

Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

International Journal of Educational Research

journal homepage: www.elsevier.com/locate/ijedures

Socio-emotional interaction in collaborative learning: Combining individual emotional experiences and group-level emotion regulation



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ARTICLE INFO

Keywords:

Socio-emotional interaction
Emotions
Emotion regulation
Collaborative learning task
Physics learning

ABSTRACT

This study explores how groups' negative socio-emotional interactions and related emotion regulation during a collaborative physics task are interconnected with 12-year-old primary school students' (N = 37) situated individual emotional experiences. To accomplish this, the study relates group-level video data analysis with students' self-reported emotional experiences. The results indicate that students' negative emotional experiences related to the task prior to collaborative working increase the group's emotion regulation during the collaboration and that negative group interactions negatively affect students' emotional experiences after the task. The study also shows that even though group-level regulation is more likely to change the valence of the group's interaction from negative to positive, regulation does not always succeed in making a difference to the students' overall emotional experiences.

1. Introduction

During the past two decades, the roles of affect and emotions in learning have gained increasing recognition (Boekaerts, 2007; Pekrun & Linnenbrink-Garcia, 2014). Research on emotions in education has shown how emotions are a part of academic learning, influencing students' motivation, cognitive processes and academic attainment (Ainley, Corrigan, & Richardson, 2005; Assor, Kaplan, Kanat-Maymon, & Roth, 2005; Pekrun, Frenzel, Goetz, & Perry, 2007). There is substantial research, for example, about the effects of negative affect on learning in terms of test anxiety and students' poor self-esteem (Ng & Lee, 2015), academic performance (Chapell et al., 2005) and students' motivational variables, such as self-efficacy (Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011, 2014, Pekrun, Goetz, Titz, & Perry, 2002; Zeidner, 1998). In turn, positive affect has been connected to cognitive and motivational engagement (Helmke, 1993; Linnenbrink, 2007; Pekrun et al., 2002) and the use of adaptive regulation strategies during learning (Boekaerts & Pekrun, 2015; Pekrun, 2006).

Despite substantial progress in depicting associations between different academic emotions and learning, research on emotions has largely relied on exploring emotions with static measures at trait level and focusing on individual comparisons (Goetz, Sticca, Pekrun, Murayama, & Elliot, 2016; Moeller, Ivcevic, Brackett, & White, 2018), in which their effect on learning has been considered quite simplistically. Lately, several researchers have started to emphasise the more multifaceted role and function of affect, particularly for the learning process (Azevedo, Taub, Mudrick, Farnsworth, & Martin, 2016; Moeller et al., 2018). The areas of interest cover, for example, the variation or fluctuation of emotional states during learning (D'Mello & Graesser, 2012; Murayama et al., 2017; Schneider et al., 2016) and multiple or mixed emotional experiences (Moeller et al., 2018).

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<https://doi.org/10.1016/j.ijer.2020.101589>

Received 19 February 2020; Received in revised form 30 April 2020; Accepted 7 May 2020

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Another dimension, highlighting the multifaceted role of emotions in learning, opens when we focus on different social aspects of emotional experiences. Prior research on emotions has acknowledged the importance of the social dimension for emotional reactions and experiences. In theories on emotions in learning, social influence is recognised as a source of certain groups of emotions. Pekrun et al. (2002, Pekrun, 2006) classify different emotions according to whether they are aroused by internal or external causes. Shame and pride, or envy and sympathy, for example, are inherently social in origin (Pekrun et al., 2002; Wosnitza & Volet, 2005). Albeit the social origin, the actual physiological reactions and related cognitive appraisals are individuals' own experiences. Accordingly, most empirical studies focus primarily on these individual reactions, experiences and appraisals (for a review, see Boekaerts & Pekrun, 2015). Therefore, the social dimension in the ignition of emotions is rarely the focus of studies or is diminished to an external variable to be controlled (Järvenoja, Volet, & Järvelä, 2013; Linnenbrink-Garcia, Rogat, & Koskey, 2011). However, we argue that the role of social aspects in how emotions are experienced and how they influence learning is more multifaceted, particularly when the focus is on the learning contexts that are social in principle, such as collaborative learning tasks (Järvenoja et al., 2018).

Group learning situations add a new dimension to the role of emotions in terms of learning. Socio-emotional interactions act as a source and a context for emotional reactions and motivations for an individual (Järvenoja & Järvelä, 2013), but also in influencing, shaping and redirecting group members', as well as groups', joint emotional experiences (Näykki, Järvelä, Kirschner, & Järvenoja, 2014). Negative socio-emotional interactions, in particular, may hinder group learning unless they are regulated appropriately (Bakhtiar, Webster, & Hadwin, 2018). Emotion regulation, as a part of regulated learning, is a mechanism through which the group members can, individually and together, actively maintain, modify and change the course of socio-emotional interactions and group members' emotional and motivational states in order to fuel the learning process (Järvenoja, Näykki, & Törmänen, 2019).

This study aims to contribute to the ongoing discussion on the more multifaceted and fluctuating roles of emotions and affect in learning by investigating emotions in collaborative learning through combining multiple emotional processes: individual emotional experiences, socio-emotional interactions and group-level emotion regulation. This study explores how group-level negative socio-emotional interactions and groups' emotion regulation activities, which take place as a part of these interactions, contribute to and are contributed by students' individual emotional experiences, and how the groups succeed in changing the course of negative interactions by engaging in group-level regulation.

2. Individual emotional experiences in social learning situations

Understanding the role of emotions, particularly in educational settings, requires comprehending their multifaceted relations to individual experiences and attitudes as well as to the cognitive, motivational and social processes that are taking place in the given situation (Boekaerts & Pekrun, 2015). When considering the individual characteristics of emotional processes, earlier research supports the notion that emotions experienced as a consequence of the learning process can both hinder and accelerate present and new learning processes (Boekaerts & Pekrun, 2015; Linnenbrink-Garcia et al., 2011). Research suggests that different emotions affect the learning process, for example, by increasing the positive interpretation of the situation or decreasing it (Boekaerts & Pekrun, 2015; Linnenbrink, 2007; Zeidner, 1998, 2014). For example, emotions build on and are built upon the beliefs or cognitive appraisals that individuals assign to situations in relation to their goals (Boekaerts & Pekrun, 2015; Frijda et al., 2000; Gross, 2014; Lazarus, 1991; Shuman & Scherer, 2014). Emotions also play a part in motivation for learning, how the students' self-efficacy beliefs develop or what types of goals these students set (Boekaerts, de Koning, & Vedder, 2010), as these beliefs are not purely cognitive judgements but also include emotional appraisals and interpretations (Weiner, 1985).

Recent research has shed more light on the complex nature of emotional experiences, showing that emotions fluctuate throughout the learning situation in relation to social interactions (Linnenbrink-Garcia et al., 2011), the challenges experienced (D'Mello & Graesser, 2012; Murayama et al., 2017; Schneider et al., 2016) and the regulatory activities used (Linnenbrink-Garcia et al., 2011). For example, according to D'Mello and Graesser (2012), during a learning situation, students' emotional experiences can go through various transitions, which are triggered by cognitive or other challenges. Moeller et al. (2018), in turn, show how in a single learning situation, a learner may experience a mixture of emotions, both negative and positive, depending on the focus of those emotions. Understanding the complexity of emotions in learning situations is essential to avoid simplified conclusions of how emotions affect the learning process and its outcomes (Moeller et al., 2018).

