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AFFECT IN COLLABORATIVE AND VIRTUAL INQUIRY LEARNING

Insights into small student groups and teachers in the classroom

Tarja Pietarinen

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University of Turku

Faculty of Education
Department of Teacher Education and Center for Research on Learning and Instruction (CeRLI)
Doctoral programme on Learning, Teaching, and Learning Environments Research

Supervised by

Professor Marja Vauras
Department of Teacher Education
Center for Research on Learning and Instruction (CeRLI)
University of Turku
Finland

Professor Simone Volet
School of Education
Murdoch University, Australia
Faculty of Education
University of Turku
Finland

Reviewed by

Professor Emerita Anastasia Efklides
School of Psychology
Aristotle University of Thessaloniki
Greece

Professor Tina Hascher
Institute of Educational Science
University of Bern
Switzerland

Opponent

Professor Tina Hascher
Institute of Educational Science
University of Bern
Switzerland

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ABSTRACT

Research on affect in collaborative learning has previously focused on individual perceptions of affect or collective emotional atmosphere with respect to the learning situation or the environment. This dissertation aims to widen the perspective by capturing individual affect both within and between small groups, taking into account individual differences. The aim is also to investigate the role of the teacher in computer-supported collaborative learning and the importance of teacher affect. Participants were 120 students in six high schools and four teachers and their 19 small groups (56 students). A mixed-method approach was used, consisting of statistical analyses for survey data, systematic video observations, case studies and social network analysis. This dissertation is comprised of three empirical studies.

In *Study I*, the aim was to extend understanding of affect in computer-supported collaborative science learning by examining discrete affective states in a face-to-face small group setting in high schools. The results showed the significance of positive affect, especially self-assurance, in collaborative learning, but also the impact of individual differences within the group. In *Study II*, the aim was to examine affect within and between distinct outcome groups, and the consistency between self-reported and observed affect in the groups. The findings showed convergence in affect with the performance in the extreme groups, but more complex affect patterns in the average groups. In *Study III*, the aim was to investigate the role of the teacher in supporting and guiding collaborative inquiry. The results demonstrated four different time management, guidance and support practices in identical situations and environments, but similarities as well. The results also indicated that the teachers were most eager to guide the groups they perceived as active collaborators.

KEYWORDS: affect, collaborative learning, computer-supported learning, inquiry learning, science learning, teacher

TURUN YLIOPISTO
Kasvatustieteiden tiedekunta
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TIIVISTELMÄ

Yhteisölliseen oppimiseen liittyvä tunnetutkimus on aiemmin keskittynyt tarkastelemaan yksilöiden kokemia tunteita tai kollektiivista tunneilmapiiriä suhteessa oppimistilanteeseen ja –ympäristöön. Tässä väitöskirjassa tunteita tutkitaan laajemmin kartoittaen niin yksilöiden kokemia tunteita pienryhmätasolla kuin myös yksilöiden välisiä eroja ryhmien sisällä. Tarkastelun kohteena on myös opettajan merkitys tietokoneavusteisen yhteisöllisen oppimisen tukemisessa ja ohjauksessa, sekä opettajan tunnekokemukset. Tutkimukseen osallistui 120 opiskelijaa kuudesta lukiosta sekä neljä opettajaa ja heidän 19 pienryhmäänsä (56 opiskelijaa). Monimenetelmällinen kyselylomakkeista sekä videoista koostuva aineisto analysoitiin tilastollisesti, systemaattisella videohavainnoinnilla, tapaustutkimuksella sekä verkostoanalyysilla. Tämä väitöskirja koostuu kolmesta osatutkimuksesta.

Tutkimuksessa I tavoitteena oli laajentaa ymmärrystä tunteista osana tietokoneavusteista yhteisöllistä luonnontieteiden oppimista tarkastelemalla yksittäisiä tunnetiloja kasvokkaisessa pienryhmäoppimistilanteessa lukioikäisillä. Tulokset osoittivat sekä positiivisten tunteiden että ryhmän yksilöiden välisten erojen merkittävyyden, ja korostivat itsevarmuutta yhteistoiminnallisen ja tutkivan pienryhmäoppimisen edistämisessä. *Tutkimuksessa II* tarkasteltiin tunteita pienryhmissä ja niiden välillä sekä itsearvioitujen ja havainnoitujen tunteiden yhdenmukaisuutta ryhmissä. Tulokset osoittivat yhdenmukaisuutta tunteiden ja suoritusten välillä, mutta keskitason ryhmissä tunnemallit olivat monimutkaisempia. *Tutkimuksessa III* tavoitteena oli tarkastella opettajan roolia yhteistoiminnallisen tutkivan oppimisen tukijana ja ohjaajana, sekä opettajan tunteita. Tulosten perusteella rakentui neljä erilaista käytäntöä tuelle, ohjaukselle sekä ajankäytölle. Tulokset myös osoittivat opettajien ohjaavan mieluiten ryhmiä, jotka he kokivat aktiivisiksi yhteistoimijoiksi.

ASIASANAT: tunteet, yhteistoiminnallinen oppiminen, tietokoneavusteinen oppiminen, tutkiva oppiminen, luonnontieteiden oppiminen, opettaja

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Feeling happy or feeling blue – the diversity of affective states varies every day, sometimes many times in one single day. I took the challenge to study this multifaceted phenomenon, and seek for the wisdom beyond the mechanisms of affect. This journey has been pawed with multiple affective states, such as happiness and anxiety, from light to the shadows and beyond. Although the affective states have been connected mainly to the learning process and this dissertation, they have still echoed with the other people involved. Hence, this dissertation would not have been possible without the help and support of the significant others who have travelled with me or who I have let to know during my journey as a doctoral student. Now, as this journey has come to an end, it is time to express my gratitude to those connected to this dissertation.

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In Lieto, June 2021
Tarja Pietarinen

Contents

Tables

Figures

List of empirical studies

This dissertation is based on the following original publications, which are referred to in the text by their Roman numerals:

I 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 Learning*, 35 (3), 334-348. doi: /10.1111/jcal.12334

Pietarinen contributed to the study conception and design. She was responsible for the data collection, analysis and writing of the manuscript.

II Pietarinen, T., Volet, S., Lehtinen, E. & Vauras, M. (2020). Affect in peer group learning during virtual science inquiry: Insights from self-reports and video observations. *Frontiers in Psychology, 10:2981.* doi: 10.3389/fpsyg.2019.02981

Pietarinen contributed to the study conception and design. She was responsible for the analysis and writing of the manuscript.

III Pietarinen, T., Palonen, T. & Vauras, M. (in press). Guidance in computer-supported collaborative inquiry learning: Capturing aspects of affect and teacher support in science classrooms. *International Journal of Computer Supported Collaborative Learning.*

Pietarinen was responsible for the study conception and design. She was responsible for the analysis and writing of the manuscript.

1 Introduction

Everyone who has been to school remembers the varied affects they encountered over the years and how those affects were connected to school subjects, other students, teachers, and most importantly the learning process. However, educational research has traditionally focused mainly on cognitive aspects of learning, due to the decisions in cultural-historical activity theory to gain objectivity and scientific generalization by excluding subjectivity i.e. individual person (Holzkamp, 1991; Roth, 2007), and also because affect has been perceived as interrupting the learning process (Schuman & Scherer, 2014), despite the extension in understanding of affect in other research fields such as humanities and psychology. The importance of affect in learning has been acknowledged as late as two or three decades ago. Since then, research on affect has been of great interest in education but the research field is fragmented and the different approaches do not correspond with each other (see Hascher, 2010). This tendency is common in affective sciences as well, as researchers generally agree that evolutionary and social contexts have shaped emotions, which are episodes with multiple components, but the fuctions of emotions are constantly under debate (Schuman & Scherer, 2014). Accordingly, many questions are still unanswered and many areas unexplored. In educational research, affect has mainly been studied in terms of briefly experienced emotional responses to certain situations (see Scherer, 2005), but other concepts have been used as well in variety of contexts. This is also associated with the complexity of affect as a phenomenon, demonstrated by the diversity of contemporary psychological emotion theories. First, basic emotion theories (e.g., Ekman & Friesen, 1971; Izard, 1992; Plutchik, 2001) stem from a Darwinian background emphasizing basic, discrete, and distinct emotions that generate an experience or behavior. Second, appraisal theories (e.g., Frijda, 1988; Lazarus, 1991; Ortony, 1990; Scherer, 2005) assume that emotions are raised by appraisals (evaluations) in a situation or event. Third, psychological constructivist theories (e.g., Barrett, 2006; Russell, 1980) use the term "core affect," which refers to a neurophysiological state that is influenced by internal and external stimuli and produces affective states, moods, and finally, nonlinear dynamic systems theories (e.g., Camras, 2011; Fogel et al., 1992) see emotions as attractor states. Such fragmentation in theoretical groundings has created challenges

for empirical research into affect, inhibiting growing efforts to study affective phenomena, but also reflecting the ambiguous nature of affect and thus the necessity for multifaceted examination.

Along with the theoretical variations, there are also various concepts connected to affective phenomena such as emotions, mood, attitudes, feelings, passions and sentiments (Mulligan & Scherer, 2012; Scherer, 2005), and a conceptual integration has been called for, especially in educational research (e.g., Efklides, 2017; see also Scarantino, 2012). Hence, different conceptualizations might influence research when using individual words that carry multiple connotations (Strauss & Allen, 2008). Currently, affective phenomena, such as mood and emotions, examined in educational contexts, have been embedded in the term affect (e.g., Boekaerts, 2007; Linnenbrink & Pintrich, 2004; Pekrun & Linnenbrink-Garcia, 2014), and thus affect denotes a range of affective phenomena and functions as an umbrella term (Barsade & Gibson, 2012; Efklides, 2017). However, attitudes are usually examined independently from other affective phenomena in learning research, in order to make a distinction between designated disciplines and also because of the domain-specificity of affect (see Boekaerts, 2007; Goetz et al., 2006).

As learning is related to individual development, research on affect in learning has mainly focused on individual affect and attitudes associated with distinct disciplines and learning related topics. Since the core competencies for the 21st century are manifesting collaborative skills together with creativity, critical thinking, and problem solving – along with information technology skills and awareness of a multitude of aspects (Care et al., 2018) – collaborative learning in groups has become a more common practice, especially in inquiry learning related to science activities. Moreover, interest for computer-supported learning tools such as virtual laboratories has increased, and together with collaborative learning created new demands for understanding affect in collaborative learning, affected by the presence of technology. Especially computer-supported collaborative learning (CSCL) environments, which have been argued to provide better knowledge gains, skill acquisition and learning outcomes than computer-supported individual learning (Chen et al., 2018). Following these, the lack of understanding on affect during group activities in advanced learning environments necessitates more exploration and detailed information on affect phenomena.

The aim of this dissertation is to contribute to the understanding of affective processes in collaborative learning in the technologically enhanced school context, with a systematic examination of the dynamic and evolving nature of affect over an extended period during group learning activities, as well as the role of the teacher as a facilitator of the learning process. This dissertation includes three studies that focused on distinct aspects of affect in collaborative learning. The first study examined students' self-reported affect and the connection to perceptions of group

collaboration and scientific thinking and group outcome level during the working period. The second study focused on in-depth exploration of the affective tone of interactions both at group and individual level by comparing and integrating self-reports and observation, and the connection to group outcome level. In the third study, the focus was on teachers' self-reported affect and guidance during the working period, in relation to students' affect. All these distinct aspects are compiled and summarized in this dissertation.

1.1 Contextualizing affect in learning

The past conception of affect as interrupting the actual learning process (Schuman & Scherer, 2014) has transformed into an understanding that affect, cognition, and motivation are inseparable aspects of learning (Fiedler & Beier, 2014; Kim & Pekrun, 2014). Affective states are essential indicators of motivation and cognition as they reflect the experiences of a learning situation (Meyer & Turner, 2006) and further, motivation and self-regulated learning mediate the impact of affect on academic achievement (Mega et al., 2014). Moreover, affect has an impact on information processing regardless of the cognitive task (Clore & Huntsinger, 2007), given that affect is an important factor in human behavior because it motivates activity (Izard & Ackermann, 2000). The interpretation that is given to situations, such as having fun or wasting time, has an impact on affect, and thus prepares and orients one for either positive or negative activity (Cahour, 2013).

Central to a more comprehensive understanding of the impact of affect is the concept of valence (pleasantness/unpleasantness). Affect and affective states have been divided according to their valence into positive and negative, or sometimes neutral (Diener et al., 1985; Feldman Barrett & Russell, 1998; Scherer, 2005; Watson et al., 1988). In addition to valence, it has been argued that affective states have certain impacts on arousal or activation (also engagement/energy/power/control) demonstrating the intensity of human action (see e.g., Bradley & Lang, 1994; Diener et al., 1985; Feldman Barrett & Russell, 1998; Plutchik, 2001; Russell, 1980; Scherer, 2005; Thayer, 1986). These dimensions are often illustrated with a circumplex model showing two orthogonal dimensions for valence and a high and low pole for activation, complemented with discrete affective states for each quarter (see e.g., Feldman Barrett & Russell, 1998; Plutchik, 2001; Scherer, 2005). These dimensions have been quite commonly used in educational research, as they are present in most emotion theories.

