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Collaborative Problem-Solving and Academic Performance of Adolescents: The role of activity achievement emotions

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ABSTRACT

This thesis examined the relative incidence, origins, and influence of achievement emotions in academic performance, including collaborative problem-solving (CPS). Achievement emotions are affective states that are linked to achievement academic, work, or sports activities (activity emotions) and their success and failure outcomes (outcome emotions) (Pekurn, 2006). In education, these emotions are experienced by students in academic situations such as studying, attending classes, completing assignments, or taking exams (Pekrun & Stephens, 2010). Recent evidence suggests that achievement emotions are linked to several motivational, self-regulatory, and cognitive processes that are crucial for academic success (Loderer, Pekrun, & Lester, 2018). Despite the importance of these emotions, syntheses of empirical findings investigating their relationship with student achievement are scarce. The first empirical study within this dissertation (Chapter Four) broadly reviewed the literature on achievement emotions with a focus on activity-related emotions including enjoyment, anger, frustration, and boredom, and their links to academic achievement with two specific aims: to aggregate all studies and determine how strongly related those emotions are to academic performance, and to examine moderators of those effects (e.g., age and nationality of participants, academic levels, subject domain, type of emotion measures, type of performance measure, and published and unpublished studies). To this end, a meta-analytical review was conducted using a systematic database of 69 studies. The 69 studies included 58 independent samples for enjoyment (N = 32,034), 25 independent samples for Anger (N = 11,153), 9 independent samples for Frustration (N = 1,418) and 67 for boredom (N = 28,576). Results indicated a positive relationship between enjoyment and academic performance (ρ = .27), whereas the relations were negative for both anger (ρ = -.38) and boredom (ρ = -.25). For frustration, the relation with performance was near zero (ρ = -.02). Moderator tests revealed that the relations of activity emotions with academic performance seemed to be stronger when (a) students are in

secondary school compared to both primary and college, (b) the emotions are measured by the AEQ-M. Theoretical and practical implications are discussed

The second empirical study (Chapter Five) investigated the relationship between adolescents' activity achievement emotions and their performance in CPS activities. CPS is a new subject domain defined as a joint activity where students work together to reach a common academic goal, and it has objective social and cognitive performance dimensions (Hesse, Care, Buder, Sassenberg, & Griffin, 2012). A theoretical model was tested to investigate whether individual differences in the intensity of achievement emotions experienced by students while completing CPS tasks would be linked to their effort regulation, which in turn, would predict CPS social and cognitive performance. It was also hypothesised that students' achievement emotions would influence their levels of participation, responsiveness, and perspective-taking during the activity affecting, in turn, their final social CPS performance. The sample consisted of 100 adolescent dyads (n = 200) who completed a series of five computer-based CPS tasks while self-report questionnaires measured their enjoyment, boredom, and anger responses. Regression analysis revealed that enjoyment was associated with higher performance on both social and cognitive CPS tasks by predicting participants' effort and social interactions between problem-solving partners during the CPS tasks. This contrasted with the experience of negative emotions, including boredom and anger, which was associated with lower motivation to invest effort, which in turn was linked to more reduced cognitive CPS task performance. These findings expand existing knowledge by highlighting the importance of commonly experienced discrete achievement emotions in predicting complex students' abilities such as the critical skills for 21st-century schooling: Collaboration, Communication, Critical Thinking, and Creativity, grouped within CPS. Theoretical and practical implications are discussed.

Given the integrative role of achievement emotions in the collaborative problem-solving of adolescents, it was essential to investigate their antecedents. The third empirical study (Chapter Six) examined the incidence and origins of enjoyment, boredom, and anger experienced by adolescents in computer-based CPS tasks. It was hypothesised, that the experience of adolescents' achievement emotions would be associated with their perceived academic control and task value appraisals as suggested by the Control-Value Theory of Achievement emotions (Pekrun, 2006). The sample consisted of 200 adolescents who worked in pairs to solve a bundle of computer-based CPS tasks. During the activity, students were asked to complete self-report questionnaires to measure their emotions, academic control, and task value. Structural equation modelling results revealed that enjoyment arousal was strongly associated with students' task value and weakly related to their perceived academic control; whereas anger and boredom results showed a negative association with both control and value. Further analysis indicated that students experienced a more intense pattern of positive activating emotions (e.g., enjoyment) as opposed to less negative activating and deactivating emotions (e.g., anger and boredom respectively) providing us with the first profile of adolescents' discrete emotions in the new CPS domain. These findings contribute new information to the field of affective computing, and specifically, are relevant to the development of advanced learning technologies (ALTs) that can be used to automatically detect and respond to adolescents' emotions in CPS scenarios.

Taken together, findings from this thesis provide valuable insights into the links of activity emotions and academic achievement, as well as represent one of the first empirical attempts to investigate the role, incidence, and antecedents of affective experiences in the growing area of Collaborative learning. Implications for educationalists, programmers, game designers, and engineers in the human-computer interaction field are discussed.

Keywords: Achievement emotions; 21st-century skills; adolescents; Collaborative Learning; enjoyment; boredom; anger

DECLARATION

I, Jesus Leonardo Camacho Morles, declare that this thesis is my original work towards the award of Doctor of Philosophy except where due acknowledgment to the work of others is made in the text. The thesis is less than 100,000 words, excluding tables, figures, reference list, and appendices.

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Jesus Leonardo Camacho Morles

PREFACE

In this preface, I present a description of the work towards this thesis that was carried out in collaboration with others, indicating the nature and proportion of the contribution of others and in general terms the portions of the work, which I claim, as original.

No work towards the thesis that has been submitted for other qualifications; neither work towards the thesis that was carried out prior to enrolment in the degree. No third-party editorial assistance was provided in the preparation of the thesis.

The contributions of all persons involved in the two multi-authored articles included in the thesis are outlined in the table below.

Journal article 1: Activity achievement emotions and academic performance: A meta-analysis

Author	**Nature of the contribution**	**Proportion of the contribution**
Jesus Leonardo Camacho Morles	Research idea; Development of research questions; Systematic review and search; Research design; Data collection; Data extraction and coding; Manuscript preparation;	70%
Gavin Robert Slemp	Analysis and interpretation of research data;	15%
Reinhard Pekrun	Contributed to the theoretical framework (Control-Value theory of Achievement emotions)	10%
Lindsay Gregory Oades	Contributed to the implication of the findings for general wellbeing	5%

Journal article 2: The role of achievement emotions in the collaborative problem-solving performance of adolescents

Author	Nature of the contribution	Proportion of the contribution
Jesus Leonardo Camacho Morles	Research idea; Development of research questions; Literature review; Research design; Ethics; Recruitment of participants; Data collection; Data analysis; Manuscript preparation; Paper submission.	70%
Gavin Robert Slemp	As a supervisor, provided general advice in all stages of the research process, and contributed to the research design and data analysis.	15%
Lindsay Gregory Oades	As a supervisor, provided general advice in all stages of the research process, and contributed to the preparation of the ethics application.	5%
Lucy Morrish	Contributed to the implication of findings for emotion regulation.	5%
Claire Scoular	Contributed to the method section by describing the Collaborative problem-solving tasks' scoring procedure and calibration.	5%

Journal article 3: Relative incidence and origins of achievement emotions in computer-based collaborative problem-solving: A control-value approach

Author	Nature of the contribution	Proportion of the contribution
Jesus Leonardo Camacho Morles	Research idea; Development of research questions; Literature review; Research design; Ethics; Recruitment of participants; Data collection; Data analysis; Manuscript preparation; Paper submission.	70%
Gavin Robert Slemp	As a supervisor, provided general advice in all stages of the research process, and contributed to the research design and data analysis.	15%

Lindsay Gregory Oades	As a supervisor, provided general advice in all stages of the research process, and contributed to the preparation of the ethics application	5%
Reinhard Pekrun	Contributed to the theoretical framework (Control-Value theory of Achievement emotions)	5%
Lucy Morrish	Contributed to the implication of findings for emotion regulation.	5%

The publication status of the three chapters presented in article format within this thesis is described below:

- Chapter Four: Activity achievement emotions and academic performance: A Meta-analysis. This manuscript is currently under review at Psychological Bulletin.
- Chapter Five: The role of achievement emotions in the collaborative problem-solving performance of adolescents. Published in Learning and Individual Differences on 12/02/2019.
- Chapter Six: Relative incidence and origins of achievement emotions in computer-based collaborative problem-solving: A control-value approach. Published in Computers in Human Behavior on 30/03/2019

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Finally, I thank the children who participated in my research. I hope it contributes to their learning and success in their future lives and careers.

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CHAPTER ONE

GENERAL INTRODUCTION

Technology is transforming the way we live, learn, work, and communicate with each other. Today, routine and manual jobs performed by humans (e.g., bookkeeping and factory work lines) typical of the industrial-age are disappearing, while jobs involving more complex thinking and communication skills such as critical thinking, creativity, communication, and collaboration are in high demand (Care, Kim, Anderson, & Gustafsson-Wright, 2017). Traditionally, educational systems have been responsible for adapting their curricula to these constant and dynamic labour market requirements and for contributing to the preparation of students for the future challenges they will face in workplaces and communities. Given that today's curricula do not adequately prepare students to live and work in an information-age society (Graesser et al., 2018; Griffin, Care, & McGaw, 2012), a new set of skills need to be taught in schools in addition to traditional skills such as reading, writing, mathematics, and sciences (Slemp et al., 2017; White, Slemp, & Murray, 2017). This shift will further empower students for life in the 21st century.

Today, our lives are surrounded and shaped by collaboration. Whether at home or work, people are required to make good use of their social skills to coordinate with each other and to solve problems. Collaborative and social skills, however, have not been systematically taught at any school level, probably because they were traditionally understood as something that will develop naturally and thus did not require any further facilitation (Hesse et al., 2012). This assumption has changed, and not only have collaborative and social skills been named among the 21st century (Care et al., 2017), but it has been demonstrated that they are teachable and

measurable for large-scale assessment, and can be elicited through classroom tasks (Griffin, McGaw, & Care, 2012).

Collaboration, Communication, Critical Thinking, and Creativity (also known as the Four Cs) are considered essential skills for children and adolescents, and are also labelled as critical factors for success in the 21st century work environment (Care et al., 2017; Griffin, McGaw, et al., 2012). Consequently, several nations have incorporated these skills into their curricula and teaching pedagogy (Care, Anderson, & Kim, 2016). With the aim of teaching and assessing the four C's in schools, in 2012, a new subject domain called Collaborative Problem Solving (CPS) was created and is defined as "a joint activity where dyads or small groups execute a number of steps in order to transform a current state into a desired goal state" (Hesse et al., 2012, p. 39).

Within the CPS definition, *collaboration*, on the one hand, is defined as the activity of working together towards a common goal. According to Hesse et al. (2012), it consists of three fundamental elements. C*ommunication*, which relates to the exchange of knowledge or ideas with the aim of facilitating understanding by a recipient. In CPS contexts, this element needs to go beyond the mere exchange of opinions. It also involves *cooperation*, which implies agreement on sharing tasks or jobs. For CPS purposes, cooperation requires nuanced, responsive contributions to planning, and problem analysis. Finally, it involves *responsiveness*, implying a tendency to participate in an active and insightful way.

Problem-solving, on the other hand "is an activity in which a learner perceives a discrepancy between a current state and the desired state, recognises that this discrepancy does not have an obvious or routine solution, and subsequently tries to act upon the given situation in

order to achieve that goal state" (Hesse et al., 2012, p. 38). This concept is also comprised of mental and behavioural processes that can be summarised as an examination of the problem space to identify elements of space, recognition of patterns and relationships between elements and formulation of these into rules, generalisation, and testing of the rules (Griffin, 2014).

The stages of individual problem-solving also apply to collaborative problem-solving. The main difference between them relies on the fact that, in collaborative scenarios, each of these steps can be directly observable and measured, facilitating the assessment of problem-solving activities (Hesse et al., 2012). According to Care et al. (2012), these observable steps in the CPS process can be described as follows: a problem statement must be jointly recognised, and partners must identify and agree on which aspects of the problem each can control and monitor. A representation of the problem must be shared, and agreement on an action plan must be reached. Then, the plan must be executed, which may require a coordinated effort by collaborators acting together or in sequence; and progress towards the desired solution must be monitored, different options evaluated, plan reformulated if necessary, and decisions need to be made on how to proceed when feedback is provided.

Given its recent creation, research on CPS is scarce. The limited studies available have focused primarily on investigating how the skills of CPS can be measured and taught in the classroom (see Care, Scoular, & Griffin, 2016; Pöysä-Tarhonen, Care, Awwal, & Häkkinen, 2018; Scoular & Care, 2019), and providing immediate feedback to students on their CPS performance (Graesser et al., 2018). However, research on the links between CPS and student outcomes is limited. To date, there is no evidence showing how the performance of students in this new subject domain can be predicted.

Collaborative Problem-solving and achievement emotions

Among the various student factors associated with learning and performance (see Hattie, 2008 for a review), student emotions deserve special attention as evidence shows they affect several cognitive and self-regulated processes which influence academic success such as motivation, attention, effort regulation and engagement (Hattie, 2012; Pekrun, Goetz, Titz, & Perry, 2002; Tze, Daniels, & Klassen, 2016). In collaborative learning, for instance, the experience of enjoyment is likely to enhance task engagement and participation, which, in turn, could enhance social interaction between problem-solving partners (Kwon, Liu, & Johnson, 2014; Nelson & Sim, 2014). This is in contrast to the experience of boredom, which may reduce students' motivation to invest effort in the social and cognitive challenges that arise during collaborative learning, such as communication, sharing of ideas, and task regulation (Do & Schallert, 2004).

In this dissertation, emotions are conceptualised as processes consisting of sequential intra-organismic information processing and complex interactions between various components in response to an internal or external stimulus (Scherer, 1982, 2009). These components are cognitive appraisal or evaluation of a stimulus, physiological activation, expressive reactions, motivational tendencies, and subjective feelings. Achievement emotions, in turn, are affective states that students experience in academic achievement situations such as studying, attending classes, completing tasks, or taking tests or exams (Pekrun & Perry, 2014). Within the achievement emotion's framework (Pekrun, 2006; Pekrun et al., 2002), we can categorise emotions into two general groups, namely outcome-related and activity-related emotions. For outcome-related emotions, the focus is on whether success can be achieved in a given achievement situation. Before taking a test, for instance, a student may experience anticipatory joy because a successful outcome is perceived as achievable. For activity-related emotions, in contrast, the focus is on the activity itself and not on

the outcome of such activity. For example, a student may experience enjoyment when taking an exam because the test itself is perceived as a challenge that is enjoyable, regardless of whether a successful result is attained.

The focus of this thesis was on activity emotions such as enjoyment, anger, frustration, and boredom, as these are among the most frequently experienced by high school students in activity-related settings (Buff, 2014; Frenzel, Pekrun, & Goetz, 2007b; Tze et al., 2016). The experience of these emotions is related to the performance of the task at hand, and not necessarily to its outcome. For instance, enjoyment can be elicited when the activity itself is perceived as worth doing, even if the desired goal is not reached (Lumby, 2011). In addition, according to Pekrun (2006), enjoyment anger, frustration, and boredom, are among the most likely emotions to occur during achievement-related activities (e.g., studying, completing an assigned task), which are relevant to collaborative problem-solving settings.

Although outcome emotions (e.g., test anxiety) continue to receive most of the research attention, the last two decades have witnessed an increased interest on activity-related emotions and their influences on educational outcomes (Loderer et al., 2018). However, such studies remain narrow in focus dealing primarily with emotions in individual learning contexts. Very little is known about how achievement emotions influence the performance of students in cooperative learning settings, such as collaborative problem-solving (see Barron, 2003; Teasley, 1995; Tudge, 1992 for a few exceptions). Given the global relevance of collaborative learning in the 21st-century curricula and pedagogy (Care, Anderson, et al., 2016; Care, Scoular, et al., 2016), investigating the links between emotions and the performance of students in collaborative problem-solving activities is an urgent need. Such findings may bring insights into how discrete activity emotions influence students' social and cognitive skills that are deemed crucial for CPS

success, such as participation, perspective-taking, task regulation, and knowledge building (Hesse et al., 2012). For instance, enjoyment of the CPS activity is likely to enhance engagement, communication, and willingness to share ideas with problem-solving partners, improving in turn, CPS outcomes (Nelson & Sim, 2014).

Evidence also suggests that discrete activity emotions influence motivational and self-regulatory processes differentially which mediates learning and performance (Tze et al., 2016). Among these, effort regulation is understood as a general capability that involves student attempts to govern energy expended on doing well in schoolwork, even when this may result in confusing, dull, or uninteresting experiences (Pintrich, 2004). Thus, it is likely that effort regulation, which has also been strongly linked to educational outcomes (Donker, de Boer, Kostons, Dignath van Ewijk, & van der Werf, 2014; Hattie, 2008; Tangney, Baumeister, & Boone, 2004), may be a mediator between emotions and CPS performance. Investigating this absence of evidence is crucial because it could be demonstrated that commonly experienced emotions such as enjoyment, anger, frustration, and boredom, are associated with the performance of adolescents in CPS settings via effort regulation. This assumption would suggest that students need to be able to regulate their emotions while completing joined problem-solving activities in order to achieve good academic results. Emotion regulation refers to the ability of recognising, managing and modifying the experience of emotions to reach a personal goal (Thompson, 1994). Such findings could help principals and teachers to implement targeted emotion regulation practices and interventions in classrooms (e.g., mindfulness) to assist students controlling their emotional experiences during CPS situations, improving academic performance, as a result. An empirical study was conducted to address this critical gap and it is presented in Chapter Five of this thesis.

As the number of studies focusing on activity emotions continues to increase, one of the most significant challenges in the field is to summarise the inconsistent findings that have emerged. For instance, there is contradictory evidence on the effects of enjoyment on academic performance. Despite the majority of studies reporting a positive correlation, there are findings suggesting that positive emotions have no effect (Trevors, Muis, Pekrun, Sinatra, & Winne, 2016), or even negative relationship with learning outcomes (Ellis, Seibert, & Varner, 1995), mainly when positive emotions draw attentional resources away from the task at hand (Meinhardt & Pekrun, 2003). The argument for this non-obvious negative relationship between enjoyment and performance is that positive emotions can reduce performance on tasks that require sustained attention. A synthesis of empirical findings examining the links between activity emotions and academic performance may help to identify an overall pattern and strength of these relationships. Thus, a meta-analysis was conducted with the aim of addressing this critical gap, and it is presented in Chapter Four of this dissertation.

Given the integrative role that activity emotions play in student learning and performance, it has been critical to explore their incidence and antecedents. There has been a growing research interest in investigating the origins of achievement emotions in individual learning contexts during the last 20 years (see Frenzel, Pekrun, & Goetz, 2007a; Muis, Psaradellis, Lajoie, Di Leo, & Chevrier, 2015; Pekrun, Daniels, Goetz, Stupnisky, & Perry, 2010). However, the investigation of students' emotional arousal processes in collaborative learning scenarios has largely been overlooked. Some noticeable exceptions are qualitative efforts coming from computer-based collaborative learning studies (see Jarvenoja & Jarvela, 2005; Naykki, Jarvela, Kirschner, & Jarvenoja, 2014; Robinson, 2013; Wosnitza & Volet, 2005), which usually have adults as participants and focus on diffuse positive versus negative affect opposed to discrete emotions.

Therefore, the association between discrete activity emotions such as enjoyment, anger, frustration, and boredom, and their origins or antecedents in computer-based collaborative learning involving adolescents are yet to be explored quantitatively. A quantitative evaluation will allow for the estimation of the relative incidence of emotions in collaborative settings, and whether these emotional experiences can be predicted. Such investigation is paramount to gather evidence that can help with the development of advanced learning technologies (ALTs). The result will be to adapt automatically to students' emotion states in an effort to reduce the frequency and arousal of emotions such as boredom and anger that have been found to be harmful for learning and performance in CPS settings, and to promote the experience of beneficial emotions such as enjoyment (Camacho-Morles, Slemp, Oades, Morrish, & Scoular, 2019). We conducted an empirical study with this purpose, and it is presented in Chapter Six of this dissertation. In this study, we used the Control-value theory of achievement emotions (Pekrun, 2006) as a framework to investigate the antecedents of achievement emotions in CPS settings. This theory states that the experienced of emotions during achievement activities (e.g., studying, attending classes) is associated with two appraisal factors such as academic control or task value. Academic control refers to the perceived ability of individuals to complete the tasks at hand successfully, whereas value is linked to the relevance or importance attributed to the achievement situation (Pekrun, 2006).

Finally, evidence suggests that achievement emotions are content-domain dependent (CocoradĂ, 2016; Goetz, Frenzel, Ludtke, & Hall, 2011; Goetz, Frenzel, Pekrun, & Hall, 2006; Goetz, Frenzel, Pekrun, Hall, & Lüdtke, 2007), implying that the study of students' achievement emotions is more appropriate using domain-specific rather than domain- transcending emotional approaches. Thus, it is possible that the relative incidence of emotions may vary as a function of

whether the learning environment involves CPS. Investigating this apparent absence of evidence is pertinent because it may generate insight into academic control and value as predictors of achievement emotions experienced by adolescents in various subject domains. This, in turn, will offer useful guidance for the development of affect-sensitive advanced learning technologies (ALTs) in CPS settings, which may use student emotions to potentially facilitate optimum levels of academic control and value into the ALTs.

Based on the above considerations, this thesis aims to address the following four research questions.

1. What is the strength of the association between activity-related achievement emotions and academic performance?
2. To what extent do activity achievement emotions predict the CPS performance of adolescents, and what mechanisms mediate these relationships?
3. What are the origins and the relative incidence of activity achievement emotions experienced by adolescents during CPS activities?

Dissertation Structure

Chapter Two briefly introduces the Assessment and Teaching of the 21st Century Skills (ATC21s) project. This is necessary because this project presents the origin of the dependent variable for two of the studies: collaborative problem-solving performance. Chapter Three elaborates on the adopted definition of emotions for this study, which was the component process definition of emotions (Scherer, 2009), and moves into a more specific definition of achievement emotions and their taxonomy. It also critically reviews the issues of measuring achievement emotions in academic settings with a focus on the Achievement Emotions Questionnaire (AEQ) (Pekrun, Goetz, & Perry, 2005). Finally, this chapter presents a broad literature review of

achievement emotions and educational outcomes with a focus on enjoyment, anger, frustration and boredom.

A meta-analytical review of activity-related achievement emotions and academic performance is presented in Chapter Four (Study 1). This study aggregates all studies conducted until September 2019 with the aim of examining the direction and strength of the relationship between enjoyment, anger, frustration, and boredom, and academic achievement, and also examines different factors (e.g., age and nationality of participants, subject domain, type of emotion measure, type of outcome measure, education context or level) that may moderate these relationships.

Chapter Five comprises an empirical study that has been published in *Learning and Individual Differences* (Camacho-Morles, Slemp, Oades, Morrish, et al., 2019) (Study 2). This study aims to answer the primary research question of this dissertation by investigating the role of achievement emotions in predicting the CPS performance of adolescents, as well as the mechanisms that mediate these relationships. It reviews the literature about achievement emotions and links to educational outcomes with a focus on collaborative learning; it also presents a detailed definition and operationalisation of the multidimensional construct of CPS, including its measurement and scoring procedures. Importantly, it uses structural equation modelling to test the hypothesis that discrete activity achievement emotions differentially affect the CPS performance of adolescents via effort regulation.

Chapter Six presents another empirical study that has been published in *Computers in Human Behavior* (Camacho-Morles, Slemp, Oades, Pekrun, & Morrish, 2019) (Study 3). This paper investigates the third research question of this dissertation by examining the incidence and origins of adolescents' achievement emotions in CPS settings. It uses the Control-Value Theory

of Achievement Emotions (Pekrun, 2006) to review the literature about the emotion arousal process of students, and explores the domain-specificity of achievement emotions proposed by (Goetz et al., 2011; Goetz, Frenzel, et al., 2006) in the new subject domain of CPS. A conceptual model is tested that posits that both perceived academic control and task value appraisals are associated with the experience of discrete achievement emotions of adolescents performing CPS activities.

Chapter Seven provides an overall discussion of the dissertation and offers general commentary on the findings and implications and explores directions for future research.

To summarise, a key aim of this thesis is to investigate further the new subject domain of CPS by empirical examination of its links with discrete activity achievement emotions and effort regulation. To do so, I also conduct a systematic meta-analytic examination of activity achievement emotions in general academic performance so that it can be established whether disparate effects exist for CPS scenarios. This thesis will thus provide some of the first empirical findings into CPS and its associations with essential predictors of adolescents' outcomes, such as achievement emotions and effort regulation. In addition, this research aims to contribute to the understanding of the complex emotional arousal process of adolescents working in groups.

This thesis is presented in line with the University of Melbourne guidelines as a "thesis with publication," and, as such, two of its chapters consist of published journal articles, and another chapter consists of an article in preparation for submission.

CHAPTER TWO

THE ASSESSMENT AND TEACHING OF THE 21ST CENTURY SKILLS (ATC21s) PROJECT

Three global institutions namely Microsoft, Intel, and Cisco, collaborated with The University of Melbourne to create the Assessment and Teaching of the 21st-century skill project (ATC21S) which aimed to define the 21st century skills and to develop innovative methods for their assessment and teaching. The project was launched at the Learning and Technology World Forum in London in 2009 and brought together more than 250 education researchers to scope what the framework of the 21st century skills was, what skills could be taught in primary and secondary education globally, and how they could be measured.

Teams were formed in all founder countries including Australia, Finland, Portugal, Singapore, England, and the USA that joined a year later; specifically, these working groups collaborated with the aim of addressing the following: a) Identification and definition of twenty-first century skills, b) the appropriate methodology of assessment, c) the influence of technology on education, d) the changes in classroom practice, and e) the issues of scale and policy development (Griffin, McGaw, et al., 2012). Finally, an executive board and an advisory panel were constituted with the participation of several global organisation such as the Organization for Economic Co-operation and Development (OECD), the International Association for the Evaluation of Educational Achievement (IEA), the United Nations Educational, Scientific and Cultural Organization (UNESCO), and the World Bank among others (Griffin, McGaw, et al., 2012).

As a result of the first stage of the project, research teams produced five conceptual documents called "The White Papers", namely *Defining Twenty-First Century Skills* (Binkley et al., 2012), *Perspectives on Methodological Issues* (Wilson et al., 2012), *Technological Issues for Computer-Based Assessmen*t (Csapó, Ainley, Bennett, Latour, & Law, 2012), *New Assessments and Environments for Knowledge Building* (Scardamalia, Bransford, Kozma, & Quellmalz, 2012), and *Policy Frameworks for New Assessments* (Darling-Hammond, 2012). These papers established the conceptual framework of the project and importantly, proposed four new groups of skills that included: ways of thinking, ways of working together, tools of working and skills for living productively in the world. According to Care, Griffin, Woods, and Mountain (2012), these could be broken down into skills and learning foci as follows:

a) *Ways of thinking*: creativity and innovation, critical thinking, problem-solving, decision-making, learning to learn, and metacognition;

b) *Ways of working*: Communication and collaboration;

c) *Tools of working:* Information and communication technology (ICT) and information literacy (including research on sources, evidence, biases, etc.); and

d) *Skills for living in the world*: citizenship (local and global), life and career, and personal and social responsibility (including cultural awareness and competence).

Two new subject domains were created to teach and assess the recently named 21st-century skills in schools. First, Collaborative problem-solving (CPS) that implies "working with others to solve a common challenge, including the contribution and exchange of ideas, knowledge, or resources in order to achieve a shared goal" (Care et al., 2012, p. 2); and Information computing and technology (ICT) literacy which includes "functioning as a consumer and producer in networks, and participating in the development of social and intellectual capital through networks" (Care et al., 2012, p. 2). For this thesis, the focus will be on CPS.

The subsequent stage of the project consisted of developing assessment tools (including learning progressions and computer-based assessment tasks) for CPS. A detailed description of the CPS theoretical framework and assessment material is presented in Chapter Five.

Finally, the content of the project has been disseminated globally by different means that including two published books: *Assessment and Teaching of 21st-Century Skills* (Griffin, McGaw, et al., 2012), and *Assessment and Teaching of 21st-Century Skills: Methods and Approach* (Griffin & Care, 2014). In addition, in 2014, the ATC21S Massive Open Online Course (MOOC) was launched enrolling thousands of students from numerous countries (see https://www.coursera.org/learn/atc21s). This MOOC was primarily designed to help teachers incorporating 21st-century skills into their pedagogy practices.

CHAPTER THREE

ACHIEVEMENT EMOTIONS

Defining emotions is complicated, particularly in terms of observable behaviours that can facilitate their measurement in school settings. In this chapter, I first address the issues and contrasting views around the definition of emotions and introduce the concept of achievement emotions. I discuss about self-report questionnaires, which, I will argue, are the most accessible method available for their measurement at schools. I finish with a broad review of the literature on achievement emotions and educational outcomes.

A Component Process Definition of Emotions

Across the literature, there is no one accepted and universal definition of emotions. This is exemplified in work undertaken by (Kleinginna & Kleinginna, 1981), who reviewed more than one hundred scientific definitions of emotions and classified them into 11 categories on the basis of the emotional phenomena or theoretical issues that were emphasised. These categories were as follows: *affective* (emphasising feelings of arousal and/or hedonic value); *cognitive* (related to appraisal and/or labelling processes); *external stimuli* (emphasising external emotion-generating stimuli); *physiological* (highlighting the internal physical mechanism of emotions); *emotional/expressive behaviour* (emphasising externally observable emotional responses); *disruptive* (emphasising disorganising or dysfunctional effects of emotion); *adaptive* (emphasising organising or functional effects of emotion); *multi-aspect* (emphasising several interrelated components of emotion); *restrictive* (distinguishing emotions from other psychological processes);

motivational (emphasising the relationship between emotion and motivation); *sceptical statements* (questioning the usefulness of the concept of emotion).

One of the *affective* definitions of emotion by James (1884, p. 41) is: "my theory… is that the bodily changes follow the perception of the exciting fact directly and that our feeling of the same changes as they occur is the emotion". A *cognitive* definition of emotion would be, for instance, "emotions have in common the fact that they involve appraisals elicited by external conditions which are of concern to us or by things which we have brought about or suffered" (Peters, 1970). A *physiological* definition is, "emotion is a behaviour that is primarily influenced by conditioned visceral responses. Our viscera are always reacting; but in emotion, their reaction affects perception, learning, thinking, and virtually everything we do" (Silverman, 1975). Emotions are, therefore, a complex, indeterminate, and elusive, yet universal, essential and exciting scientific construct.

In this dissertation, I adopted an integrative approach that describes emotions as "multi-component", coordinated processes of psychological subsystems including affective, cognitive, motivational, expressive, and peripheral physiological processes" (Pekrun, 2006, p. 316; Scherer, 2005). This multi-component process definition of emotions was adopted in order to be consistent with the existing achievement emotions literature (Pekrun, 2006, 2018), which is central to my research. In addition, this definition of emotions is arguably the most accepted among researchers in the field as it proposes a holistic approach to the measurement of emotions (Scherer, 1982).

