulation behavior during emotion regulation episodes were observed. Third, students’ conditions and products of emotion regulation were detected. Fourth, statistical analysis and process models were applied. Fig. 1 presents the analysis procedure of conditions, group-level emotion regulation, and products in relation to the different data channels. The analysis procedure is described in detail below.

2.3.1. Locating group level emotion regulation from the video data

The video data were processed with Observer XT software (Noldus Information Technology). First, all the episodes that included socio-emotional interaction between group members were identified. Socio-emotional interaction was considered to emerge when the group members were expressing emotions or taking other actions contributing to socio-emotional aspects of group work (e.g., group formation and dynamics, social relationships, a sense of community) (Kreijns et al., 2013; Kwon et al., 2014). Socio-emotional interaction was coded when at least two group members expressed emotions or made emotionally charged comment. The criteria for emotional expressions included observable verbal (e.g., “We are so good”) or bodily (e.g., laughing, lack of focus) indicators of positive or negative emotions and negatively or positively charged interactions (e.g., joking, arguing). For the socio-emotional interaction coding, the interrater reliability analysis was performed for 40% of the coded videos using Cohen’s kappa statistic, and substantial agreement was reached (κ = 0.69).

The socio-emotional interaction episodes were further observed to identify actualized group-level emotion regulation episodes. Emotion regulation was identified from 33% of the socio-emotional interaction episodes. These emotion regulation episodes were the focus of the analysis. The starting time of an episode was marked when students made the first regulatory action, and the ending time was noted immediately following the last regulatory action. From the different regulatory processes present during the regulated learning cycle, the coding covered the moments of controlling emotions (Lobczowski, 2020). That is, emotion regulation was coded when at least one group member aimed to influence group members’ affective states, or alternatively, improve, maintain, or restore the group’s socio-emotional grounds for collaboration (Järvenoja et al., 2019). Emotion regulation consisted of co- and socially shared regulation activities in which the regulation attempts were made visible with clear verbal statements. These episodes could include attempts to decrease negative or increase positive emotions with emotional and motivational strategies such as encouragement (e.g., “We will make it on time!”) and social-reinforcing (e.g., joking together) (Järvenoja et al., 2019), or modulating other group members’ emotional responses (e.g., “Please stop fooling around!”) (Gross & Thompson, 2007). Furthermore, when negative or positive socio-emotional aspects were hampering the collaboration, emotion regulation could include strategies that targeted at groups’ cognitive functioning with an aim to simultaneously modify the socio-emotional aspects of the situation. These strategies included structuring the task activities (e.g., suggesting an alternative way to do the task), directing group’s attention back to the task activities (e.g., noting the remaining time and prompting the task execution), and reappraising the emotionally laden situation (e.g., noting the positive aspects of the situation) (Gross & Thompson, 2007). The coding covered all the emotion regulation attempts and did not necessitate the change in the students’ affective states. The interrater reliability analysis for locating emotion regulation episodes was performed for 30% of the coded videos, resulting in substantial agreement between the two raters (κ = 0.71).

2.3.2. Observing students’ regulatory behavior

The students’ regulatory behavior during group-level emotion regulation was coded into four categories. The student who made the first regulatory action was coded as an initiator. A student was coded as a contributor when they verbally participated in the regulatory actions but had not been the initiator. Students were coded as observers if they did not take any regulatory actions during the episode. Finally, if the regulatory actions were targeted toward a specific student who was not participating in the regulation as such, that student was coded as a target for emotion regulation. For the regulatory behaviors, the interrater reliability analysis was performed for 30% of the coded videos, and almost perfect agreement was reached (κ = 0.82).

2.3.3. Detecting students’ conditions and products of emotion regulation

Students’ conditions during a one-minute period before and products during a one-minute period after regulation were defined in terms of emotional valence, activation, and participation in collaborative task execution. In case there was an overlap in the conditions and products episodes (e.g., the next condition episode started during the products episode of the previous regulation episode), they were still considered and coded as separate one-minute episodes. Valence and participation were detected using video data observations, whereas activation was determined based on students’ EDA data. The one-minute time window derived from the traditional peaks per minute (ppm) variable used in the EDA data analysis (Braithwaite et al., 2013; Dawson et al., 2007). In addition, a preliminary video analysis was done to explore the length of the socio-emotional interaction episodes (Törnänen et al., 2021). The average duration of one episode was 24.6 s. Accordingly, one minute was considered as an appropriate time window and long enough to capture the students’ arousal level as well as related emotional expressions prior and after the emotion regulation episode.