Given that affect is a multifaceted phenomenon consisting of distinct interrelated components such as physiological reactions, subjective experience, and expressive behavior (Gross & Levenson, 1993), research on affect related to learning requires careful elaboration. Accordingly, central to research on affect is the unit of analysis

and the methods of documentation. There is a large variety of methods that have been developed and used to study affects in individual and collaborative learning processes. Self-reports (e.g. questionnaires) before and after the learning situation have been considered to be an adequate method of collecting information about affective processes (e.g., Graesser et al., 2014), but to present too narrow a view of affect (Op't Eyende & Turner, 2006; Wosnitza & Volet, 2005). Measures used during the learning process (e.g., observation) or methods that are based on interaction (e.g., interviews) allow for an in-depth and longitudinal perception of affective processes. Thus, combinations of distinct methods are of great importance in researching classroom practices (Meyer & Turner, 2006). For a deep understanding of affect in small group learning, the unit of analysis guides the examination and thus self-reports, observation, and measurement can be seen as complementary methods for scrutiny of affect.

1.1.1 The effects of affect on engagement, interest and problem solving

The important role of affect in learning has been established in the research literature through empirical findings, highlighting connection to cognition, motivation, goal orientation, self-conceptualization, information processing, performance, and the learning processes (Boekaerts, 2007; Boekaerts & Rozendaal, 2010; Gläser-Zikuda et al., 2013; Hascher, 2010; Pekrun & Linnenbrink-Garcia, 2014). According to research findings by Pekrun et al. (2002) academic emotions are especially closely related to students' motivation, cognitive resources, self-regulation, learning strategies, and academic achievement – together with personality and classroom antecedents. Hence, emotional diversity in academic settings should address the full range of emotions that are experienced by students at school and university. Taking into account affect that is related to the learning process and social interaction in the classroom, affective states can be classified into four separate groups based on their object focus (Pekrun, 2006). Achievement emotions are related to academic activity (enjoyment and boredom) or the outcome (hope, pride, anger, anxiety, shame, and hopelessness), whereas epistemic emotions such as surprise, curiosity, interest, enjoyment, delight, boredom and frustration (see Efklides, 2017) are related to epistemic beliefs and the epistemic nature of the learning task or content (see, Muis et al., 2015). Further, social emotions such as trust, and loyalty, (see Barbalet, 1996) associate with interactions in a social context (Pekrun & Linnenbrink-Garcia, 2014), while topic emotions like interest and boredom are related to the learning content and may directly impact on students' interest, motivation, and engagement with the topic (Sinatra, Broughton & Lombardi, 2014).

Specifically students' declining interest and engagement with science has been of great concern, which has spurred research on science education and learning (Ainley & Ainley, 2011; Schneider et al., 2016). Research has evidenced the relationship between affect and interest, engagement, and experiences related to science learning (King et al., 2015; Lin et al., 2012; Tomas et al., 2016). Previous experiences of learning science serve as the basis for enjoyment, interest, personal value, and future expectations and thus engagement with science learning and knowledge acquisition (Ainley & Ainley, 2011). Accordingly, lack of emotional enjoyment and interest in learning results in low or lost behavioral participation and engagement, leading to disaffection. The impact of students' self-perceptions, especially of autonomy and teacher support are deeply connected to engagement with science learning (Skinner et al., 2008). It is also suggested that if students are appropriately challenged according to their skills, they are more likely to feel positive, happy, confident, and successful and to perceive science as important (Schneider et al., 2016).

In addition to the perceived value of learning the subject, engagement in learning is related to task difficulty and challenges in performance. Clear goals, competence in mastering the task and confronted obstacles, and sense of purpose enhance students' engagement as well as motivation regulation strategies (Boekaerts & Rozendaal, 2010). It is also argued that if expectancy and utility of the task is perceived as high and difficulty as low that might result in higher interest and lower boredom levels within individuals (Tanaka & Murayama, 2014). Furthermore, too much information to organize produces a negative effect on learning and engagement, as in order to cope with the demands, students limit their attention, adopting a narrower approach to learning. Repetition of overly demanding experiences can turn into patterns or habits that deteriorate higher-order cognitive processes such as critical thinking and analysis. This repetition also causes students to develop insecurity and negative attitudes toward their learning abilities and education in general (Ahern & de Kirby, 2011). However, according to Ahmed et al. (2010) there is not a clear association between the task difficulty level and students' affect, as positive and negative affect is experienced in all achievement levels regardless of the task. Individual differences are significant factor in experienced affect, even though some patterns may emerge. Notably, students' perceptions of task difficulty might not be in line with the teacher perceptions, which could affect the emotional experiences (Ahmed et al., 2010).

Similarly, valence appears in the division of affects that are beneficial or detrimental for learning. Evidence from research highlights positive affect and positive emotional experiences as essential for engagement and thus beneficial for learning, whereas negative affect can create detachment from learning (Boekaerts & Rozendaal, 2010; Gong & Bergey, 2020; Knight & Eisenkraft, 2015; Linnenbrink-

Garcia et al., 2011). In particular, positive affect can facilitate creative, flexible, and critical thinking and can enhance students' self-regulation and motivation to learn (Pekrun et al., 2002) as well as consolidate a deep approach to learning (Trigwell et al., 2012). Skinner et al. (2014) argue that students who are highly engaged to the task use productive coping strategies and have high tolerance of stressful situations, whereas students with negative attitudes have weaker coping strategies and thus are more vulnerable when facing problems. It is also indicated that a positive, supportive learning environment is necessary for motivation to learn (Meyer & Turner, 2006; Naude et al., 2014). Interestingly, it has been found that positive emotions foster academic achievement only when mediated by motivation to learn and self-regulatory strategies (Mega et al., 2014). In addition, Mega et al. (2014) suggests that positive emotions have greater impact on self-regulated learning and motivation than negative emotions. In contrast to positive affect, negative affect might be related to external regulation and task-irrelevant thinking, thus decreasing motivation. Furthermore, as positive affect is related to high achievement, negative emotions are related to low achievement. Still, under certain conditions negative emotions can be beneficial for learning (Knight & Eisenkraft, 2015; Pekrun et al., 2002). Recent research has suggested that neutral affect is not neutral as such, but is associated with understanding and adapting to the situation such that attention to the situation is not needed (Gasper et al., 2019).

Arousal that is connected to learning-related achievement emotions consists of four categories: positive and negative activating emotions, and positive and negative deactivating emotions. These emotions are constructed by the interaction of arousal and valence that can reflect the effects of academic emotions on students' engagement and performance, although the variation of emotions relevant to education is more extensive (Pekrun & Linnenbrink-Garcia, 2014; Pekrun et al., 2007). Positive activating emotions (e.g., enjoyment and pride) can increase interest and strengthen intrinsic and extrinsic motivation. Negative deactivating emotions (e.g., boredom and hopelessness) function differently. For example, boredom is associated with instructional demands and often occurs in situations perceived as having no subjective value, lacking sufficient stimulation, or receiving tasks beyond students' competence (Pekrun et al., 2002). Positive deactivating emotions (e.g., relief and relaxation) and negative activating emotions (e.g., anxiety, anger, and shame) are more complex and ambivalent in nature. For example, anxiety and shame may decrease interest and intrinsic motivation to learn but could strengthen motivation to avoid failure, whereas task-related anger may activate motivation to overcome obstacles (Pekrun et al., 2007). However, shame appears to have distinct effects with respect to context (see Gong & Bergey, 2020). In addition, it has been suggested that high perceptions of competence and value of the task might be related to enjoyment, whereas low perceptions of competence and value might be related to

anger and/or anxiety (Ahmed et al., 2010). Furthermore, perceptions of low value and high competence might lead to boredom. In this situation, high-perceived competence denotes the belief that the individual has control over the activity at hand, and the high value denotes the incentive values of the activity.

In sum, previous research has indicated that affect is deeply intertwined with the learning process and positive affect has been shown to be related to higher achievement. Hence, due to declines in students' interest in science learning, more emphasis has been placed on students' attitudes, engagement, and affective processes related to learning. Thus, when studying affects that are beneficial or detrimental to learning, the concept of valence and arousal together with discrete affective states can provide more in-depth understanding on the relationship between affect and performance. Accordingly, the terms affect and affective states were adopted for this dissertation to elaborate both individual and aggregating members' reported or observed affect in a small group in the classroom.

1.1.2 From research on individual affect to research on affect in small group

Affect in learning has been considered to be an individual experience and educational research has mainly focused on individual students' affects, thus less attention has been paid to affect in collaborating groups even though an increased emphasis has been placed on collaborative activities in classroom learning since the early 2000s (e.g., Greeno, 2006). In their review, Van Kleef and Fischer (2016) demonstrated the fragmentation of research perspectives and hence a lack of complete understanding of the role of emotions in groups, especially combined with the social context that groups function within. The findings also demonstrated a common assumption in the literature that all members of a group experience the same emotions, and thus neglected to take into account the emotional diversity of groups – that is, individual differences. As previous research has demonstrated, affect has an impact on self-regulated learning and motivation, and thus on academic achievement (Mega et al., 2014). Such findings, however, are focused on individual affect in learning that differs from affect in collaborative learning in small groups. A small group consists of individuals, but the social context and relations have an influence on individuals within the group and vice versa (Järvelä et al., 2010). Additionally, given that individual group members interpret task characteristics and organizational-structural group processes differently, as well as the cognitive benefits of collaboration, their affects can also vary (Zschocke et al., 2016). Hence, the role of individual differences, groups' working practices, and social processes need to be taken into account to better understand divergence in group activity and performance (see Järvelä et al., 2010; Summers & Volet, 2010).

When students enter a learning situation, they bring with them their personal attitudes, beliefs, interest, and prior knowledge. Thus the characteristics of each individual contribute to the collective. The affect of individuals in a group can be examined separately or aggregated to represent the group level, as well as the affective tone of interaction on an individual or collective level (Kelly & Barsade, 2001; Polo et al., 2016; Van Kleef & Fischer, 2016). In a group situation, individual mood can transfer to other members through emotional contagion, and thus have an impact on both, individual-level attitudes and group performance (see, Barsade, 2002; Barsade & Knight, 2015; Collins et al., 2016; McEneaney & Nieswandt, 2017). The findings show that the relationship between the valence of individual affect and group interaction support a link between positive affect and positive interaction as well as the contrary (Linnenbrink-Garcia et al., 2011). Furthermore, group interaction patterns are established early in the group and maintained throughout. These interactions have an impact on students' affect and their social-behavioral engagement (Linnenbrink-Garcia et al., 2011). Recent research has demonstrated that the affective behavior of individuals in a group has an influence on collaborative learning, either positive or negative. For example, positive individual students may provide socio-emotional support for the others in the group (Näykki et al., 2017), whereas negative individual students may insult other students or behave offensively and thus deteriorate the quality of conversation (Baker et al., 2013; Polo et al., 2016).

Essentially group interactions can be divided into task performance and the socioemotional activity during collaborative processes (Greeno, 2006; Kelly & Barsade, 2001). Accordingly, task performance can be seen as content-related work and social emotional activity associated with collaboration and support. Co-construction of understanding and knowledge among group members as well as mutual help and support, along with appropriate teacher support, enables a better achievement for the group than independent performance (Kirschner et al., 2006). This idea is equivalent to Vygotsky's (1978) concept of the zone of proximal development that with adequate support from peers, social interaction, and teacher scaffolding, students are able to achieve tasks beyond their own competence. However, effective collaboration relies on social interaction and a shared goal structure that guides the interaction in a group (see Dillenbourg, 1999). In such collaborative contexts, individuals are positively or negatively interdependent depending on the degree of consistency among achievement goals of the group members. Positive interdependence provides a precondition for success in accomplishing individual goals that require all group members to succeed and work together to achieve a common goal. Quite contrary, negative interdependence in a group may generate competitiveness among individuals, where the individual achievement actualizes at the expense of others (O'Donnell & Hmelo-Silver, 2013).

Still, collaborative efforts may have an influence on motivation through shared task performance, responsibility, and ownership, rather than personal progress, interest, and working manners (Rogat et al., 2013).

Socioemotional aspects such as positive interdependence, group cohesion, sense of community and mutual trust among group members define the affective structure of a group. They also strengthen social interaction and thereby collaboration (Kreijns et al., 2003). Accordingly, individual perceptions of affect and collaboration in a small group can unveil the socioemotional interaction of a group, addressing the positive and negative quality of action in group formation and group dynamics such as communication, group cohesion, and help-seeking. Positive group interaction implies active and productive group work with mutual respect and encouragement emphasizing shared knowledge and ideas, whereas negative group interaction is associated with discouragement, ignorance or rejection, disrespect of others and their ideas and social comparison (Kempler & Linnenbrink, 2006; Rogat & Adams-Wiggins, 2015; Rogat & Linnenbrink-Garcia, 2011).