Achievement Emotions

Within the component process definition of emotions (Scherer, 2005), an essential definition for the purpose of this study is *achievement emotions,* which are seen as emotions

directly related to achievement activities (pertaining to ongoing achievement-related activities) or achievement outcomes (referring to the outcomes of these activities) (Pekrun, 2006; Pekrun et al., 2002). Achievement emotions can be classified into three groups based on their object focus (Activity/Outcome), and timeframe (Prospective/Retrospective), namely: prospective outcome emotions (e.g., hope for success in an upcoming test), retrospective outcome emotions (e.g., shame for achieving a low score in a past exam), and activity emotions (e.g., enjoyment experienced when learning or completing classroom tasks). For prospective outcome emotions, the central point is whether success can be achieved or failure can be avoided (e.g., anticipatory anxiety), while retrospective emotions are experienced when the outcome is linked to oneself (e.g., retrospective shame), or external factors such as other people or the environment (e.g., retrospective gratitude). Finally, for activity emotions, the focus is on the action during the achievement situation rather than the outcome of such activity (e.g., boredom). From a more general psychological point of view, achievement emotions can also be defined in terms of two dimensions: valence (positive vs. negative) and arousal (activating vs. deactivating). In other words, a student's emotion can be conceptualised according to how pleasant and aroused he or she feels (Pekrun et al., 2002; Lumby, 2011). This allows, for example, distinctions to be made between positive activating emotions such as enjoyment, and unpleasant activating emotions like anger (See table 1).

Table 1

A three-dimensional taxonomy of achievement emotions

Object focus/ Timeframe	Positive (Pleasant)		Negative (Unpleasant)	
	Activating	**Deactivating**	**Activating**	**Deactivating**
Activity	Enjoyment	Relaxation	Anger Frustration	Boredom
Outcome/Prospective	Anticipatory Joy Hope	Anticipatory Relief	Anxiety	Hopelessness
Outcome/Retrospective	Joy Pride Gratitude	Contentment Relief	Shame Anger	Sadness Disappointment

Adapted from (Pekrun & Stephens, 2010).

Component Process Definitions of Activity Achievement Emotions

Based on the bidimensional circumplex model of valence and activation, we can define activity achievement emotions as follows. Enjoyment is conceptualised as an affective state of pleasure, which is perceived as positive and activating (Pekrun, 2006). Boredom is understood as an emotion consisting of negatively valenced feelings of dissatisfaction, disinterest, lack of stimulation, and low physiological arousal (Pekrun et al., 2010; Vogel-Walcutt, Fiorella, Carper, & Schatz, 2012). Anger has been defined as a negatively-valenced and high arousal affective state that may arise when students face impasses or difficulties towards a desired goal (Pekrun, 2006). Finally, frustration can be seen as a blend of anger and disappointment. As such, it can be defined as unpleasant and activating or deactivating (e.g., likely activating in most cases) (Pekrun & Stephens, 2010). Similarly to anger, it is experienced when the road to goal attainment is blocked, or it can also be associated with students' inability to reach the desired solution when performing an achievement activity (Muis et al., 2015). Table 2 illustrates the symptoms experienced by students during enjoyable, bored, and angry or frustrated emotional episodes in achievement

academic situations, in relation to the internal components of emotions proposed by Scherer (1982; 2009). Each column describes the symptoms experienced by students during activity emotion episodes associated with each of the components proposed by Scherer (1982) and Pekrun (2006).

Table 2

Examples of symptoms associated with the student experience of activity-related achievement emotions based on the component process definition of emotions

	Internal component				
Emotion	Affective	Cognitive	Motivation	Expressive	Physiological
Enjoyment	Pleasant or positive feelings of satisfaction, meaning.	Perception that the activity is understood and useful	Increased participation and willingness to invest extra effort. Desire to continue performing the tasks at hand	Smiling signalling agreement or social approach tendency. Speak faster and louder.	High arousal including feeling energised, and with a rush. Body temperature: feeling warm.
Boredom	Unpleasant feelings described as monotonous, dull, dissatisfaction, or emptiness. Perception of time going slowly	Cognitive interference (e.g., daydreaming, mind wandering). Lack of concentration and attention	Urge to change the current activity, including motivation to leave, stop or postpone class, and desires to do something else instead.	Deactivation expressions, including yawning, empty gaze, and relaxed body posture. Soft voice.	Low arousal including feeling depleted, tired, sleepy (e.g., cold hands, decreases in heart and respiratory rates)
Anger /Frustration	Negative irritating and frustrating feelings	Perception of annoyance towards the quality of tasks and material	Avoidance behaviour, including the desire to quit or stop. Also, approach behaviour such as confront teachers	Facial expressions such as frown, indicating incredulity and disagreement, or lip pressing, showing aggression tendencies. Voice signals include fast and loud speech	High autonomic arousal characterised by muscle tensing, heartbeat and breathing getting faster, sweating, and perspiring.

Note: The information presented in table 2 is a combination of the findings from Daschmann, Goetz, and Stupnisky (2014), Pekrun et al., (2010), Fontaine, Scherer, and Soriano (2013), Harley, Bouchet, Hussain, Azevedo, and Calvo (2015), and (Scherer & Fontaine, 2019).

Measuring Achievement Emotions: The Achievement Emotions Questionnaire (AEQ)

Researchers have various ways of assessing achievement emotions; these include self-report questionnaires, facial expression analysis, analysis of voice (speech), body language, posture, text, physiological signals, and brain imaging (see Calvo & D'Mello, 2010 for a comprehensive review). Amongst these methods, self-report questionnaires have been the most commonly used in academic settings, most likely because they are relatively easy to administer, cost-effective, and due to technical and logistical limitations, they are sometimes the only measure that can be used.

Most self-report questionnaires used for emotion assessment in education have been designed to measure single emotions, such as anger and boredom, with most instruments developed to individually assess anxiety (Pekrun & Buhner, 2014; Zeidner, 1998). This has created a scarcity of instruments assessing multiple emotions at the same time. The most noticeable exception of this has been the Achievement Emotions Questionnaire (AEQ) (Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011; Pekrun et al., 2002) that can be used to assess a number of discrete students' achievement emotions in three broad categories of academic situations: attending class, studying, and taking tests or completing tasks. Please see also the Academic Emotions Scale (Govaerts & Gregoire, 2008) for another validated instrument designed to assess multiple student emotions. I decided to use the AEQ for my research as it is the most well-established measure of achievement emotions in academic settings (Pekrun & Buhner, 2014), and has been validated with samples from all academic levels.

The AEQ is a multidimensional instrument initially designed to examine college students' emotions in achievement situations. In its original version, the AEQ is comprised of three sections that can be used to measure class-related, learning-related, and test-related

achievement emotions. The class-related emotions and the learning-related emotions sections consist of 80 and 75 items respectively for the assessment of eight discrete emotions, namely, enjoyment, hope, pride, anger, anxiety, shame, hopelessness, and boredom. In the test-related emotions section, comprising of 77 items, a relief scale replaces the boredom scale because boredom is thought to occur only during the achievement situation. Students respond to each statement rating their emotional experiences on a 5-point Likert scale from 1, "Strongly disagree," to 5, "Strongly agree." Reliabilities of all scales range from adequate to excellent (α=.75 to α=93) (Pekrun & Buhner, 2014; Pekrun, Goetz, & Perry, 2005). With the aim of helping students remember their emotional episodes, each of these sections consists of three blocks of items organised to measure emotions before, during and after each achievement situation (Pekrun et al., 2005; Wosnitza & Volet, 2005).

The AEQ allows researchers to vary instructions and adapt the instrument to measure the desired students' trait emotions (typical reactions in achievement situations), course-specific emotions (emotions related to a domain), and state emotions (emotions experienced at specific points of time) according to their needs. The AEQ has become one of the most commonly used multidimensional instruments for assessing emotions in academic settings worldwide. Versions of the questionnaire include adaptations for emotional assessment in different content-domains, such as The Achievement Emotions Questionnaire Mathematics (AEQ-M) (Frenzel, Thrash, Pekrun & Goetz, 2007) which is available in English, German, and Chinese, and The Achievement Emotions Questionnaire Language AEQ-L (Goetz, Pekrun, Hall, & Haag, 2006). For test-related emotions specifically, a version of the instrument was validated: The Achievement Emotions Questionnaire Test AEQ-T (Pekrun et al., 2004). Researchers have also adapted The Achievement Emotions Questionnaire for cross-cultural use, such as the AEQ-Filipino (King, 2010), the AEQ-

Chinese (Zhao & Cai, 2012), the AEQ-Japanese (池田 & Ikeda, 2015), and the AEQ-Spanish (Paoloni, Vaja, & Muñoz, 2014). Versions have also been validated for assessment of emotions in different education levels, namely, the AEQ-Elementary schools (Lichtenfeld, Pekrun, Stupnisky, Reiss, & Murayama, 2012), and the AEQ-Preadolescents (Peixoto, Mata, Monteiro, Sanches, & Pekrun, 2015). Other specialised versions include the AEQ for assessment of teacher's emotions (Hong et al., 2016), and two AEQ versions developed by Raccanello, Brondino, and Pasini (2014) that can be used to assess a broad range of achievement emotions in children with the use of pictorial representations.

Based on the multicomponent definition of achievement emotions (Scherer, 1982, 2009), a specific number of indicators within each emotional scale of the AEQ is intended to assess the internal components of emotions proposed by Scherer, namely, affective, cognitive, motivational and neurophysiological, with the exception of the expressive component which cannot be measured by means of self-report questionnaires. For example, in the boredom scale, some items are intended to assess the affective component (e.g., "I find this class fairly dull"), the cognitive component (e.g., "Because I get bored my mind begins to wander"), some items for the motivational component (e.g., "I think about what else I might be doing rather than sitting in this boring class"), and finally, there are items assessing the neurophysiological component (e.g., "I get restless because I can't wait for the class to end"). The purpose of this is to model emotions as hierarchical structures consisting of items at the lowest level nested within four latent factors. Evidence from college students' samples suggests that emotions are best modelled this way as opposed to the single latent factor model representing the emotion and all items of the scale as indicators (Pekrun et al., 2011; Pekrun et al., 2004).

However, limited research has explored the AEQ's ability to measure the internal structure of achievement emotions experienced by adolescents. Addressing this gap is vital because children tend to express their emotions more freely than adults who tend to conceal them (Ekman, 1992; Ekman & Friesen, 1969). Current findings with adult samples cannot, therefore, be generalised to younger populations, and more research on adolescents' achievement emotions is warranted and indeed needed.

To summarise, measuring achievement emotions in education settings is a complex endeavour. Although there have been contrasting views on this topic, evidence indicates that achievement emotions can be measured by assessing the changes they produce in students' internal organismic subsystems (components) as suggested by Scherer (1982, 2009). Self-report questionnaires represent the most cost-effective, accessible, and valid way of achieving this in education settings. In particular, the AEQ is a reliable and valid measure that allows several achievement emotions to be measured at the same time. Finally, I discuss the limitations of self-report questionnaires on page 121 of this dissertation.

Activity-Related Achievement Emotions and Educational Outcomes: A Literature Review

This section provides a critical overview of the current state of the literature on activity-based achievement emotions, focusing on enjoyment, anger, frustration, and boredom. I concentrate on these emotions for three key reasons. First, a vast literature already exists on test-related emotions such as anxiety, hope, and shame (Pekrun et al., 2002), whereas much less is known about activity emotions. Second, activity emotions are more relevant to the present dissertation than outcome emotions because according to Pekrun (2006, 2017), activity emotions are most likely to occur in academic achievement situations such as studying or completing learning tasks where the outcome is not the focus, but the activity itself. Finally, the review I

present in this section will set the foundation and establish the empirical background for the meta-analysis that follows in the subsequent chapter.

This literature review has three aims. First, it aims to examine how the experience of achievement emotions varies across different subject domains. This domain-specificity principle of achievement emotions (Goetz et al., 2011; Goetz, Frenzel, et al., 2006) is central to my research as it suggests that students experience different profiles of achievement emotions according to the subject-domain they work on. The second key aim is to highlight the importance of activity emotions for cognitive and self-regulatory processes, critical for learning and performance. Therefore, I review the literature with this purpose and criticise its focus, which remains narrow by primarily examining emotions in individual learning settings, mainly ignoring their role in collaborative learning contexts. I propose that emotions may also be significant predictors of learning and performance during group learning activities and discuss the relevance such findings may have for contemporary research and pedagogy. Finally, this review aims to establish the growth trajectory of studies focusing on activity emotions in the field. For this purpose, I summarise the studies investigating the links between discrete activity emotions and performance over time, discuss the distribution of studies according to the academic levels of participants (e.g., primary, secondary, college, etc.), and describe the percentage of studies based on the country of nationality of participants. I conclude by making predictions about future trends and suggestions about future research.

Domain Specificity of Achievement Emotions

Research suggests that emotions vary across different subject areas, with much of this research being led by Thomas Goetz and colleagues. Goetz et al. (2006), for example, sampled 721 high school students and examined relationships between their emotional experiences in four different domains: Mathematics, Latin, German, and English. Between-

domain correlations were found to be very weak, confirming the domain-specificity of emotions. They concluded suggesting that the study of students' emotions seems to be more appropriate using domain-specific rather than domain-transcending emotional approaches. In a similar study, Goetz et al. (2007) explored eight graders' emotions in mathematics, physics, German, and English in comparison to eleven graders'. They argued that the domain-specificity of achievement emotions might increase as a function of year level, as they found a more domain-specific pattern of emotions in the year 11 sample.

Goetz et al. (2011) further refined their research to determine if the domain-specificity of achievement emotions vary when controlling for the effect of the same instructor in different classes of mathematics and physics. In a sample of 1687 German adolescents, results between domain relations were significantly stronger in classes having the same instructor. However, they were not sufficiently strong enough to reject domain-specific conceptualisation of academic emotions. This suggests that emotions are primarily associated with the content domain, even when having the same instructor.

In addition, CocoradĂ (2016) suggests that undergraduate students may experience different sets of discrete emotions depending on the subject domain they work on. For instance, a student may report negative emotions such as boredom and anger in science courses, and positive emotions in humanistic topics. Thus, evidence suggests that emotions are linked to the context in which they are elicited. Therefore, the set of emotions students may experience when completing CPS tasks cannot be established with the present literature, which has not yet examined achievement emotions within the context of CPS. Investigating this apparent gap is pertinent, as it will increase further our understanding of the different patterns of achievement emotions experienced by adolescents in various subject domains.

This is, in turn, vital information for the development of advanced learning technologies (ALT's) designed to detect and react to students' emotions, and it would be of great value for teachers in terms of implementing emotion regulation strategies into classrooms, particularly in the context on the 21st century skills (Collaboration, Communication, Critical thinking, and Creativity) grouped within the new subject domain of CPS.

Links between Activity-Related Achievement Emotions and Educational Outcomes

Recent studies have provided valuable information on the influences of activity-related achievement emotions on student beliefs, attitudes, and dispositions. Among these, self-efficacy is understood as the student's self-belief in the ability to be successful in the completion of a given task within a specific subject domain (Bandura, 1997). Evidence suggests that this construct is positively associated with the levels of student enjoyment in different subject-domains such as mathematics (C. Kim, Park, & Cozart, 2014; Luo, Ng, Lee, & Aye, 2016), sciences (Jack, Lin, & Yore, 2014; Sakiz, 2017), physical education (Lodewyk & Muir, 2017), and computer-based learning (Artino & Jones, 2012). In contrast, self-efficacy is negatively associated with the experience of boredom (Cho & Heron, 2015; Tze, Daniels, Klassen, & Li, 2013) and anger (Obergriesser & Stoeger, 2015; Pekrun et al., 2011). These findings highlight the importance of achievement emotions for learning and performance, given that self-efficacy is considered one of the most powerful predictors of educational outcomes (Hattie, 2008).

In a similar vein, research has shown that achievement emotions influence the levels of student interest and attention to content domains as well as engagement with learning activities. Ainley and Ainley (2011), for example, analysed data from four independent samples: Colombia (N = 4,412), United States (N = 5,444), Estonia (N = 4,837), and Sweden (N = 4,351) and found that enjoyment promoted not only students' initial interest in learning about science, but also

enhanced their desire to further engage with the topic and acquire new content knowledge. This positive relationship between positive activating emotions such as enjoyment and interest and engagement has been confirmed in several similar studies (see Ahmed, Minnaert, van der Werf, & Kuyper, 2010; Ganotice, Datu, & King, 2016; Jack et al., 2014 for a few examples). The opposite has been found for boredom, which tends to undermine student engagement (Garn, Simonton, Dasingert, & Simonton, 2017), reduce on-task concentration and attention (Pekrun et al., 2010), and negatively predict study interest (Pekrun et al., 2002; Schukajlow & Rakoczy, 2016), and situation interest (e.g., interest and attention during school excursions such as visits to museums) (Stavrova & Urhahne, 2010).

There is also a growing body of literature that recognises the influence of activity-related emotions in the use of different cognitive and metacognitive learning strategies. The experience of enjoyment, for instance, has been found to promote the use of cognitive learning strategies that are beneficial for learning and achievement such as elaboration and organisation (Ahmed, van der Werf, Kuyper, & Minnaert, 2013; Artino & Jones, 2012), academic help-seeking (Sakiz, 2012), learning effort (Pinxten, Marsh, De Fraine, Van den Noortgate, & Van Damme, 2014; Richter, Lehrl, & Weinert, 2016), homework effort (Luo et al., 2016), and time management (Ranellucci, Hall, & Goetz, 2015). King and Areepattamannil (2014) suggest that students who experience enjoyment also report more use of metacognitive strategies such as planning and monitoring, which are powerful predictors of achievement (Hattie, 2008). On the other hand, negative deactivating emotions like boredom have been linked to the use of superficial and shallow cognitive learning strategies such as rehearsal (Pekrun et al., 2010), and negatively linked to elaboration (Artino, 2009; Perry, Hladkyj, Pekrun, & Pelletier, 2001) and organisation (King & Areepattamannil, 2014) as they lead students to experience irrelevant thinking, potentially creating a distraction from the task at hand (Pekrun et al., 2002). Similarly, unpleasant emotions

like anger may negatively influence effort regulation and change students' learning-style preferences (Obergriesser & Stoeger, 2015; Pekrun et al., 2011); regarding metacognition, anger has been negatively associated with planning, monitoring, and regulating strategies (King & Areepattamannil, 2014).

A great deal of previous research into achievement emotions has focused on exploring their effects on student motivation. This evidence suggests that emotions influence students intrinsic motivation to learn (e.g., intrinsic personal interest and curiosity about the content), as well as extrinsic motivation to either achieve positive educational outcomes (e.g., high letter grade or academic rewards), or to avoid punishment or adverse outcomes (e.g., poor test results) (Pekrun et al., 2002; Pekrun & Stephens, 2010). For instance, students who experience enjoyment during academic activities tend to be both intrinsically motivated to learn new things because of their own pleasure and sake, and extrinsically motivated because of their desire to attain good results (Bailey, Taasoobshirazi, & Carr, 2014; Buil, Catalan, & Martinez, 2016; Pekrun et al., 2011).

The experience of boredom, on the other hand, undermines students' intrinsic motivation as it triggers desires to escape or avoid the situation (Pekrun et al., 2010; Pekrun, Hall, Goetz, & Perry, 2014; Tze et al., 2016). Finally, for negative activating emotions like anger, findings are more complex, as it can fuel motivation to invest effort in order to achieve a particular desired goal (approach motivational orientation); while it could, in contrast, impair motivation and induce feelings to escape from an undesirable achievement situation (avoidance motivational orientation) (Carver & Harmon-Jones, 2009). These findings highlight the importance of achievement emotions in modulating students' motivation to learn.

In all, the literature reviewed here, achievement emotions are recognised as influences affecting different motivational, cognitive, and metacognitive processes associated with student

learning and performance. However, the research to date has tended to focus on emotions' influences on individual learning and performance, ignoring largely the role of emotions in the performance of students in collaborative learning scenarios. Addressing this gap is critical, given the global relevance of CPS for the assessment and teaching of the 21st-century skills in modern society. Such findings can determine whether activity emotions are associated with CPS learning and performance, increasing our understanding of such an important topic.

Activity Emotions Research: Historical Trends and Future Projections

As previously reviewed, the influence of emotions on performance is particularly relevant in academic settings, where students experience a wide range of affective states when attending classes, studying, taking tests, and completing tasks that modulate their attitudes, beliefs, motivation, effort, interest, and self-regulation of learning, among other factors that are critical for academic success. Investigating the strength of these relationships is a continuing concern within the educational psychology field that may bring insights into how principals and teachers can promote the experience of beneficial emotions and mitigate the detrimental effect that negative emotions have on student performance.

While outcome-related emotions (e.g., test anxiety, shame) have been traditionally the most highly investigated emotions (Pekrun et al., 2002), research into activity-related discrete achievement emotions has become increasingly available during the last 20 years. As a way of illustration, the following sections present a brief descriptive overview of the available literature on the associations between four discrete activity-related achievement emotions, namely, enjoyment, anger, frustration, and boredom, and objective academic performance. This review included both published and unpublished sources and was based on a systematic search of the available literature that was conducted in September 2019. The details about the search strategy,

inclusion criteria, and selection strategy are fully described in Chapter Four of this thesis.

As shown in Figure 1, the results indicate that there has been a steady rise in the number of studies investigating the links between enjoyment, anger, frustration, and boredom, and academic performance over time (See Figure 1). Given that I found studies covering more than one of the emotions of interest, from this point onwards, I report the number of independent samples in an effort to be more precise. Boredom has been the emotion receiving most of the research attention with 57 distinct studies including 67 independent samples in total, followed closely by enjoyment with 51 distinct studies (58 independent samples), there were 23 distinct studies available for anger (25 independent samples), and only nine studies for frustration with an equal number of independent samples. I believe this lack of research on frustration is due to the fact that this emotion was not initially included in the Achievement Emotion Questionnaire (Pekrun et al. 2005) even though it is considered an activity-related emotion in the Control-Value Theory of achievement emotions (Pekrun, 2006). This absence of a multi-item self-report scale to measure frustration has led researchers to use alternative emotion measures such as facial expression analysis (automated or coded by judges), which can be challenging to implement in education settings due to ethical restrictions and financial limitations. With the recent validation of the epistemic emotions scale (Pekrun, Vogl, Muis, & Sinatra, 2017), which includes a multi-item adjective scale for frustration, it is likely that the number of studies on this emotion will increase in the future.

Figure 1 shows the substantial growth in the number of studies, with a particularly sharp increase in the number of such studies from 2008 onwards. This latter growth may be attributable to the publication of the Control and Value theory of achievement emotions in 2006 (Pekrun, 2006), which posed equal importance on both outcome and activity achievement emotions.

With research devoting more attention to how affective factors such as moods, feelings, and emotions influence student learning and performance (Hattie, 2017), and also the gradual increment of research investigating the role of achievement emotions on educational outcomes (see Loderer, Pekrun & Lester, 2018), the number of studies on the topic is likely to continue increasing in the future. Finally, this proliferation of studies is producing contrasting findings that may justify the need to conduct a quantitative review of the literature to investigate the relationship between activity emotions and performance further. A synthesis of empirical findings examining these connections may help to identify an overall pattern and strength of these relationships and is the focus of the next chapter.

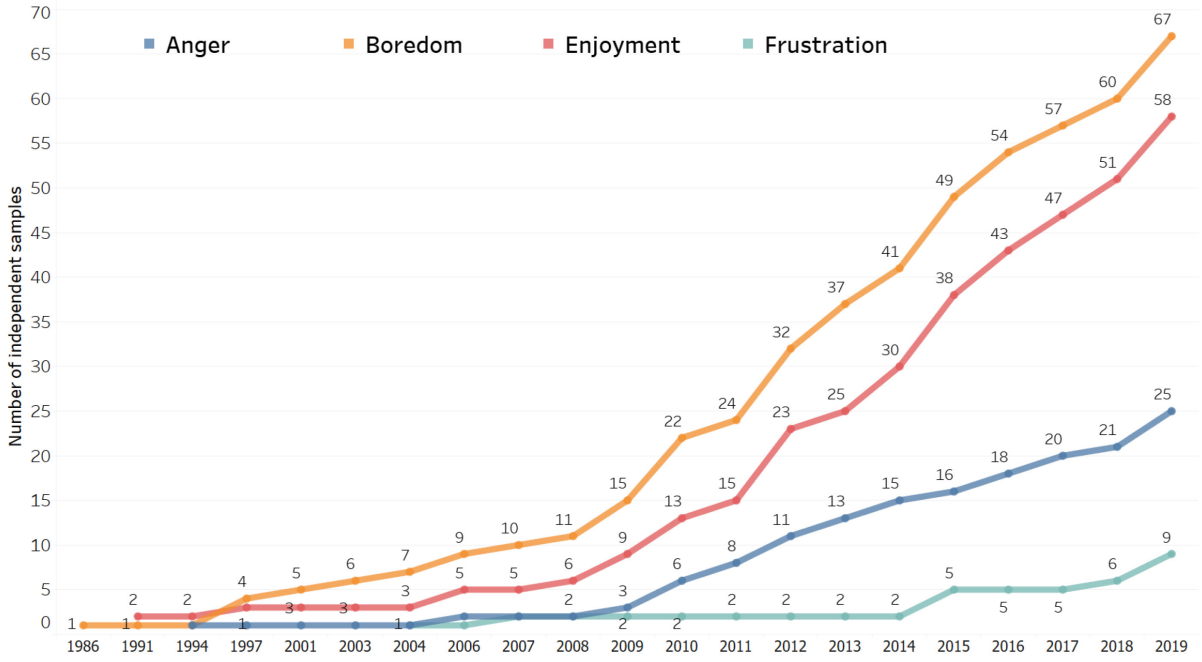

Figure 1. Studies investigating the relation between activity emotions and academic performance (displayed are the numbers of independent samples).

Figure 2 presents the breakdown of independent samples according to school levels, namely primary or elementary, secondary, and college or undergraduate. Most studies have used college students as participants with more than 70 independent samples in total. A similar but

smaller number of independent samples have explored how enjoyment, boredom, frustration, and anger, influence the performance of adolescents in secondary school, whereas considerably fewer studies have explored the role of achievement emotions in primary and elementary school settings. Considering that self-report questionnaires are the most common measures used to assess achievement emotions in academic settings, these results may be due to the fact that the Achievement Emotions Questionnaire (Pekrun et al., 2005), which has been the most widely used instrument, was initially validated with adults, while new versions of the AEQ for Pre-adolescents (Peixoto et al., 2015), and elementary school children (Lichtenfeld et al., 2012) are far more recent. This evidence shows that there is a broad research interest in investigating the links between achievement emotions and academic performance at all school levels, particularly for adolescents and adults. However, much more investigation is needed to understand the role of emotions in young populations.

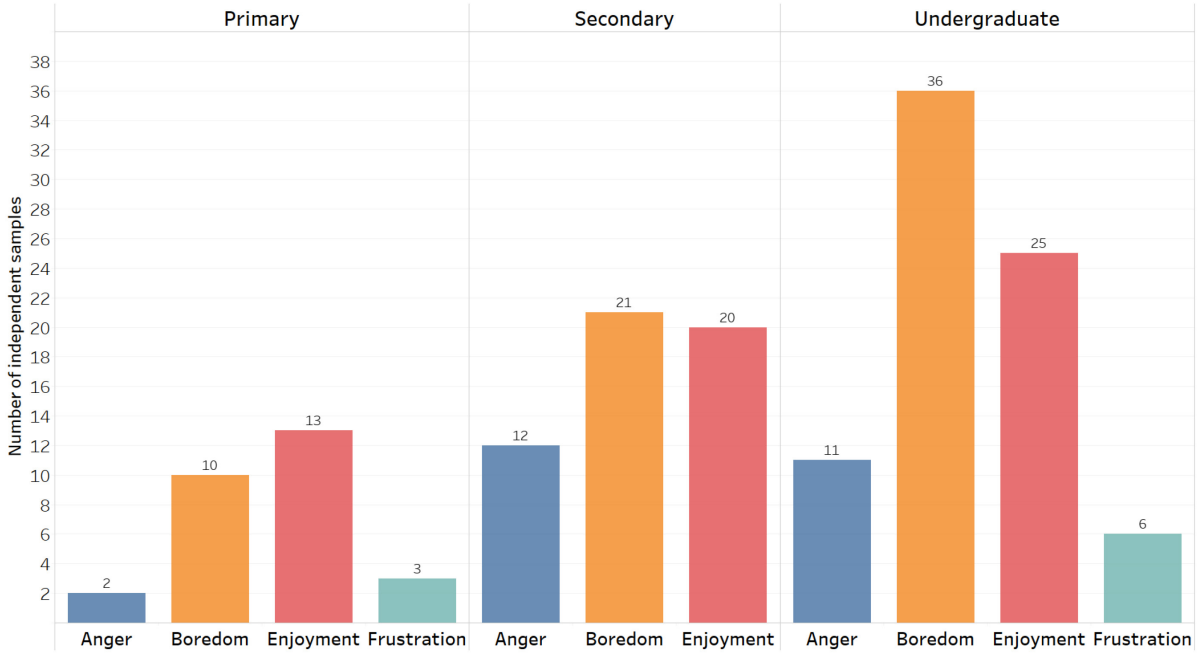

Figure 2. Number of independent samples investigating the role of activity emotions on academic performance by school settings

Figure 3 shows the distribution of research studies on this topic by the country of nationality of participants. Out of the 159 independent samples included in this quantitative analysis, almost 85% of them have used either North American or European students' samples, whereas studies from Asia, Oceania, South America, and Africa combined only account for 15%. The most significant number of studies have used North American learners, specifically from the United States of America and Canada, with 68 independent samples in total. There is also a large proportion of studies that have worked with European students, 55 independent samples in total (most of them are German students), representing 37.9%. Contrastingly, only 9.6% of studies have used student samples from Asia, including countries such as Philippines, Singapore, South Korea, Taiwan, Hong Kong, and China, combined; even fewer studies used Australian students (3.45%), whereas from South America there were only three independent samples consisting of Chilean students, representing only 2%. There were no available studies from Africa.

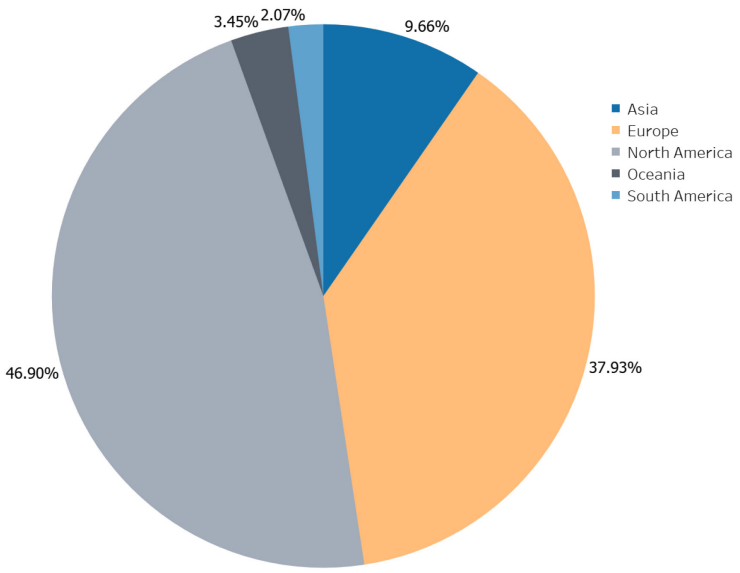

Figure 3. Percentage of independent samples investigating the role of activity emotions on academic performance by country of nationality of participants.