When learning becomes a social process, even more aspects contribute to the emotional experiences of the individual. In group interactions, socio-emotional experiences of group members and the interpretations they give to the interactions frame the unique group dynamics and situational motivation during group learning (Järvenoja et al., 2013; Rogat & Adams-Wiggins, 2014). During group interactions, negative affects of the participants have been connected to less productive group interactions, such as social loafing and disengagement (Zschocke, Wosnitza, & Bürger, 2015). Negative affect, being strong and persistent, has resulted in lower performance and satisfaction, resulting at worst in detrimental outcomes of group learning (Bakhtiar et al., 2018; Chiu & Khoo, 2003; Duffy & Shaw, 2000; Linnenbrink-Garcia et al., 2011; Näykki et al., 2014). The positive affect of individuals in collaborative groups, in turn, has been shown to boost positive socio-emotional interactions and socio-behavioural engagement within the group (Linnenbrink-Garcia et al., 2011). However, the relations that emotional experiences have with learning activities are not straightforward but may vary depending on where they are directed (Moeller et al., 2018; Pekrun et al., 2002; Wosnitza & Volet, 2005) and how they are regulated (Bakhtiar et al., 2018).

3. Socio-emotional interactions in learning

Emotions participate in the collaborative learning process, particularly through socio-emotional interactions that take place

between the group members. Socio-emotional interactions refer to the purposeful interchanges between group members to express and shape the perceptions of emotions and the socio-emotional climate (Bakhtiar et al., 2018; Kreijns, Kirschner, & Jochems, 2003; Rogat & Linnenbrink Garcia, 2011). Overall, groups' positive socio-emotional interactions have been linked to positive outcomes in groups' engagement, motivation (Linnenbrink-Garcia et al., 2011) and regulated learning processes (Lajoie et al., 2015; Rogat & Adams-Wiggins, 2015). At best, groups' positive socio-emotional interactions can boost the learning of the individual group members, but also the group as an entity, if all group members' goals are aligned and if they are motivated and contribute to the learning process (Bakhtiar et al., 2018; Rogat & Linnenbrink-Garcia, 2011; Volet, Summers, & Thurman, 2009; Zschocke et al., 2015). However, earlier research demonstrates the delicate nature of socio-emotional interactions in shaping the group atmosphere and making a difference to the cognitive processes in learning (Isohäätä, Näykki, Järvelä, & Baker, 2018). For example, when positive interactions are taken too far, collaborative groups may avoid exchanges that create tension and, instead, focus on maintaining the favourable socio-emotional atmosphere at the expense of cognitive processes (Andriessen, Pardijs, & Baker, 2013).

In the previous research literature, negative socio-emotional interactions have been seen as the ones that often challenge a group's learning process, affecting the quality of learning activities (Rogat & Adams-Wiggins, 2015; Rogat & Linnenbrink-Garcia, 2011) and the emotional and motivational reactions of group members (Linnenbrink-Garcia et al., 2011). Negative interactions can derive from various sources, such as cognitive challenges (Andriessen et al., 2013; Järvenoja & Järvelä, 2009), motivational issues or interpersonal dynamics (Blumenfeld, Marx, Soloway, & Krajcik, 1996; Järvenoja et al., 2013). At worst, they can turn into conflicts with disruptive outcomes for interpersonal relations, motivation and the learning process (Näykki et al., 2014; Rogat & Linnenbrink-Garcia, 2011). However, even though these interactions may challenge the group and raise various emotional reactions, they are also the situations that bring negative experiences to the surface at the group-level. This, in turn, may open up possibilities for joint attempts to solve the issue and share emotions and experiences (Järvenoja et al., 2013) and even for opportunities to create new ideas and elaborate on learning results if regulated appropriately (Andriessen, Baker, & van der Puil, 2011; Järvenoja et al., 2013).

4. Regulating emotions when learning together

For students to participate in effective and enjoyable group learning situations, they need skills to be able to collaborate and manage the learning process together, but they also need to be able to adapt to their socio-emotional context (Kershner, Warwick, Mercer, & Kleine Staarman, 2014; Pietarinen, Vauras, Laakkonen, Kinnunen, & Volet, 2019; Tomas, Rigano, & Ritchie, 2016). Therefore, social learning situations need both individual (Kershner et al., 2014; Tomas et al., 2016) and group-level regulation of emotions (Järvenoja et al., 2019; Kwon, Liu, & Johnson, 2014). One key prerequisite for successful collaboration is the ability to identify the situations where the activation of appropriate individual and group-level regulation of emotions is needed to manage motivated learning (Bakhtiar et al., 2018; Järvenoja et al., 2019). Research shows, for example, that successful group-level emotion management relates positively to a group's learning and collaboration skills (e.g. Xu, Du, & Fan, 2013). However, the need for regulation is not always recognised (Järvelä, Järvenoja, Malmberg, & Hadwin, 2013; Miller & Hadwin, 2015), which can have detrimental effects on the group's learning process (Kreijns et al., 2003; Näykki et al., 2014).

Emotion regulation can target directly at the emotion itself or the cause of emotion (Lobczowski, 2020; Smith & Lazarus, 1990). In learning situations, this means that emotion regulation can manifest as influencing one's learning activities by, for example, increasing motivation in different ways (Wolters, 2003) and managing feelings and emotional reactions that can potentially disrupt the learning process (Corno & Kanfer, 1993), but also by managing the aspects of the task (Boekaerts, 2007). From a group perspective, to manage a coordinated activity within a group, the members need to also be able to overcome challenges evoked by the social nature of the collaborative task activities. In these situations, active group-level emotion regulation is essential as group learning often creates more complex and challenging interactions in changing learning contexts (Järvelä, Volet, & Järvenoja, 2010). The concepts of co- and socially shared regulation have been developed to describe, in particular, how group members regulate each other and the group process during learning (co-regulation) and further, how group members together build on each other's regulatory activities (socially shared regulation) to overcome the socio-emotional and cognitive challenges they face (Hadwin, Järvelä, & Miller, 2011). The socially shared regulation of emotions as a concept demonstrates the ways in which the group members together take charge of the socio-emotional climate of the group (Järvenoja et al., 2013; Linnenbrink-Garcia et al., 2011).

Both in individual and group learning situations, emotional processes are often strongly intertwined with the cognitive activities of the learning process (Järvelä, Järvenoja, Malmberg, Isohäätä, & Sobocinski, 2016). Thus, emotion regulation on group level is not only targeted directly at affecting emotions or motivation of the group members but it can also manifest as regulation of the task and interactions related to it, such as negotiating task responsibilities or planning task activities to manage the socio-emotional challenges (Järvenoja et al., 2019; Jermann & Dillenbourg, 2007). In addition to all this, group-level emotion regulation requires abilities to maintain a favourable socio-emotional atmosphere for the whole group (Järvelä et al., 2010). Overall, through effective self- and group regulatory activities, it is possible to reach enhanced interaction and communication and the co-construction of knowledge within a group (Järvenoja et al., 2013) and, at best, to achieve a process that boosts everyone's learning more than in individual situations.