The importance of affect in the experience of group work has been found significant (Wosnitza & Volet, 2014), yet understanding of the emergence of affect in the interaction process in small group learning is limited. Linnenbrink-Garcia et al. (2011) found in their study on affect and social-behavioural engagement during small group instruction that positive group interactions and positive affect were interrelated, whereas negative affect was related to disengagement and social loafing. Zschocke et al. (2016) broadened the view on student emotions and group work appraisals showing that the quality of peer interaction and collaboration were important elements in promoting positive and negative emotional experiences of a group assignment. It is also important to note the significance of discrete emotions in collaboration (Van Kleef & Fischer, 2016) and accordingly, more investigation on the effects of discrete emotions in groups and associations with computer-supported environments are called for (Barsade & Gibson, 2012).

In-depth analyses of discourses in collaborative learning contexts demonstrate the importance of emotions on the quality of discussion in collective reasoning and argumentation. In their work, Polo et al. (2016) suggest that group emotions have social and cognitive functions in collaborative discussions. The social dimension corresponds with diverse politeness rules and facework dynamics associated with (socially relevant) emotions that determine the orientation between specific types of group talk, for example constructively critical exploratory talk that is efficient for collaboration (see Wegerif & Mercer, 1997). Further, on the cognitive side, emotions are more closely associated with the objects under discussion, addressing the significance and hence the distance to the matter (Polo et al., 2017). Accordingly, high-quality group interaction is achievable in groups where participants behave politely and expressing ideas is safe from strong criticism, addressing psychological

safety (see McEneaney & Nieswandt, 2017). However, high quality group interaction is not sufficient unless it results in successful learning. There is empirical evidence that positive learning and achievement-related emotions predict academic performance (Niculescu et al., 2015). Researchers have argued that the role of affect can be dissimilar in situations based on the negotiation of meaning and can require mutual engagement and high levels of social interaction (Linnenbrink-Garcia et al., 2011; Zschocke et al., 2016). In their study on collaborative learning, Linnenbrink-Garcia et al. (2011) demonstrated that both positive and neutral affect can facilitate constructive group interactions, whereas negative affect seemed to hinder productive group interactions.

To summarize, when individual students enter the group, they bring along their personal attributes, such as their existing internal emotional state, to collaborative discussions. This relates to the objects being discussed and the subjects being involved in the task (see Polo et al., 2017). Hence, group performance is influenced by the affect, attitudes, beliefs, interests, and prior knowledge of each individual student in the group as well as group dynamics like communication, group cohesion, and help-seeking. All these aspects together determine the affective tone in the group, and this collective affect has remarkable impact on collaboration and group performance, and finally the outcome. Still, as groups do not function in a vacuum, the implications of the classroom context need to be considered as well.

1.2 Perceptions of affect during collaborative and computer-supported inquiry learning

It is not only social factors that have an impact on affect in collaborative learning, but also the learning context. Wosnitza and Volet (2005) argued that in technology-supported social learning, emotions are typically directed to the self, other(s), the task, and the technology, thus creating challenges to researching affect in computer-supported collaborative settings. Even though the importance of affect in collaborative and computer-supported learning has been widely acknowledged (e.g., Järvenoja & Järvelä, 2005; Loderer et al., 2018; Molinari, 2013; Noteborn et al., 2012; Reis et al., 2015), studies that combine all these aspects with inquiry learning in classrooms are still scarce. Some studies have examined collaborative learning in science, technology, engineering, and mathematics (STEM) diciplines (e.g., Kerr et al., 2004; Swan & O'Donnell, 2009; Tsovaltzi et al., 2010; Tüysüz, 2010; Wolf, 2010). However, the focus has mainly been on learning, achievement, and attitudes toward the learning environment or research on emotion awareness related to CSCL gaming (e.g., Eligio et al., 2012; Feidakis et al., 2013). Recently, more emphasis has been directed to emotions in technology-rich learning environments, especially with respect of self-regulated collaborative learning (Järvenoja et al., 2020; Lajoie et al.,

2019; Lajoie et al., 2015). However, some studies with approach to affect in collaborative learning have interesting findings in computer-supported settings. For example, Järvenoja and Järvelä (2005) examined face-to-face collaborating dyads' emotional experiences during computer-supported inquiry learning in secondary school and found that emotional experiences were self or context-driven in most cases, particularly at the beginning of a project. Contrarily, task, performance, and socially driven emotional experiences were less frequent, while socially based emotional experiences were difficult to recognize.

Recently, more emphasis has been placed on collaborative learning in advanced learning settings partly due the increase in computer-supported learning and various virtual environments and laboratories, especially in science education. As experimental skills in the laboratory are essential to scientific work, virtual learning environments can provide access to authentic and effective learning contexts with an affordable cost (Swan & O'Donnell, 2009; Wolf, 2010). The increase in computer-supported learning and various virtual learning environments has addressed the importance of understanding of the occurrence and influence of affect during learning or problem-solving processes, as well as in designing these environments, as affects in these environments may have a different impact than in the traditional learning context (Hove & Corcoran, 2008).

Many of the studies examining affect related to computer-supported learning have concentrated on individuals or pairs, while affect in a group has been a rather neglected area of research. Still, understanding the affect of individuals is the basis for further examinations and thus of great importance. It has been found that the most common affective states for individuals and pairs in computer-supported learning environments were confusion and engaged concentration (Baker et al., 2010; Baker et al., 2011). In their review, Graesser et al. (2014) examined moment-to-moment emotions in three advanced learning environments during problem-solving when individuals interacted with intelligent tutoring systems and serious online games in STEM fields, such as computer science, mathematics, physics, and biology. The most often reported emotions were confusion, frustration, boredom, and engagement or flow and some moments of delight, happiness, sadness, curiosity, surprise, and anxiety. The impact of emotion valence in computer-supported learning is rather unexamined, but researchers such as Muños et al. (2011) studied individual students' online learning and showed more positive achievement emotions than negative emotions. Similar conclusions were suggested by Tomas et al. (2016) when they examined discrete emotions during socio-scientific lessons of coal seam gas mining as part of a unit on energy in traditional classroom. Self-reports highlighted positive emotions such as happiness, excitement, and enjoyment, whereas negative emotions were reported less frequently, with the exception of frustration. In addition, Wortha et al. (2019) recently investigated emotions during digital learning about human

biology and demonstrated positive, negative, and neutral affect profiles, while also indicating that although single resolved negative emotions might benefit learning strategies and outcomes, multiple negative emotions are detrimental to learning.

One challenge in research concerning affect in computer-supported collaborative learning is the question of unit of analysis. In collaborative learning, small groups are the unit of analysis, addressing both individual activity and performance, and collective achievement. However, these aspects have unique features that require independent examination (Stahl, 2013). When collaboration takes place in a computer-supported learning environment, both situational and individual factors need to be considered. Students' motivation, experiences of flow, opportunities for social interaction, and the environment itself impact responsiveness in computer-supported learning. Ainley and Armatas (2006) argued that active decision-making and control have positive implications for learning, whereas uncertainty due to multiple choices within virtual learning environment and lack of confidence in knowledge and abilities may have negative implications. Given that affect is connected not only to social elements but to context as well (see Wosnitza & Volet, 2005), the unit of analysis determines what kind of information can be collected. In affect research, self-report is considered a useful method of collecting information about affective processes (Graesser et al., 2014) providing opportunity to explore affect of the students both individually and as part of a group. However, to capture a more in-depth understanding of affect during the collaborative learning process in the classroom, independent observation is another prominent method for scrutinizing what is happening (Meyer & Turner, 2006; Op't Eynde & Turner, 2006; Wosnitza & Volet, 2005).

Altogether, besides the individuals' perceptions of their own affect, challenges for capturing the affect from individual behavior during collaborative activities when engaged with technology are manifold. In a social context, individuals tend to regulate their affect to avoid distractions in interaction and focus on task performance (Rogat & Lisa Linnenbrink-Garcia, 2011) or to hide inappropriate affect for that specific situation with masking, thus expressing a more socially appropriate affect instead (Cahour, 2013). Accordingly, subjective feelings such as affective states can be collected as verbal descriptions, for example by rating using questionnaires or by discussing during an interview. On the contrary, bodily reactions and non-verbal expressions such as facial expressions, gestures, and postures, as well as vocal utterances, i.e., paralanguage (see, James, 2017), require external investigation such as video-based observation (Scherer & Ellgring, 2007).

1.3 Teacher's affective guidance and support in the classroom

The role of a teacher in computer-supported collaborative inquiry learning has been found to be important (see e.g., Asterhan et al., 2012; Dillenbourg, 2008; Greiffenhagen, 2012), as integrated scaffolding features in the technological system might lack important supplementary information that is needed or appears novel to the students. Also the systems are not yet sensitive enough for students' emerging needs in learning (e.g., affective support). Hence, a human coach has a significant role in both individual and collaborative learning activities. It has been suggested that in computer-supported collaborative learning, the role of a teacher is to support and guide the collaboration process as a facilitator in addition to the role of being a knowledge expert (Hsieh & Tsai, 2012; Chen et al., 2018). However, the teacher has earlier been disregarded from studies of computer-supported collaborative learning (Greiffenhagen, 2012; Urhahne et al., 2010), but more emphasis has been paid for teacher support and guidance lately (e.g., Janssen et al., 2012; Vauras et al., 2019). There is evidence of the significance of teacher support in the motivational dynamics of engagement, showing that both actual support and students' perceptions of teacher support are related to sentiments of competence and autonomy (Skinner et al., 2008), as well as task value and ability beliefs (Fryer & Bovee, 2016). Thus, intense teacher support and emphasis of the relevance and meaningfulness of learning can have remarkable and long-term influences on student motivation.

The concept of core competencies in the 21st century emphasize creativity, critical thinking, problem solving, decision-making, collaborative skills, communication, and information technology skills (Care et al., 2018). This competence orientation has been rather smooth to adopt in learning, as there exists a variety of technological tools to integrate into the classroom practices, and research findings support computer-supported learning, especially in collaborative inquiry learning. For example, a recent meta-analysis of Chen and colleagues (Chen et al., 2018) suggested that using collaborative computer-supported learning was predicting better knowledge gains, skill acquisition, and positive perceptions of collaboration, group task performance, social interaction and learning outcomes, than computer-supported individual learning. Computer usage was also related to an active learning approach, increased levels of interest, and high-level thinking. Furthermore, computer-supported environment was supporting communication for more vulnerable and passive students, and thus increased psychological safety. However, as emphasized by Ainley and Armatas (2006), students' responsiveness to computer-supported learning is dependent on the individual and situational factors such as motivation, experiences of flow, opportunities for social interaction, and the environment itself. Active decision-making and control of the environment support

computer-supported learning, whereas lack of confidence with knowledge, abilities, and multiple options in the environment might be detrimental to learning.

A constructivist learning approach enhances autonomous and learning-centered practices as compared to traditional teacher-centered practices, which is why it has been a commonly applied method for science education and inquiry learning (McNeill et al., 2013). The teacher's role in inquiry learning has been seen as a coach and facilitator of students' thinking and modelling the learning process (Anderson, 2002). Empirical findings have demonstrated that integrating technology with inquiry instruction can assist teachers to engage their students in experimental investigations, especially in secondary science (Maeng et al., 2013). However, technological tools such as virtual learning environments cannot support students' learning independently, thus the role of the teacher is emphasized in computer-supported learning (Dillenbourg & Jermann, 2010). Given that collaborative activities have been widely adopted in scientific inquiry, as group work is positively associated with achievement and better performance together than independent work (Kirschner et al., 2011), the opportunity to work in a group is not sufficient to support high-level science learning (e.g., Sampson & Clark, 2009; Vauras et al., 2019; Volet et al., 2013). Thus, the role of the supporting teacher remains of great importance in collaborative problem solving (Kirschner et al., 2006; Rosenfeld et al., 2000).

In addition, collaborative skills are not embedded in technology or adopted spontaneously, as was indicated by Kwon et al. (2014) when they found that most of the undergraduate student groups in medicine did not demonstrate ideal collaborative interaction patterns. Chang et al. (2017) showed in their study that successful and unsuccessful groups vary in their collaboration patterns and problem solving strategies, as successful groups use analytical reasoning strategy with discussions and re-examinations to solve the problem, whereas the unsuccessful groups mainly apply a trial-and-error strategy. Accordingly, targeted teacher guidance and support would help students to structure their problem-solving actions for a shared understanding. Notably, the importance of teacher-student interactive talk and support in scientific reasoning and knowledge building has been emphasized in all science learning, and expert teachers establish science understanding by eliciting and acknowledging student responses and by clarifying and extending students' ideas (Tytler & Aranda, 2015). Further, as evidenced by Janssen et al. (2012), students' engagement in social activities might disturb effective collaboration, although too-complex inquiry tasks might have a negative impact on working memory. Still, it is suggested that learning tasks should be sufficiently challenging and complex that they are beyond individual success and demand group work (Kirschner et al., 2011).