Valence was coded into three categories (positive, negative, neutral) based on students’ emotional expressions. Valence was coded as positive when a student expressed observable signs of positive emotions or made a positively charged comment and as negative in opposite cases. If the student’s expressions included mixed indicators (e.g., negative verbal sign with positive bodily sign), valence was coded primarily based on the verbal indicator, and if the valence changed during the episode, it was coded based on the indicator closest to emotion regulation. If the student did not clearly express emotions during the minute, valence was coded as neutral. The valence coding categorization is presented in Supplementary file.

Participation in collaborative task execution was coded with a binary variable (participating/not participating). If the student executed the task by, for example, making notes or constructing the house, or participated verbally in the task-related interaction, the student was coded as participating. If the student performed non-task-related activities, such as playing with task equipment or holding
off-topic discussions, the student was coded as not participating. If the student performed task- and non-task-related activities simultaneously (e.g., constructing the house and having an off-topic discussion), the student was coded as participating. Table 1 demonstrates an example situation in which all group members were participating in the house building. The table presents the individual valence codes and related interaction in conditions, emotion regulation, and products episodes. For the valence and participation coding, the interrater reliability analysis was performed for 30% of the coded videos; substantial agreement for valence ($\kappa = 0.72$) and almost perfect agreement for participation ($\kappa = 0.85$) were achieved.

Activation was determined based on students’ arousal state depicted in the EDA data. The EDA data were processed using Python programming language. The baseline was computed using a third-order low-pass filter, and NS-SCR peaks were detected using the minimum value of 0.05 $\mu$S between the baseline and peak (Boucsein, 2012; Dawson et al., 2007). The EDA data were further processed using Excel. First, each group member’s EDA recordings were synchronized. Second, the EDA data sets were synchronized with the group’s video data coding. The students’ level of arousal (i.e., activation) one minute before (conditions) and one minute after (products) the regulatory episode were determined with the number of NS-SCR peaks per minute (ppm). For each student, the ppm values were counted for each minute of collaboration using a one-minute moving window with a moving step of one second. Then, the average ppm value for each student was calculated. The ppm values were used to define the students’ activation during conditions and products episodes. When the ppm value was higher than the average, the level of arousal was considered activated; otherwise, it was considered de-activated. However, during learning situations the students are not experiencing emotions all the time and thus, might be expected to operate mostly in their optimal (i.e., medium) level of arousal (Yerkes & Dodson, 1908). While the binary categorization used in this study aimed to follow the affective circumplex approach (Russell & Barrett, 1999), it should be noted that in the categorization the medium arousal was categorized as de-activated. However, the activation level was not used as a sole measure of experienced emotions; the video data was used to differentiate the negative and positive from neutral conditions. That is, the chosen approach still indicated the possible neutral conditions prior to regulation. Finally, the codes were inserted into the software Observer XT for further analysis.

### 2.3.4. Statistical analysis and process models

In the statistical analyses and process models, this study used a case as the unit of analysis. The case refers to one condition-emotion regulation-products episode, as illustrated in Fig. 1. To find similarities among the conditions for the first research question, IBM SPSS two step cluster analysis was applied to cluster the condition cases based on emotional valence, activation, and participation. The analysis was applied with automatic determination of the number of clusters, allowing a maximum of six clusters. Cases were randomly ordered, and the analysis was repeated multiple times with different random orders to verify the stability of the clustering results. This resulted as four clusters that differed in terms of emotional conditions of valence and activation as well as participation. The clusters are presented in Results section in relation to research question one. Next, for the second research question, the sequences from different condition clusters to regulatory behaviors were investigated using the Observer XT state lag sequential analysis function with lag order 1. State lags with lag order 1 consider the transitions between events that directly follow each other (in this case, the transitions from conditions to regulatory behaviors). After locating the number of different sequences, chi-square statistics were calculated for the results. The significant associations between conditions and regulatory behaviors were further explored with

### Table 1

An example situation from a group of four students building their house.