Although there exists a considerable proportion of studies coming out of North America and Europe, these results suggest that achievement emotion research remains a nascent field; in particular, much more research is needed to explore the influences of activity emotions in the academic performance of students in Asia, Oceania, South America, and Africa. With the recent validation of new version of the Achievement Emotions Questionnaire for Asian languages such as the AEQ-Filipino (King, 2010), the AEQ-Chinese (Zhao & Cai, 2012), and the AEQ-Japanese (池田 & Ikeda, 2015), it is likely that the number of students in those countries will increase.

CHAPTER FOUR

ACTIVITY ACHIEVEMENT EMOTIONS AND ACADEMIC PERFORMANCE: A META-ANALYSIS

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Abstract

Achievement emotions are affective states that are linked to achievement academic, work, or sports activities (activity emotions) and their success and failure outcomes (outcome emotions). In education, these emotions are experienced by students in academic situations such as studying, attending classes, completing assignments, or taking exams. Recent evidence suggests that achievement emotions are linked to several motivational, self-regulatory, and cognitive processes that are crucial for academic success. Despite the importance of these emotions, syntheses of empirical findings investigating their relationship with student achievement are scarce. We broadly review the literature on achievement emotions with a focus on activity-related emotions including enjoyment, anger, frustration, and boredom, and their links to educational outcomes with two specific aims: to aggregate all studies and determine how strongly related those emotions are to academic performance, and to examine moderators of those effects (e.g., age and nationality of participants, academic levels, subject domain, type of emotion measures, type of performance measure, and published and unpublished studies). To this end, a meta-analytical review was conducted using a systematic database of 69 studies. The 69 studies included 58 independent samples for enjoyment (N = 32,034), 25 independent samples for Anger (N = 11,153), 9 independent samples for Frustration (N = 1,418), and 67 for boredom (N = 28,576). Results indicated a positive relationship between enjoyment of learning and academic performance (ρ = **.**27), whereas the relations were negative for both anger (ρ = **-.**38) and boredom (ρ = **-.**25). For frustration, the relation with performance was near zero (ρ = **-.**02). Moderator tests revealed that the relations of activity emotions with academic performance seemed to be stronger when (a) students are in secondary school compared to both primary and college, and (b) the emotions are measured by the AEQ-M. Theoretical and practical implications are discussed.

Keywords: academic achievement; emotions; affective states; emotional states;

Achievement emotions are affective states that are linked to achievement academic, work, or sports activities and their success and failure outcomes (Pekrun, 2006). In education, these emotions are experienced by students in academic situations such as studying, attending classes, completing assignments, or taking exams (Pekrun, 2014). Within the achievement emotion's framework (Pekrun, 2006; Pekrun, Goetz, Titz, & Perry, 2002), we can categorize emotions into two general groups, namely outcome-related and activity-related emotions. For outcome-related emotions, the focus is on whether success can be achieved, or failure avoided, in a given achievement situation. Before taking a test, for instance, a student may experience anticipatory joy because a successful outcome is perceived as achievable. For activity-related emotions, in contrast, the focus is on the activity itself and not on the outcome. For example, a student may experience enjoyment when taking an exam because the test itself is perceived as a challenge that is enjoyable, regardless of whether a successful result is attained.

There is a growing body of literature that recognizes the importance of achievement emotions for educational outcomes at all levels (e.g., primary, secondary, and college). For instance, empirical research suggests that adolescents' discrete achievement emotions play a critical role in their learning and performance in traditional subject domains such as literacy, maths, and sciences (e.g., Luo, Lee, Ng, & Ong, 2014; Muis, Ranellucci, Trevors, & Duffy, 2015; Pekrun, Lichtenfeld, Marsh, Murayama, & Goetz, 2017). More recently, achievement emotions have been found to be critical factors also associated with student' competence in 21st-century skills of communication, collaboration, critical thinking, and creativity grouped within the new subject domain of collaborative problem solving (Camacho-Morles, Slemp, Oades, Morrish, & Scoular, 2019).

Although outcome-related emotions (e.g., test anxiety, pride, and shame) have been traditionally the most frequently investigated achievement emotions (Pekrun et al., 2002), the last

two decades have seen a growing trend towards the study of activity-related emotions, namely, enjoyment, anger, frustration, and boredom (See figure 1 of this dissertation). As the number of research studies focusing on these four emotions continues to increase, one of the most significant challenges in the field is to summarize the findings that have emerged. A synthesis of empirical findings examining these connections may help to identify an overall pattern and strength of these relationships. It can also help organize the literature, resolve inconsistencies between studies, yield an indication about how much predictive validity emotions might have in explaining performance, and offer directions for future research. This study was conducted with a view toward addressing these aims.

The Control-Value Theory of Achievement Emotions

The Control-Value Theory (CVT) of Achievement Emotions (Pekrun, 2006, 2018) proposes a theoretical framework that integrates constructs and assumptions from diverse theoretical approaches to emotions in education and to achievement emotions more generally (Pekrun, Frenzel, Goetz, & Perry, 2007). The central assumption of this theory is related to the arousal process of achievement emotions. It is stated that achievement emotions are elicited by two-factor appraisals. Perceived academic control, concerning to the students' belief about several external and personal factors (e.g., intellectual aptitude, educational experience, among others) that may affect the performance of individuals in achievement situations (Perry, Hladkyj, Pekrun, & Pelletier, 2001). And, Task value referring to the importance or perceived value attribute by individuals to the activities and their success and failure outcomes (Eccles & Wigfield, 1995; Pekrun, 2006). In other words, the experience achievement emotions depends on how much control individuals feel they have on achievement activities that have importance or value to them. Further, the CVT proposes the multiplicative relations of control and value, suggesting that the

intensity of positive emotions increases as it does controllability, while negative emotions will be more intense as lack of control and subjective value and higher (Pekrun et al., 2007).

Another assumption of the CVT states that achievement emotions are linked to academic engagement and achievement, and that these relationships are mediated by several cognitive and self-regulated processes that are critical for success in academic settings, such as motivation, cognitive resources, effort regulation, and use of learning strategies (Pekrun et al., 2002). Finally, the CVT assumes that the general functional mechanisms of achievement emotions are universal, meaning that emotions depend on both control and value appraisal regardless of the gender and cultural background. Specific contents and parameters of emotions (i.e., the intensity of emotions), however, may differ among individuals, gender, and culture (See Frenzel et al., 2007)

Functions of Activity Emotions for Academic Performance

Enjoyment is conceptualized as an emotion that is experienced as positive (i.e., pleasant) and activating (Pekrun, 2006). In the literature on achievement emotions, the relative importance of enjoyment for academic achievement and performance has been subject to considerable discussion. While the vast majority of studies report a moderate positive correlation between enjoyment and achievement, as it facilitates the use of flexible learning strategies and increases motivation and effort (see Ahmed, Minnaert, van der Werf, & Kuyper, 2010; Baek & Touati, 2017; Goetz, Cronjaeger, Frenzel, Ludtke, & Hall, 2010; Pekrun et al., 2017), there is also a significant amount of research evidence suggesting no correlation or even negative relationships (Beck, 2011; Chambers, 1997; Pekrun, Elliot, & Maier, 2006; Ranellucci, Hall, & Goetz, 2015). One argument for observed negative relationships between enjoyment and performance is that positive emotions can reduce performance on tasks that require sustained attention (Meinhardt & Pekrun, 2003). Also, from a mood-as-information approach, the experience of positive affect (e.g., enjoyment) during ongoing achievement activities may negatively influence motivation to invest effort and

attention (Carver & Scheier, 2001). For example, when progress towards successful completion of a task is above expectations, positive emotions arise, signalling that everything is going well, and the activity, therefore, is no longer perceived as a high priority. This 'reordering of priorities', in turn, may lead individuals to think that effort is not needed, and the attention to the task at hand is shifted, allocating cognitive resources to fulfilling other needs, compromising task performance, and achievement (Carver, 2003).

Anger has been defined as a negatively-valenced and high arousal affective state that may arise when students perceive impasses or difficulties during achievement activities as being caused by other persons, such as teacher-defined task demands that are seen as unfair (Pekrun, 2006). The mechanisms underpinning the relationship between anger and academic performance are complex. According to Pekrun (2006), anger can be detrimental for academic achievement as it reduces intrinsic motivation and promotes the use of rigid learning strategies. This is reflected in the existing evidence that shows, in most cases, a negative link between anger and achievement (Peixoto, Sanches, Mata, & Monteiro, 2017; Pekrun, Elliot, & Maier, 2009; Villavicencio & Bernardo, 2013). Given there are also studies reporting zero correlation between these two constructs (see Beck, 2011; Kirwan, 2018; Pekrun et al., 2006), there is an ongoing debate on whether the experience of anger during academic activities reduces academic performance or if there is no association between them.

Frustration also is an unpleasant emotion, which typically is activating (Pekrun & Stephens, 2010). Students experience frustration in response to obstacles that hinder successful task completion, such as the inability to reach the desired solution when performing an achievement activity (Muis et al., 2015). Although the evidence for this emotion is significantly more limited, existing findings show very weak (close to zero) correlation coefficients between frustration and academic performance (Graesser, D'Mello, Chipman, King & McDaniel, 2007;

Novak, Daday & McDaniel, 2018). Although the relationship between frustration and academic achievement can be usually assumed as unfavourable, there are authors that argue it may be beneficial for task performance. Carver and Scheier's (1998), for instance, proposed that making unsatisfactory progress (e.g., a signal of falling behind) in achievement activities elicits negative emotions (e.g., frustration), which in turn increases effort towards task completion.

Finally, *Boredom* is understood as an achievement emotion consisting of negatively valenced feelings, disinterest, lack of stimulation, and low physiological arousal (Pekrun et al., 2010; Vogel-Walcutt, Fiorella, Carper, & Schatz, 2012). One of the most significant current discussions in the academic emotion literature is the influence of boredom on learning and performance. On the one hand, a substantial body of literature has shown the adverse effects of boredom on student outcomes as it undermines attention, effort, motivation, and engagement during achievement activities as well as resulting task performance (Camacho-Morles et al., 2019; Craig, Graesser, Sullins, & Gholson, 2004; Haager, Kuhbandner, & Pekrun, 2018; Pekrun, Daniels, Goetz, Stupnisky, & Perry, 2010; Pekrun et al., 2017; Perry, Hladkyj, Pekrun, & Pelletier, 2001; Putwain, Becker, Symes, & Pekrun, 2018; Tze, Daniels, & Klassen, 2016). On the other hand, there is evidence suggesting potential benefits of boredom for academic performance as it can lead students to initiate creative processes and greater self-reflection (Mann & Cadman, 2014; Seib & Vodanovich, 1998), and can also create an urge to make changes to the current achievement situation as it may be perceived as demotivating (Bench & Lench, 2013).

Previous Meta-Analytical Studies on Achievement Activity Emotions and Educational Outcomes

The number of meta-analytic reviews investigating the relationship between activity emotions and academic achievement is minimal (only two studies, to be more specific). We review them individually, as follows. Firstly Tze et al. (2016) conducted a meta-analysis on the

links between boredom and educational outcomes. They found a moderate negative correlation between boredom and overall performance (r = -.24), as well as negative correlations with academic motivation, and study learning strategies. Loderer et al. (2019) provided a meta-analytic review of the origins and outcomes of achievement emotions in technology-related scenarios. They found a small positive correlation between enjoyment and learning outcomes (r =.18), whereas, for the rest of the discrete activity emotions, the link with academic achievement was nearly zero (anger and frustration r = -.07; boredom r = -.08).

Although these studies provide some evidence for the expected direction of associations between activity emotions and academic achievement, we feel a further meta-analysis is needed for several reasons. First, Tze et al. (2016) only investigated boredom and did not investigate other achievement emotions. Thus, we still know little about how the activity emotions of enjoyment, anger, and frustration relate to academic achievement. While Loderer et al. (2019) provided a review of a broader range of activity emotions, they only did so within technology-related learning scenarios, limiting the ability to infer to traditional learning settings. Finally, both meta-analyses did not make corrections for the biasing effects of measurement error, which is a known statistical artefact that systematically attenuates correlations. Thus, to the extent that these meta-analyses contained unreliability in the measurement instruments of performance or emotions, their correlations will be systematically biased downwards. We address this limitation by correcting for measurement error across all activity emotions.

In conclusion, despite the fact that there have been considerable efforts in summarizing the existing literature on activity emotions with the aim of addressing some of the major current concerns in the field (e.g., contrasting evidence, the role of moderatos, strength and direction of relationships), we believe that a more comprehensive study would include all activity emotions,

summarize the findings from all existing learning scenarios and environments, and investigate the moderation role of a broader range of variables.

Aims of the Present Study

We had two aims in the present study. Our first aim was to systematically locate and meta-analytically review the empirical findings on the relationship between activity achievement emotions: enjoyment, anger, frustration, and boredom, with academic achievement, quantifying the aggregate strength of associations. Second, we examine if meta-analytic associations are generalizable across age groups, country or culture, subject domains, and academic levels, and if these possible moderators can explain any heterogeneity of findings. We aim to do this because the relative universality principle of the control-value theory of achievement emotions states that these functional links between achievement emotions and academic performance are universal (see Pekrun, 2009, 2018).

Our purpose is to integrate existing findings to inform researchers, practitioners, and guide future research. In addition, while some meta-analytic research has been carried out on the relationship of achievement emotions and educational outcomes (Hembree, 1988; Tze et al., 2016), no studies cover a broad range of activity achievement emotions and explore their links with academic achievement (except for Loderer et al., 2018, who conducted a meta-analysis with an exclusive focus on emotions in technology-based scenarios).

Method

Search Strategy

Our search covered all types of scientific publications, including published journal articles and chapters, as well as unpublished material (e.g., unpublished dissertations). From this point, we refer to each of these items as a source. First, we searched online databases, including Web of

Science, Educational Resources Information Centre (ERIC), PsycINFO, and EBSCOhost, to identify both published and unpublished sources. We also searched for unpublished dissertations in ProQuest Dissertations and Theses Global. We used the following search terms in all possible pairwise combinations and various truncations: *emotion states*, *enjoyment*, *boredom*, *frustration*, *anger*, along with the linking terms*, performance, academic achievement, student,* and *school*. Other search methods included contacting principal authors in educational psychology to identify unpublished sources and reference list checking (retrospective and prospective). The search includes publications from 1986 to 2019.

Inclusion Criteria

Studies had to meet the following five criteria to be included in the meta-analysis. First, the study had to use a student sample. We limited our inclusion to studies in which samples consisted of students at any academic level, such as university or college, secondary or high school, and primary or elementary school. Studies sampling employees or other professionals, or clinical samples, were excluded. Second, because our focus was on discrete activity emotions, we included studies using any scale that measured discrete affective states. This encompassed self-reports, other-reports, and facial expression analysis. We thus excluded studies that only used physiological measures (e.g., electrodermal activity, heart rate variability, etc.) or indicators derived from neuroimaging (e.g., EEG, MRT) which do not represent discrete emotions (Calvo & D'Mello, 2010; Calvo, D'Mello, Gratch, & Kappas, 2015). We also excluded studies assessing general positive or negative affect, as well as studies using bipolar items that combine discrete emotions (e.g., happy – angry). To evaluate whether items were capturing activity emotions, we assessed the item wording to ensure it was activity- and not outcome-related. For instance, "This activity is a challenge that is enjoyable" (Pekrun, Goetz, & Perry, 2005) gives a clear indication that the emotion is related to the activity. Third, studies had to include an objective measure of

academic achievement or performance (e.g., test scores or grades). In studies with both subjective and objective measures of performance (see Daniels et al., 2008; Peixoto et al., 2017 for a couple of examples), we used the objective measure only in line with our inclusion criteria. All studies using a subjective measure of performance (e.g., perceived competence, perceived success) were excluded. Fourth, studies had to report sufficient statistical information for effect size estimation (e.g., correlation coefficients). Finally, we only included English-language publications.

Selection Strategy

The identification of sources for potential inclusion consisted of four stages, as outlined in Figure 1. Data searches were conducted in September 2019 and yielded 4,871 records. We added 19 sources based on manual searches of reference lists of articles). After removing duplicates, studies with no original data (e.g., reviews and meta-analyses), and publications that were written in a different language to English, 1,672 sources were selected for further consideration. We screened the titles and abstracts and removed 1,362 sources for failing to meet our inclusion criteria, leaving 310 sources for full-text review. Altogether, a pool of 69 sources met our inclusion criteria, which contained 58 independent samples for enjoyment (N = 32,034), 25 for anger (N = 11,153), 9 for frustration (N = 1,418), and 67 for boredom (N = 28,576).

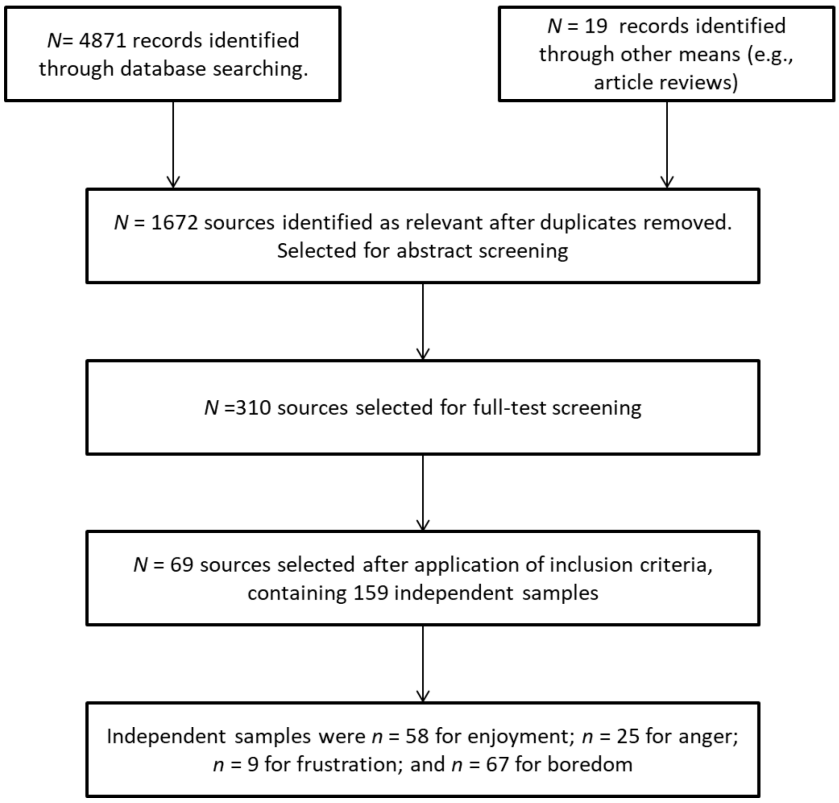

Figure 1. Diagram illustrating the process for selection of studies included in the quantitative analysis. *N* = number of sources; *n* = number of independent samples

Coding Procedure

The initial database of sources, produced by database searches and reference list snowballing, were coded by two authors using a systematic coding sheet. See Appendix A of this dissertation for our interrater agreement statistics. Disagreements were resolved by discussion. For nominal variables (subject domain, emotion measure, performance measure, nationality, context), Cohen's Kappa was computed between the two coder's ratings. Our resulting Kappa's showed solid agreement between the coders (K = .68 to .99). For continuous variables (*r*, *N*, R_{xx}, R_{yy}, Age), we calculated a two-way, absolute, single measures intraclass correlation coefficient (ICC; McGraw & Wong, 1996), which also showed solid agreement between codes (ICCs .97 to 1). We coded studies based on seven pieces of information: (a) age, (b) nationality of participants, (c)

academic levels or settings (e.g., primary, secondary, and college), (d) subject domain (e.g., maths, sciences, literacy), (e) type of emotion measures (e.g., self-report questionnaire, judgement made by raters, judgement made by peers, facial expression analysis, thinking aloud protocols, etc.), (f) type of performance measure (e.g., test scores, and grades), and (g) published and unpublished studies. Two independent coders performed the data extraction of the totality of studies coding for descriptive statistics reported on selected studies, achieving an inter-rater correlation on .97. The discrepancies between raters were later solved, and a 100% agreement was achieved.

Data Transformation

Our approach required some transformations of the data. Specifically, where necessary, we used the formulas provided by Schmidt and Hunter (2015) to aggregate within-study correlations when a study provided correlations between emotions and two or more objective measures of academic performance. Noteborn et al. (2012), for example, provided correlations between students' emotions and two metrics of student performance: a) an exam grade, and b) a class presentation grade. In this case, we used the intercorrelations between the two performance measures to arrive at composite correlations between each student's emotion and their *overall* academic performance. We followed the same procedure for all studies that used two or more measures of academic performance. In cases where the correlations between disparate measures of performance were unavailable (and authors did not respond to emails), we used a relatively conservative estimated correlation of $r = .70$ between the measures to generate the composite correlations with emotions (Rosenthal, 1993).

Similarly, there were some studies (e.g., Goetz et al., 2010) that provided correlations between subject-level emotions and subject-level performance across several different subject domains (e.g., mathematics, physics, English). In these cases, calculating composite correlations would require the aggregation of domain-specific emotions with domain-specific and domain-

irrelevant performance—which was not justifiable given the domain specificity of emotions (Goetz et al., 2006). Thus, so that we could include these studies in our meta-analysis and take account of emotion-performance relations across all subject domains, in both instances where this occurred we contacted the corresponding author of the studies to request the original data, which they both provided. We then used the original data to generate the composite variables for emotions and performance across subjects for each student, which we then used to compute the composite correlations between emotions and performance for these two studies. We then entered these estimates into the meta-analysis.

Meta-Analytic Procedure

To conduct our meta-analysis, we used the Schmidt and Hunter (2015) meta-analytic procedure, using the "psychmeta" package (Dahlke & Wiernik, 2018) of R. We first calculated a sample-size weighted mean correlation between each emotion and performance, and then disattenuated both variables for measurement error. To do this, we used the reliability coefficients that were reported in the available primary studies. Because incomplete artifactual information was available, we constructed artifact distributions for reliability coefficients (see Appendix B of this dissertation for reliability distributions), and then applied artifact distribution meta-analytic methods across all variables (Schmidt, 2015). All analyses were performed with the unbiased sample variance estimator, which is the default in psychmeta (Dahlke & Wiernik, 2018). The unbiased sample variance estimator uses a *t*-distribution to estimate confidence intervals (CIs) and credibility intervals (CVs) and tends to yield less biased estimates with more conservative CIs, particularly for analyses that contain a small number of studies (*k)* (Dahlke & Wiernik, 2018).

The Schmidt and Hunter (2015) approach to meta-analysis is based on the random effects model, which allows parameters to vary across studies and provides an estimate of the variance in effect sizes. Random effect models are preferable to fixed effect models because they lead to more

accurate and generalizable estimates with more realistic confidence intervals (Field 2003; Hunter & Schmidt 2000; Kisamore & Brannick 2008; Schmidt 2010). Because random effect analyses require at least three studies, this was the minimum number required for inclusion in our study for any analysis we conducted.

For all main effect and moderator analyses, we report combined sample size (*N*), number of studies (*k*), the meta-analytic correlation corrected only for sampling error (i.e., the "bare bones" estimate: $\overline{r}$; Schmidt & Hunter, 2015), as well as the observed standard deviation SD_r and residual standard deviation (SD_{res}) of the bare bones estimate. We report the correlation corrected for both sampling and measurement error (the estimate for the true-score correlation: ρ). We also report the standard deviation (SD_ρ) and the observed standard deviation of corrected correlations (SD_{r_c}), and the 95% confidence interval for true-score correlations.

Heterogeneity was assessed in three ways. First, we report the 80% credibility interval (CV), which provides an estimate of heterogeneity around each effect size. The CV is based on SD_ρ and is interpreted such that 80% of the distribution of true score correlations (i.e., the ρ distribution) lie within this interval. Second, we use SD_ρ, which serves as an indicator of cross-study heterogeneity; greater values of SD_ρ indicate greater heterogeneity. Finally, we report I^2 (Higgins et al., 2003), which represents the percentage of variance in each effect not explained by sampling error or other study artifacts. Higgins et al. (2003) tentatively assigned benchmarks of low, moderate, and high to values of 25%, 50%, 75% for I^2, which we apply here, and examined effects of moderators wherever I^2 was at least moderate. Moderators were explored by conducting a series of meta-analyses across different levels of the moderator. We concluded that variables depended on a moderator if the separated CIs across each level of the moderator did not overlap (Borenstein et al., 2009).

Results

Study Codes and Reported Statistics

Before presenting our meta-analytic results, we first present our included sources showing their most relevant coded variables, reported statistics, and characteristics assigned (Table 1). See Appendix C of this dissertation for a list of sources eligible for inclusion in the meta-analysis

Table 1

List of studies included in the quantitative analysis showing authors, publication year, sample size, emotion, age, nationality of participants, academic level, subject-domain, type of emotion measure, type of achievement measure, and correlation coefficient.

Study	Emotion	N	Age	Nationality of participants	Academic level	Subject-domain	Type of emotion measure	Type of achievement measure	Correlation coefficient
Ahmed et al. 2010	Enjoyment	238	13.2	Netherlands	Secondary	Maths	AEQ-M	Achievement	.50
Ahmed et al. 2013	Enjoyment	495	12.8	Netherlands	Secondary	Maths	AEQ-M	Achievement	.22
Artino et al. (2010)	Enjoyment	136	not specified	USA	Undergraduate	Introduction to clinical reasoning (ICR)	AEQ	NBME shelf exam score	.19
Baek & Touati (2017)	Enjoyment	164	not specified	South Korea	Primary	Computer game	Enjoyment Scale (Fang, Chan, Brzezinski, and Nair, 2010)	Performance on game tasks	.44
Bailey et al. (2014)	Enjoyment	102	not specified	USA	Secondary	Maths	AEQ -G	Achievement in geometry	.26
Beck (2011)	Enjoyment	74	21	USA	Undergraduate	Not specified	AEQ	Final anatomy examination	.02
Behrens et al. (2019)	Enjoyment	53	23.8	Chile	Undergraduate	Nursing	AEQ	Ward round simulation performance	-.11

Study	Emotion	N	Age	Nationality of participants	Academic level	Subject-domain	Type of emotion measure	Type of achievement measure	Correlation coefficient
Bowe (2012)	Enjoyment	160	17.32	USA	Secondary	Science	AEQ- Science	Georgia high school graduation test (GHSGT), science component	.06
Butz et al. (2016)	Enjoyment	100	31.12	USA	Undergraduate	Business	AEQ	GPA	.25
Camacho-Morles et al. (2019)	Enjoyment	200	13.48	Australia	Secondary	Collaborative problem-solving	AEQ	Collaborative problem-solving performance	.40
Chevrier et al. (2019)	Enjoyment	114	21.3	Canada	Undergraduate	Literacy	Think-aloud procedure	Text comprehension achievement	-.11
Daniels et al. (2008)	Enjoyment	1002	not specified	Canada	Undergraduate	Not specified	AEQ	Cumulative GPA	.12
Daniels (2009)	Enjoyment	251	17 to 26	Canada	Undergraduate	Psychology	AEQ	Final grade	.07
Daniels et al. (2009)	Enjoyment	669	17.5	Canada	Undergraduate	Not specified	AEQ	Aggregate performance	.17
Di Leo et al. (2019)	Enjoyment	138	11	Canada	Primary	Maths	EES	Math achievement	.06
Ganotice Jr et al. (2016)	Enjoyment	341	13.53	Philippines	Secondary	Maths	AEQ-M	Maths grade	.30
Gibbons et al. (2018)	Enjoyment	758	not specified	USA	Undergraduate	Chemistry	AEQ	Exam grade	.26
Goetz et al. (2012) (sample 1)	Enjoyment	289	14.09	Germany	Secondary	German/English/Math/Physics	AEQ-M	Achievement	.15

Study	Emotion	N	Age	Nationality of participants	Academic level	Subject-domain	Type of emotion measure	Type of achievement measure	Correlation coefficient
Goetz et al. (2012) (sample 2)	Enjoyment	262	17.16	Germany	Secondary	German/English/Math/Physics	AEQ-M	Achievement	.41
Goetz et al. (2010) (sample 1)	Enjoyment	973	14.37	Germany	Secondary	English/German/Math/Physics	AEQ-M	Achievement	.19
Goetz et al. (2010) (sample 2)	Enjoyment	737	17.46	Germany	Secondary	English/German/Math/Physics	AEQ-M	Achievement	.40
Hall (2006)	Enjoyment	477	20.46	Canada	Undergraduate	Not specified	AEQ	Performance	.13
Kim et al. (2014)	Enjoyment	72	16.7	USA	Secondary	Maths	AEQ-M	Final grade score	.41
Kirwan (2018)	Enjoyment	155	Less than 30	USA	Undergraduate	Nursing	AEQ	ATI exam - nursing performance	.06
Lichtenfeld et al. (2012) (sample 1)	Enjoyment	594	9.05	Germany	Primary	Maths	AEQ-ES	Aggregate performance	.23
Lichtenfeld et al. (2012) (sample 2)	Enjoyment	595	10.1	Germany	Primary	Maths	AEQ-ES	Aggregate performance	.22
Lichtenfeld et al. (2012) (sample 3)	Enjoyment	163	8.69	USA	Elementary	Maths	AEQ-ES	Math grades	.14
Luo et al. (2014)	Enjoyment	273	14.39	Singapore	Secondary	Maths	AEQ	Achievement	.31
McGeown et al. (2015)	Enjoyment	203	6.8	UK	Primary	Reading	Enjoyment of learning to read (McGeown et al. 2015)	Word reading test	.27