Central to an effective use of technology in the classroom is the knowledge and skills, self-efficacy, pedagogical beliefs, as well the school and subject culture of the teacher (Ertmer & Ottenbreit-Leftwich, 2010). Although the teacher has the

knowledge and skills to use technology, a lack in self-efficacy to teach with technology or a lack of belief in the value of technology (traditional versus constructivist beliefs) contrasted with a school culture that supports technology usage has an impact on teachers' ability to integrate technology in their instruction. However, despite quite stable pedagogical beliefs, continuous technology usage can transform these beliefs towards more student-centered constructivist beliefs (Tondeur et al., 2017). It has been suggested that teachers' self-efficacy is positively related to students' motivation and achievement (Mojavezi & Tamiz, 2012), and that high self-efficacy teachers tend to be effective managers in classrooms and be able to motivate and engage even the disruptive students to learn (Dibapile, 2012). However, as Dibapile emphasizes, teachers' lack of belief in themselves as competent agents and this lack of competence has an impact on classroom instruction, as well as students' learning and performance. Similarly, Rubie-Davies et al. (2012) found that students' academic outcomes are influenced by variations in teachers' efficacy, beliefs, expectations, goal orientation, instructional practices, and the socio-emotional climate of the classroom they create.

Accordingly, one challenge in understanding the role of a teacher in collaborative and computer-supported inquiry or even classroom learning in general is related to teacher individual differences. Empirical findings indicate that teachers differ from each other in regard to their pedagogical beliefs (Tondeur et al., 2017) and their practices with the whole class, but these practices correspond to the practices they implement with small groups (Webb et al., 2009). In addition, teacher behavior varies between the lessons and the groups, and notably, teachers get involved with the groups with high student activity (Van Leeuwen et al., 2013). This finding is alarming, as stronger teacher's emotional support could benefit emotional and social engagement of students with low self-efficacy in relation to the subject (Martin & Rimm-Kaufman, 2015). A teacher's dominant focus on students who already are motivated and active can deteriorate the performance of the others.

However, a teacher's activity in the classroom involves different dimensions, and thus the apprehension of teacher's guidance and support is fragmented to some extent. The research literature emphasizes, for example, classroom management (e.g., Harris & Rooks, 2010), instructional strategies or practices (e.g., Osborne et al., 2013; Shoulders & Krei, 2015), classroom discipline (Martin & Sass, 2010) and teacher behaviors (e.g., Mainhard et al., 2011). These dimensions are present in studies related to teacher guidance and support, but with ample variation in content. The research findings of Hamre et al. (2013) emphasize teacher emotional support, classroom organization, and instructional support, whereas Harris and Rooks (2010) suggest management of the science ideas, instructional materials, tasks, students, and the overall social context during inquiry-based science instruction in order to support and sustain learning. According to Anderman et al. (2011), supportive teacher

practices build and maintain rapport while engendering understanding and classroom management. In addition, social support provided by the teacher can be divided into instructional, instrumental appraisal and emotional support (Malecki & Demaray, 2003; Tardy, 1985). Accordingly, instrumental and emotional support from the teacher (giving time and attention) are related to higher academic achievement (Tennant et al., 2014). Interestingly, Greiffenhagen (2012) demonstrated a more content-focused approach to teacher guidance and support, indicating that during collaborative learning the teacher starts with joint introduction, then walks around the classroom, monitoring and assessing group performance, maintaining order in the classroom and making whole-class announcements.

Moreover, when providing help, advice, instruction, and support for students in the classroom, teachers display their own attitudes and affect to the classroom. There is evidence that a supportive environment can foster students' positive ability beliefs and task value, hence belief in success together with the value of the task and the amount of support from the teacher influence students' motivation to engage in education (Zhang et al., 2012). Further, Danielsen et al. (2010) found that students' perceptions of teacher support is related to their academic initiative, but there is great variation in perceived teacher support between classes. Accordingly, a supportive climate for a class may be provided through pedagogical caring and autonomy support, but some classes appear more encouraging than others. Similar findings have been emphasized by Klem and Connell (2004), indicating that teacher support, i.e., creating a caring, well-structured learning environment with high, clear, and fair expectations, was perceived as important to engagement, higher attendance, and achievement by both teachers and students. Furthermore, the teaching approach, instructional behavior, and students' affect are all influenced by teacher affect (Becker et al., 2014), emphasizing the association between positive affect and student-focused teaching approach (Trigwell, 2012). Similarly, teacher perceptions of student performance, motivation, and discipline (see also, Zembylas, 2002) influence teacher affect and further, teacher affect has an impact on their instructional behavior, such as cognitive and motivational stimulation and social support (Frenzel et al., 2009). It has also been found that a teacher's communication competence has an impact on students' affect and thus to their engagement (Mazer et al., 2014). Hence, a positive emotional tone in the classroom enables better learning possibilities and experiences for both the students and the teacher (Frenzel et al., 2009; Hagenauer et al., 2015; Meyer, 2014).

Overall, the role of the teacher in computer-supported collaborative inquiry learning appears crucial, as learning with technology may not automatically result in greater engagement in learning activities and better learning outcomes (Sinha et al., 2015), and some students are not eager to learn at all from a technology-integrated constructivist approach (Tondeur et al., 2017). However, successful computer usage

can help teachers engage their students in learning, but the importance of guidance for collaboration and scientific inquiry together with social-emotional support is undisputable. Yet individual differences among both the students and the teachers have to be considered in the learning situation. It is argued that the teacher cannot make learning happen, but a teacher's sensitivity to students' ongoing efforts to learn can create supporting classroom conditions for learning (see Ahern & de Kirby, 2011).

2 Aims and structure of the dissertation

This dissertation has theoretical, methodological, and empirical aims to expand the dynamic and evolving nature of affect during small group inquiry learning in science. The theoretical aim is to extend and deepen the understanding of affect in collaborative learning, especially in a computer-supported learning context. The methodological aim is to develop tools such as measurement scales for affect and collaboration. Finally, the empirical aim is to provide educational implications for the role of affect in collaborative learning. In order to understand the often hidden nature of affect, especially in a social context such as collaborative learning, a multimethod, systematic approach is needed. As research on affect in learning has usually concentrated on perceptions of individual affect as part of learning or the learning context, this dissertation aims to deepen this understanding with an in-depth exploration into the complex construction of affect and collaborative learning, and the role of a teacher in the classroom. These distinct aspects together unveil a more comprehensive understanding of affect in collaborative learning in a classroom than only one perspective and thus are the basis for the theoretical, methodological, and empirical aims of this dissertation. Each of the three studies in this dissertation have their specific aims and these are presented in Figure 1.

The three studies in this dissertation complement each other, as they widen the perspective on affect in collaborative learning one at a time. The first focuses on individual affect and students' own perceptions of the valence and arousal of their affect during the working period as quantitative analysis. In addition, individual perceptions of group collaboration and support together with the group outcome level are analyzed (Study I). Second, students' affect and behavior are elaborated on at both individual and group levels, within and between the chosen small groups, by comparing and integrating student perceptions and objective evaluations and the group outcome, with in-depth micro-level analysis (Study II). That method makes it possible to extend the scope of the analysis and capture detailed information that would otherwise be left hidden. Finally, the focus is shifting from students to the role of the teacher as a guide and facilitator of the collaborative learning. Teachers' observed guidance and support, as well as their own perceptions of their guidance

and affect are explored and reflected by small group activities, group outcome, and student affect in their classrooms (Study III). These different perspectives and specific aims are intertwined in this dissertation to accomplish the general aims and conclude this multifaceted research process.

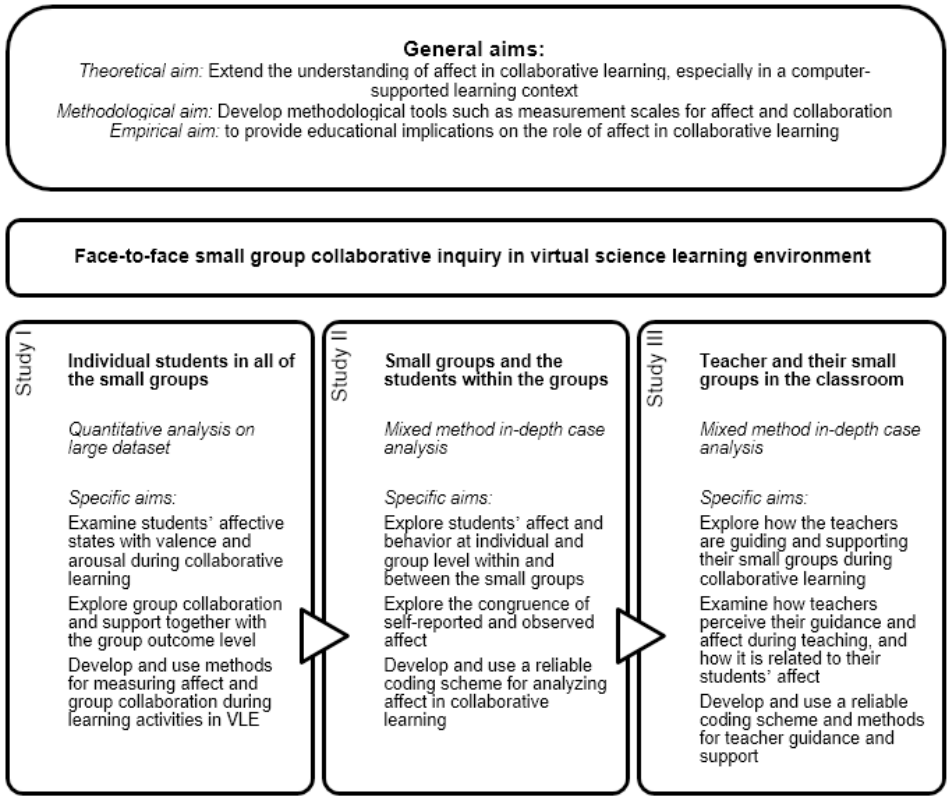

Figure 1. Overview of the studies and aims of the dissertation.

3 Method

3.1 Participants

All three studies were conducted in six high schools in Southwest Finland during the spring and autumn semesters of 2015 and 2016. The reason for the selection was that the students in high schools are at the phase when plans for future studies are made, especially in respect of science. Two of the high schools were in rural areas and four were urban. Participating students (N = 120) were between 16 and 19 years old (M = 17.27; SD = 0.68) and over half of them (65%) were female. Participants in the three studies that are reported in this dissertation included both the individual students in small groups and selected teachers. These are presented in **Table 1**.

Table 1. Participants.

	ORIGINAL SAMPLE OF PARTICIPANTS
	High school students (N = 120) in 39 small groups, and the science teachers (n = 13) from Science Learning Environments for the Future Schools (*SciLeS)* project*
STUDY I	All students (N = 120) individually
	SELECTED SAMPLES OF PARTICIPANTS
STUDY II	Six small groups (n = 18) representing distinct productive outcome groups (two *high,* two *average,* two *low*)
STUDY III	Four science teachers (two biology and two chemistry) with pseudonyms: Paula, Elisa, Henrik and Leo The 19 small groups in the four teachers' classrooms, 56 students

* The project was funded by Grant No. 274117 from the Council of Cultural and Social Science Research, the Academy of Finland awarded to Professor Marja Vauras.

Study I

Participants were the 120 individual students who attended the Science Learning Environments for the Future Schools (SciLeS) research project. Participation was voluntary, and a signed consent including permission to videotape all class and small group interactions, was completed by the students or their legal guardians and by the teachers. In addition, as the study was an integral part of students' coursework, they gained course credits for their participation. Students worked in 36 small peer groups of three students each, and in three dyads. All groups were assigned by the teacher to form functional groups for the analysis. Group formation was based on the balance of disciplinary knowledge in the course topics, biology and chemistry, as well as English language to ensure equal opportunities for the groups to accomplish the task in the English-speaking science-learning environment.

Study II

Six intact groups, totaling 18 students (4 male and 14 female) were chosen out of 36 three-student groups for exploratory, in-depth analysis of each of the six group. Selection criteria for the groups was that they were intact groups of the same three students during the entire process (three working sessions). These six groups were selected based on their group outcome (two Low, two Average, and two High outcome groups) for the group level analysis.

Study III

Participants were 4 high school science teachers and their classrooms, altogether 19 small peer groups, and 56 individual students. The majority of the students (68%) were female. The selected four science teachers were two biology subject teachers (female and male) and two chemistry subject teachers (female and male). The female biology teacher was an experienced teacher, whereas the male biology teacher was in the beginning of his career. Similarly, the male chemistry teacher was an experienced teacher and the female chemistry teacher in the beginning of her career. Still, all the teachers were piloting the virtual learning environment used in this study for the first time, and thus positioned as novices in this regard. The selection criteria were based on the number of the small groups in the teachers' classrooms being comparable, as in some high schools there were more groups or a substitute teacher being involved with the groups.