Fluctuations in both socio-emotional interactions and the regulatory processes related to them during group learning are at the core of building an understanding of how students engage and participate in social learning contexts and how they build their emotional and motivational grounds through these interactions (Järvelä et al., 2010; Järvenoja et al., 2013). In particular, regulatory activities in situations where emotions are generated by socio-emotional challenges during group learning processes need examination as, in these situations, appropriate group-level regulation is critical for the continuation of successful collaboration (Efklides & Volet, 2005; Rogat & Adams-Wiggins, 2015). Although research examining emotions in collaborative settings is growing,

there is still less research on regulatory behaviours and actions that contribute to or are influenced by positive or negative socio-emotional processes (Bakhtiar et al., 2018; Dillenbourg, Järvelä, & Fischer, 2009; Järvelä et al., 2015). Understanding the interplay between emotional experiences and group-level emotion regulation activities during collaborative learning is essential for exploring how groups succeed in turning their interactions into positive and effective ones in terms of learning activities.

5. Aims

This study focuses on negative socio-emotional interactions and group-level emotion regulation taking place during a 12 year-old students' collaborative physics task. It explores how individual group members' self-reported emotional experiences, groups' negative socio-emotional interactions and groups' regulation activities are interweaved with each other in the group learning process. The research questions are the following:

- 1 How is negative socio-emotional interaction during group learning related to group members' emotional experiences before and after the collaborative task?
- 2 How is group-level emotion regulation in negative socio-emotional interactions related to group members' emotional experiences before and after the collaborative task?
- 3 How does group-level emotion regulation in negative socio-emotional interaction relate to groups' further interaction during the collaborative task?

6. Methodology

6.1. Participants

The participants of this study were 6th grade (approx. 12 years old) students from one primary school in Finland. Altogether, 37 students participated in the study. The students were assigned to groups of 3–4 students heterogeneously based on their task interest in learning which was assessed by the Task Interest Inventory (Cleary, 2006). This resulted in the formation of 12 groups in total.

6.2. Context and data collection

The groups were working in a classroom-like learning and research space conducting a collaborative physics task. There were three groups present at a time. The group work was recorded with 360° cameras. Overall, 18 h of video data were gathered from the groups' collaborative activities. Students' situated emotional experiences were detected using the situation-specific emotion (EmA) self-report tool (Järvenoja et al., 2018) before and after the task (see Picture 1, scale 1–5, from negative to positive via neutral, presented with smiley faces). First, the EmA tool was used after the students were presented with the task but before their work started, so the students had information about the task when they answered it for the first time. After the collaborative task, the EmA tool was used for the second time. The tool measured students' emotional experiences with two single questions targeted at emotions in general and emotions related to the task (1. How do you feel right now? and 2. How do you feel about the task?).

6.2.1. Collaborative physics task

The physics task that the groups of students conducted was designing and constructing a model for an energy efficient house that

How do you feel right now?



How do you feel about the task?



Picture 1. EmA tool.

makes use of solar energy. Students could use different materials (e.g. cardboard, tape, aluminium foil, cotton wool, Styrofoam sheets) to build the house and had to follow some rules.

Before the building task, some basic information about heat energy was presented to the students by the teacher. After this, the task consisted of four different phases: 1) becoming an expert (15 min), 2) brainstorming (10 min), 3) sketching (20 min) and 4) building (60 min). The remaining time for each phase was visible for students throughout the task. The aim was to follow a normal classroom activity, where there is normally a limited time to perform a task. The time was made visible to make sure the students were able to organize their work to finish their houses on time. In the first phase, each individual student received information about one specific area related to heat energy and the building of houses. The students had 15 min to read the material and make notes about their own subtopics individually. After that, the students started to work collaboratively in groups. In phase two, the instructions were to share the expertise and brainstorm a list of things to keep in mind while sketching and building the houses. After brainstorming, students started phase three in which they made sketches and floor plans of their houses. The instructions were that the sketch should demonstrate how the house should be built and which materials should be used. Then, the last phase followed, which was the actual building of the houses.

6.3. Data analysis

6.3.1. Video data analysis

The video data was first analysed by detecting episodes of socio-emotional interaction during the group task and calculating the overall duration of these interactions (time as seconds). The unit of analysis was a meaningful episode that lasted for as long as the socio-emotional interaction between the group members continued. When coding the video data, the socio-emotional interactions were categorised according to the observable emotional valence of the situation (Pekrun et al., 2002; Russell & Barrett, 1999), which was applied to group level (Järvenoja et al., 2018) and included codes of negative, mixed or positive group valence. Indication of a socio-emotional interaction could be both, a verbal and a nonverbal expression of emotion followed by at least one comment or a reaction from another group member (Krejins et al., 2003; Kwon et al., 2014), such as an expression of frustration or excitement from one group member followed by a response from another. Examples of the socio-emotional interactions and their valence are presented in Table 1. In coding the episodes, negative socio-emotional interactions (e.g. arguing, criticising others, teasing) were considered as interactions that started when at least one group member made a negatively charged comment (e.g. "We are idiots") or

Table 1
Coding criteria for valences of socio-emotional interactions.

Valence	Criteria for coding	Expressions	Examples	
Negative	Clear negative indicators from at least two of the group members	Verbal expressions (e.g. "We are idiots")	Lars: "Let's design a modern house, not an ugly one like that."	
		Bodily expressions (e.g. sighing)	Annika: "You yourself are ugly."	
		Lack of focus (e.g. playing with equipment, wandering around)	Lily: "Can you do this better?"	
		Negatively charged interaction (e.g. arguing, criticising others, teasing)	Annika: "Yeah."	
		Tensioned silence	Lily: "If you are not satisfied with how I do it, maybe you should do it yourself then." Lars: "Okay."	
Positive	Clear positive indicators from at least two of the group members	Verbal expressions (e.g. "We are so good")	Jenny: "This (the house) is going to be so nice!" Chris: "Yes it is, the end result, for real!"	
		Bodily expressions (e.g. laughing, giggling)		
Mixed	Clear positive indicator from at least one group member and clear negative indicator from at least one group member in the same segment Multiple different indicators, both positive and negative (e.g. positive bodily sign + negative verbal sign)	Positively charged interaction (e.g. joking, praising, encouraging)	Lily: "Oh, it sounds nice!"	
		Positive and negative expressions or valence of expressions is not clear	Lars: "No, it doesn't."	
Neutral	No indicators or indicators from only one group member	No emotional expressions or expressions from only one group member	Jessie: "We didn't have time to do the colouring for the outside walls ... Now, let's put the roof here." James: "Wait, we should put the tape like this so that this fur won't come out ..." (joking and laughing) James: "Now this tape is furry too, damn it. I hate the furry tape." Jessie: "Mm ..." (laughing)	

Table 2

Descriptive of the variables of self-reported emotional experiences and group level negative interactions.

Variable	N	Min.	Max.	M	SD
Start: Emotional experience in general (scale 1–5)	37	2	5	3.73	.769
Start: Emotional experience related to the task (scale 1–5)	37	1	5	3.81	.877
End: Emotional experience in general (scale 1–5)	37	2	5	4.24	.796
End: Emotional experience related to the task (scale 1–5)	37	2	5	4.27	.838
Regulated negative interactions (%)	12	16	58	32.61	12.308
Negative interaction (seconds)	12	302	2085	1130.39	611.503

expressed negative emotions (e.g. groaning, sighing, playing with equipment), which were followed by a reaction from a group member. Positive interactions (e.g. joking, praising, encouraging) were coded similarly, but in terms of exploring participants' positive interactions. Mixed interaction contained both negative and positive interactions or the valence of the interaction was not clear (e.g. laughing while verbally indicating negative emotions). If no coding was carried out, the interaction was neutral.