Study	Emotion	N	Age	Nationality of participants	Academic level	Subject-domain	Type of emotion measure	Type of achievement measure	Correlation coefficient
Muis, Pekrun et al. (2015)	Enjoyment	439	21.77	Canada, Germany & USA	Undergraduate	Climate change	EES	Climate change task	.11
Muis, Pekrun et al. (2015)	Enjoyment	56	21.89	Canada	Undergraduate	Climate change	EES	Climate change task	.17
Muis, Psaradellis et al. (2015)	Enjoyment	79	11	Canada	Primary	Maths	EES	Math achievement	.24
Muis, Ranellucci et al. (2015) (Sample 1)	Enjoyment	31	6.13	Canada	Primary	Literacy	AEQ-ES	Performance	.25
Muis, Ranellucci et al. (2015) (Sample 2)	Enjoyment	33	5.5	Canada	Primary	Literacy	AEQ-ES	Performance	-.02
Niculescu et al. (2015)	Enjoyment	3451	19	Europe	Undergraduate	Maths	AEQ	Performance	.21
Noteborn et al. (2012)	Enjoyment	139	21.45	not specified	Undergraduate	Virtual world	AEQ	Aggregate performance	.10
Obergriesser & Stoeger (2016)	Enjoyment	200	10.24	Germany	Primary	Not specified	AEQ	GPA	.24
Peixoto et al. (2017)	Enjoyment	1219	12.53	Portugal	Secondary	Maths	AEQ-PA	Math achievement	.43
Pekrun et al. (2006)	Enjoyment	187	22.39	Germany	Undergraduate	Not specified	AEQ	GPA	.04
Pekrun et al. (2009)	Enjoyment	216	19.43	not specified	Undergraduate	Psychology	AEQ	Exam performance	.08
Pekrun et al. (2011)	Enjoyment	389	20.63	Canada	Undergraduate	Not specified	AEQ	GPA	.15
Pekrun et al. (2017)	Enjoyment	2528	15.6	Germany	Secondary	Maths	AEQ-M	End of the year grades	.45

Study	Emotion	N	Age	Nationality of participants	Academic level	Subject-domain	Type of emotion measure	Type of achievement measure	Correlation coefficient
Pinxten et al. (2014)	Enjoyment	4724	9 to 13	Belgium	Primary	Maths	The SDQ I (Marsh, 1992)	Achievement	.17
Putwain et al. (2018)	Enjoyment	1057	9.45	UK	Primary	Maths	AEQ-M	Achievement	.42
Putwain et al. (2013)	Enjoyment	200	20.44	UK	Undergraduate	Not specified	AEQ	Academic performance	.21
Raccanello et al. (2019)	Enjoyment	767	7.97	Italy	Primary	Maths	AEQ-ES	Math achievement	.12
Raker et al. (2019)	Enjoyment	553	Not specified	USA	Undergraduate	Chemistry	AEQ-OCHEM	Exam score	.16
Ranellucci, et al. (2015)	Enjoyment	138	19.75	USA	Undergraduate	Not specified	AEQ	GPA (winter 2009)	-.17
Rennie & Punch (1991) (sample 1)	Enjoyment	183	13	Australia	Secondary	Not specified	Affect scale (Rennie, 1986)	Achievement	.29
Rennie & Punch (1991) (sample 2)	Enjoyment	159	13	Australia	Secondary	Not specified	Affect scale (Rennie, 1986)	Achievement	.12
Respondek et al. (2017)	Enjoyment	883	20.23	Germany	Undergraduate	Not specified	AEQ	GPA	.06
Schukajlow & Rakoczy (2016)	Enjoyment	144	15.22	Germany	Secondary	Maths	AEQ	Performance	.21
Tan & Chun (2014)	Enjoyment	225	14.5	Singapore	Secondary	Chemistry	AEQ	Performance	.24
Tang (2019)	Enjoyment	202	18 to 25	Hong Kong	Undergraduate	Not specified	AEQ	GPA	.12
Tempelaar et al. (2012).	Enjoyment	730	20	Several	Undergraduate	Maths	AEQ	Stats exam	.20
Villavicencio & Bernardo (2016)	Enjoyment	1345	16.49	Philippines	Undergraduate	Maths	AEQ-M	Final grade	.36
Westphal et al. (2018)	Enjoyment	1803	13.8	Germany	Secondary	Maths	AEQ	Achievement	.16

Study	Emotion	N	Age	Nationality of participants	Academic level	Subject-domain	Type of emotion measure	Type of achievement measure	Correlation coefficient
Beck (2011)	Anger	74	21	USA	Undergraduate	Not specified	AEQ	Final anatomy examination	-.04
Behrens et al. (2019)	Anger	53	23.8	Chile	Undergraduate	Nursing	AEQ	Ward round simulation performance	-.26
Boekaerts (1994)	Anger	248	11.3	Netherlands	Primary	Not specified	Anger Expression-Control scale (Maes, Van Elderen, and Spielberger, 1987)	GPA	-.09
Bowe (2012)	Anger	160	17.3	USA	Secondary	Science	AEQ- Science	Georgia high school graduation test (GHSGT)	-.19
Camacho-Morles et al. (2019)	Anger	200	13.48	Australia	Secondary	Collaborative problem-solving	AEQ	Collaborative problem-solving performance	-.37
Cho & Heron (2015)	Anger	229	21.64	not specified	Undergraduate	Online mathematics course	AEQ	Final performance	-.24
Ganotice Jr et al. (2016)	Anger	341	13.5	Philippines	Secondary	Maths	AEQ-M	Maths grade	-.27
Goetz et al. (2012) (sample 1)	Anger	289	14.09	Germany	Secondary	German/English/Math/Physics	AEQ-M	Achievement	-.13
Goetz et al. (2012) (sample 2)	Anger	262	17.1	Germany	Secondary	German/English/Math/Physics	AEQ-M	Achievement	-.43

Study	Emotion	N	Age	Nationality of participants	Academic level	Subject-domain	Type of emotion measure	Type of achievement measure	Correlation coefficient
Goetz et al. (2010) (sample 1)	Anger	973	14.3	Germany	Secondary	English/German/Math/Physics	AEQ-M	Achievement	-.34
Goetz et al. (2010) (sample 2)	Anger	737	17.4	Germany	Secondary	English/German/Math/Physics	AEQ-M	Achievement	-.41
Kim et al. (2014)	Anger	72	16.7	USA	Secondary	Maths	AEQ-M	Final grade scores	-.51
Kirwan (2018)	Anger	155	less than 30	USA	Undergraduate	Nursing	AEQ	ATI exam - Nursing performance	-.02
Obergriesser & Stoeger (2016)	Anger	200	10.2	Germany	Primary	Not specified	AEQ	GPA	-.27
Peixoto et al. (2017)	Anger	1219	12.5	Portugal	Secondary	Maths	AEQ-PA	Math achievement	-.31
Pekrun et al. (2006)	Anger	187	22.3	Germany	Undergraduate	Not specified	AEQ	GPA	-.05
Pekrun et al. (2009)	Anger	216	19.4	not specified	Undergraduate	Psychology	AEQ	Exam performance	-.28
Pekrun et al. (2011)	Anger	389	20.6	Canada	Undergraduate	Not specified	AEQ	GPA	-.27
Pekrun et al. (2017)	Anger	2528	15.6	Germany	Secondary	Maths	AEQ-M	End of the year grades	-.42
Putwain et al. (2013)	Anger	200	20.4	UK	Undergraduate	Not specified	AEQ	Academic performance	-.16
Raker et al. (2019)	Anger	553	not specified	USA	Undergraduate	Chemistry	AEQ-OCHEM	Exam score	-.17
Stavrova & Urhahne (2010)	Anger	96	14.1	Germany	Secondary	Science	AEQ-M	Knowledge post test	-.26
Tan & Chun (2014)	Anger	225	14.5	Singapore	Secondary	Chemistry	AEQ	Chemistry performance	-.14

Study	Emotion	N	Age	Nationality of participants	Academic level	Subject-domain	Type of emotion measure	Type of achievement measure	Correlation coefficient
Tang (2019)	Anger	202	18 to 25	Hong Kong	Undergraduate	Not specified	AEQ	GPA	-.09
Villavicencio & Bernardo (2013)	Anger	1345	16.49	Philippines	Undergraduate	Maths	AEQ-M	Math performance	-.31
Chevrier et al. (2019)	Frustration	114	21.3	Canada	Undergraduate	Literacy	Think-aloud procedure	Text comprehension achievement	-.06
Craig et al. (2004)	Frustration	34		USA	Undergraduate	Reasoning, causality, and explanations	Judgement made by trained coders	Learning gains	-.06
Di Leo et al. (2019)	Frustration	138	11	Canada	Primary	Maths	EES	Math achievement	-.18
Graesser et al. (2007, July)	Frustration	30		USA	Undergraduate	Reasoning, causality, and explanations	Post-experiment Self-judgement based on video	Post test score	.04
Huang, & Yeh, (2019)	Frustration	72	10.77	Taiwan	Primary	Literacy	EATQ-R	Literacy score	-.06
Muis, Pekrun, et al. (2015) (Sample 1)	Frustration	439	21.7	Canada, Germany & USA	Undergraduate	Climate change	EES	Climate change task	.07
Muis, Pekrun, et al. (2015) (Sample 2)	Frustration	56	21.9	Canada	Undergraduate	Climate change	EES	Climate change task	-.10
Muis, Psaradellis, et al. (2015)	Frustration	79	11	Canada	Primary	Maths	EES	Math achievement	.21

Study	Emotion	N	Age	Nationality of participants	Academic level	Subject-domain	Type of emotion measure	Type of achievement measure	Correlation coefficient
Novak, Daday & McDaniel, (2018) (Sample 1)	Frustration	456	20.4	USA	Undergraduate	Medicine students	Student frustration with using e-texts scale (Novak et al. 2018)	Math scores	-.07
Ahmed et al. (2013)	Boredom	495	12.8	Netherlands	Secondary	Maths	AEQ-M	Achievement	-.26
Artino et al. (2010)	Boredom	136	Not specified	USA	Undergraduate	Introduction to clinical reasoning (ICR)	AEQ	Exam score	-.23
Bailey, Taasoobshirazi, & Carr (2014)	Boredom	102	Not specified	USA	Secondary	Maths	AEQ	Achievement	-.01
Beck, G. (2011)	Boredom	74	21	USA	Undergraduate	Not specified	AEQ	Final anatomy examination	.07
Behrens et al. (2019)	Boredom	53	23.8	Chile	Undergraduate	Nursing	AEQ	Ward round simulation performance	-.24
Bowe, M (2012)	Boredom	160	17.32	USA	Secondary	Science	AEQ- Science	Georgia high school graduation test (GHSGT), science component	-.14
Butz et al. (2016)	Boredom	100	31.12	USA	Undergraduate	Business (MBA)	AEQ	GPA	-.31

Study	Emotion	N	Age	Nationality of participants	Academic level	Subject-domain	Type of emotion measure	Type of achievement measure	Correlation coefficient
Camacho-Morles et al. (2019)	Boredom	200	13.48	Australia	Secondary	Collaborative problem-solving	AEQ	Collaborative problem-solving performance	-.38
Chevrier et al. (2019)	Boredom	114	21.3	Canada	Undergraduate	Literacy	Think-aloud procedure	Text comprehension achievement	-.09
Cho & Heron (2015)	Boredom	229	21.64	Not specified	Undergraduate	Online mathematics course	AEQ	Final performance	-.16
Cowan & Piepgrass (1997)	Boredom	159	Not specified	USA	Undergraduate	General studies	not specified	Performance	-.32
Cowan & Piepgrass (1997)	Boredom	215	Not specified	USA	Undergraduate	Science	not specified	Performance	.08
Craig et al. (2004)	Boredom	34	Not specified	USA	Undergraduate	Reasoning, causality, and explanations	Judgement made by trained coders	Learning gains	-.39
Daniels et al. (2008)	Boredom	1002	Not specified	Canada	Undergraduate	Not specified	AEQ	Aggregate performance	-.18
Daniels (2009)	Boredom	251	17 to 26	Canada	Undergraduate	Psychology	AEQ	Final grade in introductory psychology	-.33
Daniels et al. (2009)	Boredom	669	17.5	Canada	Undergraduate	Not specified	AEQ	Aggregate performance	-.31
Di Leo et al. (2019)	Boredom	138	11	Canada	Primary	Maths	EES	Math achievement	-.19

Study	Emotion	N	Age	Nationality of participants	Academic level	Subject-domain	Type of emotion measure	Type of achievement measure	Correlation coefficient
Eren, & Coskun (2016)	Boredom	557	15.58	Turkey	Secondary	Maths	Level of boredom scale (Van Tilburg & Igou, 2012)	Graded performance	-.22
Fritea & Fritea (2013)	Boredom	187	Not specified	Romania	Secondary	Literacy	AEQ	Average grades for Romanian language and literature	-.19
Ganotice Jr et al. (2016)	Boredom	341	13.53	Philippines	Secondary	Maths	AEQ-M	Maths grade	-.25
Goetz et al. (2012) (sample 1)	Boredom	289	14.09	Germany	Secondary	English/German/Math/Physics	AEQ-M	Achievement	-.08
Goetz et al. (2012) (sample 2)	Boredom	262	17.16	Germany	Secondary	English/German/Math/Physics	AEQ-M	Achievement	-.31
Goetz et al. (2010) (sample 1)	Boredom	973	14.37	Germany	Secondary	English/German/Math/Physics	AEQ	Achievement	-.22
Goetz et al. (2010) (sample 2)	Boredom	737	17.46	Germany	Secondary	English/German/Math/Physics	AEQ	Achievement	-.27
Graesser et al. (2007, July)	Boredom	30		USA	Undergraduate	Reasoning, causality, and explanations	Post-experiment Self-judgement based on video	Post test score	-.14
Hall (2006)	Boredom	477	20.46	Canada	Undergraduate	Not specified	AEQ	Performance	-.30
Kim et al. (2014)	Boredom	72	16.7	USA	Secondary	Maths	AEQ-M	Final grade scores	-.19

Study	Emotion	N	Age	Nationality of participants	Academic level	Subject-domain	Type of emotion measure	Type of achievement measure	Correlation coefficient
Kirwan (2018)	Boredom	155	Less than 30	USA	Undergraduate	Nursing	AEQ	ATI exam - nursing performance	.04
Laukenmann et al. (2003)	Boredom	600	Not specified	Germany	Secondary	Physics	Single item scale (I felt bored)	Final test in physics	-.17
Lichtenfeld et al. (2012) (sample 1)	Boredom	594	9.05	Germany	Elementary	Maths	AEQ-ES	Aggregate performance	-.21
Lichtenfeld et al. (2012) (sample 2)	Boredom	595	10.1	Germany	Elementary	Maths	AEQ-ES	Aggregate performance	-.16
Lichtenfeld et al. (2012) (sample 3)	Boredom	163	8.69	USA	Elementary	Maths	AEQ-ES	Maths grades	-.23
Luo et al. (2014)	Boredom	273	14.39	Singapore	Secondary	Maths	AEQ	Achievement	-.25
Maroldo (1986)	Boredom	223	20.13	USA	Undergraduate	Not specified	College Student Boredom Scale (No details)	GPA	-.15
Muis, Pekrun et al. (2015)	Boredom	439	21.77	Canada, Germany & USA	Undergraduate	Climate change	EES	Climate change task	-.09
Muis, Pekrun et al. (2015)	Boredom	56	21.89	Canada	Undergraduate	Climate change	EES	Climate change task	-.20
Muis, Psaradellis et al. (2015)	Boredom	79	11	Canada	Primary	Maths	EES	Math achievement	.14
Muis, Ranellucci et al. (2015)	Boredom	31	6.13	Canada	Primary	Literacy	AEQ-ES	Aggregate performance	-.47

Study	Emotion	N	Age	Nationality of participants	Academic level	Subject-domain	Type of emotion measure	Type of achievement measure	Correlation coefficient
Muis, Ranellucci et al. (2015)	Boredom	33	5.5	Canada	Primary	Literacy	AEQ-ES	Aggregate performance	.02
Niculescu et al. (2015)	Boredom	3541	19	Europe	Undergraduate	Maths	AEQ	Performance	-.20
Noteborn et al. (2012)	Boredom	139	21.45	Not specified	Undergraduate	Virtual world	AEQ	Aggregate performance	.10
Obergriesser & Stoeger (2016)	Boredom	200	10.24	Germany	Primary	Not specified	AEQ	GPA	-.18
Peixoto et al. (2017)	Boredom	1219	12.53	Portugal	Secondary	Maths	AEQ-PA	Math achievement	-.06
Pekrun et al. (2006)	Boredom	187	22.39	Germany	Undergraduate	Not specified	AEQ	GPA	-.04
Pekrun et al. (2009)	Boredom	216	19.43	Not specified	Undergraduate	Psychology	AEQ	Exam performance	-.13
Pekrun et al. (2010) (sample 1)	Boredom	122	23.43	Germany	Undergraduate	Not specified	AEQ	GPA	-.32
Pekrun et al. (2010) (sample 2)	Boredom	389	20.63	Canada	Undergraduate	Not specified	AEQ	GPA	-.24
Pekrun et al. (2010) (sample 3)	Boredom	211	19.75	Canada	Undergraduate	Not specified	AEQ	Final course grade	-.36
Pekrun et al. (2011)	Boredom	389	20.63	Canada	Undergraduate	Not specified	AEQ	GPA	-.15
Pekrun et al. (2014)	Boredom	424	20.46	Canada	Undergraduate	Psychology	AEQ	Achievement grade introductory psychology	-.31
Pekrun et al. (2017)	Boredom	2528	15.6	Germany	Secondary	Maths	AEQ-M	End of the year grades	-.45

Study	Emotion	N	Age	Nationality of participants	Academic level	Subject-domain	Type of emotion measure	Type of achievement measure	Correlation coefficient
Perry et al. (2001)	Boredom	234	19	Canada	Undergraduate	Not specified	College students' Boredom scale (Pekrun, 1993; Pekrun et al. 2002)	Final grade	-.37
Putwain et al. (2018)	Boredom	1057	9.45	UK	Primary	Maths	AEQ-M	Maths achievement	-.42
Putwain et al. (2013)	Boredom	200	20.44	UK	Undergraduate	Not specified	AEQ	Academic performance	-.10
Raccanello et al. (2019)	Boredom	767	7.97	Italy	Primary	Maths	AEQ-ES	Aggregate performance	-.17
Raker et al. (2019)	Boredom	553	Not specified	USA	Undergraduate	Chemistry	AEQ-OCHEM	Exam score	-.13
Randler, C. (2009)	Boredom	426	Not specified	Germany	Secondary	Science	Student emotions scale (Gläser-Zikuda et al., 2005)	Achievement	-.27
Ranellucci et al. (2015)	Boredom	138	19.75	USA	Undergraduate	Not specified	AEQ	GPA (winter 2009)	-.06
Respondek et al. (2017)	Boredom	883	20.23	Germany	Undergraduate	Not specified	AEQ	GPA	-.14
Schukajlow & Rakoczy (2016)	Boredom	144	15.22	Germany	Secondary	Maths	AEQ	Maths performance	-.16
Stavrova & Urhahne (2010)	Boredom	96	14.14	Germany	Secondary	Science	AEQ-M	Knowledge post test	-.08
Tang (2019)	Boredom	202	18 to 25	Hong Kong	Undergraduate	Not specified	AEQ	GPA	-.29
Tempelaar et al. (2012)	Boredom	730	20	Several	Undergraduate	Maths	AEQ	Aggregate performance	-.28

Study	Emotion	N	Age	Nationality of participants	Academic level	Subject-domain	Type of emotion measure	Type of achievement measure	Correlation coefficient
Tze et al. (2013) (sample 1)	Boredom	254	23.29	China	Undergraduate	Not specified	AEQ	GPA	-.12
Tze et al. (2013) (sample 2)	Boredom	151	21.03	Canada	Undergraduate	Not specified	AEQ	GPA	.05
Westphal et al. (2018)	Boredom	1803	13.8	Germany	Secondary	Maths	AEQ	Achievement	-.17

Note: UK = United Kingdom; USA = United States of America; AEQ = Achievement Emotions Questionnaire; AEQ-M = Achievement Emotions Questionnaire for Maths; AEQ-S = Achievement Emotions Questionnaire for Science; AEQ-PA = Achievement Emotions Questionnaire for Pre-adolescents; AEQ-ES = Achievement Emotions Questionnaire for Elementary school; AEQ-OCHEM = Achievement Emotions Questionnaire for Organic Chemistry; AEQ-G = Achievement Emotions Questionnaire for Geography; EES = Epistemic Emotion Scale; EATQ-R = Early Adolescence Temperament Questionnaire – Revised; SDQ I = Self-Description Questionnaire I

Meta-Analytic Main Effects

Meta-analytic main effect results are displayed in Table 2. We used the magnitudes of .10, .20, and .30 as benchmarks for small, moderate, and strong effect sizes (Gignac & Szodorai, 2016). As shown in the table, enjoyment exhibited a moderate positive correlation with academic performance (ρ = .27 [95% CI = .23, .32]; *k* = 58; *N* = 32,034,). In contrast, anger showed a strong negative correlation with student achievement (ρ = -.38 [95% CI = -.44, -.32]; *k* = 25; *N* = 11,153), while for boredom our results indicated a moderate negative association with academic performance (ρ = -.25 [95% CI = -.28, -.22]; *k* = 67; *N* = 28,576). Finally, frustration showed a near zero and non-significant meta-analytic correlation with academic performance (ρ = -.02 [95% CI = -.11, .07]; *k* = 9; *N* = 1,418).

Table 2

Meta-Analytic Main Effect Correlations between Enjoyment, Boredom, Anger, and Frustration with Performance in Academic Settings

Variable	***k***	***N***	$\overline{r}$	SD_r	SD_{res}	ρ	SD_{r_c}	SD_ρ	95% CI	80% CV	I^2
Enjoyment	58	32,034	.24	.14	.13	.27	.16	.15	[.23, .32]	[.08, .47]	91
Anger	25	11,153	−.32	.13	.12	−.38	.15	.15	[−.44, −.32]	[−.57, −.19]	89
Frustration	9	1,418	−.02	.10	.06	−.02	.11	.07	[−.11, .07]	[−.12, .08]	39
Boredom	67	28,576	−.23	.13	.12	−.25	.14	.13	[−.28, −.22]	[−.42, −.08]	85

Note: k = number of studies contributing to meta-analysis; *N* = total sample size; $\overline{r}$ = mean observed correlation; SD_r = observed standard deviation of r; SD_{res} = residual standard deviation of r; ρ = mean true-score correlation; SD_{r_c} = observed standard deviation of corrected correlations (r_c); SD_ρ = residual standard deviation of $\overline{\rho}$; CI = confidence interval around ρ; CV = credibility interval around ρ. Correlations corrected using artifact distributions.

Also shown in table 2 is the substantial amount of between-studies heterogeneity in the strength of the observed correlations, indicated by the broad width of the credibility intervals as well as the amount of variance in effects *not* explained by the combination of sampling and measurement error (represented by I^2). These results suggest that the substantial variability in effect sizes across studies may be caused by moderating factors, which we turn to shortly.

Moderator Analyses

We next examined whether correlations systematically varied according to the presence of potential moderating variables. Specifically, where I^2 was at least 25%, we used categorical moderator analyses to examine whether the strength of the correlations varied depending on (a) the educational context – whether samples were recruited from a primary/elementary, secondary, or tertiary setting; (b) the use of different measures to quantify achievement emotions; (c) the measure of performance (grades vs. test scores); (d) the subject domain; and (e) the country in which the study took place. We also used meta-regressions to examine whether the magnitude of correlations was related to the mean age of participants in the study samples. Table 3 displays the results of these analyses for categorical moderators.

Table 3

Moderator analysis

Moderator, Emotion, and Level	k	N	$\overline{r}$	SD_r	SD_{res}	ρ	SD_{r_c}	SD_ρ	95% CI	80% CV
EDUCATIONAL CONTEXT										
Enjoyment										
Primary	13	8 748	0.21	.10	.09	0.24	.11	.10	[0.17, 0.30]	[0.10, 0.38]
Secondary	20	10 569	0.34	.15	.15	0.39	.17	.17	[0.31, 0.47]	[0.16, 0.61]
Undergraduate	25	12 717	0.18	.10	.09	0.21	.12	.10	[0.16, 0.25]	[0.07, 0.34]
Boredom										

Moderator, Emotion, and Level	k	N	$\overline{r}$	SD_r	SD_{res}	ρ	SD_{r_c}	SD_ρ	95% CI	80% CV
Primary	10	3 657	−0.25	.13	.12	−0.27	.15	.14	[−0.38, −0.17]	[−0.46, −0.08]
Secondary	21	11 630	−0.26	.15	.14	−0.29	.16	.15	[−0.36, −0.21]	[−0.49, −0.08]
Undergraduate	36	13 289	−0.19	.10	.09	−0.21	.11	.09	[−0.25, −0.18]	[−0.34, −0.09]
Anger										
Secondary	12	7 102	−0.38	.11	.10	−0.45	.13	.12	[−0.53, −0.37]	[−0.61, −0.28]
Undergraduate	11	3 603	−0.23	.10	.08	−0.26	.12	.10	[−0.34, −0.19]	[−0.40, −0.13]
Frustration										
Primary	3	289	−.04	.20	.17	−.05	.22	.19	[−.60, .50]	[−.41, .31]
Undergraduate	6	1 129	−.01	.08	.02	−.01	.08	.02	[−.10, .07]	[−.04, .01]
EMOTION MEASURE										
Enjoyment										
AEQ	26	13 055	0.17	.08	.07	0.20	.09	.08	[0.16, 0.24]	[0.09, 0.30]
AEQ-ES	6	2 183	0.18	.06	.03	0.20	.07	.04	[0.13, 0.28]	[0.14, 0.26]
AEQ-M	11	8 337	0.41	.11	.10	0.46	.12	.12	[0.38, 0.54]	[0.30, 0.62]
EES	4	712	0.12	.06	.00	0.14	.07	.00	[0.03, 0.24]	[0.14, 0.14]
Other	10	6 528	0.17	.08	.07	0.19	.09	.08	[0.13, 0.26]	[0.08, 0.30]
Boredom										
AEQ	33	14 141	−0.20	.09	.07	−0.22	.10	.08	[−0.25, −0.19]	[−0.32, −0.12]
AEQ-ES	6	2 183	−0.18	.05	.01	−0.20	.06	.01	[−0.27, −0.14]	[−0.23, −0.18]
AEQ-M	10	6 850	−0.37	.11	.10	−0.41	.12	.11	[−0.49, −0.32]	[−0.56, −0.25]
EES	4	712	−0.09	.11	.08	−0.10	.12	.09	[−0.29, 0.09]	[−0.25, 0.04]
Other	12	4 316	−0.15	.11	.10	−0.16	.13	.11	[−0.24, −0.08]	[−0.31, −0.01]
Anger										
AEQ	12	2 330	−0.20	.11	.08	−0.23	.13	.10	[−0.31, −0.15]	[−0.37, −0.10]
Other	4	2 180	−0.24	.09	.09	−0.28	.11	.10	[−0.46, −0.11]	[−0.45, −0.12]
AEQ-M	9	6 643	−0.39	.10	.09	−0.46	.12	.11	[−0.55, −0.37]	[−0.62, −0.31]
Frustration										
EES	4	712	.02	.14	.12	.03	.15	.13	[−.22, .27]	[−.19, .24]
Other	5	706	−.06	.02	.00	−.07	.03	.00	[−.10, −.03]	[−.07, −.07]

Moderator, Emotion, and Level	k	N	$\overline{r}$	SD_r	SD_{res}	ρ	SD_{r_c}	SD_ρ	95% CI	80% CV
SUBJECT DOMAIN										
Enjoyment										
Maths	24	21 316	0.29	.13	.13	0.33	.15	.14	[0.27, 0.39]	[0.14, 0.52]
Science	6	2 038	0.21	.07	.05	0.23	.08	.06	[0.15, 0.32]	[0.15, 0.32]
Boredom										
Literacy	4	365	−0.16	.13	.09	−0.18	.15	.10	[−0.42, 0.06]	[−0.34, −0.03]
Maths	23	15 795	−0.26	.13	.12	−0.29	.14	.13	[−0.35, −0.23]	[−0.47, −0.11]
Science	6	2 050	−0.15	.10	.09	−0.16	.12	.10	[−0.28, −0.04]	[−0.31, −0.02]
Anger										
Science	4	1 034	−0.18	.04	.00	−0.21	.04	.00	[−0.27, −0.14]	[−0.21, −0.21]
Maths	10	7 995	−0.38	.10	.09	−0.44	.12	.11	[−0.53, −0.36]	[−0.60, −0.29]
NATIONALITY OF PARTICIPANTS										
Enjoyment										
Germany	12	9 195	0.30	.17	.17	0.34	.20	.19	[0.22, 0.47]	[0.08, 0.61]
Canada	11	3 239	0.12	.06	.03	0.14	.07	.03	[0.09, 0.19]	[0.10, 0.18]
United states	12	2 577	0.16	.13	.12	0.18	.15	.13	[0.08, 0.27]	[−0.00, 0.36]
Uk	3	1 460	0.37	.10	.09	0.42	.11	.10	[0.14, 0.70]	[0.22, 0.61]
Australia	3	542	0.28	.14	.12	0.32	.16	.14	[−0.07, 0.71]	[0.06, 0.58]
Boredom										
Germany	16	10 439	−0.27	.13	.13	−0.30	.15	.14	[−0.38, −0.22]	[−0.49, −0.11]
Canada	16	4 648	−0.24	.11	.10	−0.26	.12	.11	[−0.33, −0.20]	[−0.40, −0.12]
United states	16	2 480	−0.11	.14	.12	−0.12	.16	.13	[−0.21, −0.04]	[−0.30, 0.06]
Anger										
Germany	8	5 272	−0.41	.12	.12	−0.48	.14	.14	[−0.60, −0.36]	[−0.67, −0.28]
United states	5	1 014	−0.17	.13	.11	−0.19	.15	.13	[−0.38, −0.01]	[−0.39, 0.00]
Frustration										
Canada	4	387	−.05	.17	.13	−.06	.18	.14	[−.35, .23]	[−.29, .18]
United states	3	520	−.06	.03	.00	−.07	.03	.00	[−.16, .02]	[−.07, −.07]
PERFORMANCE MEASURE										
Enjoyment										

Moderator, Emotion, and Level	k	N	$\overline{r}$	SD_r	SD_{res}	ρ	SD_{r_c}	SD_ρ	95% CI	80% CV
Test score	42	21 797	0.20	.13	.12	0.23	.15	.14	[0.18, 0.28]	[0.05, 0.41]
Grades	13	8 318	0.34	.13	.12	0.39	.14	.14	[0.30, 0.48]	[0.20, 0.58]
Both	3	1 919	0.25	.04	.01	0.28	.04	.01	[0.17, 0.39]	[0.27, 0.30]
Boredom										
Test score	46	18 564	−0.21	.11	.10	−0.23	.13	.11	[−0.27, −0.19]	[−0.38, −0.08]
Grades	17	7 957	−0.27	.16	.15	−0.30	.17	.17	[−0.39, −0.21]	[−0.52, −0.08]
Both	4	2 055	−0.22	.06	.03	−0.25	.06	.04	[−0.34, −0.15]	[−0.31, −0.18]
Anger										
Test score	17	4 650	−0.30	.18	.17	−0.36	.21	.20	[−0.46, −0.25]	[−0.62, −0.09]
Grades	8	6 503	−0.34	.09	.08	−0.40	.10	.09	[−0.48, −0.31]	[−0.53, −0.27]
PUBLISHED										
Enjoyment										
Yes	52	30 751	0.25	.14	.13	0.28	.15	.15	[0.24, 0.33]	[0.09, 0.47]
No	6	1 283	0.07	.07	.00	0.08	.08	.00	[0.00, 0.16]	[0.08, 0.08]
Boredom										
Yes	61	27 293	−0.23	.12	.11	−0.25	.13	.12	[−0.29, −0.22]	[−0.41, −0.09]
No	6	1 283	−0.16	.21	.20	−0.18	.23	.22	[−0.42, 0.06]	[−0.50, 0.14]
Anger										
Yes	22	10 764	−0.33	.12	.12	−0.39	.15	.14	[−0.45, −0.32]	[−0.57, −0.21]
No	3	389	−0.09	.10	.05	−0.11	.12	.06	[−0.40, 0.18]	[−0.21, −0.01]

Results showed evidence of moderation by educational context, with secondary school settings showing significantly stronger findings for enjoyment and anger. For every emotion, tertiary settings showed the weakest effects. We also found evidence of moderation by type of emotion measure, with the AEQ-M showing stronger correlations than the other measures. This was consistent with the subject domain, where correlations in mathematics were slightly stronger than in other subjects, though these differences did not reach significance for any emotion. Moderator analysis also showed that effects were in some instances moderated by country,

including for enjoyment where effects were stronger for German than Canadian samples, and for boredom where effects were stronger for German than US samples. Finally, for enjoyment, correlations were consistently stronger for studies that quantified performance using grades rather than test scores. A similar trend can be observed for the other emotions, although the moderation was not significant with all CIs overlapping.