<table>
<thead>
<tr>
<th>Student</th>
<th>Utterance</th>
<th>Emotional expression</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conditions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Luna</td>
<td>We could have made the beds later because we’re not even doing anything with them.</td>
<td>Verbal</td>
<td>Negative</td>
</tr>
<tr>
<td>Ariel</td>
<td>Yes.</td>
<td>Verbal</td>
<td>Negative</td>
</tr>
<tr>
<td>Demi</td>
<td>I thought that we need those.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Luna</td>
<td>We do not have any other furniture than the beds.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leon</td>
<td>Did you have to make the beds?</td>
<td>Criticizing</td>
<td>Negative</td>
</tr>
<tr>
<td>Demi</td>
<td>I thought that they would look inside as well.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Luna</td>
<td>So did I.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ariel</td>
<td>They won’t look at it.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Luna</td>
<td>Won’t they?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demi</td>
<td>We made the beds for nothing.</td>
<td>Verbal</td>
<td>Negative</td>
</tr>
<tr>
<td><strong>Emotion regulation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leon</td>
<td>Maybe we’ll get some bonus points.</td>
<td>Verbal</td>
<td>Initiator</td>
</tr>
<tr>
<td>Demi</td>
<td>Yes, let’s say that we made the beds also.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leon</td>
<td>Yes, and no one else did. We are the best.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Luna</td>
<td>(no verbal contribution)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ariel</td>
<td>(no verbal contribution)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Products</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leon</td>
<td>These won’t be the prettiest ones, but you can say that Leon made them.</td>
<td>Criticizing</td>
<td>Negative</td>
</tr>
<tr>
<td>(task execution and neutral discussion)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leon</td>
<td>Five minutes!</td>
<td>Verbal</td>
<td>Negative</td>
</tr>
<tr>
<td>Ariel</td>
<td>Oh no!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demi</td>
<td>Oh no!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Luna</td>
<td>We haven’t even put the house together yet!</td>
<td>Verbal</td>
<td>Negative</td>
</tr>
</tbody>
</table>

Note: The students are having a negatively charged interaction about whether they should have made beds to decorate the house or not (conditions). Leon initiates emotion regulation by saying that maybe they will get extra points for the beds. After emotion regulation, the group executes the task and engages in neutral discussion. However, after a while the interaction becomes negative again (products).
significant \( z \) scores from adjusted residuals with alpha levels 0.05 (\( z > 1.96 \)) and 0.001 (\( z > 2.58 \)).

For the third research question, to visualize and investigate process patterns between different conditions, emotion regulation behaviors, and products during a collaborative learning process, Fluxicon’s Disco analysis software (https://fluxicon.com/disco/) was used to create process models of different sequences for each condition cluster. For the process models, the products were divided into the same clusters that resulted from the clustering of conditions. Because the model includes each possible path and interconnection, it can provide very complex illustrations (Bannert et al., 2014). To simplify the complex illustration of each possible sequence and their interconnections, the process models were restricted to show only the strongest (i.e., the most frequent) paths of interconnectivity (although 100% of the activities were included). The strongest paths were explored further using qualitative case examples which demonstrated individual students’ emotional expressions and regulatory behavior in relation to the group’s socio-emotional interaction. The case examples were selected so that they would represent the typical flow of the particular path.

3. Results

3.1. Which combinations of affective states and participation do students have as conditions for group-level emotion regulation?

Altogether, the video data included 321 group-level emotion regulation episodes, and thus, 1012 cases with different condition combinations. For the valence, the most frequent condition was negative (\( f = 456 \)), followed by positive (\( f = 369 \)) and neutral (\( f = 187 \)). In terms of activation measured with EDA, students were more often de-activated (\( f = 619 \)) than activated (\( f = 393 \)). Furthermore, they were mostly participating in the task execution (\( f = 774 \)). In the two-step cluster analysis, four different condition clusters were identified with a good cluster quality and all predictors used for the clustering: activated, positive/negative de-activated, negative de-activated, and not participating. Table 2 presents the characteristics of the different clusters in terms of valence, activation, and participation.

The activated cluster (\( f = 299 \)) included all cases when the activated state was combined with participation and negative (\( f = 158 \)), positive (\( f = 81 \)), or neutral (\( f = 60 \)) valence. The positive/negative de-activated cluster (\( f = 240 \)) included conditions with positive (\( f = 135 \)) or neutral (\( f = 105 \)) de-activation combined with participation. The negative de-activated cluster (\( f = 235 \)) consisted of all the cases where negative valence was combined with de-activation and participation in task execution. The not-participating cluster (\( f = 238 \)) included all cases where the student had not participated in the task execution before the regulatory event. All of these cases included different valences and both activation and de-activation.