3.2 Virtual learning environment

The context for small group collaborative inquiry learning was a computer-supported science learning environment, Virtual Baltic Sea Explorer (ViBSE), designed by professionals in education, biology, and chemistry (Kinnunen et al., 2015). The aim of the virtual learning environment (VLE) was to offer an authentic research context for learning, containing the key concepts and integrated scientific information on biology and chemistry and to improve scientific practices and reasoning skills (see e.g., Vauras et al., 2019; Koretsky et al., 2019; Vauras et al., 2017). ViBSE took students on a virtual expedition in a real research vessel, the R/V Aranda, to study environmental changes in the Baltic Sea. ViBSE provided multiple tools for inquiry learning, such as a library with information about key concepts and topics of scientific phenomena, interviews, minilectures by the crew and researchers of the actual environmental research vessel Aranda, virtual laboratory tasks, photos, and links to external web pages concerning the news and current state of the Baltic Sea. The problem-solving activity involved running an experiment on the effects of fast pH changes in phytoplankton and certain species of copepods in the Baltic Sea's food chain, using a dominant science language, i.e., English.

In the beginning of the inquiry learning, the students chose their topic (in these studies it was the effects of pH changes on the reproduction of copepods), made hypotheses and study designs, and then proceeded to the laboratory tasks (choosing the number of sea water bottles, eggs, pH, and time). In the laboratory, the students collected data, made analyses (e.g., counting the eggs and calculating basic statistics), and finally drew conclusions and interpreted results. During the virtual exploration, students became acquainted with the nature of scientific work as characterized by experimental methods such as forming hypotheses, simulation of the research design, running experiments, and interpreting the outcomes. To ensure the authenticity of the experiments, the data was based on actual marine biology studies to guide research and conclusions to base on legitimate outcomes (see, Bonaglia et al., 2013; Engeström-Öst et al., 2014).

Collaborative problem solving in the VLE was designed to support and encourage deep-level thinking through scientific reasoning and argumentation, but it was also demanding cognitively and socially for the students. Collaborative inquiry learning that was aimed at deeper understanding of science phenomena through shared problematizing and integration of knowledge from two science disciplines in a second language created challenges for the students (Vauras et al., 2019). Thus, the role of the teacher was to provide support and guidance to the small groups when needed (see Koretsky et al., 2019; Vauras et al., 2019).

3.3 Measures for students and group performance

To enable a comparative positioning of the small groups, students' prior science competence and the joint group outcome were evaluated for the groups. The science competence measures for each individual student and aggregations for the groups were collected before the working period. In turn, the group outcome was evaluated for each group at the end of the working period. The groups' outcomes were used to define the level of achievement for all groups at the end, and to select the suitable groups for in-depth analyses.

Prior science competence

The measure for prior science competence was based on individual students' grades at science courses in high school. Students reported all their earlier grades in both biology and chemistry, which they had accomplished before the working period. The aggregated mean grade of both course grades of the group members were computed to represent each groups' average competence value. The aim was to provide background information on students` science competence to be used in Study III.

Group productive outcome

The measure for the group's productive outcome was based on each groups' joint verbal PowerPoint presentations that were used as outcome measures. All 39 participating groups were divided into three outcome levels based on the quality of their group presentation at the end of the working period (1 = low−, 2 = low+, 3 = average−, 4 = average+, 5 = high−, 6 = high+). Evaluation criteria comprised the structure of the presentation, understanding of the task, hypotheses, research plan, conclusions, and quality of scientific language used in the presentation. Two qualified science professionals in biology and chemistry evaluated the overall quality of the group outcomes from video documents. The number of distinct productive outcome groups was 6 high (13 female, 3 male), 14 average (28 female, 14 male) and 19 low (34 female, 22 male) groups. The group outcome level was used as a statistical variable in Study I, and further as a selection criterion and for the comparative analyses in Study II and Study III.

3.4 Surveys for students and teachers

In all of the three studies, quantitative analyses were used to explore affect, and to disclose individual perceptions behind the activity. Two distinct questionnaires were constructed for this purpose, one for the students and another for the teachers. The

Assesment of Group Work and Emotions was used in Study I and Study II, and the *Teacher's Evaluation Form* was used in Study III.

Assessment of group work and emotions

The students were asked to assess their group's functioning and their affect when working on the task and with the group using a systematic paper-and-pencil questionnaire after each working session, independently. The first part was a short nine-item, 10-point bipolar Likert scale, focused on the essential components of collaboration such as common goals, joint motivation, and mutual support (Dillenbourg, 1999; Järvelä et al., 2010; Kirschner et al., 2006; Rogat et al., 2013), and the learning aims embedded in the VLE, including scientific thinking, deep learning, and multidisciplinarity. The second part of the questionnaire was a systematic affect scale based on the valence of positive and negative affect, using a 10-point bipolar Likert scale. Each student evaluated 12 items from the orthogonal positive and negative affective states representing 24 affective states (*proud-ashamed; enthusiastic-bored; excited-tired; delighted-disappointed; interested-uninterested; confident-insecure; happy-unhappy; glad-angry; pleased-annoyed; satisfied-frustrated; relaxed-anxious; calm-tense*). For frequency analyses, values ranging from one to four were classified as negative, from five to six as neutral, and from seven to ten as positive. The affect scale measured valence (orthogonal positive and negative affective states) and arousal (activating and deactivating affective states) based on the circumplex model of affect (e.g., Feldman Barrett & Russell, 1998; Linnenbrink-Garcia et al., 2011; Scherer, 2005). The affective states were selected from learning related emotions highlighted in the research literature, and the primary learning-centered emotions in advanced learning technologies (Graesser et al., 2014).

Teacher's evaluation form

The teachers were asked to assess all their student groups, their own role and guidance, and their affect when working with the groups with a systematic paper-and-pencil questionnaire after each working session. The first part was to assess how each of the small groups performed, with a 10-point bipolar Likert scale (4 item) assessing a) collaboration: *Easily grasped demanding challenges/Avoided challenges; Favored working alone/Favored collaboration*, and b) motivation and emotional valence: *Worked negatively and non-enthusiastically/ Worked positively and enthusiastically; Unmotivated and off task/Strongly motivated and on task*. The second part was to assess with a ten-point Likert scale (6 item) their own role and guidance: e.g., *I found easy to observe separate groups/I found difficult to observe*

separate groups; It was easy to see when groups needed my guidance/It was difficult to see when groups needed my guidance. The third part was a systematic affect scale based on the valence of positive and negative affect, using a 10-point bipolar Likert scale. Teachers evaluated six items from the orthogonal positive and negative affective states representing 12 affective states (*calm-tense; glad-irritated; enthusiastic-unenthusiastic; satisfied-dissatisfied; energetic-tired; confident-insecure*).

3.5 Video-based observations

All teachers' and students' activity during the working sessions in the classroom was videotaped and audio-recorded with digital cameras and microphones. There was one camera for each group positioned in front of the group, and one or two cameras for the whole classroom positioned in one corner of a classroom with a wide view. In addition, the student activity at the laptop was recorded with Snagit, a screen-capturing tool. The video data from each group was used in Study II, and the video data from the whole classroom was used in Study III. In unclear cases, all available video data was used to clarify the situation, especially with respect to the teachers' and students' verbal utterances. The video data for selected segments for the in-depth analyses chosen from the total video footage from each group (Study II) and as a complete learning and teaching activity in the classroom (Study III). The selected video segments represented continuous and meaningful verbal interaction within the group and featured each of the working phases, namely, Planning, Experimentation, and Conclusions, following the steps of scientific research (see Tsovaltzi et al., 2010). In addition, group analyses were based on principles of video research for science learning, taking into account appropriate data selection and pattern-finding, systematic coding, transcription, narratives, interrater reliability, analyzing selected episodes, and protecting the human subjects (see Derry et al., 2010).

3.6 Analysis

To understand affect in socially and technologically challenging learning contexts, different methods and aspects of affect were used for analysis. In Study I, the affective experiences of an individual student as part of a group were examined through students' self-evaluation, which is considered to be a valid method of collecting information about affective processes (Graesser et al., 2014). In addition, a discrete emotions approach was used in parallel with valence and arousal to obtain particularly specific information about the emotional experiences of the students (see Scherer, 2005). In Study II, self-reports and video observations were compared using in-depth case analysis to widen the aspect of affect in collaborative learning (Meyer

& Turner, 2006; Wosnitza and Volet, 2005), and to focus on the dynamic and evolving process of affect. In Study III, the role of the teacher as a provider of cognitive and affective support for the students was explored using self-reports and video observations to constitute a specific social network video analysis. It has been argued that the influence of affect on learning and performance should be studied in a context where it actually occurs (Kim & Pekrun, 2014), and thus all three studies were conducted as part of ordinary science lessons in a classroom. The analytical methods that were used are as follows: descriptive statistics, principal component analysis (PCA), structural equation modelling (SEM), cross-lagged path modelling, in-depth case analysis, inter-coding agreement, and social network analysis (SNA).

Descriptive statistics

With respect to affect, descriptive statics were used in all of three studies to provide detailed information of the affects reported by the students and teachers. Frequencies for affect were computed using IBM SPSS Statistics Version 24 or newer software. The bipolar scales of affect were estimated at three measurement points during collaborative learning for each individual student and teacher. A histogram was used in all studies for presenting positive activating, positive deactivating, neutral, negative activating, and negative deactivating affect.

Principal component analysis

In Study I, the fully structured scales for affect and collaboration in the questionnaire were evaluated with principal component analysis (PCA) to ensure the structure of the scale and determine whether to retain or eliminate items. Principal component analysis with varimax rotation was conducted for nine collaboration items separately for each three measurement points, resulting after one item deletion in two principal components for collaboration: Scientific Understanding and Collaboration and Support. The Cronbach's α reliabilities at the three measurement points were 0.81 and 0.61; 0.72 and 0.55; and 0.77 and 0.63, respectively. Principal component analysis with varimax rotation on the 13 affect items resulted after three items deletion in three principal components for affect: Joviality, Self-assurance, and Serenity. The Cronbach's α reliabilities at the three measurement points were 0.91, 0.79, and 0.66; 0.93, 0.84, and 0.71; 0.89, 0.84, and 0.82, respectively. The item deletion was conducted due to the weak communalities.

Structural equation modelling

The hierarchically nested datasets were estimated calculating the design effects (D_{eff}) for each item using the intraclass correlation and average cluster size. The D_{eff} values were between 1.02 and 2.01 thus further analyses with structural equation modelling (SEM) were conducted at the individual level (Baquley, 2012; Muthén & Satorra, 1995). Structural equation modelling analyses were executed using Mplus Version 7 (Muthén & Muthén, 2015) for investigation of the relationship between affect, collaboration, and group outcome. The measurement models constructed with principal component analysis for affect and collaboration factors were tested with confirmatory factor analysis (CFA) to evaluate the structural validity of the models. Goodness of fit was evaluated using the χ^2 test, comparative fit index (CFI), and Tucker–Lewis index (TLI), with values = 0.90 indicating acceptable fit, the root mean square error of approximation (RMSEA) and its 90% confidence interval (90% CI), with values = 0.08 indicating acceptable fit, and the standardized root mean square residual (SRMR), with values = 0.08 indicating acceptable fit (see Hu & Bentler, 1999; Kline, 2005; Little, 2013). The factors for collaboration were labelled as Collaboration and Support, and Scientific Understanding, and the factors for affect were labelled as Joviality, Self-Assurance, and Serenity, according to the affect labels in the PANAS-X scale (Watson & Clark, 1999).

Cross-lagged path modelling

The relationship between affect and collaboration across the three measurement points, i.e. three working phases, was analyzed with a longitudinal, cross-lagged path model. Based on correlation values, the items confident-insecure and excited-tired were selected from factors Self-Assurance and Joviality for analysis on reciprocal relation between positive affect, scientific understanding, collaboration, and support. As the factor Serenity was not a significant indicator of the group work process, it was excluded from the analysis. Cross-lagged models were used for confident-insecure with Collaboration and Support, and for excited-tired with Scientific Understanding.

In-depth video analysis

In Study II, qualitative level video analysis of group interaction patterns enabled shifting to micro level moment-to-moment elaboration and thus revealed the dynamic and evolving process of affect within and between the small groups. A systematic video analysis was used to analyze the extent of similarities and differences in affect in the groups, the relationship between group outcomes and affect within groups, and the degree of within-group consistency in individual

students' affect across the working phases. Selected video segments of verbal and nonverbal interaction, and paralanguage were systematically analyzed from videos using the Observer XT 12 software. The coding categories for the observation analyses were based on affect dimensions (Linnenbrink-Garcia et al., 2011; Scherer, 2005) and group processes research (Linnenbrink-Garcia et al., 2011; Rogat & Linnenbrink-Garcia, 2011; Vauras et al., 2008). Along with the video analysis, an in-depth narrative analysis of individual affect in three groups was implemented to reveal the affective tone and challenges in the small groups.