Next, emotion regulation attempts targeted at the other group members or the whole group during the coded socio-emotional interaction episodes were located. Interaction was coded to include group-level emotion regulation when at least one group member expressed attempts to regulate the aspects of socio-emotional interaction on group level. Group-level regulation was considered to occur when regulation was made explicit to other group members. In this data set, this included clear verbal indication of the regulation attempt. Group-level emotion regulation could be directed to regulate either coordination of the task activities (e.g. "Let's divide the tasks") or other group members' behaviour (e.g. "Please concentrate on the task") as an attempt to manage the socio-emotional issue in the interaction. The group-level regulation could also be targeted directly to decrease harmful emotions within group (e.g. "It's ok, we are still on schedule"), increase positive feelings and simultaneously maintain motivation (e.g. "At least our house looks nice") or influence on the overall socio-emotional climate (e.g. joking and complimenting others). The regulation activity comprises both co- and socially shared regulation activities. Finally, the percentual amount of negative socio-emotional interactions that contained regulation were calculated by comparing them to overall amount of negative interactions within each group's task process. Socio-emotional interactions, the valences of interactions and regulation during interactions were coded for reliability by another researcher. Reliability coding was conducted for 40 % of the collaborative group sessions. For identifying socio-emotional interactions ($\kappa = 0.693$) and defining the valence of interactions ($\kappa = 0.723$), substantial agreement was reached. For identifying regulation of the negative interactions ($\kappa = 0.879$), almost perfect agreement was reached. A description of the data from the EmA self-reports and video analysis is presented in [Table 2](#).

6.3.2. Statistical analysis

Next, individual students' self-reports on their emotional experiences in general and related to the task (EmA tool) were compared with the time spent in negative socio-emotional interactions and the percentual amount of negative interactions that include group-level regulation (video data). The statistical correlations between the variables were calculated using Spearman's correlation coefficient estimates.

Further, negative socio-emotional interactions in the groups were sequentially analysed from the video data, exploring in one-minute intervals whether the regulation was followed by negative/mixed or positive/neutral (i.e. no coded socio-emotional interaction) socio-emotional interactions. That is if the next interaction occurred less than one minute after the previous interaction ended. One-minute intervals were chosen to make sure that the interval was short enough to capture the meaningful connections between previous interactions and the following ones. The analysis was prepared using the Observer XT lag sequential analysis function, where the frequencies of how often negative interaction and regulated negative interaction were followed by either negative, mixed, positive or neutral interaction was examined. After this, chi-square statistics were calculated for the results. The significant associations between sequential pairs were examined further by exploring significant z scores from adjusted residuals with alpha levels of 0.05 ($z < 1.96$) and .001 ($z < 2.58$). In this analysis, adjusted residuals show whether a particular behaviour occurs significantly more or less often before or after another behaviour than if happening by chance ([Bakeman & Quera, 1995](#)).

7. Results

7.1. RQ1 how is negative socio-emotional interaction during group learning related to group members' perceived emotional experiences before and after the collaborative task?

First, the associations between negative socio-emotional interactions during the collaborative task and group members' self-reported emotional experiences were explored using Spearman correlation coefficient estimates. Negative correlation ([Table 3](#)) was found between the amount of time spent on negative interactions during the task and the students' emotional experiences related to the task after it was completed ($rs(37) = -0.368$, $p < .05$), indicating that the more time students spent participating in negative interactions, the more negative they felt after the task regarding the task itself. Still, the amount of time groups engaged in negative socio-emotional interactions during the task did not correlate with students' emotional experiences in general after the task. Further, students' emotional experiences in general and those related to the task, reported before the task, did not correlate significantly with the amount of time the groups engaged in negative interaction during the task.

Table 3
Correlations of students' emotional experiences and (regulated) negative interactions.

Variable	1	2	3	4	5	6
1 Start: Emotional experience in general	–	,454**	0,126	0,065	–0,041	–0,087
2 Start: Emotional experience related to the task	,454**	–	–0,143	0,163	0,297	–,351*
3 End: Emotional experience in general	0,126	–0,143	–	,597**	–0,317	–0,026
4 End: Emotional experience related to the task	0,065	0,163	,597**	–	–,368*	–0,147
5 Negative interactions	–0,041	0,297	–0,317	–,368*	–	–0,055
6 Regulated negative interactions	–0,087	–,351*	–0,026	–0,147	–0,055	–

Note: * p < .05, ** p < .01 (2-tailed).

7.2. RQ 2 how is group-level emotion regulation in negative socio-emotional interactions related to group members' perceived emotional experiences before and after the collaborative task?

Significant negative correlation (Table 3) was found between the children's self-reported emotional experiences related to the task reported before the task and the percentage of regulated negative socio-emotional interactions during the task ($r(37) = -0.351$, $p < .05$), indicating that the more negative the students felt about the upcoming task, the more their groups engaged in group-level regulation during negative interactions. However, the children's emotional experiences reported after the task did not significantly correlate with the percentage of regulated negative socio-emotional interactions during the task.

7.3. RQ 3 how does group-level emotion regulation in negative socio-emotional interaction relate to groups' further interaction during the collaborative task?

Next, the sequences of interactions were analysed to explore whether the regulation activities during groups' negative interactions made a difference to how the groups' interactions continued. When exploring negative, mixed, positive and neutral interactions (Table 4), a significant difference was found between the conditions of regulated and non-regulated negative interactions ($\chi^2(3) = 8.161$, $w = .13$, $f = 439$, $p < .05$). In particular, positive interactions were found to follow regulated negative interactions in one-minute intervals significantly more often than they followed non-regulated interactions ($z = 2.3$, $p < .05$). However, the results show that activating regulation does not inevitably guarantee an instant change in the valence of the interaction. The results show that even regulated negative interactions were often followed by negative (48.7 %) or mixed (26.9 %) interactions and that negative interactions that changed into positive (16 %) or neutral (8.3 %) interactions were less common.

8. Discussion

This study addressed the multifaceted nature of emotions in learning by relating students' individual, situation-specific emotional experiences before and after a collaborative physics task with their socio-emotional interactions and the associated group-level emotion regulation during collaboration. The results indicated that socio-emotional interaction and the regulation related to it have reciprocal relations with individual emotional experiences. That is, the study showed some evidence that collaborative physics learning situation was influenced by and made a difference to the individual students' emotional experiences they reported in relation to the collaborative learning situation. Overall, the current study design is in line with recent arguments emphasising the need to acknowledge the multi-layered and fluctuating function of emotions for learning, such as the multiple emotional experiences individual learners may have during learning (Moeller et al., 2018), how emotional experiences fluctuate in relation to social and task-

Table 4
Associations of regulated and non-regulated negative interactions and the valence of further interactions in one-minute intervals.

			2nd interaction				
			Negative	Mixed	Positive	Neutral	In all
1st interaction	Non-regulated negative interactions	Observed/	165/155.4	79/78	25/32.2	14/17.4	283
		Expected f					
		Observed %	58.3	27.9	8.8	4.9	~100
		Z	1.9	.2	–2.3*	–1.4	
	Regulated negative interactions	Observed/	76/85.6	42/43	25/17.8	13/9.6	156
		Expected f					
		Observed %	48.7	26.9	16.0	8.3	~100
		Z	–1.9	–.2	2.3*	1.4	
		In all	241	121	50	27	439
		In all %	54.9	27.6	11.4	6.2	~100

Note. * p < .05.

related conditions (Bakhtiar et al., 2018; D'Mello & Graesser, 2012; Murayama et al., 2017) and how social interactions act as a context and a source for emotional experiences in collaborative learning (Järvenoja & Järvelä, 2013; Linnenbrink-Garcia et al., 2011).