3.2. How are students’ conditions related to their group-level emotion regulation behavior?

The condition clusters resulting from the first research question were used to explore whether students’ conditions before group-level emotion regulation were related to their behavior in regulation situations. The results indicated that regulatory behavior differed depending on the preceding conditions (\( \chi^2 (9) = 78.750, V = 0.161, f = 1012, p = 0.000 \)). \( Z \) scores from adjusted residuals are presented in Table 3. The students with the negative de-activating condition were likely to initiate group-level emotion regulation (\( z = 2.0 \)) and less likely just to observe, whereas those with the activated condition were likely to follow by contributing to already initiated regulation (\( z = 2.7 \)) and less likely to be targets. In turn, if a student was not participating in the collaboration before the emotion regulation event, that student was likely the target for emotion regulation (\( z = 6.7 \)) and less likely to initiate or contribute to groups’ regulation efforts. Finally, if a student was positive/negative de-activated before the regulatory event, the student was likely to adopt an observer role (\( z = 3.8 \)) and less likely to be a target.

3.3. What kinds of sequential patterns can be found between conditions, emotion regulation behavior, and products of regulation during a collaborative learning process?

To investigate process patterns between different conditions, emotion regulation behavior, and products during a collaborative learning process, separate process models were created for each condition cluster to illustrate the most typical paths within the cases. Figs. 2, 4, 6, and 8 illustrate the process models (covering 100% of the activities) and the strongest paths between the conditions, regulatory behaviors, and products.

Emotion regulation most typically emerged during the activated condition (\( f = 299 \)). When students were in this condition, they
often participated actively in emotion regulation as either initiators ($f = 97$) or contributors ($f = 69$) and stayed physiologically activated after regulation. However, the process model in Fig. 2 shows that the activated condition could lead to different regulatory behaviors. All regulatory behaviors were most often followed by an activated product, indicating that group-level emotion regulation did not change the students’ activated conditions for further collaboration.

Though the activated state often remained after the regulation, in 48% of the cases ($f = 44$) emotion regulation did calm down the physiological arousal for the student who was the initiator, leading to a positive/neutral ($f = 28$) or negative de-activated product ($f = 16$). The case example marked with the green color in Fig. 2 and presented in detail in Fig. 3 demonstrates this condition-regulation-product path. It describes an emotion regulation episode where acting as an initiator transformed Jade’s negative activated condition into a positive de-activated product. In the condition state, Jade is worried about the holes in the roof while the group constructs its house. Mila comforts Jade by saying that it does not matter; this, however, does not change Jade’s negative activated affective state. Rather, Mila enters a negative affective state and increases the negative affect within the group by comparing their house with the other group’s house. This seems to trigger Jade to initiate co-regulation of emotions targeting Mila’s negative comment. In this situation, Jade’s concrete emotion regulation utterance seems to be sufficient to overcome the emergent negativity and return the group to building the house. After a while, Jade expresses positive affect by complimenting their house and proudly noting that they also have a second floor.

The positive/neutral de-activated condition resulted in emotion regulation in 240 cases. As demonstrated in the process model in Fig. 4, this condition often led to regulatory behaviors from initiators ($f = 88$) and observers ($f = 80$). Again, students most often remained in the same state after the regulation. However, if emotion regulation was targeted particularly toward the student in the positive/neutral de-activated condition, physiological arousal was often higher after regulation, indicating the activated product state ($f = 12$) as illustrated in the following case example.

The second case example in Fig. 5 displays how physiological arousal changed for Aaron, the target of regulation, leading to a positive activated affective state as a product. At the beginning of the conditions episode, Aaron is talking to another group during a building phase. He then returns to his own group and tells them that the other group is going to build an outhouse. Aaron then starts to advise Nico on what to do next, indicating a neutral valence combined with de-activation. When Aaron manages to open a cardboard box successfully, Naomi initiates emotion regulation by complimenting him. In the products episode, the entire group indicates a positive activating affective state. Aaron’s state changes from neutral de-activated into positive activated, and he even says that it is time to stop fooling around and get back to work. He also expresses positive affect by singing.