We also used meta-regressions to examine whether correlations were related to the mean age of participants. Results showed no evidence of moderation for enjoyment (β = -.009, *SE* = .005, [95% CI = -.019, .002]), boredom (β = .002, *SE* = .004, [95% CI = -.007, .010]), or anger (β = .008, *SE* = .009, [95% CI = -.011, .026]), with all CIs encompassing zero. We did not run this analysis for frustration due to lack of power (Keppes et al., 2012).

Publication Bias

Our final step was to test whether the studies we included in our meta-analyses represented a biased subset of the available literature. To do this, we used three approaches. First, to examine whether published and unpublished studies reported emotion-performance relations differing in effect size, we report separate meta-analytic correlations for published and unpublished sources (e.g., unpublished articles, dissertations, conference presentations). We did this whenever three or more studies were available across the published and unpublished sub-groups for an emotion. Results suggest that the effect sizes for unpublished studies are closer to zero for both enjoyment and anger, suggesting stronger effects in the published literature (Table 3).

Second, we examined each emotion for evidence of funnel plot asymmetry (Egger et al., 1997) to examine the impact of not publishing studies with weak effects (Figure 2). Funnel plots display the standard error (*SE*) of each study plotted against effect sizes. If bias is present, funnel plots show an asymmetric distribution, with small (high *SE*) studies more often showing strong rather than weak effects as compared with the average effect size. Interestingly, while the funnel

plots show some evidence of asymmetry, the direction of the asymmetry indicates smaller effects in published than in unpublished studies for enjoyment, boredom, and anger.

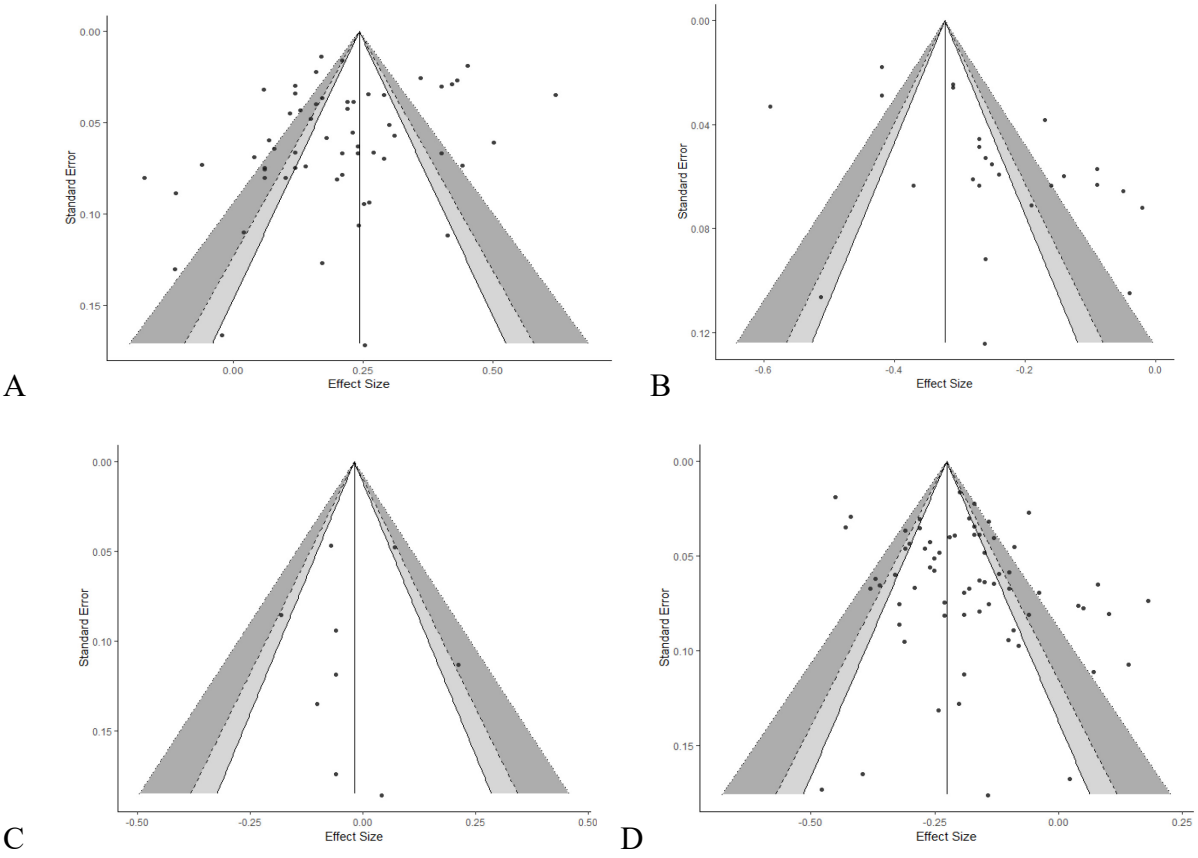

Figure 2. Funnel plot diagrams showing studies plotted against effect size and standard error. A = Enjoyment, B = Anger, C = Frustration, D = Boredom. Plots generated using barebones method.

Finally, we used cumulative meta-analysis (CMA) to examine for bias as small studies are added into the analysis (Schmidt & Hunter, 2015). In CMA, studies are ranked based on sample size and are then entered into the analysis one at a time, starting with the largest study. If publication bias is present, it will cause the mean effect size to trend upwards as smaller studies are added (Borenstein et al., 2009; Schmidt & Hunter, 2015). We compared the average effect sizes based on the largest studies (those making up the top tertile of the set), against average effects

where all studies are included. If the CIs for the two effect sizes are overlapping, then it suggests a high degree of similarity and bias is likely absent. Using this procedure, we found little evidence of bias for enjoyment (**top tertile:** k = 19, N = 24,883, ρ = .30 [CI = .22, .37]; **full set:** k = 58, N = 32,034, ρ = .27 [CI = .23, .32]); anger (**top tertile:** k = 8, N = 8,085, ρ = -.44 [CI = -.54, -.33]; **full set:** k = 25, N = 11,153, ρ = -.38 [CI = -.44, -.32]); boredom (**top tertile:** k = 22, N = 20,979 , ρ = -.27 [CI = -.33, -.22]; **full set:** k = 67, N = 58,576, ρ = -.25 [CI = -.28, -.22]), or frustration (**top tertile:** k = 3, N = 1,033, ρ = -.03 [CI = -.33, .27]; **full set:** k = 9, N = 1,418, ρ = -.02 [CI = -.11, .07]), with effect size CIs overlapping in each case. Moreover, in agreement with the funnel plots, the effect sizes in the full sets (with both large and small studies included) are closer to zero, showing evidence of smaller effects in smaller studies. Overall, we take these analyses to conclude that publication bias is not inflating effect sizes in this literature.

Discussion

The term ‘achievement emotions’ refers to affective states that learners experience when completing academic activities, namely, tests or exams, attending classes, doing homework, and studying (Pekrun, 2014). The number of studies focusing on activity emotions (e.g., enjoyment, anger, frustration, and boredom) and academic performance has increased exponentially in recent years.

This proliferation of studies, though, has observed inconsistent results that have been the subject of debate and discussion within the field. The primary objective of this work, therefore, was to aggregate all existing studies investigating the role of activity emotions and academic performance to determine the strength and general direction of these relationships. We also aimed to examine whether relevant moderators (e.g., age and nationality of participants, academic levels,

subject domain, type of emotion measures, and type of performance measure) could explain current discrepancies in the literature.

Study Findings and Contributions

Our results contribute to the literature in several ways. First, our findings affirm the positive association of enjoyment and student achievement. These findings provide further support for existing theoretical propositions stating that positive emotions are beneficial for learning and performance as they enhance attention and flexible cognition (Fredrickson & Joiner, 2002) and creative thinking (Ashby & Isen, 1999), perhaps because they strengthen intrinsic motives for learning (Ryan & Deci, 2017), facilitate the use of flexible learning strategies, and self-regulation of learning (Pekrun, 2006).

Consistent with previous meta-analytical reviews on boredom and educational outcomes (Tze et al., 2016), our results offered evidence that corroborates the detrimental impact of negative deactivating emotions such as boredom for student academic achievement. We found an almost identical but slightly stronger correlation coefficient (r = -.25) than the one reported by Tze et al., (2016) (r = -.24). All together, we can infer that student performance decreases as boredom experienced by students during class or studying increases. An explanation for these results may be that boredom reduces intrinsic motivation and engagement during academic activities (Pekrun et al., 2010), creates cognitive interference which in turn undermines on-task attention (Sarason, Pierce, & Sarason, 1996), and reduces effort regulation and task performance (Camacho-Morles, Slemp, Oades, Morrish, et al., 2019). These findings are particularly relevant in today's education as recent evidence indicates that academic boredom is not only routinely experienced (Bieg, Goetz, & Hubbard, 2013), but it is also considered a persistent or long-lasting emotion (D'Mello, Lehman, & Person, 2010).

This work confirms the negative association between negative activating emotions, such as anger and academic achievement. Out of all the activity emotions included in this review, our results showed that anger exhibited the strongest correlation with student performance. These results further support the idea that anger undermines motivation (ChanMin Kim & Hodges, 2012; Pekrun et al., 2011), and reduces students' willingness to learn (Darban & Polites, 2016), leading to low performance.

An interesting finding was that frustration, a negative activating emotion, showed no association with academic achievement. This is consistent with the literature that shows close to zero correlations between frustration and performance (see Chevrier, Muis, Trevors, Pekrun, & Sinatra, 2019; Novak & Johnson, 2012). A possible explanation for this may be that frustration has been found to be weakly associated with self-regulating learning behaviours such as metacognition (Artino & Jones, 2012), and meaningful use of learning strategies (Marchand & Gutierrez, 2012). Much more research on this emotion is needed to understand its relationship with educational outcomes better.

The relevance of activity achievement emotions is clearly supported by the current findings by showing their significant links to the performance of students in different educational contexts and levels. This was particularly strong for secondary students where emotion effects were stronger than for primary and university students. This relationship may partly be explained by the propositions made by Ekman, Friesen, and Ancoli (2001), suggesting that young adolescents experience emotions in different ways to adults who tend to conceal their feelings and emotions and are considerably less expressive. For example, students tend to enjoy learning more when they are young, whereas older adults tend to have less enjoyment (Vierhaus, Lohaus, & Wild, 2016). This lessened enjoyment in older-aged samples might create less variance in enjoyment for these

population groups, which can potentially attenuate the correlation magnitudes among such samples.

Findings emerging from this investigation indicate that the links between activity emotions and students' achievement vary depending on the subject domain and the type of emotion measure. In particular, for mathematics where the correlations between enjoyment and anger with achievement are significantly stronger than for other subject domains (e.g., literacy, science). There are several possible explanations for these results. According to the Control-value theory (Pekrun, 2006), high value combined with high academic control should lead to the enjoyment of the activity, whereas high value combined with low control may lead to anger. It is likely that students have high value for maths because they believe it encompasses skills that are critical for success in their future careers. So, it is possible that the higher value placed on numeracy skills coupled with different levels of control to successfully complete maths activities are explaining the stronger correlations between enjoyment and anger with performance on this domain.

In addition, our results indicate that activity emotions are critical factors associated with the performance of students from different countries and cultures. We found a stronger association between the performance of German and American students and their levels of boredom and anger. These results confirm previous findings indicating that mean levels of emotions vary among different countries (Anne Frenzel, T. Thrash, R. Pekrun, & T. Goetz, 2007).

In this study, the links between activity emotions and performance were found to be stronger for academic grades than for test scores. These results are likely to be related to the nature in which the performance outcomes have been measured. Grades are typically provided by the direct teacher of the students, whereas test scores provide a standardized metric to quantify student achievement or competence and are typically detached from everyday classroom activities. Grades

are more proximal measures of achievement and are thus more relevant activity-settings, whereas test scores are divorced from the actual activity.

Theoretical and Practical Implications

First, the overall findings are in line with the Control-value theory (CVT) of achievement emotions predictions. Second, they also confirm the relative universality hypothesis of CVT. The moderator analyses do not contradict this conclusion for two reasons. First, the direction of effects was consistent across moderators for all emotions, it is only the strength of relations that differed. Second, the strength of relations differed according to the domain specificity of the emotion measures used, which is as expected – higher correlations for domain-specific emotions as measured by the AEQ-M, and for studies with secondary school samples and German samples that likely used domain-specific measures (whereas studies with university students and Canadian studies likely focused on domain-general measures).

The findings of this study have several important implications for future pedagogy practice. For instance, our results suggest that achieving good academic results may depend on students' ability to regulate the set of emotions elicited by achievement activities effectively. Emotion regulation understood as a process of recognizing, managing, and modifying emotional episodes (Gross & Thompson, 2007) could assist students to successfully engage in academic achievement activities and increase performance. Teachers are encouraged to implement emotion regulation practices and interventions in the classroom in the effort to promote the occurrence of positive emotions, such as enjoyment (see reviews from Morrish, Rickard, Chin, & Vella-Brodrick, 2017; Quoidbach, Mikolajczak, & Gross, 2015), and to reduce the incidence of harmful states such as boredom and anger (e.g., mindfulness) (Broderick & Jennings, 2012). Finally, evidence suggests that teachers' affect and emotions experienced during classes are transmissible to students (Frenzel, Goetz, Ludtke, Pekrun, & Sutton, 2009). We, therefore, encourage teachers to monitor

their emotions closely (see Frenzel et al., 2016, for a scale to measure teacher emotions), as they are relevant not only for their own wellbeing but to class functioning (Frenzel, Becker-Kurz, Pekrun, Goetz, & Lüdtke, 2017).

There are also further implications for school education in terms of student learning about emotional regulation, social-emotional learning and positive education (Ng & Vella-Brodrick, 2019). These endeavours have in common the aim of enabling students to understand wellbeing better and learn skills to apply it in their own lives, including academic performance. In education contexts, wellbeing is often viewed as instrumental to student academic performance. A focus on achievement emotions provides a natural bridge between academic performance and explicit education regarding emotions and wellbeing. That is, students can be taught and experience the relationship between their achievement emotions and their academic performance. This makes learning emotional regulation immediately relevant and proximal in ways that more abstract notions of future wellbeing may not be. Moreover, to many education administrators and some parents, academic performance is paramount and hence can be leveraged as a way of learning about emotions, rather than it usually being framed in terms of illness prevention. That is, school curriculum and pedagogy need to focus on academic performance and emotions rather than academic performance or emotions. Our results also support this emotional skill is particularly needed in secondary schools. Current research on wellbeing literacy is consistent with these aims (Oades, 2018).

Limitations and Recommendations for Future Research

Despite the strengths of meta-analysis (Schmidt & Hunter, 2015), our results should be interpreted in light of some limitations. First, our results for frustration should be interpreted with caution, given the comparatively small number of studies for this emotion. A possible explanation for this paucity of research on frustration may be the lack of adequate self-report measures to

assess this emotion in academic settings. Still, we believe that the number of studies for this emotion will increase in upcoming years due to the recent validation of the Epistemically-Related Emotion Scales (Pekrun, Vogl, Muis, & Sinatra, 2017), which include a multi-item scale to measure frustration. Second, while our results shed light on the strength of associations between activity achievement emotions and academic performance, as well as moderators of those associations, given the cross-sectional or correlational nature of many of the included studies, we cannot infer causal processes. While it is likely that emotions affect academic performance, attaining high or low performance is also likely to yield corresponding emotional experiences. We suggest a fruitful direction for future research is to use experimental procedures that allow for stronger causal inferences.

Conclusion

The relevance of activity-related emotions to academic achievement is clearly supported by the current findings. Specifically, students' performance is related to activity-related enjoyment. Contrastingly, negative emotions such as boredom and anger are negatively associated with student achievement, whereas frustration shows no substantive association with academic achievement. Our findings contribute to identify an overall pattern and strength of the links between four commonly experienced academic emotions and education outcomes, and the factors moderating these relationships, which remained unclear. Importantly, activity emotions seem to have a stronger influence on the academic performance of adolescents compared to university or elementary students. Finally, the evidence from this study establishes the foundations for education systems and researchers to pay more attention to the affective factors (e.g., emotions, feelings, and moods) associated with learning and performance, which have been largely ignored to date, despite their relevance.

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CHAPTER FIVE

THE ROLE OF ACHIEVEMENT EMOTIONS IN THE COLLABORATIVE PROBLEM-SOLVING PERFORMANCE OF ADOLESCENTS

by

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Abstract

We explored the relationship between adolescents' activity-based achievement emotions and their performance during collaborative problem solving (CPS) tasks, which was defined as having objective social and cognitive performance dimensions. Participants were 100 adolescent dyads (n = 200) who completed a series of five computer-based CPS tasks while their activity emotions of enjoyment, boredom, and anger were recorded. It was hypothesized, using a partially mediated structural regression model, that individual differences in students' activity emotions would be linked to effort regulation, which in turn, would be associated with both CPS social and cognitive performance. On the basis that more effective collaboration efforts enable better cognitive performance, we also expected CPS social performance to influence CPS cognitive performance. Our hypothesized model fit the data well. All emotions were associated with effort regulation, and effort regulation influenced cognitive performance but showed a weak association with social performance. Instead, anger and enjoyment affected CPS social performance directly. Our findings provide valuable insight into the role of affective experiences in the growing area of measuring 21st-century skills in educational settings.

Introduction

Collaboration, communication, critical thinking, and creativity (also known as the "four C's") have been identified amongst the most essential skills for children and adolescents to possess, and are also considered critical factors for success in the twenty-first century work environment (Care, Kim, Anderson, & Gustafsson-Wright, 2017; Griffin, McGaw, & Care, 2012). Consequently, education systems in at least 50 nations have progressively begun to incorporate these skills into their curricula and teaching pedagogy (Care, Anderson, & Kim, 2016). In response to this global shift in pedagogical demands, many studies have identified Collaborative Problem Solving (CPS) as an essential component of modern academic curricula within the focus of teaching and assessing the "four C's (see Care, Griffin, & Wilson, 2017).

Collaborative Problem Solving (CPS) is defined as "a joint activity where dyads or small groups execute a number of steps in order to transform a current state into a desired goal state" (Hesse, Care, Buder, Sassenberg, & Griffin, 2015, p. 39). Some studies have examined student-related factors that affect collaborative learning, including how collaborative interactions influence problem-solving outcomes (see Barron, 2003), the effect of non-verbal collaboration (Teasley, 1995), or the effect of having a more competent problem-solving partner (Tudge, 1992). However, there is a dearth of research examining emotions as factors associated with adolescents' CPS performance, despite it being recognized as a critical skill for educational and professional success. Evaluating the links between student emotions and CPS performance is particularly important, as recent evidence shows that emotions play a fundamental role in educational outcomes (Pekrun, Goetz, Titz, & Perry, 2002; Tze, Daniels, & Klassen, 2016). In a CPS context, for instance, emotions such as enjoyment are likely to enhance task engagement and willingness to externalize thoughts, which could help improve social cooperation (Kwon, Liu, & Johnson, 2014;

Nelson & Sim, 2014). Similarly, negative emotions such as boredom can undermine motivation to invest effort in the challenges that arise during collaborative settings, such as communication or sharing ideas (Do & Schallert, 2004), and may also prompt cognitive interference (Sarason, Pierce, and Sarason 1996).

Hence, the influence of emotions on performance is complex, and discrete emotions are thought to differentially impact motivational and regulatory processes that mediate learning and performance (Pekrun, 2006). Among these, effort regulation is understood as a general capability that involves student attempts to govern energy expended on doing well in schoolwork, even when this may result in difficult, boring, or uninteresting experiences (Pintrich, 2004). Effort regulation has been strongly associated with both students' emotions (Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011; Pekrun, Goetz, Titz, & Perry, 2002) and educational outcomes (Donker, de Boer, Kostons, Dignath van Ewijk, & van der Werf, 2014; Hattie, 2008; Tangney, Baumeister, & Boone, 2004) and may operate as an intermediary link between emotions and CPS performance. This hypothesis will be tested in this study. In particular, we aim to address a) the extent to which emotions experienced by adolescents when working on CPS tasks are linked to CPS performance, (b) the extent to which effort regulation meditates these performance relations, and (c) how different aspects of CPS performance are related.

We begin with an examination of the growing area of collaborative problem-solving in more detail, and then explore the proposed relations between the constructs in our proposed model. Finally, we turn to the study itself.

Theoretical framework

Collaborative Problem-Solving in Educational Settings

Two sets of hierarchical skills are deemed crucial to CPS: *social skills* and *cognitive skills* (Hesse, Care, Buder, Sassenberg, & Griffin, 2015). First, we will discuss each in turn individually,

followed by a brief discussion of how they interact.

The use of social skills is essential to CPS, particularly three core strands, including *participation, perspective-taking, and social regulation* (Hesse et al. 2015). Participation refers to the individual becoming actively involved in the stages of the problem-solving process, their readiness to engage in information-sharing, and willingness to externalize thoughts (Hesse et al., 2015). Perspective-taking refers to the ability to perceive and understand a state of affairs from the viewpoint of another (Järvelä & Häkkinen, 2002; Trötschel et al., 2011; Care, Griffin, Woods, & Mountain, 2012), and involves socio-emotional skills including empathy, understanding, and identification with others. Finally, social regulation has been defined as involving the ability to manage and integrate different points of view, opinions, and strategies introduced by participants into the interaction (Hesse et al., 2015). Such diversity is valuable to CPS only in a situation in which participants can sufficiently manage these differences and have the social regulation skills necessary to make sense of them (Hesse et al., 2015). Table 1 outlines the full set of social skills included in the social domain of CPS.

Table 1

Social skills measured in Collaborative Problem-Solving

Domain/Strand	Indicative behaviour
Participation	
Action	Conducting activities within the environment
Interaction	Interacting with, prompting and responding to the contributions of others
Task completion	Undertaking and completing a task or part of a task individually
Perspective-taking	
Adaptive responsiveness	Ignoring, accepting or adapting contributions of others

Domain/Strand	Indicative behaviour
Audience awareness (mutual modelling)	Awareness of how to adapt behaviour to increase suitability for others
Social regulation	
Negotiation	Achieving a resolution or reaching a compromise
Self-evaluation (metamemory)	Recognizing own strengths and weaknesses
Transactive memory	Recognizing the strengths and weaknesses of others
Responsibility initiative	Assuming responsibility for ensuring parts of the task are completed by the group
Social regulation element	Indicative behaviour

Note: Adapted from (Griffin et al., 2015, pp. 135-136)

In contrast to social skills, cognitive skills applicable to CPS are similar to those required for individual problem-solving and refer to how problem-solvers use reasoning skills and manage the problem at hand (Hesse et al., 2015). Two strands are relevant to the cognitive domain of CPS – *task regulation*, and *knowledge building*.[1] Task regulation allows problem solvers to analyze the "problem space" to understand what the problem is, what the best approach for its solution may be (applying a strategy to solving the problem), what the elements of the problem are, what resources are available, and to then determine which part of the problem or task will be solved by each participant (Care, Scoular, & Griffin, 2016; Järvelä & Järvenoja, 2011). Finally, the knowledge building strand focuses on participants' ability to monitor outcomes, find patterns, rules, and contingencies in the solution of the problem, to ideally come to generalization and hypothesis-testing at the end of the process (Hesse et al., 2015). See table 2 for the skills within the cognitive CPS domain.

[1] See the method section for a more in-depth outline of how students do well or poorly on CPS activities according to the CPS scoring procedure.

Table 2

Cognitive skills measured in Collaborative Problem-Solving

Domain/Strand	Indicative behaviour
Task regulation	
Resource management	Managing resources or people to complete a task
Collect elements of information	Explores and understands elements of the task
Systematicity	Implements possible solutions to a problem and monitors progress
Tolerance for ambiguity/tension	Accept ambiguous situations
Organization (problem analysis)	Analyze and describe the problem in a familiar language
Setting goals	Sets a clear goal for a task
Knowledge building	
Knowledge acquisition	Follows the path to gain knowledge
Relationships (representation and formulation)	Identifies patterns and connections between among elements of the knowledge associated with the problem
Rules "if… Then"	Uses an understanding of cause and effect
Hypothesis "what if…" (Reflection on Solution)	Adapts reasoning or course of action as the problem is solved

Note: Adapted from (Griffin et al., 2015, pp. 135-136)

While social and cognitive skills are deemed to be crucial to CPS, they are not necessarily separate entities. In contrast, it is possible that both skill sets interact, whereby enhancing one domain could facilitate upward effects in the other domain. In particular, a growing body of research suggests that strengthening social resources may allow people access to a broader range of potential cognitive and behavioural responses to new or challenging goals and experiences (Deci & Ryan, 2000; Fredrickson, 2001), which will likely facilitate the cognitive domain of CPS. We return to this possibility later when outlining our hypothesized model.

Achievement Emotions

In this study, emotions are understood as episodes of synchronized and interrelated changes in the state of five organismic subsystems (components) including affective, cognitive, motivational, expressive, and peripheral physiological processes in response to the evaluation of an internal or external stimulus (Pekrun, 2006; Scherer, 2005). For instance, when a student is about to take an important test, he or she may feel anxiety, which could be experienced with uneasiness and nervous feelings (affective component), worries about not being capable enough to successfully complete the exam (cognitive component), impulses to escape the situation (motivational component), anxious facial expressions (expressive component), and increased heart rate (physiological component).

Within this component process framework of emotions (Scherer, 2005), achievement emotions are emotions directly related to achievement activities such as attending classes, studying, completing assigned tasks, or achievement outcomes such as taking a test or exam (Pekrun, 2006; Pekrun et al., 2002). Students in academic settings may experience several activity-related achievement emotions, such as enjoyment, frustration, anger, and boredom. At the same time, they could experience different outcome-related achievement emotions, namely, joy, hope, gratitude, anxiety, hopelessness, pride, relief, sadness, and shame (Pekrun, 2006; Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011). Achievement emotions share some overlap with epistemic emotions, which are emotions elicited from the cognitive aspects of task information and the processing of such information (see Muis, Chevrier, & Singh, 2018; Muis, Psaradellis, Lajoie, Di Leo, & Chevrier, 2015; Pekrun, Vogl, Muis, & Sinatra, 2017 for epistemic emotions). Depending on the focus of attention, some emotions can be experienced either as achievement emotions or as epistemic emotions. For instance, a student's enjoyment working on a problem-solving task can be regarded as an epistemic emotion if the focus is on the delight generated by

recombining information such that the problem gets solved. Instead, it is considered an achievement emotion if the focus is on personal ability to solve the problem (Pekrun & Stephens, 2012).

Achievement emotions can be grouped based on two dimensions: valence (positive/pleasant vs. negative/unpleasant), and levels of arousal (activating vs. deactivating) (Pekrun et al., 2002). This allows, for example, distinctions to be made between positive activating emotions such as enjoyment, and unpleasant deactivating emotions like boredom. The focus of this investigation was on enjoyment, boredom, and anger, as these emotions are amongst the most frequently experienced by high school students in activity-related settings (Buff, 2014; Frenzel, Pekrun, & Goetz, 2007; Tze et al., 2016). Similarly, according to Pekrun (2006), anger, boredom, and enjoyment are the most likely emotions to occur during achievement-related activities (e.g., studying, completing an assigned task), which are relevant to collaborative problem-solving settings. Moreover, these three emotions each align to different groupings within the valence-arousal circumplex, ensuring sufficient breadth of the achievement emotion taxonomy is covered (Pekrun, 2006; Pekrun & Stephens, 2010).

To date, most available literature has focused on the study of *outcome* emotions in achievement situations, such as test anxiety, whereas the study of *activity-related* emotions including enjoyment, boredom, and anger has received less attention (Pekrun, Daniels, Goetz, Stupnisky, & Perry, 2010; Pekrun et al., 2002; Pekrun & Perry, 2014; Tze, Daniels, & Klassen, 2016). While some recent research has explored activity-related emotions that are separate from the achievement emotions framework (e.g., confusion, frustration, curiosity in several contexts such as interactions with different computer-based learning environments) (Baker, D'Mello, Rodrigo, & Graesser, 2010; Lehman, D'Mello, & Graesser, 2012; Muis, Pekrun, et al., 2015), it is essential to continue examining the role of activity-related emotions such as enjoyment, boredom

and anger in CPS within assessment scenarios, which our context involves (as we describe later). Because non-achievement emotions research tends to focus on the experience during computer-based learning environments, it seems more appropriate to focus on emotions that are related to performance in the target context (the assessment). Examining emotions that commonly arise during CPS tasks is important, given their ability to influence later motivation and performance in that activity. For example, enjoyment of a learning task is likely to increase a student's motivation to engage with, and perform well in, that same task in the future.

In support of this relationship, research on computer-based collaborative learning with adults has found the experience of enjoyment to be strongly correlated with motivation and perceived learning (Gomez, Wu, & Passerini, 2010). The impact of discrete emotions such as enjoyment, boredom, and anger on motivation and performance of adolescents in computer-based collaborative learning tasks is yet to be tested. Hence, as we outline in more detail later, our study will extend the existing literature in two ways. First, we will examine the affective component of CPS in a laboratory setting specifically designed to quantify the performance of computer-based CPS in matched dyads. Second, we will be the first to use an adolescent sample. An exploration of young adolescents is critical because they are known to experience emotions differently to adults (Vierhaus, Lohaus, & Wild, 2016), and may be less well equipped to regulate their emotions (Zeman, Cassano, Perry-Parrish, & Stegall, 2006), which may affect their motivation and CPS performance. For example, adolescents tend to be more expressive with their emotions (Ekman & Friesen, 1969), which is likely to impact motivation and effort in collaborative settings, which we review in more detail below.