The first conclusion to be drawn from the results of this study is that general emotional experiences and task-related emotional experiences seem to be somewhat different experiences and thus also contribute differently to socio-emotional interactions during group learning. The results demonstrated that students' emotional experiences related to the task were connected to the groups' interactions, whereas their general experiences of emotions were not. This result is similar to earlier research showing how different emotions can occur together depending on their target or the situation at hand (Moeller et al., 2018). Previous research has shown that emotions and affect in learning function on several layers in group interactions, particularly showcasing the connections between individual emotions and their regulation in relation to social and task-related factors (Tomas et al., 2016; Zheng & Huang, 2016). In the present study, students' self-reported general emotional experiences before the task were not related to the negative socio-emotional interactions per se. Nor were they related to group-level regulation during the collaborative task. This is not to say that emotional valence, when entering a collaborative learning task, does not play a role: The results showed that the more negative the students rated their task-related emotions, the more their group engaged in group-level regulation during socio-emotional interactions.

Second, the results of this study provide evidence that features of socio-emotional interactions during learning can affect individual emotional experiences in more than one way. Negative socio-emotional interactions during collaboration did not make a difference to students' general emotional experiences but did negatively affect students' emotions related to the task. Also, activated group-level regulatory actions did not automatically influence students' emotional experiences after the task, but they were connected to changes of valence in the learning situation. In the end, whether the student feels happy or not is influenced by many different emotional factors, and the emotional state can also be mixed; the student can be happy that the task is over and report positive emotions, but feelings related to the completed task or the collaborative group activity may remain negative. It may be relevant to consider this aspect even further in future research in terms of theoretical and methodological choices, because the way we experience our emotions can vary, depending not only on the context they occur in (Meyer & Turner, 2006; Zembylas, 2003) but also on the target they have, and thus, this makes a difference in terms of the emotions' impact on our activities (Goetz et al., 2014; Moeller et al., 2018).

Third, the results of this study also raise the question of how group-level regulation in negative interactions succeeds during collaborative working among groups. The analysis of the associations of students' emotional experiences revealed that group-level regulation did not seem to affect students' emotional experiences after the task. Based on this result it was assumed that regulation may have not been successful in helping to solve issues causing negative socio-emotional interactions and maintaining or creating enjoyable learning experiences for the students. This result is in line with earlier notions that not all regulation is adaptive (Bakhtiar, Hadwin, & Järvenoja, 2019; Engelschalk, Steuer, & Dresel, 2017; Kurki, Järvenoja, Järvelä, & Mykkänen, 2017). Particularly, in attempts to regulate groups' socio-emotional interactions, there are more players and variables involved and, thus, more uncertainties related to the group process than when one is only regulating one's own emotions. Therefore, the analysis in this study proceeded with exploring what happened during collaboration: whether group-level regulation was able to make a difference to groups' interactions within collaborative tasks. When exploring the sequences of interactions, it was found that group-level regulation of negative socio-emotional interactions seemed to make a difference to groups' further valence of interaction. Still, there were many instances where regulation did not seem to change the valence of interaction. The results indicate that group-level regulation activities during negative interactions had the potential to make a difference in the valence of groups' further interactions, but regulation did not always succeed in doing this.

It is evident that a group's ability to appropriately regulate, in particular, negative socio-emotional interactions is important with respect to the interactions turning into more beneficial ones in terms of learning activities (Lajoie et al., 2015; Rogat & Adams-Wiggins, 2015; Rogat & Linnenbrink-Garcia, 2011). However, the reason for regulation failure may be, for example, the application of inadequate or inappropriate regulation strategies for that situation (Bembenutty, 2011; Cleary, Velardi, & Schnaidman, 2017; Järvenoja et al., 2019; Kurki et al., 2017). Also, new challenges and triggers occur during collaborative learning and cause new valences in interactions (D'Mello & Graesser, 2012), and thus, they cannot always be traced back to previous regulation attempts. Nor does the regulation of these interactions mean that it will be focused directly on changing the valence of the interactions or individual emotional experiences but rather on controlling some other aspects of collaboration and learning, such as the task process. It has been argued that the roles of particular emotions and emotional valence in learning are not that straightforward (Pekrun et al., 2002). Negative valence, such as frustration, can actually serve learning if it is activated to solve frustrating issues by progressing with the task. Also, in collaborative learning, even if group-level regulation does not always change the valence of interactions, it may still keep collaborative learning going without an escalation of conflict. In fact, depending on the nature of negative interactions, it can even boost problem solving and an awareness of challenges (Andriessen et al., 2011; Järvenoja et al., 2013).

The results of this study and their interpretations pose new questions about what makes the regulation of emotions effective on a group-level. First, it can be hypothesised that when the whole group identifies the need for regulation and shares responsibilities in regulating (socially shared regulation; Hadwin, Järvelä, & Miller, 2017), the regulation attempts do not remain individual attempts to affect others in the group, and thus, they make a stronger impact on the whole group. Second, in addition to sharing the responsibility of regulation, it is assumed that when students are able to activate well-targeted regulation strategies in relation to the issues the group faces, they can make a difference not only to the issue at hand, but also, bit by bit, to the whole socio-emotional climate of the group and, in this way, to the individual experiences of the group members too (Bakhtiar et al., 2018; Linnenbrink-Garcia et al., 2011). Further, by understanding the nature of emotion regulation specifically in a group learning situation, the success of regulatory activities needs to be understood more broadly, focusing not only on the valence of interactions or individual emotional experiences

but also on recursive phases of the regulated learning cycle (Hadwin et al., 2017), adding to the analysis, for example, the experiences of collaboration, motivational aspects or success in the learning process itself. There is a need for more detailed research of these group regulation processes, focusing both on the socially shared regulation of emotions and on group-level emotion regulation strategies. This is important for understanding what makes group-level regulation successful in terms of learning and motivated collaboration.

8.1. Limitations and future research

This study utilised both situation-specific self-reports and video data of the group process to explore the connections between individual experiences and group process. As video data is time-consuming to collect and analyse, the sample size was relatively small. For further investigation and the verification of the connections between students' emotional experiences and socio-emotional interactions, a bigger sample size is needed and a more effective way of analysing large sets of video data in terms of emotion detection may be useful (Azevedo et al., 2016). Furthermore, in the analysis of video data, only one minute interval was used to detect connections of negative interactions and their regulation to further interactions. Whilst this time frame can be sufficient in identifying interactions most likely related to one another, it is clear that negative interactions and their regulation can also have impact on further collaboration longer than this analysis takes into consideration.

There is a need to further explore how to reach the students' individual emotional experiences in a way that considers their situated and multifaceted nature. Also, the success and failure of emotion regulation attempts during negative interactions may need different types of in-depth and temporal exploration of the interactions in order to understand what makes the group-level emotion regulation successful and what does not. And finally, more research is needed to understand the situational factors that make a difference to socio-emotional interactions and their regulation, for example, the triggers of these interactions and students' personal appraisals of them (Järvenoja et al., 2019; Pietarinen et al., 2019).

8.2. Conclusions

This study contributes to research on emotions in learning by providing information about the complex relations between individual emotional experiences and group-level socio-emotional interactions, and it also demonstrates new directions for further research into socio-emotional aspects in collaborative learning. Further, the study provides an insight of group processes for educational practitioners by highlighting the importance of supporting students in identifying the emotional and motivational pitfalls during learning activities and in regulating them not only on an individual but also on a group level.