### Table 3

<table>
<thead>
<tr>
<th>Regulatory Role</th>
<th>Codes in total</th>
<th>Cluster</th>
<th>Initiator</th>
<th>%</th>
<th>z</th>
<th>Observer</th>
<th>%</th>
<th>z</th>
<th>Contributor</th>
<th>%</th>
<th>z</th>
<th>Target</th>
<th>%</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activated</td>
<td>299</td>
<td>F</td>
<td>97</td>
<td>30.2</td>
<td>0.3</td>
<td>71</td>
<td>29.0</td>
<td>-0.2</td>
<td>69</td>
<td>37.9</td>
<td>2.7**</td>
<td>62</td>
<td>23.5</td>
<td>-2.5*</td>
</tr>
<tr>
<td>Positive/Neutral de-activated</td>
<td>240</td>
<td>F</td>
<td>88</td>
<td>27.4</td>
<td>1.9</td>
<td>80</td>
<td>32.7</td>
<td>3.8**</td>
<td>36</td>
<td>19.8</td>
<td>-1.4</td>
<td>36</td>
<td>13.6</td>
<td>-4.5**</td>
</tr>
<tr>
<td>Negative de-activated</td>
<td>235</td>
<td>F</td>
<td>87</td>
<td>27.1</td>
<td>2.0**</td>
<td>37</td>
<td>15.1</td>
<td>-3.5**</td>
<td>47</td>
<td>25.8</td>
<td>0.9</td>
<td>64</td>
<td>24.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Not participating</td>
<td>102</td>
<td>F</td>
<td>49</td>
<td>15.3</td>
<td>-4.2**</td>
<td>57</td>
<td>23.3</td>
<td>-0.1</td>
<td>30</td>
<td>16.5</td>
<td>-2.5*</td>
<td>102</td>
<td>38.6</td>
<td>6.7**</td>
</tr>
<tr>
<td>Total</td>
<td>1012</td>
<td>F</td>
<td>321</td>
<td>100.0</td>
<td></td>
<td>245</td>
<td>100.0</td>
<td></td>
<td>182</td>
<td>100.0</td>
<td></td>
<td>264</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

* $p < 0.05$.  
** $p < 0.001$
The negative de-activated condition was a condition for regulation in 235 cases, and it most often led to the initiator behavior \((f = \text{87})\) (Fig. 6). Furthermore, when student was acting as the initiator, the regulation shaped that student’s conditions for further collaboration in 64% of the cases, leading most often to an activated \((f = \text{30})\) or positive/neutral de-activated \((f = \text{23})\) product. The regulation most often led to the positive/neutral de-activated product if the student was the target \((f = \text{22})\) or an observer \((f = \text{13})\). The process model indicates that if the condition before emotion regulation was negative de-activated, emotion regulation was often able to shape the students’ conditions into more positive conditions for further collaboration.

Fig. 3. A case example demonstrating an emotion regulation episode in which acting as an initiator transformed Jade’s negative activated condition into a positive de-activated product. Green columns represent Jade’s emotional indicators for the video coding, which were combined with activation codes from EDA data. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Fig. 4. A process model illustrating the strongest paths between conditions, emotion regulation, and products for the positive/neutral de-activated cluster. An example path used in the second case example is marked in green. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

The negative de-activated condition was a condition for regulation in 235 cases, and it most often led to the initiator behavior \((f = \text{87})\) (Fig. 6). Furthermore, when student was acting as the initiator, the regulation shaped that student’s conditions for further collaboration in 64% of the cases, leading most often to an activated \((f = \text{30})\) or positive/neutral de-activated \((f = \text{23})\) product. The regulation most often led to the positive/neutral de-activated product if the student was the target \((f = \text{22})\) or an observer \((f = \text{13})\). The process model indicates that if the condition before emotion regulation was negative de-activated, emotion regulation was often able to shape the students’ conditions into more positive conditions for further collaboration.

Fig. 7 shows the fourth case example, which includes a shared emotion regulation episode where the initiator, Benjamin, is having a negative de-activating condition before regulation. After regulation, he manages to shift into a neutral de-activated affective state. In
Table 1. A case example demonstrating an emotion regulation episode where Naomi co-regulated Aaron by complimenting him, which led Aaron to activate physiologically. After emotion regulation, the entire group indicated a positive activated affective state. Green columns represent Aaron’s emotional indicators for the video coding, which were combined with activation codes from EDA data. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

<table>
<thead>
<tr>
<th>Code</th>
<th>Neutral de-activated</th>
<th>Target</th>
<th>Positive activated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aaron</td>
<td>They said they are going to build an outhouse.</td>
<td>Aaron</td>
<td>Ok.</td>
</tr>
<tr>
<td>Nico</td>
<td>Hmph... Should we...</td>
<td>Nico</td>
<td>No...</td>
</tr>
<tr>
<td>Aaron</td>
<td>Ok, so do it like this...</td>
<td>Naomi</td>
<td>Ok...</td>
</tr>
<tr>
<td>Naomi</td>
<td>Do it so that we can cut it better.</td>
<td>Aaron</td>
<td>(opens a cardboard box)</td>
</tr>
<tr>
<td>Aaron</td>
<td>Oooh, you did it!</td>
<td>Like this.</td>
<td></td>
</tr>
<tr>
<td>Nico</td>
<td>Good to know.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 5. A process model illustrating the strongest paths between conditions, emotion regulation, and products for the negative de-activated cluster. An example path used in the fourth case example is marked in green. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
the conditions episode, the group is having a negatively charged interaction, criticizing and making sarcastic comments about their house while building it. Then, Benjamin initiates emotion regulation by joking that if the house is supposed to be inviting, they have succeeded. Vanessa and Ella participate by agreeing. The joking continues when Benjamin says that they can move into the house if