Activity Emotions, Motivation, and Performance in Collaborative Learning Settings

Enjoyment can be understood as positive (pleasant) and activating (high arousal) emotion. Evidence suggests that activity-related enjoyment positively affects student motivation to invest

effort (Pekrun et al., 2011), leads to the use of more flexible and creative learning strategies such as elaboration (King & Areepattamannil, 2014; Muis, Psaradellis, Lajoie, Di Leo, & Chevrier, 2015), facilitates students' self-regulation of learning, and enhances academic outcomes and individual problem-solving performance (Baek & Touati, 2017; Goetz, Hall, Frenzel, & Pekrun, 2006; Pekrun, 2006).

Positive emotions are related to a range of components of social functioning. For instance, positive emotions can influence social cognition by facilitating interpersonal perspective-taking and cooperation and enhancing open-minded flexibility (Nelson & Sim, 2014). This set of skills is fundamental for the effective resolution of problems that emerge in group settings. A growing body of research also suggests that enjoyment, amongst other positive emotions, serves as a vehicle for individual growth and social connection. Known as the Broaden and Build Theory of positive emotions (Fredrickson, 2001), this model posits that experiencing positive emotions, such as enjoyment, can facilitate the strengthening of social resources, while also allowing individuals access to a broader range of potential cognitive and behavioural responses to new or challenging experiences, which will likely facilitate CPS.

In computer-supported collaborative learning, evidence suggests that a continuous pattern of positive socio-emotional interaction leads groups of adults to achieve higher levels of collaboration and later performance when working on decision-making tasks (Kwon, Liu, & Johnson, 2014). Similarly, positive emotions have been associated with heightened attention and participation of college students during classroom discussions (Do & Schallert, 2004). Low activation positive affect, such as feeling happy or calm, has been shown to be positively related to engagement, cohesion, and respect among team members (Linnenbrink-Garcia, Rogat, & Koskey, 2011).

Boredom can be conceptualized as low arousal (deactivating) and negative (unpleasant) emotion (Pekrun & Stephens, 2010). It has been found to be not only frequent but persistent in learning settings (Baker, D'Mello, Rodrigo, & Graesser, 2010; D'Mello, Lehman, & Person, 2010). Importantly, boredom has a detrimental impact on academic performance due to its tendency to reduce motivation and effort, self-regulation of learning, and attention, as well as the promotion of task-irrelevant thoughts (see Sarason, Pierce, and Sarason (1996) for cognitive interference), and the use of shallow learning strategies (e.g., rehearsal), which undermines performance (Craig, Graesser, Sullins, & Gholson, 2004; Muis et al., 2015; Pekrun et al., 2010; Pekrun et al., 2002; Tze et al., 2016). In interactive learning environments, boredom leads students to "game the system" or engage in maladaptive learning behaviours (Baker et al., 2010). In collaborative learning contexts in college students, for example, negative emotions such as boredom may lead students to adopt avoidance behaviours, such as disengaging from classroom discussions, compromising the interactions between group members (Do & Schallert, 2004).

Anger is conceptualized as a negative (unpleasant) and activating (high arousal) emotion. It may lead to antisocial behaviour and impair student's interpersonal functioning (Fryxell & Smith, 2000) and affects students learning by promoting the use of rigid learning strategies (e.g., rehearsal), which are associated with poor learning and performance (Pekrun, 2006). The relationship between anger and motivation is complex; experiencing anger can reduce intrinsic motivation, but it can also serve as a powerful extrinsic motivator to overcome obstacles and avoid failure (Pekrun et al., 2002). While a dearth of research has examined the role of anger in the CPS performance of adolescents, evidence from collaborative group learning suggests that dysfunctional interactions between adults in collaborative learning situations can generate social-emotional challenges and conflicts among group members that trigger negative emotions such as frustration, and anger (Ayoko, Callan, & Härtel, 2008). These negative emotions make it difficult

for students to maintain harmony within the group, leading them to adopt avoidance-focused emotion regulation behaviour and to lower their on-task engagement (Naykki, Jarvela, Kirschner, & Jarvenoja, 2014).

Overall, there is a dearth of empirical research investigating the role of discrete achievement emotions in the context of the CPS performance of adolescence. Examining this gap in the literature is essential as it may shed light on the mechanisms underpinning CPS performance, a rapidly growing area of 21st-century skills pedagogy in secondary schools (Care et al., 2017). It is possible that the emotions we review here exert even stronger effects in collaborative situations that involve adolescents, and the predominant focus on college students at the individual level does not necessarily generalize to adolescents, who tend to experience emotions very differently to adults (Vierhaus, Lohaus, & Wild, 2016). For example, adolescents tend to be more expressive with their emotions (Ekman & Friesen, 1969) and may be less well equipped to effectively regulate their emotions (Zeman et al., 2006) as compared to adults. This may make adolescent samples more prone to "catching" like emotional experiences from their CPS group-members (Hatfield et al., 1993), which may, in turn, affect effort regulation and CPS performance. Further research on emotions in collaborative learning with adolescents, particularly with the use of complex tasks, such as that experienced during CPS, is essential, which we address in the present study.

Effort Regulation as an Intermediary Link Between Activity-Emotions and the CPS Performance of Adolescents

Effort regulation is a general capability that involves attempts to control effort to do well in schoolwork, even when this may result in difficult, boring, or uninteresting experiences (Pintrich, 2004). Effort regulation has emerged as a strong predictor of the grade point average (GPA) (Richardson, Abraham, & Bond, 2012; Robbins et al., 2004), and has been implicated in the

academic success of secondary students (Duckworth & Seligman, 2005). We propose that effort regulation is an essential mechanism through which emotions might affect CPS performance. If the collaborative tasks are experienced as too easy or difficult, for example, it may engender higher levels of anger and boredom, and lower levels of enjoyment in the CPS groups. These experiences are likely to require effort regulation skills to persevere and push through these unpleasant experiences and ultimately perform well (Donker et al. 2014; Hattie, 2011). This is particularly true for collaborative situations that involve shared responsibility, negotiation, perspective-taking, and finding sources of shared motivation (Hesse et al., 2015). Students require effort regulation not only to navigate the challenges associated with the tasks but also to resolve the challenges proposed by the collaborative contexts themselves.

The Present Study

Given the complexity of the effects of achievement emotions on educational outcomes which can be both direct or mediated by motivational and self-regulatory processes (Pekrun, 2006), and based on the evidence suggesting the existence of a strong correlation between effort regulation and achievement emotions such as enjoyment, boredom and anger (Pekrun et al., 2010; Pekrun et al., 2011), the present study aimed to empirically examine how adolescents' activity achievement emotions are related to their performance in both dimensions of CPS: *social and cognitive*. More precisely, we addressed the following research questions: (a) to what extent are activity emotions experienced by adolescents during CPS tasks linked to CPS performance, (b) to what extent does effort regulation meditate these performance relations, and (c) to what extent social CPS performance is associated with cognitive CPS performance.

We predict that enjoyment is associated with a greater investment of effort, which in turn, associates with higher cognitive CPS performance. In contrast, we expect that the experience of boredom and anger is detrimental to cognitive CPS due to their tendency to undermine motivation

to invest the effort to complete tasks (Pekrun, 2006; Tze et al., 2016). We also predict that enjoyment, boredom, and anger have a direct relationship with the social domain of CPS, as this is consistent with the notion that they may affect group climate and students' willingness to communicate with peers, as well as their levels of participation, and responsiveness.

Finally, we believe these social skills, in turn, are a prerequisite for the development of cognitive skills needed for task completion, such as engagement, attention, and knowledge building. A growing body of research suggests that positive emotions, such as enjoyment, operate as a pathway for individual growth and social connection. Positive emotions (Fredrickson, 2001) can facilitate the strengthening of social resources, which in turn, may also allow individuals to access a broader range of potential cognitive and behavioural responses to new or challenging experiences, which will likely facilitate cognitive CPS. Thus, we predicted a positive directional pathway between social CPS and cognitive CPS. Our full hypothesized model is depicted in Figure 1.

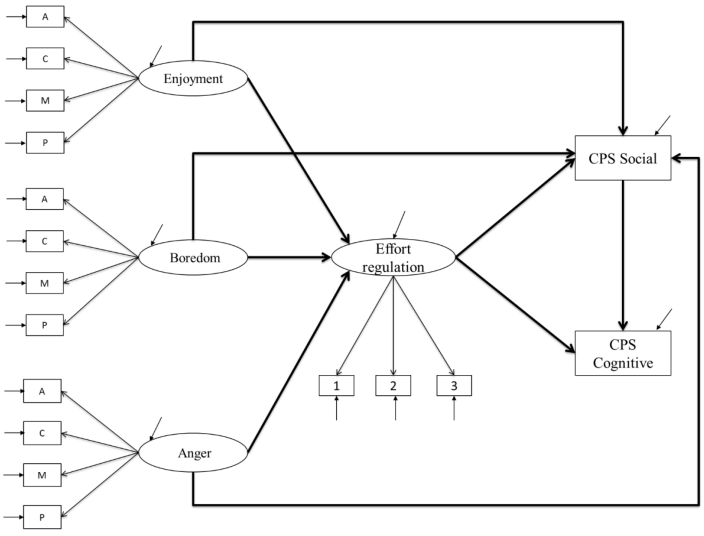

Figure 1. Hypothesized partially mediated structural equation model whereby activity emotions affect effort regulation and CPS social performance, which in turn influence CPS cognitive performance. Bold arrows indicate structural components of the model. Internal components of emotions: Affective (A), Cognitive (C), Motivational (M), and Physiological (P).

Method

Participants

Participants were a sample of 200 students (n = 100 female) with a mean age of 13.48 years (*SD* = 1.14), who were recruited from five government secondary schools located in the Melbourne metropolitan area, Victoria, Australia. Because 77% of secondary schools in Australia are government schools (ACARA, 2018), our sample was representative of a substantial proportion of the high school population in the country. Informed consent was provided by parents and students prior to participation. No incentives were provided.

Procedure

All procedures used in the study were formally approved by the University Human Research Ethics Committee, as well as the relevant government education body. The activity consisted of students working in dyads matched by age and gender to complete five computer-based CPS tasks and two self-report questionnaires intended to measure their achievement emotions and effort regulation.

Students within each pair were well known to their partners and were willing to work together. Students had individual access to a computer and were positioned five meters apart and facing in opposite directions. They could communicate through an online chat box in each task.

Students had 60 minutes to complete the five CPS tasks, and had as much time as they needed to complete the Achievement Emotions Questionnaire (AEQ) (Pekrun, Goetz, & Perry, 2005; Pekrun et al., 2002) and the effort regulation scales (Pintrich, Smith, Garcia, & McKeachie, 1991). The process was structured such that students entered the classroom and first completed the “before” section of the AEQ. They next completed 30 minutes of CPS tasks prior to completing the “during” section of the AEQ. Students then had 30 remaining minutes to complete the CPS tasks before they were invited to complete the “after” section of the AEQ, as well as the

effort regulation scale (see below for an explanation of the measurement sequence of the AEQ). Students received individual log-in credentials for the CPS tasks so that their performance could be objectively monitored and their data identified after their completion.

Collaborative Problem-Solving Tasks.

With the aim of measuring CPS competence, participants completed five collaborative problem-solving tasks while their activity emotions were measured by self-report questionnaires. The tasks are designed to be assessment tools that initially help to identify a student's baseline level but can also be administered at various future points in time to monitor growth. CPS tasks are categorized as either content-free or content-dependent (Griffin et al., 2012). Content-free tasks were designed to emphasize the enhancement of inductive and deductive thinking skills, whereas content-dependent tasks require students to draw on knowledge acquired through traditional learning areas or subjects within the curriculum such as mathematics and sciences (Care, Griffin, Scoular, Awwal, & Zoanetti, 2015a).

The CPS assessment tasks were designed to share three essential characteristics, which were applied in the same way across all tasks for all dyads. These were: ambiguity (an unclear direction in which to proceed towards the solution of the problem), asymmetry (presenting different information to each participant in each dyad), and unique access to resources (resources are divided between students, which they need to share to solve the problem). These three characteristics are designed to create an inter-dependence between learners, which is a central feature of problems that require collaboration (Care, Griffin et al., 2015a).

The tasks were designed to be completed by two students working collaboratively who can communicate with each other through a chatbox. At the beginning of each task, an instruction stem was presented, followed by a problem. To complete the task satisfactorily, students are required to work together to understand the nature of the problem, its elements, the resources available to

them, and ultimately outline a possible solution. All students with each pair must contribute. Otherwise, a solution cannot be reached.

Task length and difficulty varied, with some tasks, for example, requiring less collaboration but at the same time being cognitively more challenging. For illustrative purposes, a brief description of one content-free and one content-dependent CPS task is provided below, and we outline our measurement approach in more detail in the following section. In our study, the mean task duration was 10 minutes, 8 seconds (SD = 5.74). The total completion time for all tasks was approximately one hour.

Laughing clowns is a content-free CPS task that consisted of a clown machine with 12 balls which were presented to each student. The goal was to find out whether those machines work in the same way. To do that, partners needed to communicate with each other, share resources, find patterns, form rules, and reach conclusions about how to move forward. Students could not see each other's screen, so they were unable to determine the rule governing the other's clown machine (Care, Griffin, et al., 2015). See Figure 2 for a visual from the perspective of the participant. CPS skills measured in this task included interaction, audience awareness, resource management, and relationships. See Appendix D of this dissertation for examples of indicative behaviours for each skill in this task.

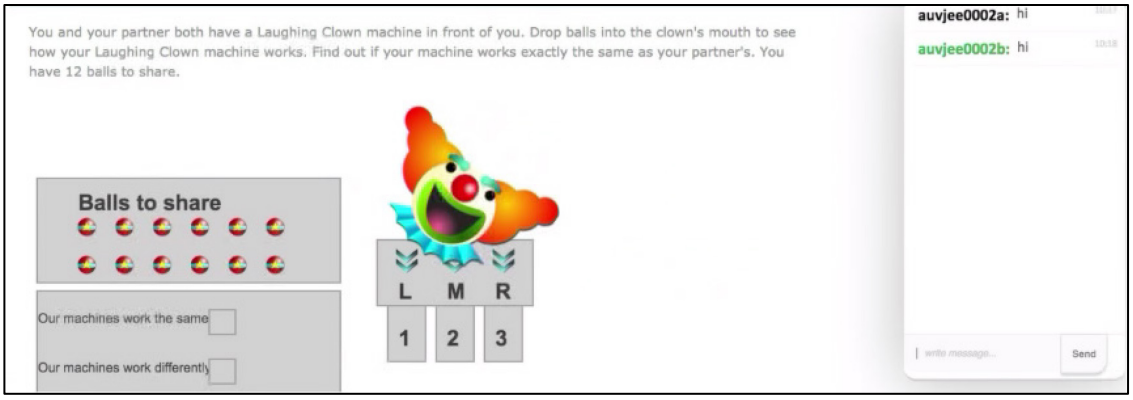

Figure 2. Content-free Laughing Clowns task from the perspective of each participant within each student dyad. *Note:* Taken with permission from (Care, Griffin, et al., 2015)

In contrast, *Game of 20* is a content-dependent task whereby students are faced with the problem of reaching a value of 20 by placing counters sequentially on a grid. In this task, they were playing against the computer, and they needed to use their previous knowledge in mathematics to collaboratively reach the desired value of 20 before the computer (Care, Griffin, et al., 2015). See Figure 3 for a visual from the perspective of the participant. Skills measured were task completion, adaptive responsiveness, responsibility initiative, rules "if…then", hypothesis "What if", as well as collect elements of information.

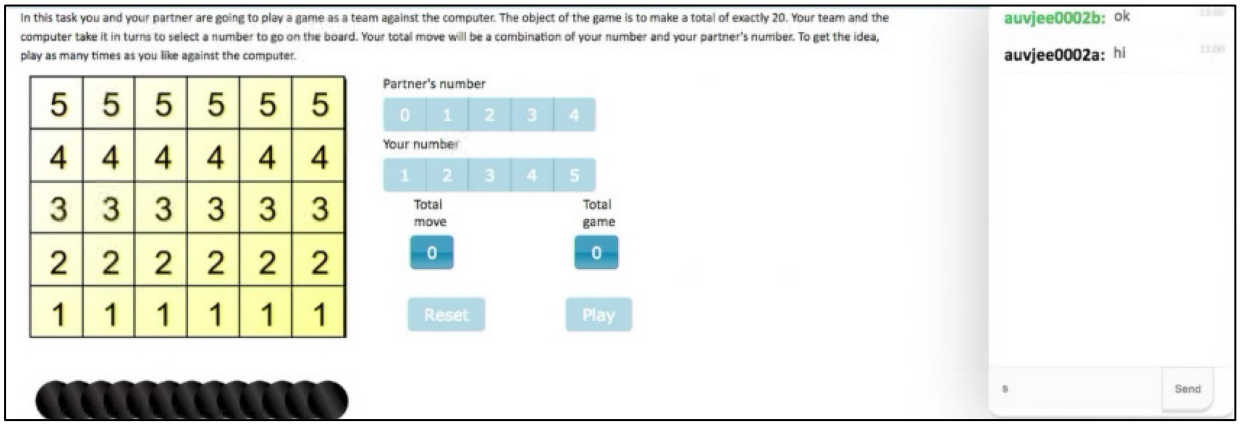

Figure 3. Content-dependent 'Game of 20' task from the perspective of each participant within each student dyad. *Note:* Taken with permission from (Care, Griffin, et al., 2015)

Measures

Achievement Activity Emotions

We used the Achievement Emotion Questionnaire (AEQ), adapted from (Pekrun et al., 2005; Pekrun et al., 2002) to measure participants' enjoyment, boredom, and anger before, during, and after completing the CPS tasks. Measuring emotions at three points during the activity provides closer access to the range of emotions during learning compared to questionnaires given only at the beginning or end of the activity (Wosnitza & Volet, 2005). Students read a range of statements about each emotion and responded on a 5-point Likert scale from 1, "Strongly disagree" to 5, "Strongly agree." The scales are structured such that items assess emotions at three different time-points relative to the achievement activity: before, during, and after. This was true only for enjoyment and anger; for boredom, only one time-point (during) is needed because boredom is an emotion that is experienced in relation to the current situation or ongoing activity (rather than future or past activities), as recommended by the AEQ user's manual (Pekrun et al. 2005). The scale consisted of nine items for enjoyment ($\alpha = .78$; three completed before, three during, and three after); sample item (before): "I look forward to demonstrating my knowledge"; sample item (during): "For me these tasks are a challenge that is enjoyable"; sample item (after): "My heart beats faster with joy". 11 items for boredom ($\alpha = .93$); sample item: "I am so bored that I have problems staying alert". And, seven items were used to measure anger ($\alpha = .86$; two completed during, and five after); sample item (during): "I think the questions are unfair"; sample item (after): "I am fairly annoyed".

The AEQ can be adapted to meet the specific requirements of different research contexts. The items do not contain any references to temporal generality, such that they can be used under instructions of different temporal and situational specificity. Hence, we changed the original statements to meet the needs of our CPS activity and research purposes. For instance, one of the

original items for measuring anger stated, "I wish I could tell the teacher off"; we changed the word "teacher" to "researcher". Similarly, for boredom, one of the original items was "This class bores me", we then changed it to "These tasks bored me". Thus, adapting the items was necessary to make them more relevant to our research context.

Aligned with the multicomponent definition of achievement emotions (Scherer, 2005), a determined number of items within each emotional scale of the AEQ is designed to measure four of the five internal components of emotions: namely, affective, cognitive, motivational and neurophysiological components. For example, in the anger scale, some items pertain to the affective internal component (e.g., “I am fairly annoyed”), other items to the cognitive component (e.g., “I think the questions are unfair”), to the motivational component (e.g., “I wish I could tell the researcher off”), and finally, to the neurophysiological component (e.g., “My anger makes the blood rush to my head”).

Finally, based on the work of Pekrun et al. (2011), composite scores were calculated by creating a mean score across the measurement time-points (before, during, and after) for each internal component of emotions, namely, affective, cognitive, motivational, and physiological. These composite scores were then used as the observed variables for each emotion latent variable. The idea behind this is to be able to model emotions as hierarchical structures consisting of indicators at the lowest level (internal components of emotions) nested within latent factors (emotions), as suggested by Pekrun et al. (2011). Please see Pekrun et al. (2005) for a full description of the items used to measure each internal component of emotions as well as items and scales characteristic.

Effort Regulation

The Effort Regulation subscale of the Motivated Strategies for Learning Questionnaire (MSLQ) adapted from Pintrich, Smith, Garcia, and McKeachie (1991) was used to measure effort regulation. Participants reported on a 7-point Likert scale ranging from 1, "Not at all true of me" to 7, "Very true of me.". The subscale contains items designed to "measure the extent to which students control their effort and attention in the face of distraction or tedious tasks. Effort regulation reflects the commitment to completing one's study goals, despite difficulties and distractions" (Pintrich et al., 1991, p. 27). The effort regulation scale originally consists of four items ($\alpha = .69$; sample item: "I worked hard to do well in these tasks even when I did not like what I was doing"). However, based on reliability analyses, we removed one item from the scale ("When the tasks were difficult, I gave up or only did the easy parts") and kept the remaining three (see Pintrich et al. 1991, p. 27 for the full scale) which enhanced internal consistency ($\alpha = .79$).

Collaborative Problem-Solving Performance

Because CPS performance was our focal dependent variable and its scoring procedure differs from the scales previously outlined, we cover its use in more depth here. However, we refer interested readers to Adams, Vista, Scoular, Awwal, Griffin, & Care, (2015) and to Griffin, Care, & Harding, (2015) for more detail about its reliability, validity, task calibration, and scoring procedure. Essentially, the scoring procedure penalizes speculative approaches to the solution of problems (i.e., guessing), whereas more systematic approaches (i.e., making good use of resources, taking steps to understand the problem and its elements) are rewarded.

To quantify social and cognitive CPS performance, as students completed the tasks, all activities, including actions and chats, were recorded in log files. Algorithms were developed to identify patterns of behaviour in the log files. Algorithms are written to search relevant log stream data for specific patterns or sequences of events. The patterns of events or indicators identified in

the log stream data are considered the input, and a record file based upon the search algorithms is considered the output. Therefore, each algorithm will search through each task undertaken by the student and consider each task as a separate instance. Once applied to each task the indicator is fundamentally transformed into an item and acts much like an item in a traditional test. Second, output recorded must be meaningful in relation to the construct being measured. In this case, the indicators are mapped to one of the subskills in the Hesse et al. (2015) framework. In this sense, the behaviour pattern identified by the search algorithm is interpreted as reflecting the subskill to which it is mapped.

There were approximately 12 behaviour patterns identified per task, each indicatively related to one of the social or cognitive strands on the Hesse et al. (2015) CPS framework. The number of social and cognitive patterns identified in each task depends upon the nature and activity of the task. Therefore, some tasks may have more or fewer social than cognitive patterns (see Care et al., 2015, for further details). Action and time were taken into consideration in the scoring procedure through the adoption of search algorithms. The algorithms chunked and clustered the log files so that the various patterns could be investigated in relation to the sets of actions, chats, and times that were to be identified. These patterns of behaviour were then each treated as individual items on a test and coded so that where a pattern was found in the log file a score of '1' was allocated to that student, where that pattern was absent in the log file a score of '0' was allocated to that student. This resulted in record files, including a score for each student on each behaviour pattern in each task. This data was analyzed using Item Response Theory, in particular, the Rasch model (Rasch, 1960). This psychometric model can be used to evaluate the quality of an assessment, but more importantly, for this study, it can also be used to scale the students in regards to their performance on the test. The Rasch model assumes only one parameter for the item (difficulty) and one parameter for the person (ability). Therefore, it is assumed that a student's ability to perform an

indicative behaviour is affected only by their ability on the construct. The calibration of the test items (behaviour patterns) and student responses to those items generates student ability estimates that can be presented on a vertical scale. Both items and students are presented on the same scale with the positioning of item difficulty location on that scale defined by the probability that a student answers the item correctly is at 0.5 (Wu & Adams, 2006). Students with higher ability will have a greater probability of answering an item correctly. The item difficulty and person ability estimates are mapped onto a single interval scale; both measured using the same units, called logits. Two scales were produced, one for each of the social and cognitive dimensions, each ranging from -4 to 4 logits.

This assessment material (CPS tasks) and scoring procedure have been tested in several field trials around the world, including Australia (Care, Scoular, & Bui, 2015), Singapore (Poon, Tan, Cheah, Lim, & Ng, 2015), and the United States of America (Comfort, 2015), showing exceptional person separation reliability and validity (Griffin, Care, & Harding, 2015). There are two Rasch indices used to identify reliability, the item separation, and the person separation. In each case, the reliability is found by dividing the mean square of the measurement error by the observed variance. The reliability of item separation demonstrates the extent to which the items are well separated to define the direction and meaning of a variable. Similarly, the reliability of person separation indicates how well a subset of items separates the person from a sample. In this study, both item separation and person separation reliabilities are high at 0.790 and 0.730, respectively. These indices indicate that items on the continuum are well separated and differentiate well between student CPS abilities.

Control Variables

Because numeracy explains variance in academic performance (Hattie, 2008) and the CPS tasks completed by participants involved a mathematical component, we controlled for students'

prior knowledge in numeracy as measured by the Numeracy component of the National Assessment Program for Literacy and Numeracy (NAPLAN), which was provided by each participating school.

Data Analysis Strategy

Data for this study were hierarchically organized, with students at the lowest level nested within pairs at the highest level. Thus, structural equation modelling (SEM) for complex surveys with cluster data was used for analysis in this study (Muthén & Muthén, 1998-2015). Because the items on the AEQ and the effort regulation scales produce ordinal scale data, the weighted least squares (WLSMV) estimator was used for the analyses, based on evidence that it is a robust estimator which does not assume normally distributed variables and provides the best option for modelling categorical or ordered data (Brown, 2015). Using the two-step approach introduced by Anderson and Gerbing (1988), we first tested the validity of the measurement model, and then examined the hypothesized structural model. Analyses were performed using Mplus version 7.2 (Muthén & Muthén, 1998-2015).

We created four first-order composite scores for each emotion latent factor based on the internal component structure of achievement emotions proposed by Pekrun (2006); (Scherer, 2005, 2009). This procedure has been used before in SEM studies and suggests that "emotions are best modelled as hierarchically organized structures, with the components comprising an emotion being first-order factors and the emotion itself being represented by a second-order factor" (Pekrun et al., 2011, p. 37). This approach ensured that our procedure contained theoretical and empirical foundations. Finally, we followed recommendations about reporting SEM results from Schreiber, Nora, Stage, Barlow, and King (2006).

Results

Measurement Model Validation

To investigate the validity of the measurement model, we used confirmatory factor analysis (CFA). We used several goodness of fit indices to make decisions about the accuracy of the model, namely: chi-square, the comparative fit index (CFI), the Tucker and Lewis Index (TLI), as well as one closeness of fit indicator in the root mean square error of approximation (RMSEA). Although there is no universally agreed cut-off criteria, rule of thumb conventions (See Hu & Bentler, 1999) suggest values greater than 0.95 for the CFI and the TLI, and values less than 0.08 for the RMSEA are indicative of a fitting model (Hooper, Coughlan, & Mullen, 2008; Kline, 2011).

In the case of SEM studies, Kline (2011) recommends a minimum sample size of between 100 and 200 participants. Other authors such as Grimm (2009) and Worthington and Whittaker (2006) recommend that there should be five to 10 participants per parameter to produce stable estimates. We specified 15 factor loadings, and six correlations, totalling 21 parameters that needed to be estimated. Given our sample size of 200, we obtained an adequate ratio of 9.52 participants to each parameter estimated. We examined assumptions of linearity in SPSS 24, and no outliers were identified. There were no missing data.

CFA results indicated a good fit between the measurement model and the observed data (χ^2 (84) = 130.274, $p < .01$, CFI = .96, TLI = .95, RMSEA = .052 [90% CI = .034, .070]). Most of the standardized factor loading estimates were consistently high ($\beta > 0.70$) suggesting convergent validity. Table 3 shows both standardized and unstandardized factor loading values. The residual analyses did not indicate any problems and no post-hoc modifications were indicated from the analysis.

Estimated factor correlations ranged from -0.71 to 0.58, suggesting discriminant validity and no multicollinearity. Correlations, descriptive statistics, and scales' reliabilities are solid and in the expected pattern, presented in Table 4. The measurement model is shown in Figure 4.

Table 3

Standardized and Unstandardized Estimates for the CFA Measurement Model

Observed variable	Latent construct	*β*	*B*	*SE*
Affective	Enjoyment	0.82	1.00	
Cognitive	Enjoyment	0.88	1.17	0.10
Motivational	Enjoyment	0.56	0.85	0.11
Physiological	Enjoyment	0.63	0.92	0.11
Affective	Boredom	0.87	1.00	
Cognitive	Boredom	0.93	1.06	0.06
Motivational	Boredom	0.86	0.81	0.08
Physiological	Boredom	0.85	0.74	0.07
Affective	Anger	0.70	1.00	
Cognitive	Anger	0.49	0.61	0.13
Motivational	Anger	0.80	1.26	0.21
Physiological	Anger	0.67	0.87	0.14
Item 1	Effort regulation	0.60	1.00	
Item 2	Effort regulation	0.81	1.27	0.25
Item 3	Effort regulation	0.83	1.66	0.26

Notes: β = Standardized estimates; *B* = Unstandardized estimates; *SE* = Standard errors

Table 4

Latent Factor Correlations, Descriptive Statistics, and Scale Reliabilities

Variables	1	2	3	4	5	6	7
1. Enjoyment	--						
2. Boredom	-.71**	--					
3. Anger	-.47**	.58**	--				
4. Effort regulation	.57**	-.56**	-.48**	--			
5. CPS (Cognitive)	.34**	-.34**	-.32**	.41**	--		
6. CPS (Social)	.33**	-.30**	-.30**	.26	.40**	--	
7. Prior scores (Numeracy)	.42**	-.30**	-.34**	.27	.33**	.14*	--
M	3.63	1.66	1.51	5.38	1.20[a]	1.47[a]	634.48[b]
SD	0.79	0.82	0.60	1.48	0.86	0.65	75.88
Reliability (α)	0.85	0.91	0.81	0.79	--	--	--

Notes: ** $p < .01$; * $p < .05$; [a] Possible range = -4.00 to 4.00; [b] Possible range = 0 to 999

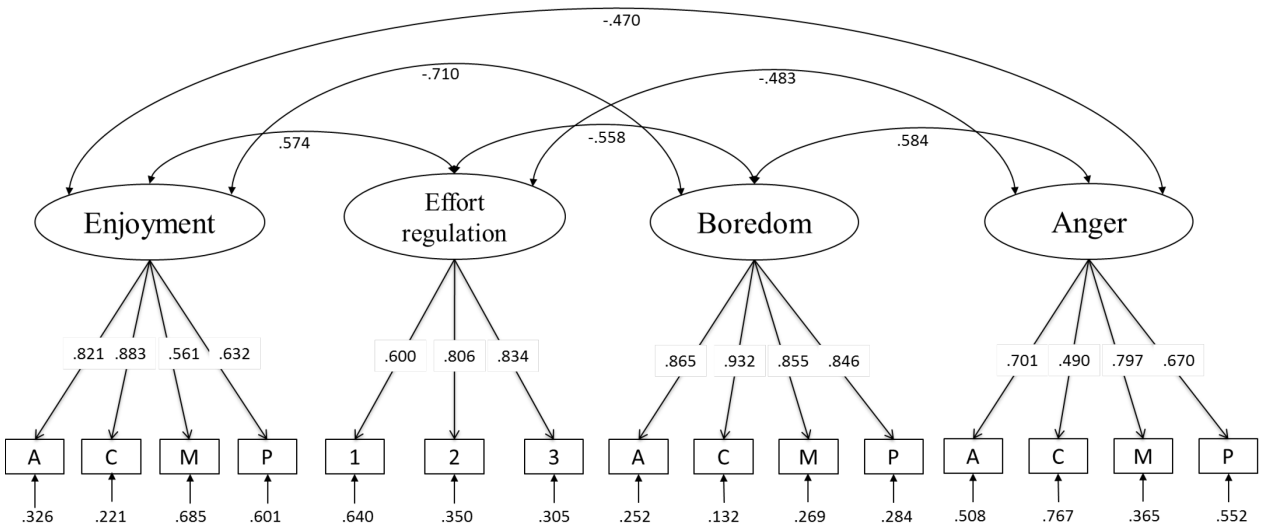

Figure 4. Standardized parameter estimates for the full measurement model using CFA. Model fit indices: $\chi 2$ (84) = 130.274, p < .01, CFI = .96, TLI = .95, RMSEA = .052 [90% CI = .034, .070]. Standardized parameter estimates, and residual variances are shown. Internal components of emotions: Affective (A), Cognitive (C), Motivational (M), and Physiological (P).