Acknowledgements

This research was funded by the Academy of Finland (Grant number 297686) and carried out with the support of Leaf Research Infrastructure, University of Oulu, Finland.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <https://doi.org/10.1016/j.ijer.2020.101589>.

References

- Ainley, M., Corrigan, M., & Richardson, N. (2005). Students, tasks and emotions: Identifying the contribution of emotions to students' reading of popular culture and popular science texts. *Learning and Instruction*, 15(5), 433–447. <https://doi.org/10.1016/j.learninstruc.2005.07.011>.
- Andriessen, J., Baker, M. J., & van der Puil, C. (2011). Socio-cognitive tension in collaborative working relations. In S. Ludvigsen, A. Lund, I. Rasmussen, & R. Säljö (Eds.), *Learning across sites: New tools, infrastructures and practices* (pp. 222–242). Abingdon: Routledge.
- Andriessen, J., Pardijs, M., & Baker, M. J. (2013). Getting on and getting along: Tension in the development of collaboration. In M. J. Baker, J. Andriessen, & S. Järvelä (Eds.), *Affective learning together: Social and emotional dimensions of collaborative learning* (pp. 205–230). New York: Routledge.
- Assor, A., Kaplan, H., Kanat-Maymon, Y., & Roth, G. (2005). Directly controlling teacher behaviors as predictors of poor motivation and engagement in girls and boys: The role of anger and anxiety. *Learning and Instruction*, 15(5), 397–413. <https://doi.org/10.1016/j.learninstruc.2005.07.008>.
- Azevedo, R., Taub, M., Mudrick, N., Farnsworth, J., & Martin, S. A. (2016). Interdisciplinary research methods used to investigate emotions with advanced learning technologies. In M. Zembylas, & P. A. Schutz (Eds.), *Methodological advances in research on emotion and education* (pp. 231–243). Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-319-29049-2_18.
- Bakeman, R., & Quera, V. (1995). Log-linear approaches to lag-sequential analysis when consecutive codes may and cannot repeat. *Psychological Bulletin*, 118(2), 272–284. <https://doi.org/10.1037/0033-2909.118.2.272>.
- Bakhtiar, A., Hadwin, A., & Järvenoja, H. (2019). Strategies for regulating salient motivation challenges in online collaboration. *Published in Doctoral Thesis Regulating Self, Others' and Group Motivation in Online Collaboration*.
- Bakhtiar, A., Webster, E., & Hadwin, A. (2018). Regulation and socio-emotional interactions in a positive and a negative group climate. *Metacognition and Learning*, 13(1), 57–90. <https://doi.org/10.1007/s11409-017-9178-x>.
- Bembennuty, H. (2011). Meaningful and maladaptive homework practices: The role of self-efficacy and self-regulation. *Journal of Advanced Academics*, 22(3), 448–473.
- Blumenfeld, P., Marx, R., Soloway, E., & Krajcik, J. (1996). Learning with peers: From small group cooperation to collaborative communities. *Educational Researcher*, 25(8), 37–40.
- Boekaerts, M. (2007). Understanding students' affective processes in the classroom. In P. A. Schutz, & R. Pekrun (Eds.), *Emotion in education* (pp. 37–56). Amsterdam, Netherlands: Academic Press. <https://doi.org/10.1016/B978-0-12-372545-5.X5000-X>.
- Boekaerts, M., & Pekrun, R. (2015). Emotions and emotion regulation in academic settings. In L. Corno, & E. M. Anderman (Eds.), *Handbook of educational psychology*