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**Fig. 7.** A case example describing an emotion regulation episode in which, following a negatively charged interaction, Benjamin initiated shared regulation through joking. Regulation enabled the group to continue their task and helped Benjamin shift his negative de-activated affective state into neutral de-activated. Green columns represent Benjamin’s emotional indicators for the video coding, which were combined with activation codes from EDA data. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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**Fig. 8.** A process model illustrating the strongest paths between conditions, emotion regulation, and products for the not-participating cluster. Example paths used in the third case example are marked in green. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
they must. Vanessa points out that it depends on what kind of house they are looking for, and Benjamin agrees, saying that in this case they would be looking for a cardboard box. In the products episode, the group continues working and discuss how the time has passed quickly.

The not-participating condition was found in 238 cases, of which the majority led to the student being a target for emotion regulation ($f = 102$) (Fig. 8). If the student was not a target—in other words, the student was an observer, initiator, or contributor—, the student most often continued not participating in task execution after regulation ($f = 145$). However, when the regulation targeted them directly, emotion regulation could lead to a positive/neutral de-activated ($f = 19$), activated ($f = 17$), or negative de-activated ($f = 8$) product, indicating that in 43% of the cases regulation could restore the student’s participation in task execution ($f = 44$). This is illustrated in the following example.

The third case example presented in Fig. 9 shows how one group member, Linda, co-regulates two fellow group members, Robin and Max; this regulation seems to restore their participation in task execution. However, returning to the learning activities leads to different kinds of affective products for the two group members, demonstrating how emotion regulation is situation-specific and can lead to different products for different students. During a sketching phase, Robin and Max are having fun and playing with two pens while Linda is making notes and sketching their house. Linda initiates co-regulation and stops the game by stating that they now have a fine house and only six minutes left. This draws the boys’ attention back to task execution. In the products episode, Robin starts to joke and indicates a positive affective state by clapping his hands together. However, after continuing task execution Max becomes worried that the windows are not in the right place and asks about it. This leads to the start of a new emotion regulation episode, wherein Linda co-regulates Max, saying he should not worry, the windows are just fine. The end of the product episode shows how the products of emotion regulation become the conditions for further collaboration and the next attempts at emotion regulation.

4. Discussion

This study explored the affective conditions for and products of students’ group-level emotion regulation behavior by implementing the COPES architecture (Winne & Hadwin, 1998), which describes the interplay between conditions, operations, and products in regulated learning. We operationalized affective conditions and products through emotional valence and activation and addressed students’ participation in task execution to capture the collaborative nature in this connection. The results identified four different condition clusters that highlighted the varying conditions students can have for group-level emotion regulation. Furthermore, the results specified how the different conditions were related to the students’ regulatory behavior: emotion regulation was more likely initiated by students in need of restoring their emotional grounds for collaboration. In turn, regulation was more likely targeted to those students not participating in task execution; thus, it aimed to restore the participation of these students in the joint activities. The results further showed that emotion regulation seemed to be particularly influential for the initiators and the targets of the regulatory attempts.

About one-fifth of the conditions included positive valence combined with participation and either activation (positive cases in the activated cluster) or de-activation (positive cases in the positive de-activated cluster) prior to emotion regulation, indicating an experience of positive activated or de-activated task-related emotions (Harley et al., 2019). However, a more characteristic feature found from the cluster analysis was negative valence (particularly present in the activated and negative de-activated clusters) that preceded group-level emotion regulation. This is in line with previous research findings that particularly challenging situations and negative or disconcerting emotions can disturb learning and may require activation of group-level emotion regulation to reduce negative effects on learning (Ben-Eliyahu & Linnenbrink-Garcia, 2013). For example, in the activated conditions negative valence may indicate negative activating emotions such as anxiety (Pekrun et al., 2002; Roos et al., 2020). Anxiety, in turn, has been studied broadly in academic contexts and been found to be harmful for individual learning and performance when not controlled (Zeidner, 2014). To situate this in a collaborative learning context, it can be further hypothesized that anxiety can challenge a group’s joint processes, such as sharing knowledge or exploring divergence in understanding, and invite group-level regulation (Järvenoja et al., 2019). Furthermore, in line with the results gained in this study, prior research has recognized that a negative de-activated condition, such as boredom, could also be considered a condition warranting emotion regulation to restore students’ active participation and neutral or positive emotional grounds for collaboration (Linnenbrink-Garcia et al., 2011).