Inter-coding agreement

Inter-coding agreement was established in Study II in order to ensure the reliability of the coding. In the first phase, episodes of affect were located from the entire video data manually using three independent coders, and the inter-coder agreement was calculated using percentace agreement. In the second phase, video segments for in-depth analyses were randomly selected among the episodes of affect using two coders who viewed selected video segments independently. The inter-coder agreement at the last phase was calculated using percentage agreement and Cohen's kappa showing substantial or almost perfect values (see Landis & Koch, 1977). Minor disagreements were resolved with discussions.

Social network analysis

In Study III, a systematic video analysis was used to capture the distribution and focus of teachers' guidance and support during collaborative science learning. The distribution of teacher guidance and support of the groups was documented systematically from the videos by calculating the number of times teachers visited each group, and the number of times teachers visited a group requesting the teacher to provide guidance and help. The focus of teacher guidance and support was coded from the verbal interactions between teachers and groups, to present the nature of guidance and support. Teachers' real-time activity together with the guidance and support directed to the small groups was coded according to the developed coding categories based on teacher activity research on socioemotional, instructional, cognitive and classroom management (e.g., Anderman et al., 2011; Malecki & Demaray, 2003). The number of visits per group, as well as the number for the groups requesting the teacher to attend their group conversation to give guidance and help, was coded from verbal interaction between the teacher and the groups. Further, silent attention provided by the teacher on each particular group was captured from the video data.

The frequencies of teacher activity were analyzed using UCINET (Borgatti et al., 2002), a standard network analysis software to model network topography for each teacher's connections to their small groups in their classrooms and how the connections were distributed among the groups of students in each classroom that indicate centralization of interaction. Social network analysis (SNA) was executed with three categorical variables: 1) student groups' shared prior science competence in biology and chemistry, 2) teachers' perceptions for each group's motivation and collaboration, and 3) groups' productive outcomes. The distribution of teachers' communication with the student groups in their classroom were tested using Blau's heterogeneity measure to reveal factors that had an impact on teachers' equal communication with their small groups.

4 Overview of the empirical studies

This dissertation includes three studies that examine and deepen the understanding of affect that emerges during face-to-face collaborative virtual science learning. Each study applied diverse methods and supplemented the others by proceeding from a wide perspective towards a detailed elaboration on different aspects of affect. Study I was a quantitative investigation that demonstrated the significance of affect during virtual inquiry learning and the impact of individual differences within as well as between the groups. Study II was an exploratory case study that extended the elaboration of affect from individual perceptions to group analysis. Study III explored teacher guidance and support associated with teacher affect aimed at uncovering the situational and environmental basis for collaborative learning in the classroom.

4.1 Study I

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 Learning*, 35 (3), 334-348.

The overall aim of this study was to extend understanding on affect in computer-supported collaborative science learning by examining discrete affective states in face-to-face small group settings in high school. The aim was also to elaborate on the associations between student affect (valence and intensity), collaboration, and scientific understanding with respect of the level of productive group outcome.

Students' affects as well as their perceptions of group collaboration and scientific understanding were based on questionnaire data (N = 120) that was collected in six high schools during a small group collaborative virtual inquiry combining biology and chemistry. Student groups worked in a virtual science learning environment (ViBSE) in three sessions, 75-95 minutes each. The three sessions were three phases of a scientific inquiry, namely planning, experimentation, and conclusions. All working sessions were videotaped and audio recorded. After each session, students evaluated their affect and perceptions of group collaboration and scientific thinking with a paper-and-pencil questionnaire individually. Along with the questionnaire

data, the group outcome measure was used for analysis. The outcome was the groups' verbal presentation evaluated by two qualified science professionals in biology and chemistry, and the participating groups were divided into six levels based on the quality of their group presentation (from 1 low− to 6 high+). The fully structured scales to measure affect and the groups' perceived functioning were examined with a principal component analysis (PCA), a structural equation modelling (SEM), a confirmatory factor analysis (CFA) and longitudinal, cross-lagged path model. The analyses resulted in two factors for collaboration and three factors for affect, and the group outcome measure.

The results showed that positive affect prevailed whereas negative affect was infrequent in students' self-reports. Especially students in the highest performing groups reported positive activating affect significantly more than did students in other groups. Furthermore, the results from the path models revealed that self-assurance had a significant effect on collaboration, intertwined with scientific understanding and the group outcome. Hence, self-assurance was predicting the nature of collaboration, and the effort to attend to scientific thinking and deeper understanding, as well as the level of the group's outcome. Additionally, there was a relation between positive affect, scientific understanding, and collaboration.

In conclusion, the study showed the importance of self-assurance and particularly confidence in enhancing collaboration and support, as well as co-construction of shared understanding during small group inquiry learning. Moreover, this study provided evidence of the significance of affect during virtual science learning, but also the impact of individual differences within a peer group and between the groups with distinct outcomes. Although this study validated the quantitative data for affect, multimethod, in-depth analyses on affect were needed. These findings created the basis for using self-reports combined with the video-based data to explore the consistency between students' perceptions and group observation in Study II.

4.2 Study II

Pietarinen, T., Volet, S., Lehtinen, E. & Vauras, M. (2020). Affect in peer group learning during virtual science inquiry: Insights from self-reports and video observations. *Frontiers in Psychology, 10:2981.*

The specific aim of this study was to explore and deepen the understanding of affect (valence and intensity) in small groups during the three phases of collaborative learning activity. The second aim was to examine the relationship between group outcomes and affect within groups (valence, intensity). As a third aim, the degree of within-group consistency in individual students' affect (reported, observed; valence,

intensity) across phases was explored and complemented by an in-depth narrative analysis of individual affect in three selected groups, two extreme and one average. Finally, consistency between self-reported affect and observed affect in the groups was examined.

The data for this exploratory study was extracted from the larger dataset that was used in Study I to allow an in-depth, detailed analysis of each selected group. Six intact groups, totaling 18 students were selected for closer analysis based on their group outcome (two Low, two Average, and two High). The video segments for the in-depth analyses of observed affect were chosen from the total video footage from each group, resulting in the total amount of 6390 turns, and 1542 turns (24%) of them contained affect. Inter-coder reliability was obtained through percentage agreement and Cohen's kappa values being substantial or almost perfect and thus reliable (see Landis & Koch, 1977). The observed affect was examined together with students' self-reports on their affect from the questionnaire data during the three phases of scientific inquiry, i.e. Planning, Experimentation, and Conclusion.

The results revealed the dominance of positive over negative affect overall in all groups, in self-reports and observations, but variation in affect within and between the groups. Although the dominance of positive affect was obvious in self-reports, there was more variation in observed affect. However, the intensity of positive and negative affect was higher in self-reports than in observations, but only a few groups showed high intensity negative affect. Further, the observations revealed some negative affect in all groups, irrespective of the group outcome. Still, no direct effect of affect on group outcome was found. Yet, the findings also demonstrated only positive arousal in all high and average performing groups for the last phase, but high negative arousal in the lowest performing groups. This finding, however, suggests a connection between students' affect and group performance. Overall, the results showed that affect in the extreme groups was convergent with their performance, but in the average group, affect patterns appeared more complex.

In sum, the results of this study were in line with the previous study indicating the impact of individual differences within a peer group and between the groups with distinct outcomes, when explored with multimethod approach. As the intensity of affect appeared stronger in self-reports than in observations, the possibility of emotion regulation in students' behavior does exist. However, self-reports and observations showed similar results underlining the dominance of positive affect, confirming them as adequate measures of students' affect in learning situations, either separately or in combination. The discourse examples of this study also revealed a need for stronger teacher support, and this consideration formed the basis for Study III.

4.3 Study III

Pietarinen, T., Palonen, T. & Vauras, M. (in press). Guidance in computer-supported collaborative inquiry learning: Capturing aspects of affect and teacher support in science classrooms. *International Journal of Computer Supported Collaborative Learning*

The aim of this study was to expand the research on affect in small group collaborative virtual science inquiry to the role of the teacher in the classroom. Particularly the aim was to elaborate on the the real-time focus and distribution of guidance and support that teachers provided to small groups during the learning period, and teachers' own perceptions of their guidance and affect together with their students' affect.

Four high school science teachers and their 19 student groups (n = 56) were selected from the larger sample for an in-depth analysis. Two teachers (female and male) were majors in biology, and two teachers (female and male) were majors in chemistry, addressing their expertise particularly in knowledge regarding their discipline. Teacher support and guidance was systematically analyzed from video data of each working period including three sessions of 75 to 95 minutes, total amount of video data for each teacher ranging from 2h 59min 47s to 3h 55min 31s. Coding moment-to-moment activity aggregated a total of 913 activity sequences. Teachers' own perceptions of their guidance and affect, as well as their perceptions of group collaboration, motivation and emotional valence in each group, were examined together with student group attributes (group outcome and prior science competence) using social network analysis.

The results demonstrated that the teachers spent more than a third of the time observing the groups, and only a third of the time on the actual science task. Socio-emotional support for the groups was scarce, which might be of concern as the findings also revealed that teachers preferred to guide groups they perceived as active and cooperative, although this effect was not systematically found for all teachers. Hence, parallel examination of the four distinct science classrooms showed visible variance between the teachers in respect of the time and distribution of their guidance and support ranging from full-time attention to only half-time engagement. Further, teachers' own perceptions of their guidance and support, along with self-reported teacher and student affect showed that teachers' affect and instructional behavior were related to their students' affect and academic performance.

To sum up, findings from this study emphasized four unique practices in teachers' guidance and support in similar situations and environments, but similarities in teacher activity across the classrooms as well. The results show that the classroom is an emotional place where teaching and learning are intertwined, suggesting that the affect and activity of both the teacher and the students are interacting and thus influence learning performance and outcomes.

5 Main findings and discussion

5.1 Main findings of the studies

The main purpose of this dissertation was to examine the dynamic and evolving nature of students' affect during face-to-face computer-supported small group collaborative inquiry learning in science, and to explore the role of the teacher in collaborative learning activities. This goal was grounded in traditional research on affect in learning, in which the focus has been on perceptions of individual level affect or collective group affect. From that perspective, the aim of this dissertation was to widen and deepen the understanding of affect in computer-supported collaborative science learning by drawing attention to discrete affective states in a face-to-face small group setting and individual differences. In addition, one objective was to deepen the understanding of the role of teacher guidance and support as well as teacher affect in respect of the computer-supported collaborative learning activities. Further, the aim was to develop methods to analyze the dynamic and evolving nature of affect in collaborative settings, and teacher activity. To achieve these aims three empirical studies were conducted in collaborative computer-supported inquiry learning environment using a mixed-method approach with quantitative measures, in-depth case studies and systematic video observations. In Study I, the data of individual students and small groups were scrutinized to reveal generalized patterns in affect and in Study II, the focus was shifted to the collaborating small groups and individual students within the groups. In Study III, the context and particularly the role of the teacher was taken under examination to demonstrate teacher guidance and support together with the affect during classroom activity.

The main findings of this dissertation demonstrate that both positive and negative affect are present in collaborative group activity and although affective experiences in collaborative context appear positive in general, individual differences can be claimed to have a strong impact on learning and group achievement. The findings also suggest a link between high-level performance and positive affect, whereas low-level performance is connected to negative affect. As the findings highlighted the importance of self-assurance to the learning and performance, the role of the teacher appears essential in guiding the learning process and supporting students' self-

competence and perseverance. However, individual differences in teachers' guidance and support together with differences in their own affect and perceptions of students and groups necessitate careful further elaboration.

Study I found that collaborative learning in the VLE was perceived positively, as positive affect was dominant and negative affect subordinate overall during collaborative learning, irrespective the outcome levels. However, positive activating affect was related mainly to high outcome. Furthermore, the findings indicated the importance of self-assurance and particularly confidence in enhancing collaboration and co-construction of shared understanding and scientific thinking, as well as group performance. This study suggested that strengthening confidence would promote individual action and agency, and thus mutual trust and belonging in the group, and thereby group performance. Moreover, this study provided evidence of the significance of discrete affective states and positive affect during virtual science learning, but it emphasized differences in affect between the small groups. The findings of this study established the basis for Study II.

Study II confirmed the findings of Study I for dominance of positive over negative affect also at group level in both student perceptions and researcher observations, confirming both methods as applicable measures of students' affect in learning situations, either separately or in combination. However, the intensity of positive and negative affect appeared higher in student perceptions than in researcher observations, suggesting the possibility of regulation in students' behavior. The findings demonstrated that students' affect in the extreme groups was consistent with their performance, but the affect patterns in the average groups appeared more complex. Accordingly, this study revealed evidence that the relationship between affect within groups and group outcome is complicated and ambiguous. Furthermore, the findings also unveiled the impact of individual differences within a peer group and between the groups showing variation in affect, although negative affect appeared in all groups. As the discourse examples of this study indicated a need for stronger teacher support, the shift from small groups to the role of the teacher was adopted for Study III.