- (pp. 76–90). (3rd ed.). New York, NY: Routledge. <https://doi.org/10.4324/9781315688244>.
- Boekaerts, M., de Koning, E., & Vedder, P. (2010). Goal-directed behavior and contextual factors in the classroom: An innovative approach to the study of multiple goals. *Educational Psychologist*, 41(1), 33–51. https://doi.org/10.1207/s15326985ep4101_5.
- Chapell, M. S., Blanding, Z. B., Takahashi, M., Silverstein, M. E., Newman, B., Gubi, A., ... Mccann, N. (2005). Test anxiety and academic performance in undergraduate and graduate students. *Journal of Educational Psychology*, 97(2), 268–274. <https://doi.org/10.1037/0022-0663.97.2.268>.
- Chiu, M. M., & Khoo, L. (2003). Rudeness and status effects during group problem solving: do they bias evaluations and reduce the likelihood of correct solutions? *Journal of Educational Psychology*, 95(3), 506–523. <https://doi.org/10.1037/0022-0663.95.3.506>.
- Cleary, T. J. (2006). The development and validation of the Self-Regulation Strategy Inventory—Self-report. *Journal of School Psychology*, 44(4), 307–322. <https://doi.org/10.1016/j.jsp.2006.05.002>.
- Cleary, T. J., Velardi, B., & Schnaidman, B. (2017). Effects of the Self-Regulation Empowerment Program (SREP) on middle school students' strategic skills, self-efficacy, and mathematics achievement. *Journal of School Psychology*, 64, 28–42. <https://doi.org/10.1016/j.jsp.2017.04.004>.
- Corno, L., & Kanfer, R. (1993). Chapter 7: The role of volition in learning and performance. *Review of Research in Education*, 19(1), 301–341. <https://doi.org/10.3102/0091732X019001301>.
- D'Mello, S., & Graesser, A. (2012). Dynamics of affective states during complex learning. *Learning and Instruction*, 22(2), 145–157. <https://doi.org/10.1016/j.learninstruc.2011.10.001>.
- Dillenbourg, P., Järvelä, S., & Fischer, F. (2009). The evolution of research on computer-supported collaborative learning: From design to orchestration. In N. Balacheff, S. Ludvigsen, T. De Jong, A. Lazonder, & S. Barnes (Eds.). *Technology-enhanced learning: Principles and products* (pp. 3–19). Dordrecht, Netherlands: Springer. https://doi.org/10.1007/978-1-4020-9827-7_1.
- Duffy, M. K., & Shaw, J. D. (2000). The Salieri syndrome: Consequences of envy in groups. *Small Group Research*, 31(1), 3–23. <https://doi.org/10.1177/104649640003100101>.
- Efkildes, A., & Volet, S. (2005). Emotional experiences during learning: Multiple, situated and dynamic. *Learning and Instruction*, 15(5), 377–380. <https://doi.org/10.1016/j.learninstruc.2005.07.006>.
- Engelschalk, T., Steuer, G., & Dresel, M. (2017). Quantity and quality of motivational regulation among university students. *Educational Psychology*, 37(9), 1154–1170. <https://doi.org/10.1080/01443410.2017.1322177>.
- Frijda, N. H., Manstead, A. S. R., & Bem, S. (Eds.). (2000). *Emotions and beliefs: How feelings influence thoughts* Cambridge University Press <https://doi.org/10.1017/CBO9780511659904>.
- Goetz, T., Frenzel, A. C., Hall, N. C., Nett, U. E., Pekrun, R., & Lipnevich, A. A. (2014). Types of boredom: An experience sampling approach. *Motivation and Emotion*, 38(3), 401–429. <https://doi.org/10.1007/s11031-013-9385-y>.
- Goetz, T., Sticca, F., Pekrun, R., Murayama, K., & Elliot, A. J. (2016). Intraindividual relations between achievement goals and discrete achievement emotions: An experience sampling approach. *Learning and Instruction*, 41, 115–125. <https://doi.org/10.1016/j.learninstruc.2015.10.007>.
- Gross, J. J. (Ed.). (2014). *Handbook of emotion regulation* (2nd ed.). New York, NY: Guilford Press.
- Hadwin, A. F., Järvelä, S., & Miller, M. (2011). Self-regulated, co-regulated, and socially shared regulation of learning. In D. H. Schunk, & B. Zimmerman (Eds.). *Handbook of self-regulation of learning and performance* (pp. 65–84). New York, NY: Routledge. <https://doi.org/10.4324/9780203839010>.
- Hadwin, A. F., Järvelä, S., & Miller, M. (2017). Self-regulation, co-regulation, and shared regulation in collaborative learning environments. In D. H. Schunk, & J. A. Greene (Eds.). *Handbook of self-regulation of learning and performance* (pp. 83–106). (2nd ed.). New York, NY: Routledge. <https://doi.org/10.4324/9781315697048>.
- Helmke, A. (1993). Die Entwicklung der Lernfreude vom Kindergarten bis zur 5. Klassenstufe [Development of affective attitudes towards learning from kindergarten to grade five]. *Zeitschrift für Pädagogische Psychologie / German Journal of Educational Psychology*, 7(2–3), 77–86.
- Isöhätälä, J., Näykki, P., Järvelä, S., & Baker, M. J. (2018). Striking a balance: Socio-emotional processes during argumentation in collaborative learning interaction. *Learning Culture and Social Interaction*, 16, 1–19.
- Järvelä, S., Järvenoja, H., Malmberg, J., & Hadwin, A. F. (2013). Exploring socially shared regulation in the context of collaboration. *Journal of Cognitive Education and Psychology*, 12(3), 267–286. <https://doi.org/10.1891/1945-8959.12.3.267>.
- Järvelä, S., Järvenoja, H., Malmberg, J., Isöhätälä, J., & Sobocinski, M. (2016). How do types of interaction and phases of self-regulated learning set a stage for collaborative engagement? *Learning and Instruction*, 43, 39–51.
- Järvelä, S., Kirschner, P., Panadero, E., Malmberg, J., Phielix, C., Jaspers, J., ... Järvenoja, H. (2015). Enhancing socially shared regulation in collaborative learning groups: Designing for CSCL regulation tools. *Educational Technology Research and Development*, 63(1), 125–142. <https://doi.org/10.1007/s11423-014-9358-1>.
- Järvelä, S., Volet, S., & Järvenoja, H. (2010). Research on motivation in collaborative learning: Moving beyond the cognitive-situative divide and combining individual and social processes. *Educational Psychologist*, 45(1), 15–27. <https://doi.org/10.1080/00461520903433539>.
- Järvenoja, H., & Järvelä, S. (2009). Emotion control in collaborative learning situations: Do students regulate emotions evoked by social challenges? *British Journal of Educational Psychology*, 79, 463–481. <https://doi.org/10.1348/000709909X402811>.
- Järvenoja, H., & Järvelä, S. (2013). Regulating emotions together for motivated collaboration. In M. Baker, J. Andriessen, & S. Järvelä (Eds.). *Affective learning together: Social and emotional dimensions of collaborative learning* (pp. 162–181). London, UK: Routledge. <https://doi.org/10.4324/9780203069684>.
- Järvenoja, H., Järvelä, S., Törmänen, T., Näykki, P., Malmberg, J., Kurki, K., ... Isöhätälä, J. (2018). Capturing motivation and emotion regulation during a learning process. *Frontline Learning Research*, 6(3), 85–105. <https://doi.org/10.14786/flr.v6i3.369>.
- Järvenoja, H., Näykki, P., & Törmänen, T. (2019). Emotional regulation in collaborative learning: When do higher education students activate group level regulation in the face of challenges? *Studies in Higher Education*, 44(10), 1747–1757. <https://doi.org/10.1080/03075079.2019.1665318>.
- Järvenoja, H., Volet, S., & Järvelä, S. (2013). Regulation of emotions in socially challenging learning situations: An instrument to measure the adaptive and social nature of the regulation process. *Educational Psychology*, 33(1), 31–58. <https://doi.org/10.1080/01443410.2012.742334>.
- Jermann, P., & Dillenbourg, P. (2007). Group mirrors to support interaction regulation in collaborative problem solving. *Computers and Education*, 51(1), 279–296. <https://doi.org/10.1016/j.compedu.2007.05.012>.
- Kershner, R., Warwick, P., Mercer, N., & Kleine Staarman, J. (2014). Primary children's management of themselves and others in collaborative group work: 'Sometimes it takes patience ...'. *Education 3-13*, 42(2), 201–216. <https://doi.org/10.1080/03004279.2012.670255>.
- Kreijns, K., Kirschner, P. A., & Jochems, W. (2003). Identifying the pitfalls for social interaction in computer-supported collaborative learning environments: A review of the research. *Computers in Human Behavior*, 19(3), 335–353. [https://doi.org/10.1016/S0747-5632\(02\)00057-2](https://doi.org/10.1016/S0747-5632(02)00057-2).
- Kurki, K., Järvenoja, H., Järvelä, S., & Mykkänen, A. (2017). Young children's use of emotion and behaviour regulation strategies in socio-emotionally challenging daycare situations. *Early Childhood Research Quarterly*, 41(May), 50–62. <https://doi.org/10.1016/j.ecresq.2017.06.002>.
- Kwon, K., Liu, Y. H., & Johnson, L. P. (2014). Group regulation and social-emotional interactions observed in computer supported collaborative learning: Comparison between good vs. Poor collaborators. *Computers & Education*, 78, 185–200. <https://doi.org/10.1016/j.compedu.2014.06.004>.
- Lajoie, S. P., Lee, L., Poitras, E., Bassiri, M., Kazemitabar, M., Cruz-Panesso, I., ... Lu, J. (2015). The role of regulation in medical student learning in small groups: Regulating oneself and others' learning and emotions. *Computers in Human Behavior*, 52, 601–616. <https://doi.org/10.1016/j.chb.2014.11.073>.
- Lazarus, R. S. (1991). Cognition and motivation in emotion. *The American Psychologist*, 46(4), 352–367. <https://doi.org/10.1037/0003-066X.46.4.352>.
- Linnenbrink, E. A. (2007). The role of affect in student learning: A multi-dimensional approach to considering the interaction of affect, motivation, and engagement. In P. A. Schutz, R. Pekrun, & G. Phye (Eds.). *Emotion in education* (pp. 107–124). San Diego, CA: Elsevier Inc. <https://doi.org/10.1016/B978-012372545-5/50008-3>.
- Linnenbrink-Garcia, L., Rogat, T. K., & Koskey, K. L. K. (2011). Affect and engagement during small group instruction. *Contemporary Educational Psychology*, 36(1), 13–24. <https://doi.org/10.1016/j.cedpsych.2010.09.001>.
- Lobczowski, N. G. (2020). Bridging gaps and moving forward: Building a new model for socioemotional formation and regulation. *Educational Psychologist*, 55(2), 53–68. <https://doi.org/10.1080/00461520.2019.1670064>.
- Meyer, D., & Turner, J. (2006). Re-conceptualizing emotion and motivation to learn in classroom contexts. *Educational Psychology Review*, 18(4), 377–390. <https://doi.org/10.1007/s10648-006-9032-1>.
- Miller, M., & Hadwin, A. (2015). Scripting and awareness tools for regulating collaborative learning: Changing the landscape of support in CSCL. *Computers in Human*