Collaborative learning situations are much more emotionally complex than individual-focused instructional settings (Järvenoja et al., 2018). As pointed out by Lobczowski (2020) and demonstrated in this study through the varying conditions that were found to precede regulation, stimulus events during a collaborative group learning process can cause diverse emotional responses. That is, some of the group members may remain positive while others encounter emotional challenges, resulting in a divergent affective state within the group (Törnänen et al., 2021). These kinds of mixed emotional situations can hamper a group’s coordinated learning efforts (Barsade & Gibson, 2012) and call for emotion regulation despite the favorable affective conditions of some of the students. Although this complex phenomenon has been recognized in discussions of the social nature of regulation (Bakhtiar et al., 2018; Lobczowski, 2020; Hadwin et al., 2018), there is a need for more empirical research exploring group members’ varying emotions during the learning process and investigating the interplay between cognitive and emotional group processes. Through process-oriented approaches, it is possible to address these complex interactions between emotions, their regulation at an individual and group level, and furthermore, how they contribute to the overall learning process (Järvenoja et al., 2020). Accordingly, an interesting future direction would be to explore the differing affective states among students in a group setting and the relation between the resulting overarching affective state and the function of group-level emotion regulation.

The findings of this study are in line, on the one hand, with previous studies highlighting the meaning of group-level emotion regulation for students’ participation in collaboration (see also Isohätälä et al., 2017) and showing that emotions can be regulated
through cognitive strategies that aim to move the focus from negative emotions back to the task execution (Järvenoja et al., 2019). This was particularly visible when regulation was targeted toward the students who were not participating in task execution, enabling them to return to the joint activities. On the other hand, the exploration of the sequenced patterns between conditions and emotion regulation behaviors revealed that students with negative de-activated conditions could also act to change these conditions themselves. Emotion regulation was more likely activated by the students who seemed in need of restoring their own emotional grounds for collaboration, highlighting individual group members’ agentic and active role in group-level regulation (Hadwin et al., 2018). The results are interesting in light of previous findings relating negative emotions and interactions to social loafing (Linnenbrink-Garcia et al., 2011) and constrained regulatory actions (Bakhtiar et al., 2018). In this study, negative de-activating conditions, in particular, seemed to prompt students to initiate emotion regulation. Interestingly, if a student was already in a favorable state of positive de-activation, the student was more likely to observe the emotion regulation situation. However, these results are not necessarily contradicting the previous findings, since as shown by previous research, regulation is highly situation- and context-specific (Järvenoja et al., 2017). For example, the learning tasks used in different studies might motivate the students differently, and thus, the students might differ in eagerness to initiate emotion regulation when needed. Still, the results further support the purposeful and agentic role of the individual learner, which is emphasized in self-regulated learning theories (for a review, see Panadero, 2017), in group-level regulation as well; if there is no personal need for regulation, the student might not engage as actively in joint regulation.

The process patterns found between conditions, emotion regulation behavior, and products of regulation raise three main points for further discussion and research. First, the initiator behavior leading to the changes in affective conditions highlights the interplay between individual and social forms of regulation (Volet et al., 2009). That is, regulation seemed to be more influential if the need to regulate rose from the self-regulatory metacognitive awareness of the need for regulation, which prompted the student to initiate regulation (Järvelä et al., 2015). Second, if the student was a target for regulation, co-regulation often enabled them to change their affective state. This highlights the importance of timely and targeted co-regulation and its support of students’ self-regulation (Bakhtiar & Hadwin, 2020; Järvenoja et al., 2017). Third, the results show that emotion regulation is not always successful in changing the

### Fig. 9. A case example demonstrating an emotion regulation episode in which positive affect and fun distracted Robin and Max from executing the task. With Linda’s co-regulation, the boys were able to restore their participation. Green columns represent Robin and Max’s emotional indicators for the video coding, which were combined with activation codes from EDA data.