Study III found that there were differences between the teachers with respect to the time and distribution of their guidance and support, ranging from full-time attention for the groups to only half-time engagement during classroom activities. From that time, when the teachers paid attention to their groups, more than a third was used for observing the groups' activity and one third was used for the actual science task (content knowledge and content management issues). Teachers also provided technical guidance, and to some extent, general guidance and off-task discussions. Rather surprisingly, socio-emotional support was scarce although the students were working with a new VLE. Furthermore, a closer analysis of the participating teachers' interactions with students unveiled four different practices of

guidance in identical situations and environments. The findings suggest that in collaborative, computer-supported learning, teachers may not provide more guidance and support for the groups with challenges. Quite contrary, the findings implied that guidance and support was directed most eagerly to those groups that teachers perceived active and most willing to collaborate. Furthermore, teachers' own perceptions of their guidance and support and their affect during the learning process resulted in four distinct pictures. Despite the overall positive appraisals in all of the classrooms, the findings indicated that teachers' affect and instructional behavior was intertwined with their students' affect and thus the academic performance of the small groups.

In sum, the three studies in this dissertation demonstrated the dynamic and evolving nature of affect in collaborative, face-to-face computer-supported inquiry learning in the classroom. The empirical findings evidenced that although joint learning in virtual environment generates positive affect, in-depth elaborations of affect and group work unveil a more complex perspective. Accordingly, affect in a group should be explored both individually and collectively. It was also established that the learning context together with the teacher guidance and support are deeply intertwined to affect and the learning process. This dissertation validated the use of both self-reports and video analysis as tools for exploring affect in small groups and social network analysis applicable for examining teacher activity and scaffolding in classroom context.

5.2 Theoretical contributions

The three studies included in this dissertation make theoretical contributions to both collaborative and computer-supported learning, and teacher practices in the classroom. The dissertation extends the understanding of positive and negative affect in collaborative, computer-supported inquiry learning and the role of teacher guidance and support in the classroom. The empirical studies link the components of valence and arousal to discrete affective states revealing the impact of collective affect of individual students to collaboration, scientific thinking, and group outcome, but also the reciprocal effect between individuals and the group. The importance of the context and particularly the role of the teacher is specified and connected to the affect in the classroom. The dissertation confirms the findings in the literature concerning the importance of affect in learning and the crucial role of the teacher in the classroom, but also extends the understanding and awareness of the relationship between individual and group affect, group performance and the affective guidance and support provided by the teacher.

First, the empirical findings from this dissertation provide evidence of self-assurance on collaboration and scientific thinking and thus group outcome. Study I

confirmed the still scarce but growing research on the importance of confidence in learning performance and achievement (e.g., Arroyo et al. 2009; Boekaerts & Rozendaal, 2010; Dunlosky & Rawson, 2012; Sheldrake, 2016; Stankov et al., 2012). In addition, the current scope of prominent affects in computer-supported learning environments was extended (see e.g., Baker et al., 2010; Baker et al., 2011; Graesser et al., 2014; Loderer et al., 2018). The findings revealed that self-assurance and particularly confidence – and pride to a certain extent – were significant predictors of the effort to attend scientific thinking and deeper understanding, and the nature of collaboration, and thus the level of group outcome. Hence, confidence with group work and the task enhance collaboration, mutual support, and co-construction of shared understanding. Notably, in a group situation, feeling confident may escalate to trust in interaction with others, indicating certainty of the correspondence of others' actions with individuals' expectations and thus promote confidence and interdependence among group members (Barbalet, 1996). This transition is supported by Kreijns et al. (2003) and Kreijns et al. (2013), which found that mutual trust and belonging, along with group cohesion and sense of community, enhance collaboration in learning groups. Moreover, trust has long been one of the key interests related to group collaboration in organizational research, implying also a link between trust and technology (e.g., Cheng & Macaulay, 2014; Wilson et al., 2006).

Second, this dissertation deepens the understanding of positive and negative affect within small groups and individual differences in affect and the relationship between affect and group outcome, as a more complex relationship between affect and group performance was introduced in Study II. The findings revealed the consistency between affect and group performance, suggesting that positive affect was related to higher group outcome, whereas more negative affect was deteriorating the performance. This finding is supported by earlier findings from Linnenbrink-Garcia et al. (2011), which revealed that positive affect was associated with positive group interactions, whereas negative affect resulted in disengagement and social loafing. Interestingly, the average outcome groups appeared more ambivalent, but these groups have been usually neglected in the literature and thus might provide more insights under scrutiny. On the other hand, it has been emphasized that computer-supported learning environments generate positive affect in some students but also negative affect in others (Chang et al., 2017). The empirical findings from Study II support this claim by indicating the fluctuating individual differences within and between small peer groups.

Third, this dissertation supplements the understanding of the relationship between individuals, groups, and the learning context where affect occurs, and provides evidence of the significant relationship between teacher guidance and support, affect and group performance, and Study III extended the understanding of

affect in small group to the learning context and the role of the teacher as a guide and facilitator of the learning process. It has been noted that despite of the importance of the teacher in collaborative and computer-supported learning (Asterhan et al., 2012; Dillenbourg, 2008; Dillenbourg & Jermann, 2010; Greiffenhagen, 2012), the teacher has often been kept aside in such studies (Greiffenhagen, 2012). Moreover, the real-time emergence of guidance and support provided by the teacher in collaborative and computer-supported learning has been a yet rather neglected area in research, as the focus has been mainly in the effects of the environment and human guidance to the learning performance. Hence, the empirical findings of Study III contribute to this research area by defining the focus and distribution of teacher guidance and support to the small groups during inquiry learning. From this perspective, Greiffenhagen (2012) has documented teacher activity in traditional and in computer-supported classrooms during collaborative learning, highlighting joint introduction, walking around the classroom, monitoring and assessing the group activity, interacting with the groups by ratifying, reminding, making suggestions, maintaining classroom control, and making whole-class announcements. Accordingly, such results are consistent with the findings of Study III in this dissertation, which supplements previous research by revealing that teachers spend more than a third of their time monitoring group work and spending only a third of time guiding the actual task when providing support in task management and content knowledge issues. However, individual differences between the teachers' guidance and support were extensive. Notably, social-emotional support was in the minority, which is alarming, as high-level emotional support from a teacher can enhance emotional and social engagement and compensate students' feelings of low self-efficacy (Martin & Rimm-Kaufman, 2015; see also Klem & Connell, 2004). In addition, the findings from Study III suggest that teacher affect and instructional behavior are connected to their students affect and thus the group performance. This finding is supported by the studies of Becker and colleagues (2014) and Meyer (2014), which also found that teachers' emotions and instructional behavior were linked to students' emotions, experiences, learning, and performance.

5.3 Methodological contributions

The methodological contributions of this dissertation expand on earlier research into affect in learning. First of all, the impact of affect on learning and performance was studied in the context where it actually occurs – the classroom (see Kim & Pekrun, 2014). The classroom context provides opportunities to gather authentic information of affect in real face-to-face collaborative learning settings, and thus the findings reflect actual affective reactions that arose in the specific situation. In addition, teachers' activities in Study III were spontaneous reactions to occurrences in the

classroom, and hence reflected expressions of the personality, working manners, and pedagogical methods of each individual teacher.

Another important methodological contribution of this dissertation is the social, interactive, and dynamic level systematic analysis of affect using a multimethod approach. In order to examine how stable affect is, evaluations were executed by using multiple measurement points. From this setting, it was possible to study the dynamic and evolving nature of affect over an extended period and to implement a micro-level analysis using both quantitative and qualitative methods. Moreover, this dissertation makes a great contribution to affective research in educational psychology by examining a wide array of discrete affective states that were experienced by students in academic settings (see Pekrun et al., 2002), specifically the small group (see, Van Kleef & Fischer, 2016) and computer-supported learning contexts (Barsade & Gibson, 2012; Lajoie et al., 2019). In addition, this dissertation contributes methodologically by unpacking the focus and distribution of guidance and support that the teachers apply in their classrooms during collaborative and computer-supported inquiry learning. This aspect has not been sufficiently examined, even though the role of the teacher has been proven important in both collaborative and computer-supported learning (e.g., Dillenbourg, 2008; Greiffenhagen, 2012). Finally, a glance at the interrelatedness of teachers and students' affect was established, broadening the almost non-existent understanding of that connection in collaborative and computer-supported contexts (see e.g., Hagenauer et al., 2015).

Distinct methods were complementary in nature, enabling the researchers to extend and deepen the understanding on affect during the classroom learning activities. In Study I, quantitative methods were implemented to an extended understanding of affect of individuals and small groups under investigation. In addition, a questionnaire assessing affect and collaboration in the small groups was validated in Study I. It is important to note that despite a different methodology and research design, the factors that were constructed for affect in Study I appeared as similar compositions as the affect labels in the PANAS-X scale for affect emphasizing Joviality, Self-Assurance, and Serenity (see Watson & Clark, 1999). Further, it was notable that one affective state, confidence, emerged as crucial for collaboration and group performance even though a wide array of discrete affective states were investigated. The findings on the valence of affect provided encouraging insights showing a dominant positive tone overall, although there were differences in group performance and achievement. It has been argued that positive affect is connected to better performance and achievement in individual mathematics and science learning (see Liu et al., 2014; Ahmed et al., 2013), but interestingly, contradictory findings in mathematics and physics education have demonstrated that positive affect does not directly predict academic achievement (Buff et al., 2011;

Linnenbrink & Pintrich, 2004; Tomas et al., 2016). Such a discrepancy calls for more coherence in scrutiny and thus more research in diverse learning settings.

In Study II, both quantitative and qualitative methods, i.e. questionnaire and video data, were used to detect affect and to examine whether students' self-reports were in line with researcher perceptions. The findings of Study II confirmed the value of both self-reports and video data analysis to examine affect, as the results appeared similar and thus reliable measures of affect. In order to examine the variations in affect within and between the distinct small groups as well as the individual differences in the groups, the affect of each group and of each individual had to be unwrapped and elaborated in three measurement points. Accordingly, Study II demonstrated that affect in a small group can be studied by in-depth analyses using multiple methods simultaneously. Tomas et al. (2016) demonstrated similar consistency in findings when using multimethod approaches such as self-reports, video analysis, and interviews to investigate emotions in collaborative science learning. Hence, a multimethod design provides a solid basis for affect research, as distinct methods can confirm or rescind the findings and thus control the conclusions. Accordingly, self-reports and video observations should be integrated and compared when studying classroom practices (see Meyer & Turner, 2006). Another important finding of Study II was the observation that affects were not stable but changing across working phases, highlighting the experimentation phase to be more challenging than the other phases as more negative affect emerged at that point. Ahmed et al. (2013) found similar fluctuation in affect, when they studied changes in four emotions (pride, enjoyment, anxiety, boredom) during mathematics learning. This notion emphasizes the necessity to apply multiple measurement points when studying affect related to a learning process. The narratives that were introduced to specify the other findings in Study II provided an illustration of some of the situations during task performance and how those moments were related to a specific affect.

In Study III, qualitative video analyses were complemented with questionnaire data to extend understanding of the role of the teacher in that particular learning process. Methodologically, a social network analysis has been seldomly used to explore processes such as instructional practices for the teachers during small group activity, a process that was systematically examined in this study. Hence, Study III confirmed the value of social network analysis as an adequate method to investigate the interaction between the teacher and the small groups. This approach made it possible to detect whether the small groups receive teacher guidance and support equally and take into account background variables concerning students' learning characteristics simultaneously. Further, Study III demonstrated the real-time focus and distribution of teachers' guidance and support in computer-supported collaborative inquiry learning among small peer groups. Observational studies with

similar systematic analyses are scarce in the literature, as research on teacher support usually addresses classroom interactions and instructional practices, such as classroom organization or management, engagement, emotional and instructional support (e.g., Anderman et al., 2011; Fredricks et al., 2004; Greiffenhagen, 2012; Hamre et al., 2013; Malecki & Demaray, 2003; Harris & Rooks, 2010; see also Tardy, 1985). Study III extended the methodological variety of studies on teacher guidance and support, and further, used a multimethod approach for scrutiny on teacher activity and teacher perceptions. From this perspective, Study III confirmed the significant role of the teacher in collaborative learning process, and especially the impact of teacher affect and instructional behavior to both teaching quality and students' affect. As earlier research has mainly combined students' perceptions of their own affect together with their perceptions of teacher affect (e.g., Becker et al., 2014; Jiang et al., 2016: Trigwell, 2012), Study III demonstrated the congruence between student perceptions and teachers' own perceptions of their affect and guidance. This aspect has been a rather neglected area in studies on teacher affect (see, e.g., Hascher, 2010). The findings thus suggest a more comprehensive approach for research on teacher guidance and support, combined with teachers and students affect during the learning process.