- Behavior*, 52, 573–588. <https://doi.org/10.1016/j.chb.2015.01.050>.
- Moeller, J., Ivcevic, Z., Brackett, M. A., & White, A. E. (2018). Mixed emotions: Network analyses of intra-individual co-occurrences within and across situations. *Emotion*, 18(8), 1106–1121. <https://doi.org/10.1037/emo0000419>.
- Murayama, K., Goetz, T., Malmberg, L.-E., Pekrun, R., Tanaka, A., & Martin, A. J. (2017). Within-person analysis in educational psychology: Importance and illustrations. *Journal of Educational Psychology*, 106(4), 1122–1134. <https://doi.org/10.1037/a0036659>.
- Näykki, P., Järvelä, S., Kirschner, P. A., & Järvenoja, H. (2014). Socio-emotional conflict in collaborative learning—A process-oriented case study in a higher education context. *International Journal of Educational Research*, 68, 1–14. <https://doi.org/10.1016/j.ijer.2014.07.001>.
- Ng, E., & Lee, K. (2015). Effects of trait test anxiety and state anxiety on children's working memory task performance. *Learning and Individual Differences*, 40, 141–148. <https://doi.org/10.1016/j.lindif.2015.04.007>.
- Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Review*, 18, 315–341.
- Pekrun, R., & Linnenbrink-Garcia, L. (2014). Introduction to emotions in education. *International Handbook of Emotions in Education*, 16, 1–10. <https://doi.org/10.4324/9780203148211>.
- Pekrun, R., Frenzel, A. C., Goetz, T., & Perry, R. P. (2007). The control-value theory of achievement emotions. An integrative approach to emotions in education. In P. A. Schutz, R. Pekrun, & G. Phye (Eds.), *Emotion in education* (pp. 13–36). Amsterdam, Netherlands: Elsevier Academic Press. <https://doi.org/10.1016/B978-012372545-5/50003-4>.
- Pekrun, R., Goetz, T., Frenzel, A. C., Barchfeld, P., & Perry, R. P. (2011). Measuring emotions in students' learning and performance: The Achievement Emotions Questionnaire (AEQ). *Contemporary Educational Psychology*, 36(1), 36–48. <https://doi.org/10.1016/j.cedpsych.2010.10.002>.
- Pekrun, R., Goetz, T., Titz, W., & Perry, R. P. (2002). Academic emotions in students' self-regulated learning and achievement: A program of qualitative and quantitative research. *Educational Psychologist*, 37(2), 91–105. https://doi.org/10.1207/S15326985EP3702_4.
- Pietarinen, T., Vauras, M., Laakkonen, E., Kinnunen, R., & Volet, S. (2019). High school students' perceptions of affect and collaboration during virtual science inquiry learning. *Journal of Computer Assisted Collaborative Learning*, 35, 334–348. <https://doi.org/10.1111/jcal.12334>.
- Rogat, T., & Adams-Wiggins, K. (2014). Other-regulation in collaborative groups: Implications for regulation quality. *Instructional Science*, 42(6), 879–904. <https://doi.org/10.1007/s11251-014-9322-9>.
- Rogat, T., & Adams-Wiggins, K. (2015). Interrelation between regulatory and socioemotional processes within collaborative groups characterized by facilitative and directive other-regulation. *Computers in Human Behavior*, 52, 589–600. <https://doi.org/10.1016/j.chb.2015.01.026>.
- Rogat, T. K., & Linnenbrink-Garcia, L. (2011). Socially shared regulation in collaborative groups: An analysis of the interplay between quality of social regulation and group processes. *Cognition and Instruction*, 29(4), 375–415. <https://doi.org/10.1080/07370008.2011.607930>.
- Russell, J. A., & Barrett, L. F. (1999). Core affect, prototypical emotional episodes, and other things called emotion: Dissecting the elephant. *Journal of Personality and Social Psychology*, 76(5), 805–819. <https://doi.org/10.1037/0022-3514.76.5.805>.
- Schneider, B., Krajcik, J., Lavonen, J., Salmela-Aro, K., Broda, M., Spicer, J., ... Viljaranta, J. (2016). Investigating optimal learning moments in U.S. And Finnish science classes. *Journal of Research in Science Teaching*, 53, 400–421. <https://doi.org/10.1002/tea.21306>.
- Shuman, V., & Scherer, K. R. (2014). Concepts and structures of emotions. In R. Pekrun, & L. Linnenbrink-Garcia (Eds.), *International handbook of emotions in education* (pp. 13–35). New York, NY: Routledge. <https://doi.org/10.4324/9780203148211>.
- Smith, C. A., & Lazarus, R. S. (1990). Emotion and adaptation. In L. A. Pervin (Ed.), *Handbook of personality: Theory and research* (pp. 609–637). New York, NY: Guilford Publications. [https://doi.org/10.1016/0191-8869\(91\)90043-b](https://doi.org/10.1016/0191-8869(91)90043-b).
- Tomas, L., Rigano, D., & Ritchie, S. M. (2016). Students' regulation of their emotions in a science classroom. *Journal of Research in Science Teaching*, 53(2), 234–260. <https://doi.org/10.1002/tea.21304>.
- Volet, S., Summers, M., & Thurman, J. (2009). High-level co-regulation in collaborative learning: How does it emerge and how is it sustained? *Learning and Instruction*, 19(2), 128–143. <https://doi.org/10.1016/j.learninstruc.2008.03.001>.
- Weiner, B. (1985). An attributional theory of achievement motivation and emotion. *Psychological Review*, 92(4), 548–573. <https://doi.org/10.1037/0033-295X.92.4.548>.
- Wolters, C. A. (2003). Regulation of motivation: Evaluating an underemphasized aspect of self-regulated learning. *Educational Psychologist*, 38(4), 189–205. https://doi.org/10.1207/S15326985EP3804_1.
- Wosnitza, M., & Volet, S. (2005). Origin, direction and impact of emotions in social online learning. *Learning and Instruction*, 15(5), 449–464. <https://doi.org/10.1016/j.learninstruc.2005.07.009>.
- Xu, J., Du, J., & Fan, X. (2013). Individual and group-level factors for students' emotion management in online collaborative groupwork. *The Internet and Higher Education*, 19, 1–9. <https://doi.org/10.1016/j.iheduc.2013.03.001>.
- Zeidner, M. (1998). *Test anxiety: The state of the art*. Boston, MA: Springer <https://doi.org/10.1007/b109548>.
- Zeidner, M. (2014). Anxiety in education. In R. Pekrun, & L. Linnenbrink-Garcia (Eds.), *International handbook of emotions in education* (pp. 265–288). New York, NY: Routledge/Taylor & Francis Group. <https://doi.org/10.4324/9780203148211>.
- Zembylas, M. (2003). Caring for teacher emotion: Reflections on teacher self-development. *Studies in Philosophy and Education*, 22(2), 103–125. <https://doi.org/10.1023/A:1022293304065>.
- Zheng, L., & Huang, R. (2016). The effects of sentiments and co-regulation on group performance in computer supported collaborative learning. *Internet and Higher Education*, 28, 59–67. <https://doi.org/10.1016/j.iheduc.2015.10.001>.
- Zschocke, K., Wosnitza, M., & Bürger, K. (2015). Emotions in group work: Insights from an appraisal-oriented perspective. *European Journal of Psychology of Education*, 31, 359–384. <https://doi.org/10.1007/s10212-015-02>.