<table>
<thead>
<tr>
<th>CONDITIONS</th>
<th>REGULATION</th>
<th>PRODUCTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code</td>
<td>Not participating</td>
<td>Target</td>
</tr>
<tr>
<td>Robin</td>
<td>Ok, here is yes and here is no.</td>
<td>Target</td>
</tr>
<tr>
<td></td>
<td>Charlie, Charlie, do you want to play with me?</td>
<td></td>
</tr>
<tr>
<td>Max</td>
<td>He is not... Was it so that we need to...</td>
<td></td>
</tr>
<tr>
<td>Linda</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Robin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linda</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Robin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linda</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Robin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linda</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linda</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*He is here! Ok, now...*

*My drawing is quite nice... (laughing)*

*Yes, it is.*

*Everyone will figure it out surely...*

*Ok, it’s ready then!*

*(claps his hands together)*

*Yes.*

*If there’s a window, shouldn’t there be one here too?*

*No, look there’s a window.*

*Why would there be a window in the roof?*

*But...*

*Look here, there’s not a roof yet.*

*There’s no need to be worried.*

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unfavorable conditions. This is in line with previous findings that group-level regulation can change the negative valence of students’ interaction, but that this is not guaranteed; regulation attempts do not always succeed (Mänty et al., 2020). In order to be adaptive, regulation needs to be timely and implemented using appropriate strategies that correspond to situational needs (Järvenoja et al., 2019). Emotions can be regulated with multiple strategies (Gross, 2002; Harley et al., 2019); however, these were not the focus of this study. Future studies may explore whether students are using appropriate strategies when trying to overcome socio-emotionally challenging situations.

In terms of methodology, this study poses interesting findings related to the usefulness of sympathetic arousal data in studying emotions and their regulation during a group learning process. Previous research has suggested that both increases and decreases in sympathetic arousal can reflect emotion regulation processes (Kinner et al., 2017; Matejka et al., 2013; Pizzie & Kraemer, 2018). In the same vein, this study showed that students in the activated condition, as indicated from their physiological arousal, were also actively involved in regulation, and activation (i.e., arousal) most often remained after emotion regulation. In some cases, however, emotion regulation calmed students’ arousal or led to an activated product of regulation if the student had not been activated before emotion regulation but was acting as an initiator or was a target for regulation. These findings suggest that when emotional challenges arise at a group level and shared regulation occurs, it can stimulate various physiological responses in the group members. Accordingly, the association between actualized emotion regulation and sympathetic arousal is by no means simple or linear and cannot be considered to indicate only regulatory activity (see also Malmberg et al., 2019). To conclude, the results of this study encourage further exploration of how students’ sympathetic arousal can be utilized to understand the complexity of emotion regulation in groups. Adding new data channels may provide new insights into emotions and emotion regulation processes in relation to the overall learning process if these data are contextualized and connected with other data sources (Järvelä et al., 2019), as this study did by contextualizing students’ arousal with the videotaped learning activity.

Even though the novel multichannel method applied in this study has benefits, it also poses some challenges and limitations. First, due to the poor-quality EDA data of some students, the already small sample size was limited further since problems with only one group members’ data excluded the whole group from the analysis. Therefore, the choice was made to focus on cases (i.e., one conditions-emotion regulation-products episode) rather than individual students’ processes. Furthermore, qualitative approaches were used to complement the analysis. Second, learning processes and emotions embedded in them form complex processes, and when these processes are described with process models, some simplifications need to be made (Bannert et al., 2014; Malmberg et al., 2015). In this study, clustering was used to reduce the number of all possible condition combinations and simplify the next steps of the analysis. This was useful for the analysis, but some nuances in the various processes and results were obscured. Furthermore, when forming the process models, only the strongest paths were visualized to highlight the strongest tendencies for the different patterns (Bannert et al., 2014). While these can be considered limitations, they were also necessary practical choices to facilitate coherent results interpretation. Despite the limitations, the results offer novel empirical insights to strengthen theories of emotion regulation during collaborative learning. In the future, more studies with larger sample sizes are needed to reach a thorough understanding of the interaction between students’ emotions and emotion regulation during a collaborative learning process.

5. Conclusions

The process-oriented approach implemented in this study can be a valuable addition to research considering the role of emotions for academic learning. To understand better how emotions influence learning, in addition to measuring emotions and their effects on outcomes, we need to know how emotions and emotional reactions interact with learning processes (Taub et al., 2019). As the results from studies relying on process analyses accumulate, they can offer new insights into changes in affective conditions during the learning process and complement research that reveals connections between emotions, learning, and performance on an outcome level (Järvenoja et al., 2018). The results of this study contribute to this goal by offering new insights into the reciprocal interaction between students’ affective conditions, group-level regulatory processes, and affective products during collaborative learning. From this point of view, the results also have implications for educational practices. They highlight the importance of supporting students’ emotional awareness and of helping them use their skills to regulate their emotions together as a group to ensure motivated collaboration.

Declaration of Competing Interest

None

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Supplementary materials