5.4 Educational implications

This dissertation has several educational implications. Even though research has emphasized the importance of affect in learning (Linnenbrink-Garcia & Pekrun, 2011; Schutz & Pekrun, 2007; Trigwell et al., 2012), understanding of the impact of affect on learning is still limited, especially of the specific discrete affective states in a collaborative, computer-supported learning context (Barsade & Gibson, 2012). The research findings focused on affect in traditional classroom contexts have mainly emphasized learning anxiety (e.g., Scovel, 1978), students' interpretations of teacher expectations and feedback (e.g., Salonen et al., 1998), achievement (e.g., Pekrun et al., 2002), or motivation and interest (e.g., Ainley, 2006), and are not adequate in technology-based learning environments. Hence, the empirical findings of this dissertation documented the value of a multidimensional insight into affect in contemporary, computer-supported learning in the classroom.

One of the educational implications of this dissertation is that especially in collaborative learning, the nature of affect is not stable but appears as dynamic and evolving during the learning process. Although the affect patterns in the larger sample emerged as positive, a detailed elaboration revealed divergence in affect between distinct small groups, and huge amounts of individual differences even within a single group (Study II). Even though research on group affect and emotional collectives (e.g., Barsade & Gibson, 2012; Kelly & Barsade, 2001; Van Kleef &

Fischer, 2016) points to the need for more studies on collective affect, in-depth analyses that take into account individual differences as well require a more diversified approach. Accordingly, the findings of this dissertation regarding individual affect within small groups lead to the conclusion that differences in individual affect should be taken into account in educational contexts as well. There is evidence that affect can be contagious in groups, and thus impact individual-level attitudes and group processes such as cooperation and task performance as much for positive or negative direction (Barsade, 2002; Barsade & Knight, 2015), also in relation to collective reasoning (see, Polo et al., 2017). Hence, to support positive mood and group processes, awareness of individual affects might assist to facilitate active collaboration in small groups. Awareness of individual differences in affect together with collective affect in a group, in relation to collaboration and group performance suggest that the role of the teacher is even more important when group formations are made and in directing adequate support and guidance to the small groups. Moreover, the relevance of the task or the technology that is used in learning cannot be ignored. The vast array of research during previous decades has demonstrated that all the different dimensions in the learning context are more or less related, and thus intertwined with students' and teachers' affect. Therefore, more attention to groups' engagement, attitudes, positive atmosphere, and self-assurance should be paid, especially in teacher-led guidance and support in computer-supported learning, as evidenced in Studies I, II and III.

Given that the research has proven that the attitudes towards science learning have declined through decades (Ainley, 2006; Ainley & Ainley, 2011), the importance of affect has increased. As the findings in this dissertation indicate, self-assurance and particularly confidence appeared to influence students' scientific thinking, collaboration and thus group outcome. Study I's findings associate with other work which correlates confidence, and thus managing uncertainty, as a predictor of academic intentions and performance (Jordan & McDaniel, 2014; Sheldrake, 2016; Stankov et al, 2012), as confidence has been suggested to influence motivation to engage in the task and the learning strategies applied (Boekaerts & Rozendaal, 2010). However, overconfidence can be detrimental to learning (Dunlosky & Rawson, 2012). Even though there is not a consensus concerning the consistency between self-confidence and self-efficacy (see e.g., Bandura, 2000) as cognitive constructs, confidence as an affective state is associated with the previous findings and thus necessitates more systematic support on students' self-assurance in collaborative learning, especially related to technology. Following these, students' perceptions of their ability to master the tasks and the technology that is used in learning, is crucial. It would also be beneficial to foster a positive atmosphere in groups to promote creative thinking and problem solving, as positive affect was consistent with higher group performance (Study II).

Learning activities in the classroom are deeply intertwined with the role of the teacher as a facilitator of the learning process, and thus more attention should be directed to professional, in-service teacher's agency and those conventional teaching practices they have adopted. Based on the findings in Study III, it is evident that teaching practices vary a lot even in similar situations. When such practices are combined with group characteristics, it implies that the students have unequal opportunities to succeed with the group task, given that even undergraduate students lack collaborative skills (Kwon et al., 2014) or are not eager to learn from a technology-integrated constructivist approach (Tondeur et al., 2017). In order to encourage students to collaborate and engage with task performance, teachers should be aware of their practices and agency, and how those affect the learning performance of the small groups. It is important to note that previous research has indicated that teachers differ in their practices with the whole class but use those same practices with the small groups (Webb et al., 2009). Furthermore, as evidenced in Study III, teachers' behaviors vary between groups and they get involved with those groups that are active and most willing to collaborate. This finding is supported by earlier research (Van Leeuwen et al., 2013) showing that teachers get involved with high activity groups. However, high activity or willingness to collaborate does not automatically result in high achievement, as evidenced in Study III, but biases the division of teacher guidance and support. Accordingly, intense guidance and support from the teacher for those groups, which are better positioned from the beginning, reduces the guidance and support for the others and generates unnecessary challenges for the more vulnerable groups. Thus the aim for professional in-service teachers as well as for pre-service teacher education should be to learn how to create equal opportunities for all student groups irrespective of their abilities and activation in the beginning of the learning process, and hence, teacher guidance and support should be directed even more intensively for those groups in need. Such sensitivity would contribute to developing better learning possibilities for students and hence better attitudes toward learning.

Moreover, the significance of affect in learning should be better established especially in pre-service teacher education. As previous research has indicated, a supportive and encouraging climate with clear expectations in the classroom created by the teacher, is connected to students' motivation, engagement and achievement (Danielsen et al., 2010; Frenzel et al., 2009; Hagenauer et al., 2015; Meyer, 2014; Klem & Connell, 2004; Zhang et al., 2012). In addition, the interaction between the teacher and the students together with their affect have a reciprocal positive or negative impact to learning and instructional behaviour in the classroom (see e.g., Becker et al., 2014; Frenzel et al., 2009; Trigwell, 2012; Zembylas, 2002). Accordingly, as suggested in earlier research, in teacher education pre-service teachers should be guided to detect student emotions from the facial expressions,

gestures, postures and utterances as part of their teaching practices (see, King, Ritchie, Sandhu, Henderson & Boland, 2017). However, based on the findings of Study III, paying attention to students' affect is not sufficient and teachers should also probe their own affect as well in order to understand the causal connection for classroom interaction. Similarly, Becker and colleagues (2014) argued that teacher's affect can influence their students affect as much as their instructional behavior. Hence, teacher education should promote awareness of the significance of affect in teaching and learning and train future teachers to pay attention to and improve the emotional atmosphere in their classrooms through their own support and instructional practices.

5.5 Future directions

The findings of this dissertation expand understanding on affect in collaborative learning but also raise new questions for future research. In Studies I and II, the focus was on discrete affective states and how they were related to collaborative learning in computer-supported environment during inquiry learning in the classroom. Although those affective states were found to be significant to a certain extent, other affective states neglected in earlier research so far should be taken into account in similar learning settings. As previous research has mainly focused on achievement emotions (see, Pekrun et al., 2002) in traditional classrooms, this perspective should be broadened in future investigations to a vaster array of affective states that might be significant in computer-supported learning environments. A few insights have already been established (e.g., Baker et al., 2010; Baker et al., 2011; Graesser et al., 2014; Lajoie et al., 2019; Loderer et al., 2018) but affective states combined with valence and arousal and particularly in collaborative context considering individual differences have been left out of the scope of those studies. Given that the findings from Study I revealed the significance of confidence (see also Efklides, 2017), an affective state that is rather undervalued in previous research, studies with a wider scope could unveil other affective states significant for computer-supported learning. It is also important to note that the more findings from distinct computer-supported learning contexts are demonstrated, the more generalizable conclusions on affect in such contexts can be constructed.

Another important direction for future studies based on the findings from Studies I and II is the impact of negative affect on collaborative and computer-supported learning. The relevance of positive affect for achievement in collaborative inquiry learning was evidenced by this dissertation, and is supported by other studies (Ahmed et al., 2013; Liu et al., 2014) thus indicating a connection between higher achievement and positive affect, but emphasis on negative affect was minor. There are arguments suggesting that mild negative affect can foster learning in certain ways

(Boekaerts, 2007; Cahour, 2013; Fiedler & Beier, 2014; George & Zhou, 2002; Wortha et al., 2019), also in collaborative learning (Jordan & McDaniel, 2014), and therefore more investigations on the impact of negative affect should be conducted in the future. Although positive affect fosters learning and collaboration in multiple ways, both positive and negative affect exist in all groups irrespective of the outcome level of the group. Accordingly, not all the negative affect is detrimental for learning, but the understanding of the relationship on negative affective states and learning in small groups and in computer-supported contexts is still limited.

Interest in affect in groups has increased gradually, but the question of how to measure affect at the group level is still unanswered (Goldenberg et al., 2020). Accordingly, as one prospect, Study II in this dissertation presented an extensive insight on affect in small groups scrutinizing both collective level and individual level affect over an extended period, but more generalizable patterns cannot be made due to lack of similar studies for comparison. One of the suggestions of this dissertation is to call for more in-depth studies on both group level and individual level affect in collaborative, computer-supported learning, taking into account the valence and arousal of discrete affective states. As the dynamic and evolving nature of affect highlights fluctuation over time, scrutiny on the variation of affect is essential as well. Notably, in the studies of this dissertation, the focus was on the relationship between affect and learning, that is, the small group and the learning context, but the question of causation in emergence of specific affective states was left out of the scope. This was affected by predetermined and systematic approach in the studies, but the question remains noteworthy for future attempts to broaden the understanding of the role of affect in collaborative and technology-based learning.

While awareness of the relationship between affect and group performance in the classroom is gradually increasing with respect to high and low performance groups, in the future studies it would be essential to collect empirical evidence of affect in the average performing groups, which are the most typical in educational settings. According to the findings in this dissertation, in average performing groups, affect appears as ambivalent and diverse, thus reflecting the positioning between the extreme groups that were associated either to more positive or negative directions. What are those components, which prevent average performing groups to shift towards more positive tone and better performance? There could be associations with the attitudes, interest, motivation and the complexity of the task or technology, as was suggested in the narrative illustrations of an average performed group in Study II, thus reflecting frustration and boredom with the task. This interpretation is supported by previous research showing a causal connection between adequate challenge and positive affect (Schneider et al., 2016), and perception that unresolved obstacles might eventually lead to boredom and disengagement (D'Mello &

Graesser, 2012). It is plausible to propose that experienced affect during group performance might not always be directly related to engagement in the group performance and the quality of learning, as fun-related emotions and entertainment can disturb productive learning (see, Collins et al., 2016; Hijzen et al., 2007; Tomas et al., 2016). Hence, as demonstrated in Study I, the apparently more task-oriented affect self-assurance, which was composed of confidence and pride, predicted significantly scientific understanding, collaboration, and group outcome. However, joviality, indicating, e.g., joy, interest, and enthusiasm, was also positively related to the level of group outcome and mediated by aiming for scientific understanding. This finding relates to Hascher's (2010)'s argument, that when students' positive mood associates with less important learning topics, positive affect might detach them from learning. Therefore, the source of joy and fun-related affect and relationship to the quality of learning in collaborative and computer-supported context should be examined more closely in future research.

Finally, in Study III, the role of the teacher as guiding and supporting student groups was found to be important and individual differences between the teachers were noteworthy. Yet, the in-depth activity analysis covering the entire learning process from beginning to the conclusion was executed for four teachers as a small-scale case study, limiting the sample size. A larger sample size in a similar context would reveal patterns that are more generalizable, regarding teacher guidance and support, especially in respect of the content of teacher activity during collaborative learning. In addition, the findings from Study III demonstrated that teachers' guidance and support was mostly directed at groups perceived as active and most willing to collaborate, even though it was not explicit for all of the teachers. This finding is supported by Van Leeuwen et al., (2013) who also found that teachers were involved with high student activity groups. When groups with more challenges have less guidance and support that can be detrimental for those groups who lack competence to accomplish the task, or who possess low self-esteem (see Martin & Rimm-Kaufman, 2015). Hence, more attention should be given in future research to teacher guidance and support that is directed at those groups with low self-esteem or low self-assurance related to the task, collaboration, and technology (Studies III and I). Better self-esteem and self-assurance could strengthen students' engagement and activity with respect to collaboration, the task, and learning performance and diminish the impact of individual characteristics of the teacher.

In conclusion, the significance of affect in collaborative, computer-supported inquiry learning is evident, as the findings from three studies of this dissertation have demonstrated. In order to understand the relationship between positive and negative affect in collaborative group performance, it is essential to capture both individual and group level affect during collaborative activities. Even though group level affect appears solid, individual differences within a group can reveal a more complex

interplay and affiliations with the group outcome. When individual and group level affect are examined alongside teacher affect and guidance, a more comprehensive understanding of affect in the classroom emerges. Thus, the findings from this dissertation highlight the need for more multidimensional studies on affect in the future that unwrap the collectives in order to attain understanding of the whole.

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