Structural Model Validation

Given the validation of the measurement model, we tested the structural part of our model to examine whether associations between enjoyment, boredom, and anger and CPS performance were partially mediated by effort regulation. After estimation of the structural model, no marked changes were seen in the factor loading estimates; thus, assumptions regarding measurement may be invariant to changes in the structural part of the model (Kline, 2011). Results showed that our initial hypothesized model fit the data very well, ($\chi 2$ (117) = 178.446, $p < .01$, CFI= .96, TLI= .95, RMSEA= .051 [90% CI = .035, .066]). Thus, we retained the model, and no modifications were performed.

The final structural model is presented in Figure 5. As can be observed in the figure, results showed that all three emotions were associated with effort regulation. Specifically, enjoyment yielded a positive association (standardized coefficient = .34), whereas both boredom and anger yielded negative associations (standardized coefficients = -.23 and -.14, respectively). Importantly, the three activity-emotions accounted for 39% of the variance in effort regulation, which in turn was positively related to CPS cognitive performance (standardized coefficient = .27), but was weakly associated with CPS social performance (standardized coefficient = .06). As hypothesized, enjoyment was linked to higher CPS social outcomes (standardized coefficient = .19), while anger was negatively associated with CPS social outcomes (standardized coefficient = -.16). The association between boredom and CPS social performance was very low (standardized coefficient = -0.05).

Prior knowledge of numeracy was significantly related to all three emotions, as well as to final CPS cognitive scores. However, it showed very weak links to effort regulation and CPS social. Finally, as predicted, CPS social scores were associated with higher CPS cognitive performance (standardized coefficient = .30). Importantly, our final model accounted for 31% of

the variance of the dependent variable CPS cognitive, and for 13% of the dependent variable CPS social performance. See Appendix E of this dissertation for the indirect/total effect analysis.

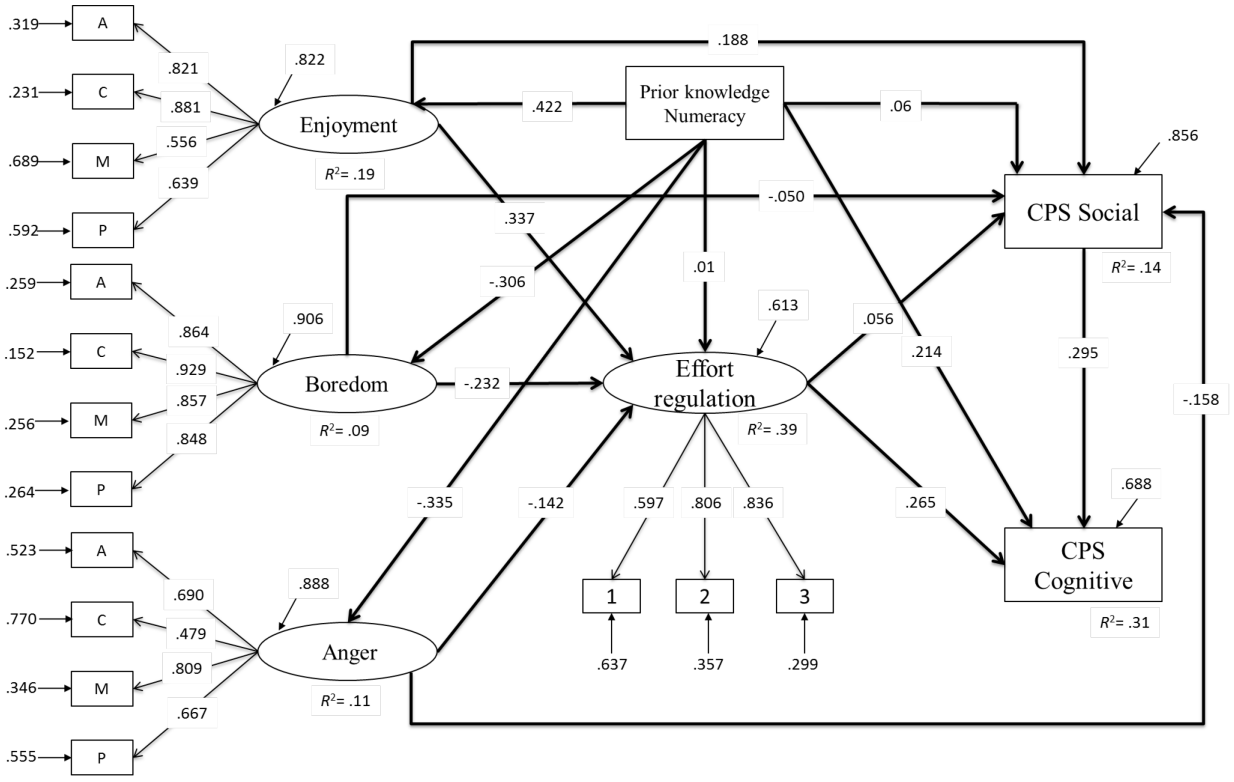

Figure 5. Standardized parameter estimates for the full structural equation model, with residual variances. Model fit indices: $\chi 2$ (117) = 178.446, $p < .01$, CFI = .96, TLI = .95, RMSEA = .051 [90% CI = .035, .066]; Internal components of emotions: Affective (A), Cognitive (C), Motivational (M), and Physiological (P); CPS Social = Social performance domain of Collaborative Problem-solving, CPS Cognitive = Cognitive performance domain of Collaborative problem-solving. Bold arrows indicate structural components of the model.

Discussion

Today, in the onset of the information age, technology is having a growing and transforming impact on the way we live, learn, work, and communicate. As a result, there has been a marked shift in job requirements, moving from routine cognitive and manual tasks to more complex thinking and communication skills, reflected by the four C's: critical thinking, creativity,

communication and collaboration (Care, Kim, Anderson, & Gustafsson-Wright, 2017). These skills are captured within collaborative problem-solving (CPS), a new subject domain of modern curricula. Yet, presently, there has been no research about what predicts CPS performance, and no study has yet explored whether the experience of activity emotions is associated with the CPS performance of adolescents.

In the current study, we aimed to address this gap. Specifically, we investigate the role of activity emotions, including enjoyment, anger, and boredom, on adolescents' performance in the new subject domain of collaborative problem solving (CPS). As hypothesized, enjoyment was associated with greater performance on both social and cognitive CPS tasks by predicting participants' effort and social interactions during the CPS tasks. This is consistent with the notion that increasing students' enjoyment of cognitive and social problem-solving exercises in the classroom may yield enhanced motivation and social collaboration, which in turn may promote effective CPS performance. This is in contrast to the experience of negative emotions, including boredom and anger, which was associated with lower motivation to invest effort, which in turn was linked to poorer cognitive CPS task performance. Aligned with our predictions, social CPS was identified as an important factor linked with cognitive CPS, implying that social skills such as participation, perspective-taking, and responsiveness may be necessary for adolescent performance in collaborative activities that require intellectual input.

Findings from this study suggest that apart from influencing traditional domains such as language, math, history, and sciences, as proposed by the Control-Value Theory of Emotions (Pekrun, 2006) and the Domain-specificity of achievement emotions literature (Goetz, Frenzel, Ludtke, & Hall, 2011; Goetz, Frenzel, Pekrun, & Hall, 2006; Goetz, Frenzel, Pekrun, Hall, & Lüdtke, 2007), emotions are also significant factors associated with more complex students' abilities such as the critical skills for 21st-century schooling: Collaboration, Communication,

Critical Thinking, and Creativity, grouped within CPS.

The current study contributes to the nascent CPS subject by demonstrating that activity emotions, including enjoyment, boredom, and anger, influence students' CPS performance. Importantly, this study builds upon previous research conducted mainly with adult samples by contributing to the understanding of affective process of adolescents in the school setting. Given the growing emphasis on teaching CPS skills, particularly in secondary education, our study contributes to the existing educational literature by examining the impact of activity emotions in relation to school-attending youth. The current findings may inform how such skills are taught in the classroom, while also highlighting some of the potential emotional enablers (i.e., enjoyment) and challenges (i.e., boredom & anger) that influence CPS performance. For example, effectively engaging in CPS tasks requires the ability to regulate emotions generated by both achievement-related experiences and social interactions (Ivcevic & Brackett, 2014). Skills of emotion regulation (i.e., the ability to identify, manage, and modify emotional experiences to meet one's goals; Thompson, 1994) may facilitate engagement and performance during CPS when emotions are experienced as distressing (i.e., anger or boredom) by reducing distraction and maintaining sufficient attention to the task at hand.

In light of these considerations, teachers are encouraged to incorporate evidence-based strategies into the classroom to assist students in managing activity emotions appropriately before, during, and after CPS tasks. Emotion regulation skills can be taught via a range of social and emotional literacy interventions (as reviewed by Osher et al., 2016). Of these, mindfulness exercises and interventions targeting executive control are particularly beneficial in managing distressing emotions including boredom and anger (see reviews by Broderick & Jennings, 2012; Chambers, Gullone, & Allen, 2009; Karbach & Unger, 2014), while positive affective states, such as enjoyment, can be enhanced by a variety of interventions purported to elicit positive emotional

responses (Morrish, Rickard, Chin, & Vella-Brodrick, 2017; Sin & Lyubomirsky, 2009). At the same time, it may be necessary to develop strategies to regulate high-arousal positive emotions, such as excitement, in order to facilitate greater task engagement (Meinhardt & Pekrun, 2003).

Outcomes of the current research also reinforce the value of positive emotions in joint problem-solving activities such as CPS. Beyond the beneficial effects of positive affect on social connection and creative, flexible cognition (Fredrickson, 2001), research with university undergraduates has shown that the experience of positive emotions facilitates improvements in broad-minded coping, defined as a generating a broad array of possible solutions to individual problem-solving tasks (Fredrickson & Joiner, 2002). It is possible that the experience of enjoyment during the current CPS task enhanced students' ability to effectively engage with their partner and adopt a more flexible cognitive approach to the task at hand, leading to more successful performance and learning outcomes.

Results of this study may be drawn upon by policymakers and educational stakeholders to support the promotion of favourable emotional climates within the classroom in order to facilitate students' positive interpersonal functioning (e.g., communication), cognitive flexibility (e.g., problem-solving ability), and beneficial achievement-related emotions (e.g., interest). A focus on emotion regulation strategies is also warranted to address detrimental achievement-related emotions (e.g., boredom, and anger) and associated cognitions (e.g., low task-related self-efficacy), and to increase students' capacity for sustained attention during challenging academic tasks.

Limitations and Future Research

Notwithstanding the contribution of the present study, it is important to note some limitations. Given this is the first study to investigate the role of emotions in the CPS performance of adolescents, we have several recommendations for future research. First, the CPS measure used

in this research is relatively new and is subject to ongoing refinement. Despite this, it has been validated with adolescent samples, has been used internationally to evaluate CPS ability, and has meaningful, real-world applications (Care, Scoular, et al., 2016; Griffin & Care, 2014). This study's reliance on self-report measures of emotions must also be noted as a potential limitation, given that self-report may be subject to reporting biases such as an unwillingness of participants to report on less favourable emotional experiences (Pekrun & Buhner, 2014). It also assumes that students are capable of correctly matching their emotional experiences to a supplied statement on a Likert scale. Future research would benefit from complementing self-report with additional objective measurements, such as facial expression analysis, for a more comprehensive assessment of emotions. Facial expression analysis also represents the expressive component within the component process definition of emotions (Scherer, 2005; Pekrun, 2006), which was not measured in our study. Hence, this could yield valuable insight and is an interesting avenue for future research. At the same time, future studies could consider more frequent sampling approaches of emotions during CPS activities.

Although the current findings provide essential inroads to understanding the role of emotions on CPS performance, only a limited number of affective states were examined. Additional students' emotions relevant to individual mathematical problem-solving outcomes may impact CPS performance and should be explored, such as confusion, frustration, and curiosity (Muis et al., 2015). Similarly, although this study exclusively focused on self-driven emotions as they are considered the principal source of emotions in collaborative learning (Jarvenoja & Jarvela, 2005), emotions elicited by other sources such as the technology (e.g., anger elicited by a poor internet connection), the context (e.g., anxiety triggered by the lab settings), and the social component (e.g., frustration because a lack of participation of the problem-solving partner) deserve future research attention. Finally, for model parsimony, we limited our activity emotions to those

identified in the AEQ. Other activity emotions, such as frustration and relaxation, which are not measured by the AEQ and present an avenue for future research.

In our CPS activity, students communicated via a chatbox, information that was then used in the scoring procedure for CPS performance. However, future research might explore the natural language patterns of adolescents that unfold during these learning scenarios and how this relates to student emotions. Finally, this study aimed to investigate the role of naturally occurring emotions in CPS performance using cross-sectional data – ultimately limiting our capacity to make causal inferences. It is possible that the relationships in our model are bi-directional. For example, final CPS scores may elicit emotional states in students within the collaborative partnerships. Future research might consider experimental manipulations of emotions to establish the causal direction between these variables more clearly and might also consider making comparisons with adults in CPS contexts.

Conclusion

The present study provides insights into the role of affective experiences in the CPS performance of young people, by exploring whether three commonly experienced activity emotions – enjoyment, boredom, and anger – affect CPS performance via motivation to invest effort, as well as social connection. It was concluded, using a partially mediated structural regression model, that students' positive activity emotions (enjoyment) were associated with greater motivation to invest effort, which in turn, influenced both CPS social and cognitive performance. The reverse pattern was found for negative emotions (anger and boredom). Given the growing relevance of CPS skills to both educational and professional settings, further examination of the emotional factors contributing to the success of CPS skill-building in adolescent samples is warranted.

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CHAPTER SIX

RELATIVE INCIDENCE AND ORIGINS OF ACHIEVEMENT EMOTIONS IN COMPUTER- BASED COLLABORATIVE PROBLEM-SOLVING: A CONTROL-VALUE APPROACH

By

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Abstract

This study applied the control-value theory of achievement emotions to investigate the antecedents of achievement emotions experienced by adolescents in computer-based collaborative problem-solving (CPS) activities. In addition, it aimed to identify the set of discrete achievement emotions that adolescents experience in CPS scenarios. Results of structural equation modelling revealed that experiencing enjoyment was associated with higher task value and small increases in perceived academic control, whereas anger and boredom were negatively associated with control and value. Further, during CPS activities students experienced stronger positive activating emotions (e.g., enjoyment) more intensely than negative activating (e.g., anger) or deactivating emotions (e.g., boredom), providing us with the first profile of adolescents' emotions in the new CPS domain. These findings contribute uniquely to the field of affective computing, and specifically, are relevant to the development of advanced learning technologies used to automatically detect and respond to adolescents' emotions in CPS scenarios.

Keywords: achievement emotions; collaborative problem-solving; enjoyment; boredom; anger

Introduction

Collaborative Problem Solving (CPS) is defined as "a joint activity where dyads or small groups execute a number of steps in order to transform a current state into a desired goal state" (Hesse, Care, Buder, Sassenberg, & Griffin, 2015, p. 39). CPS has become an essential component of modern academic curricula, used across primary and secondary schools to teach and assess the 21st-century skills of collaboration, communication, critical thinking, and creativity (Care, Griffin, & Wilson, 2017).

CPS activities are gaining increasing global recognition, with recent evidence suggesting at least 50 nations are progressively incorporating CPS into their curricula and teaching pedagogy (Care, Anderson, & Kim, 2016). Given this rapid rate of adoption, there is an urgent need to investigate the cognitive and affective factors that may be associated with student performance in this new CPS subject domain. In respect to the affective factors, existing research reveals that achievement emotions, understood as emotions experienced by students in achievement-related contexts, for example, while attending classes, studying, completing academic tasks, or sitting examinations (Pekrun, 2006), are particularly relevant to students' performance during collaborative learning scenarios. For instance, in collaborative learning situations including classroom discussions, small group instruction, and, more recently in computer-based CPS tasks, achievement emotions have been found to affect several aspects of student performance including the quality of the interaction between problem-solving partners, as well as the extent of the student's participation, attention, effort regulation, and on-task engagement (Camacho-Morles, Slemp, Oades, Morrish, & Scoular, 2019; Do & Schallert, 2004; Kwon, Liu, & Johnson, 2014; Linnenbrink-Garcia, Rogat, & Koskey, 2011)

Given the integrative role of achievement emotions in collaborative learning, it is essential to investigate their origins and causes. While the last two decades have seen a growing interest in investigating the antecedents of achievement emotions, the majority of studies have focused on individual learning contexts (see Frenzel, Pekrun, & Goetz, 2007; Muis, Psaradellis, Lajoie, Di Leo, & Chevrier, 2015; Pekrun, Daniels, Goetz, Stupnisky, & Perry, 2010), and have largely overlooked the role of students' emotional arousal process in computer-based collaborative learning scenarios. Some noticeable exceptions are qualitative studies (See Jarvenoja & Jarvela, 2005; Naykki, Jarvela, Kirschner, & Jarvenoja, 2014; Robinson, 2013; Wosnitza & Volet, 2005) which usually focus on diffuse positive versus negative affect opposed to discrete emotions. Consequentially, the links between discrete achievement emotions and their origins or antecedents in computer-based collaborative learning remain to be explored empirically. A quantitative evaluation of the experience of discrete achievement emotions in CPS scenarios will allow for the estimation of the relative incidence of emotions in collaborative settings, and whether these emotional experiences are predicted by student's appraisals about the CPS task, such as the student's perceived academic control or the value attributed to the task at hand. The following discussion examines the role of academic control and task value as predictors of achievement emotions in more detail, with reference to Pekrun's (2006, 2018) control-value theory of achievement emotions.

Conceptual Framework

Academic Control and Task Value as Predictors of Achievement Emotions

Emotions are understood as "multi-component, coordinated processes of psychological subsystems including affective, cognitive, motivational, expressive, and peripheral physiological processes" (Pekrun, 2006, p. 316; Scherer, 2005). For instance, when a student experiences

anxiety in anticipation of an exam, related component processes may include feelings of nervousness (i.e., an affective component), worries about one's aptitude to successfully complete the exam (i.e., a cognitive component), impulses to escape the situation (i.e., a motivational component), anxious facial expression (i.e., an expressive component), and increased heart rate and skin conductance level (i.e., a physiological component). Within this component process definition of emotions, *achievement emotions* are emotions directly related to activities of academic achievement such as studying, attending classes, completing tasks; or to outcomes of such achievement such as taking tests or exams (Pekrun, 2006; Pekrun, Goetz, Titz, & Perry, 2002).

Achievement emotions can be classified according to their object focus (Activity/Outcome) and timeframe (Prospective/Retrospective). Categories include prospective outcome emotions, retrospective outcome emotions, and activity emotions (Pekrun & Stephens, 2010). Concerns typical of timeframe categories include whether success can be achieved, or failure can be avoided (i.e., prospective outcome emotions), and whether the outcome was caused by oneself or external sources such as another person or the environment (i.e., retrospective outcome emotions). In contrast, the focus of activity-related emotions is not the outcome but rather the action itself (Pekrun, 2006).

In addition to the object focus and timeframe, achievement emotions can be classified according to dimensions such as valence (positive/pleasant vs. negative/unpleasant), and degree of activation or arousal (activating vs. deactivating; Pekrun et al., 2002). Considering valence and activation allows, for example, distinctions to be made between positive activating emotions (e.g., enjoyment), and unpleasant deactivating emotions (e.g., boredom). To capture a holistic spectrum of achievement emotions in computer-based CPS settings while remaining consistent

with previous research in the field (Camacho-Morles et al., 2019), the present study examined one emotion reflective of three of the four resulting groups, that is, one positive activating emotion (enjoyment), one negative activating emotion (anger), and one negative deactivating emotion (boredom). Experiencing enjoyment has been found to enhance students' engagement with their problem-solving partners, to increase motivation to invest effort, and to predict higher CPS scores. Conversely, boredom and anger were found to be detrimental to final CPS scores as they undermined the effort, and in the case of anger, to negatively impact students' participation and responsiveness (Camacho-Morles et al., 2019). Also, these three emotions each align to different groupings within the valence-arousal circumplex, ensuring sufficient breadth of the achievement emotion taxonomy is covered (Pekrun, 2006; Pekrun & Stephens, 2010). We did not include positive deactivating emotions such as relief or relaxation, as these emotions occur less frequently during achievement activities (Pekrun et al., 2002). Low frequency and relevance during achievement activities also explain why related measures have not been developed (e.g., in Pekrun et al.'s, 2011, Achievement Emotions Questionnaire, relief is included, but only as an outcome-related emotion).

The Control-Value Theory of Achievement Emotions (Pekrun, 2006, 2018; Pekrun & Perry, 2014) offers a theoretical framework that allows integrating constructs and assumptions from diverse theoretical approaches to emotions in education and to achievement emotions more generally (Pekrun, Frenzel, Goetz, & Perry, 2007). This theory states that achievement emotions can be predicted by two-factor appraisals. *Perceived academic control* pertains to the students' belief about various external and personal factors (e.g., intellectual aptitude, physical stamina, educational experience) that may affect his or her scholastic performance in achievement situations (Perry, Hladkyj, Pekrun, & Pelletier, 2001). *Task value* refers to the importance that

the students attribute to the activities and their success and failure outcomes (Eccles & Wigfield, 1995; Pekrun, 2006).

Amongst achievement emotions experienced by adolescents, enjoyment of learning is one of the most frequently expressed (Buff, 2014). From the perspective of the control-value theory of achievement emotions (Pekrun, 2006), students experience enjoyment in a given achievement activity such as studying or completing tasks when such activity is both valued and controllable. The positive affective state may range from excitement if the task is challenging, to relaxation when engaging in enjoyable, routine activities. Aligned with these assumptions, students who evaluated an at-hand task as achievable, useful, and important tended to experience increased enjoyment during task completion (Buff, 2014; Frenzel et al., 2007; Luo, Ng, Lee, & Aye, 2016; Ruthig et al., 2008). Despite this, contrasting evidence suggests that the links between perceived academic control and enjoyment are weak (Buil, Catalán, & Martínez, 2016; Butz, Stupnisky, Pekrun, Jensen, & Harsell, 2016; Garn, Simonton, Dasingert, & Simonton, 2017; Muis, Psaradellis, et al., 2015), and may suggest that students who find the activity valuable will enjoy it regardless of this being sufficiently controllable. In collaborative learning specifically, evidence suggests that the experience of enjoyment is associated with evaluations of one's own achievement, for example, making good progress towards the completion of the task (Wosnitza & Volet, 2005).

The experience of boredom in academic settings is widespread across age groups, educational needs, and ethnicity, with more than 40% of students reporting being bored at some point during lectures, classes, or when completing homework (Tze et al., 2016). Apart from being one of the most intensely rated achievement emotion (Bieg, Goetz, & Hubbard, 2013), when compared to other emotions such as confusion, frustration, and engagement, boredom

tends to be more persistent and enduring (Baker, D'Mello, Rodrigo, & Graesser, 2010; D'Mello, Lehman, & Person, 2010).

Boredom is often caused by a lack of value in a given achievement activity, due to either an insufficiently challenging activity (high-control/low-demands situations) or when activity demands exceed students' capabilities (Low-control/high demand situations; Acee et al., 2010; Goetz and Hall, 2014; Pekrun, 2006; Pekrun, Hall, Goetz, & Perry, 2014). Empirical support for these assumptions has been provided with a series of quantitative and qualitative studies (Pekrun et al., 2010), which revealed that a perceived lack of control over achievement activities, combined with an absence of perceived value, were factors contributing to boredom. Additional studies support Pekrun's (2006) control-value assumptions by demonstrating that boredom is negatively associated with academic control and reduced task value (Bieg et al., 2013; Buil et al., 2016; Butz et al., 2016; Luo et al., 2016; Muis, Psaradellis, et al., 2015; Ruthig et al., 2008), while studies drawing from the field of positive psychology indicate that if the task difficulty is not adequately coordinated with student ability or skill level boredom is likely to occur, whereas proper coordination will result in an optimal state of performance known as flow (Csikszentmihalyi & Csikszentmihalyi, 1975). In computer-based collaborative learning scenarios, research on boredom's antecedents is lacking.

Some authors consider anger amongst the universal emotions experienced by students in academic settings (Pekrun et al., 2002), while others suggest it is consistently infrequent and rare in individual learning with technology scenarios (D'Mello, 2013; D'Mello et al., 2010). From the control-value theory perspective, anger is conceptualized as a negative (unpleasant) and activating (high arousal) emotion experienced by students when the activity at hand is partially controllable but negatively valued (Pekrun, 2006). Anger can also be elicited when someone is

being blocked from achieving a goal (Stein & Levine, 1999). However, limited empirical research has investigated the control-value origins of anger. Recently, Garn et al. (2017) found a negative link between undergraduate students' experience of anger and control beliefs; however, there remains limited research of anger in the context of learning with technology, such as is used in many collaborative learning tasks (D'Mello, 2013). Anger in collaborative learning may be directed at the task (e.g., due to a lack of task clarity), and to other members of the group (e.g., resulting from poor contributions of a team member; Wosnitza & Volet, 2005). Anger may also be experienced when there is a sense of commitment imbalance among group members or when students within a group are excluded from the decisions to be made (Robinson, 2013).

Wosnitza and Volet (2005) suggest that the emotion arousal process in social learning can be directed at the self, the task, and other members of the group, and it is influenced by the personal relevance of the event to the student's agenda (task value) and the degree of familiarity with it. Similarly, Järvenoja and Järvelä (2005) suggest there are five primary sources of students' emotions in collaborative learning, namely the self, task, context, performance, and social. Among those, the self-category, described as emotions originated by students' previous endeavours, individual interests or general thoughts concerning the situation, and personal motivational beliefs about themselves when confronted with the current learning context, is the most frequent source of emotional experiences described by students. This evidence suggests that even emotions in collaborative learning can emerge from different sources, self-driven emotions are dominant and can be labelled as the primary source of emotions in collaborative learning.

In sum, although there has been encouraging progress in relation to understanding the antecedents of achievement emotions in individual learning, research of processes of emotional

arousal in computer-based collaborative learning settings remains a nascent field. Emerging evidence indicates that self-driven emotions play a crucial role in the emotional arousal process of students engaged in collaborative learning, and in the CPS performance of adolescents more specifically (Camacho-Morles et al., 2019), yet additional research is certainly warranted to determine whether previous findings extend across different subject domains (e.g., CPS) and within different student groups (e.g., adolescents).

Domain Specificity of Achievement Emotions

Emotions experienced during achievement activities have been found to vary across different subject areas (CocoradĂ, 2016; Goetz, Frenzel, Pekrun & Hall, 2006). For example, one study of 721 secondary students investigating emotional experiences across four academic domains (mathematics, Latin, German, and English) found, firstly, that the experience and intensity of students' emotions vary across different subject domains, and second, that there was no relationship between emotions experienced across each subject domain (Goetz et al., 2006). Similar results were found in later studies after controlling for the age of students (Goetz, Frenzel, Pekrun, Hall & Lüdtke, 2007) and teacher variables (Goetz et al., 2011). These findings are particularly relevant to the study of computer-based CPS tasks, which represent a novel and specific subject domain that differs from more traditional subjects such as mathematics or English. Given that domain-specificity occurs even across traditional subject domains, it is likely that the relative incidence of emotions in collaborative subjects such as CPS will vary from previous research examining individually-oriented subject domains. Understanding the role of achievement emotions, with reference to Pekrun's (2006) control-value theory, represents an apparent gap in the existing literature and is a crucial aim of the current research.

The Current Study

In conducting the current study, we had two primary goals. First, based on the control-value theory of achievement emotions (Pekrun, 2006), we aimed to investigate academic control and task value as antecedents of discrete self-related activity emotions: enjoyment, boredom, and anger, experienced by adolescent students in computer-based CPS settings, which remains quantitatively unexplored. While previous literature has examined student emotions in learning contexts, most of the literature has used college or university students as participants, ignoring the investigation of achievement emotions' origins in younger populations such as secondary and primary school children. Examining this gap in the literature is essential as it may shed light on the student emotional arousal process during computer-based CPS activities, a rapidly growing area of 21st-century skills pedagogy in secondary schools (Care et al., 2017). We suggest that this is particularly important due to the predominant focus on college students at the individual level, which may not necessarily generalize to adolescents (Vierhaus, Lohaus, & Wild, 2016). For example, adolescents tend to express their emotions more freely than adults (Ekman & Friesen, 1969) and may be less well equipped to effectively regulate their emotions (Zeman et al., 2006). This may make adolescent samples more susceptible to "catching" like emotional experiences from their CPS partners (Hatfield et al., 1993), affecting effort regulation and CPS performance within CPS groups (Camacho-Morles et al., 2019).

Our second goal was to analyze the relative incidence of student's achievement emotions in computer-based CPS, which may be different from those experienced in more traditional subject domains like reading, mathematics, or science, as suggested by the Control-Value Theory of achievement emotions (Pekrun, 2006).

To summarize, we test a theoretical model positing that adolescents' achievement emotions in computer-based CPS are associated with their perceived academic control and perceived task value. For enjoyment, we hypothesize that students will enjoy CPS activities when they find the tasks more valuable and sufficiently controllable (Hypothesis 1). In contrast, we hypothesize that anger, considered a control-dependent emotion, will exhibit negative relationships with both academic control and task value (Hypothesis 2). This is because CPS tasks present obstacles and impasses (e.g., reliance on respective input to solve the CPS tasks), which are sometimes beyond the control of students, which may elicit an angry response. Finally, we hypothesize that students will experience greater boredom when the CPS tasks are insufficiently valued, and when students perceive themselves to be less in control over the CPS tasks, such as when the CPS tasks are too difficult (Hypothesis 3). The full hypothesized model is present in Figure 1.

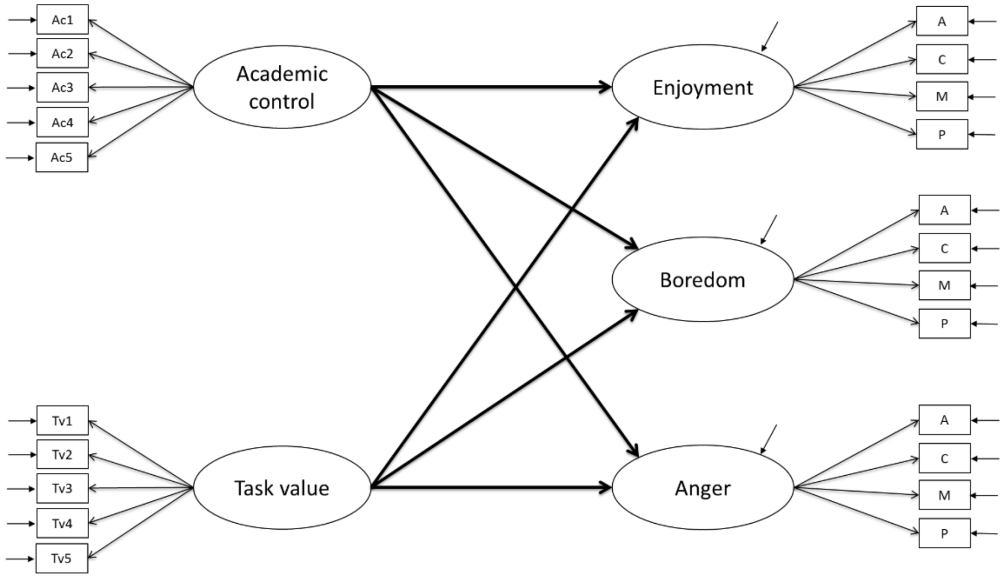

Figure 1. Hypothesized structural equation model. Bold arrows represent the structural component. Internal components of emotions: Affective (A), Cognitive (C), Motivational (M), and Physiological (P).

Method

Participants

The participant inclusion criteria were a) students formally enrolled in secondary school and b) age range of 11 to 15. After obtaining school, parental, and student consent, we recruited a purposive non-random sample of N = 200 students (100 female; M age = 13.48 years; SD = 1.14) from five public secondary schools located in the Melbourne metropolitan area, Victoria State, Australia. Given that almost 80% of secondary schools in Australia are government schools (ACARA, 2018), our sample was representative of a substantial proportion of the high school population in the country. Participation in the study was voluntary. All students were known to each other and did not receive any incentive for their participation.

Measures

Achievement Emotions

The Achievement Emotion Questionnaire (AEQ) (Pekrun et al., 2011) was adapted to measure participants' enjoyment, boredom, and anger. Students reported emotions on a 5-point Likert scale from 1, "Strongly disagree" to 5, "Strongly agree." The scales are structured such that items assess emotions at three different time-points relative to the achievement activity: before, during, and after. This was true only for enjoyment and anger; for boredom, only one time-point (during) is needed because it is considered a concurrent emotion (Pekrun et al. 2011). The scale consisted of nine items for enjoyment ($\alpha = .78$); sample item before: "I look forward to demonstrating my knowledge"; sample item during: "For me these CPS tasks are a challenge that is enjoyable", sample item after: "I glow all over". 11 items for boredom ($\alpha = .93$); sample item during: "I am so bored that I have problems staying alert". Finally, seven items for anger (α

= .86); sample item before: “I am fairly annoyed,” sample item during: “I think questions are unfair,” sample item after: “My anger makes the blood rush to my head.”

Based on the work of Pekrun et al. (2011), composite scores were calculated by creating a mean score across the measurement time-points (before, during, and after) for each internal component of emotions: namely, affective, cognitive, motivational, and physiological. These composite scores were then used as the observed variables for each emotion latent variable. This decision was made based on research that suggests that achievement emotions are best modelled as hierarchically organized structures with sub-components of emotion at the lowest level and the emotion itself as a second level latent factor (Pekrun et al., 2011).

Academic Control

The perceived Academic Control Questionnaire (ACQ), adapted from Perry et al. (2001), was used to measure subjective Academic Control. The scale consisted of five items with a 5-point Likert scales from 1, “strongly disagree” to 5, “strongly agree”; $\alpha = .78$; sample item: “In general, I have a great deal of control over my academic performance.”

Task Value

The Task Value Measure (TVM), adapted from (Muis, Pekrun, et al., 2015; Muis, Psaradellis, et al., 2015) was used to measure students’ subjective task value. It consisted of five items with a 5-point Likert scales from 1, “Not at all true of me” to 5, “Very true of me”; $\alpha = .88$; sample item: “In general, learning about Collaborative Problem Solving is useful.”

Control Variables

Given the mathematic nature of two of the CPS tasks, we controlled for the effects of prior knowledge in numeracy. For this purpose, we collected participants’ latest score in the numeracy component of the National Assessment Program for Literacy and Numeracy

(NAPLAN). This standardized test provides an assessment of the literacy and numeracy skills of students at years 3, 5, 7 and 9 across Australia (visit https://www.nap.edu.au/ for more information).

Procedure

Ethics clearance was granted by The University Human Ethics Research Committee and the Australian Department of Education and Training in the state of Victoria. The study was conducted at the Science of Learning Research Classroom, located in the Melbourne, Australia, and consisted of students working in dyads to complete five CPS tasks, as well as three self-report questionnaires to assess achievement emotions, perceived academic control and task value.

Upon arrival, students were randomly grouped into gender-matched pairs for the collaborative exercise, thus creating 100 student dyads. Students had individual access to a computer and sat five meters away from their problem-solving partner.

Overall, students had 60 minutes to complete the five CPS tasks and had as much time as they needed to complete the three questionnaires. The activity was structured such that students entered the classroom and first completed the ACQ, the TVM, as well as the "before" section of the AEQ. They then completed 30 minutes of CPS tasks prior to completing the "during" section of the AEQ. Students then had 30 remaining minutes to complete the CPS tasks before they were invited to complete the "after" section of the AEQ. A central video recording system in the classroom allowed researchers, parents, and teachers to monitor the activity from a master control room.

Computer-Based Collaborative Problem-Solving Tasks

Participants completed five collaborative problem-solving tasks while their activity emotions were monitored and recorded. The CPS tasks were designed to be assessment tools that initially help to identify a student's baseline level but can also be administered at various future points in time to monitor growth (Griffin & Care, 2014; Griffin, McGaw& Care, 2012)

The tasks were created to be completed by two students working collaboratively who can communicate with each other through a chatbox. At the beginning of each task, an instruction stem was presented, followed by a problem. To satisfactorily complete the task, students needed to make use of both social and cognitive skills to identify the elements of the problem and available resources, plan a possible solution, decide which part of the plan will be executed by each participant, and reach the desired goal. All students with each pair must contribute. Otherwise, the solution could not be reached.

Task length and difficulty varied, with some tasks, for example, requiring less collaboration but at the same time being cognitively more challenging. For instance, one of the tasks that participants completed was called Game of 20. In this task, students were faced with the problem of reaching a value of 20 by placing counters sequentially on a grid. They were playing against the computer and needed to use their previous knowledge in mathematics to collaboratively reach the desired value of 20 before the computer (Care, Griffin, et al., 2015). See Figure 2 for a visual from the perspective of participants.

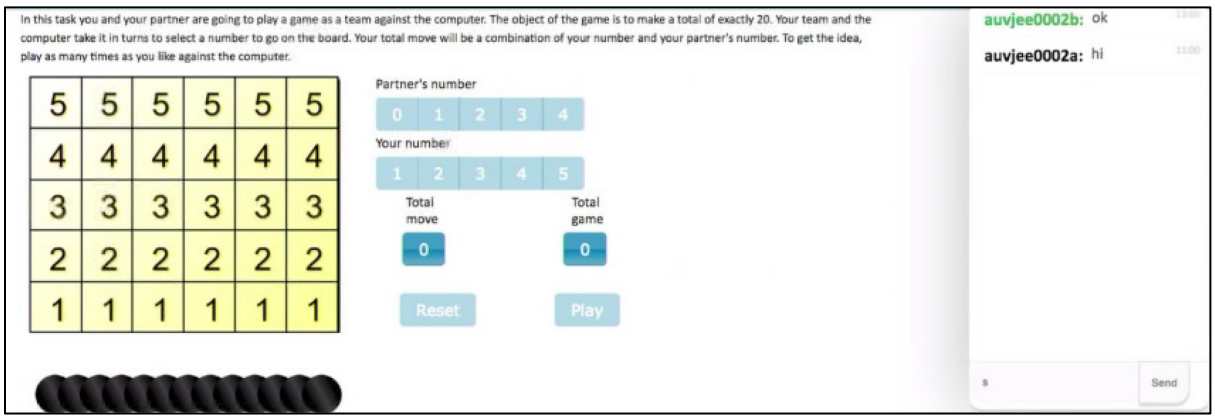

Figure 2. "Game of 20" task from the perspective of participants. Note: Taken with permission from (Care, Griffin, et al., 2015)

The mean task duration in the current study was 10 minutes, 8 seconds (SD = 5.74). The total completion time for all tasks was approximately one hour. CPS tasks were presented via a desktop computer (PC), on a 19-inch computer monitor.

Data Analysis Strategy

Due to the hierarchical nature of our data (students nested within dyads), we used Structural Equation Modeling (SEM) for complex surveys with cluster data to test our hypothesized model. Analyses were conducted using MPlus 7.2 (Muthén & Muthén, 1998-2015). Because all scales we used produce ordinal data, we used the weighted least squares (WLSMV) estimator for the Structural Equation Modelling analyses, as evidence suggests it is robust estimator which does not assume normally distributed variables and represents the best alternative for modelling categorical or ordered data (Brown, 2015). We used the two-step approach to SEM introduced by Anderson and Gerbing (1988) and followed suggestions about reporting SEM results suggested by Schreiber, Nora, Stage, Barlow, and King (2006).

Model fit was determined by four indices: Chi-square, Comparative Fit Index (CFI), and the Tucker and Lewis Index (TLI); and Root Mean Square Error Approximation (RMSEA). Cut-off values were CFI and TLI ≥ .90; RMSEA ≤ .08, as suggested by Hooper, Coughlan, and Mullen (2008).

Results

Relative Incidence of Achievement Emotions in CPS Activities

Table 1 shows scale descriptive statistics, correlations, and internal consistency reliabilities. Findings indicate that positive emotions were displayed more than negative ones, with enjoyment being the emotion exhibited the most while boredom and anger were the least reported by participants. All scales were found to be highly reliable, with Cronbach's alpha values ranging from acceptable to excellent (Cohen, 2003).

Table 1

Descriptive statistics, latent factor correlations, and scale reliabilities

Variables	1	2	3	4	5	6
1. Enjoyment	--					
2. Boredom	-.70**	--				
3. Anger	-.47**	.58**	--			
4. Perceived academic control	.30**	-.30**	-.34**	--		
5. Task value	.60**	-.36**	-.23**	.41**	--	
6. Prior scores (Numeracy)	.43**	-.31**	-.34**	.46**	.20**	--
M	3.62	1.62	1.51	4.33	3.77	634.48[a]
SD	0.65	0.73	0.60	0.58	0.69	75.88
Reliability (α)	.83	.93	.81	.78	.85	--

Note:[a] Possible range = 0 to 999. * $p < .05$. ** $p < .01$.

We then analyzed frequency tables to obtain estimates of the proportion of participants who reported agreement with emotion scale statements; in other words, students who chose

either 4 or 5 on the Likert scale (agree, and strongly agree respectively) for each of the items measuring emotions. Results confirmed that enjoyment was more highly experienced than boredom and anger. Proportions were as follows: enjoyment 73%, whereas only 5% of participants agreed with statements intended to measure boredom, and 4% for anger.

Measurement Model Validation

We used confirmatory factor analysis (CFA) to examine the validity of the measurement model (Anderson & Gerbing, 1988). We followed Kline (2011), ensuring models yielded high standardized regression weights (i.e., > .70) and correlations between factors that are not excessively high (i.e., < .85). We specified a total of 28 parameters to be estimated in our measurement model: 10 correlations and 18 factor loadings. One factor loading was fixed for model identification. These parameters were suitable for the stability of the model in our sample of 200. There were no missing data.

CFA results showed that goodness of fit indices were solid χ^2 (199) = 299.796, $p < .01$, CFI =.94, TLI = .93, RMSEA = .050 (90% CI = .038, .062). Standardized factor loading estimates were consistently high ($\beta > 0.70$), suggesting convergent validity. Although some estimates were slightly lower, such as 0.49 for the cognitive component of anger, 0.56 for the motivational component of enjoyment, and five more were between 0.60 and 0.70, we did not remove any item to preserve the internal component structure of achievement emotions in our model (Pekrun et al., 2011). Standardized and unstandardized estimates of factor loadings, as well as standard errors, are presented in table 2. Evidence of multicollinearity was not detected between latent factors, suggesting adequate discriminant validity (see correlations between all variables in table 1). The residual analyses did not indicate any problems and no post-hoc

modifications were indicated from the analysis. The measurement model is presented in figure 3. No modification was performed.

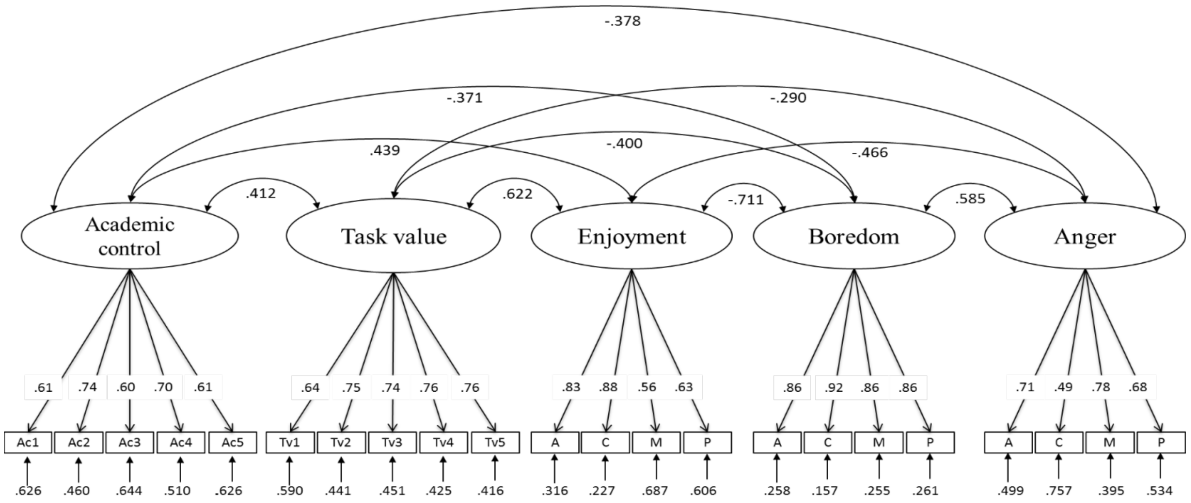

Figure 3. Standardized factor loadings and latent factor correlations for the full measurement model using CFA. Model fit indices χ^2 (199) = 299.796, $p < 0.01$, CFI = 0.94, TLI = 0.93, RMSEA = 0.050 (90% CI = .038, .062). Internal components of emotions: Affective (A), Cognitive (C), Motivational (M), and Physiological (P).

Table 2

Factor loadings of Observed Variables

Observed Variable	Latent construct	β	SE	B
Affective	Enjoyment	0.83	0.033	1.00
Cognitive	Enjoyment	0.88	0.032	1.16
Motivational	Enjoyment	0.56	0.054	0.84
Physiological	Enjoyment	0.63	0.046	0.91
Affective	Boredom	0.86	0.028	1.00
Cognitive	Boredom	0.92	0.024	1.05
Motivational	Boredom	0.86	0.034	0.82
Physiological	Boredom	0.86	0.028	0.76
Affective	Anger	0.71	0.063	1.00
Cognitive	Anger	0.49	0.085	0.62
Motivational	Anger	0.78	0.063	1.22
Physiological	Anger	0.68	0.071	0.88
Ac1	Academic Control	0.61	0.075	1.00
Ac2	Academic Control	0.74	0.059	1.38

Observed Variable	Latent construct	β	SE	B
Ac3	Academic Control	0.60	0.084	1.19
Ac4	Academic Control	0.70	0.068	1.33
Ac5	Academic Control	0.61	0.065	1.41
Tv1	Task value	0.64	0.063	1.00
Tv2	Task value	0.75	0.040	1.11
Tv3	Task value	0.74	0.036	1.28
Tv4	Task value	0.76	0.039	1.32
Tv5	Task value	0.76	0.473	1.37

Note. β = Standardized estimates. B = Unstandardized estimates. SE = Standard errors

Structural Model Validation

Having validated our measurement model, we next tested the structural part of our model with the aim of investigating the associations between academic control and task value with achievement emotions. Structural equation modeling results showed that our proposed model fit the data well χ^2 (217) = 345.436, $p < .01$, CFI = .93, TLI = .92, RMSEA = .054 (90% CI = .043, .065). No modifications were performed. The final structural model is presented in Figure 4.

As shown in the figure, consistent with our hypothesis 1, results indicated that task value and academic control was associated with greater enjoyment. At the same time, aligned with hypothesis 2, anger was predicted by lower task value and academic control. Finally, consistent with hypothesis 3, boredom was predicted by lower task value and academic control. Importantly, the model accounted for more than 50% of the variance in students' enjoyment, as well as 22% for boredom and 20% for anger. Finally, the results revealed that prior knowledge in Numeracy was positively linked to enjoyment (.26), academic control (.46), and task value (.20), while it was negatively associated with boredom (-.16) and anger (-.19).

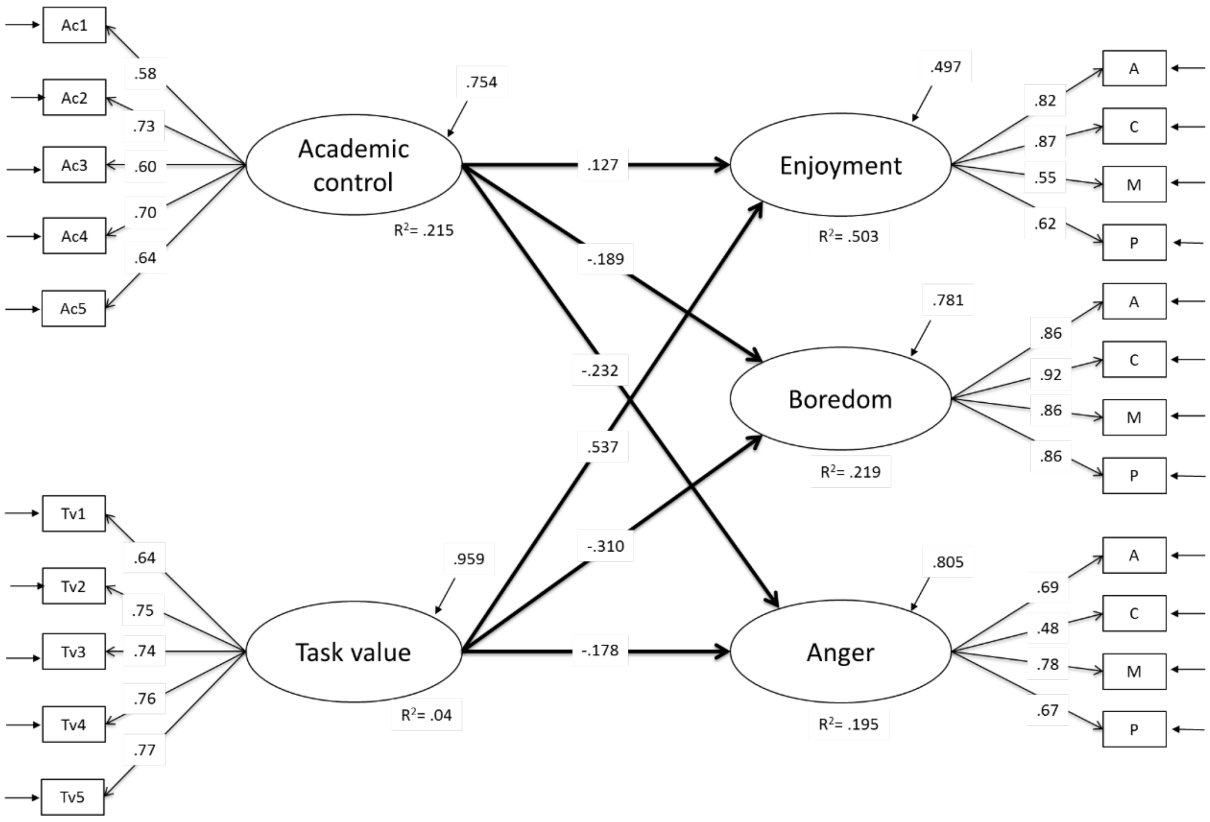

Figure 4. Standardized parameter estimates for the structural model. Model fit indices χ^2 (217) = 345.436, $p < .01$, CFI = .93, TLI = .92, RMSEA = .054 (90% CI = .043, .065). Internal components of emotions: Affective (A), Cognitive (C), Motivational (M), and Physiological (P).

Discussion

Collaboration, communication, critical thinking, and creativity (also known as the "four C's") have been identified amongst the most critical skills for children and adolescents to have as these skills are considered key factors for success in the twenty-first century work environment (Care, Kim, Anderson, & Gustafsson-Wright, 2017; Griffin, McGaw, & Care, 2012). With the purpose of teaching and evaluating the "four C's" in schools, a new subject domain named Collaborative Problem-Solving (CPS) has been created. It has been defined as "a joint activity where dyads or small groups execute a number of steps in order to transform a current state into a desired goal state" (Hesse, Care, Buder, Sassenberg, & Griffin, 2015, p. 39). This new subject-

domain has been recognized worldwide as a fundamental element of modern curricula, and its global implementation in school pedagogy is imminent (Care, Anderson, & Kim, 2016).

Recent research shows that discrete achievement emotions, namely enjoyment, boredom , and anger, play an integrative role in the performance of adolescents in this new subject domain (Camacho-Morles et al., 2019). This motivated our investigation about the antecedents of achievement emotions in CPS scenarios; mainly we were interested in whether the arousal of adolescents' enjoyment, anger, and boredom was influenced by their perceived academic control and task value appraisals. First, it is possible that students enjoy CPS activities when they find the tasks more valuable and sufficiently controllable. A second possibility is that anger, considered a control-dependent emotion, exhibits negative relationships with both academic control and task value. This is because CPS tasks present obstacles and impasses (e.g., reliance on respective input to solve the CPS tasks), which are sometimes beyond the control of students, which may elicit an angry response. Finally, students experience greater boredom when the CPS tasks are insufficiently valued, and when students perceive themselves to be less in control over the CPS tasks, such as when the CPS tasks are too complicated. Our findings offer support for all these predictions.

As hypothesized, our results indicate that both perceived academic control and task value are associated with the experience of student achievement emotions in CPS settings. By analyzing the structural regression coefficients in the final model, we can infer that the experience of enjoyment was strongly linked by the importance given by students to the CPS activity (task value), while their association with academic control was less. This suggests that when students positively value the completion of CPS tasks, they will find the activity enjoyable regardless of this being sufficiently controllable. These results are partially aligned with

Pekrun's (2006) theory which put equal importance on both control and value in the prediction of enjoyment, and corroborate recent evidence suggesting weak associations between perceived academic control and the arousal of students' enjoyment in different academic settings such as using clickers, working on synchronous hybrid learning environments, and individual mathematics problem-solving (Buil et al., 2016; Butz et al., 2016; Muis, Psaradellis, et al., 2015)

For boredom, as expected, we found a negative association between both control and value appraisals. Aligned with the control-value theory, these results suggest that when the task demands exceeded the capabilities of participants, and there was a lack of incentive value, boredom occurred. Finally, the experience of anger was more linked to the controllability of the activity than to the value given to it. This suggests that the more control students have over the activity, the less likely they are to experience anger.

The identified association between participants' previous scores in numeracy with the arousal of achievement emotions in CPS settings suggests that students with previous high scores in numeracy found the completion of CPS tasks more enjoyable, while low-capable students in math experienced more anger and boredom. This is most likely due to the mathematic-content nature of the CPS tasks used in the current study.

These findings represent an original and essential contribution to the field of student emotions origins in computer-based collaborative learning as they allow us to estimate the magnitude of the correlation between achievement emotions and their predictor, which was not possible to do until today given the qualitative nature of most of the existing literature addressing this topic. Taken together, our findings can help to understand the complexity of the emotional arousal process of adolescents working collaboratively.

This study also contributes to the body of literature exploring how students' emotions vary according to the subject domain (Goetz et al., 2011; Goetz et al., 2006; Goetz et al., 2007). Based on this assumption and given the reduced number of quantitative research about patterns of students' emotions in collaborative learning, the set of emotions that students may experience during CPS activities could not be accurately predicted. Our study addressed this critical gap and shed light on this topic by reporting that adolescents experience a more intense pattern of positive activating emotions such as enjoyment, in contrast to less negative activating and deactivating emotions like anger and boredom, respectively. These findings have key implications for the ongoing enhancement of the CPS assessment material we used in this study. Firstly, the fact that enjoyment was intensively reported by students suggests that the current features of the CPS tasks are mostly succeeding in keeping students focused and engaged. Then, although boredom was less intensively reported, we believe improvements should be made to the tasks, (e.g., the inclusion of more seductive details, increment of interactivity) to increase motivation and interest in order to reduce the arousal of boredom which plays a crucial role on students' effort regulation in CPS activities (Camacho-Morles et al., 2019)

From a similar vein, our findings contribute to the developing field of affect-sensitive ALTs in CPS scenarios. For example, by knowing the incidence and impact of negative deactivating emotions like boredom in CPS, it is possible to design learning technologies that can automatically and dynamically detect boredom from other sources apart from self-report questionnaires, namely, facial expression analysis, written text, and posture among others (See Calvo & D'Mello, 2010 for a comprehensive review), and accordingly adapt to it. A possible way in which technology could react to boredom is to alter the difficulty of the task, thus

increasing the probability of low-ability students to succeed in the completion of the CPS tasks, and in turn, potentially reduce boredom.

Limitations and Recommendations for Future Research

Notwithstanding the contribution of the present study, we note some limitations. Given this is one of the first studies to quantitatively investigate the links between discrete achievement emotions and control and value appraisals in CPS settings with adolescents, we have some recommendations for future research.

As discussed, students' emotions in collaborative learning can be directed at the self, the tasks or technology (e.g., frustration due to poor internet connection), the lab context (artificial lab settings vs. real-world collaborative exercises in schools), the performance outcomes, or even the social elements that arise in CPS contexts (e.g., anger provoked by the paltry contributions of a partner; Jarvenoja & Jarvela, 2005; Wosnitza & Volet, 2005). In this study, we focused exclusively on the self category. To increase our understanding of the adolescents' emotional arousal process in computer-based CPS, future research should explore these other sources of students' emotions.

Apart from the set of achievement emotions included in this study, future research should investigate the rate of occurrence and origins of other emotions and affective states such as engagement/concentration, confusion, frustration and curiosity in CPS, as evidence suggests they are frequently experienced by students and influence their performance in similar scenarios, namely computer-based learning environments and effortful individual problem-solving tasks (Baker et al., 2010; D'Mello, 2013; D'Mello et al., 2010). Finally, for model parsimony, we limited our activity emotions to those identified in the AEQ. Other activity emotions, such as

frustration and relaxation, are not measured by the AEQ and present an avenue for future research.

Conclusion

This study took one of the first steps in understanding the emotional arousal process of adolescents in the new subject domain of collaborative problem-solving (CPS). In conclusion, adolescents solving problems in pairs experience a more intense profile of positive activating emotions (e.g., enjoyment) as opposed to less strong negative deactivating (e.g., boredom) and activating (e.g., anger) emotions. Importantly, the arousal of these emotions is associated with adolescents' perceived academic control and task value, which confirms the propositions of the Control-Value Theory of achievement emotions (Pekrun, 2006) in collaborative learning scenarios for the first time. This study contributes to research concerning how emotions originate in collaborative groups involving adolescents. Given the crucial role that achievement emotions play on students' performance in CPS settings (Camacho-Morles et al., 2019), research investigating their origins is warranted.

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CHAPTER SEVEN

GENERAL DISCUSSION

The primary goal of this dissertation was to gain insights into emotions associated with the collaborative problem-solving (CPS) performance of adolescents. This was necessary given the global relevance of CPS as a critical component of modern curricula and its imminent implementation into classroom pedagogy worldwide (Care et al., 2017; Care et al., 2016).

In this chapter, I summarize the most significant findings that come from my three empirical studies and relate them to my original predictions. At the same time, I discuss how the findings fit in with the previous literature and discuss the broader implications for practice. Finally, I describe some limitations of the studies and make suggestions for future research. I will end with an overall conclusion.

Contributions of the Dissertation

Collaborative Problem Solving is a newly created subject domain designed to teach and assess the 21st century skills of collaboration, critical thinking, communication, and creativity in schools globally (Griffin, Care, & McGaw, 2012). Evidence indicates that 58 countries, including Chile, the United States of America, India and Italy, among others, have already incorporated CPS skills into their curricula, implying that their implementation in pedagogy practices is imminent (Care et al., 2017). Furthermore, 17 countries including Australia, Mexico, Singapore, Iceland, and United Arab Emirates, among others, have gone a step further developing learning progressions to assess student competence in 21st century

skills, and evaluate student progress over time (Care, Kim, Vista, & Anderson, 2018). Although there remain challenges for the global implementation of 21st skills into classrooms, mostly regarding the development of appropriate learning progressions, and the design of authentic assessment tasks (see Care et al., 2018 for more details), evidence suggests that the majority of education systems in the world have understood the need for adapting their curricula to the current labour market requirements (Care et al., 2018), and have embraced the educational shift toward a 21st skills agenda that could better equip students to live and work in the information-age society.

Despite its international relevance and rapid adoption, evidence of student-related factors associated with CPS performance is scarce. In other words, there is limited information about how student achievement in this new subject domain can be predicted (see Barron, 2003; Teasley, 1995; Tudge, 1992, for a few exceptions). Evaluating the links between student emotions and CPS performance seems particularly important, as recent evidence shows that emotions play a fundamental role in educational outcomes as they influence several cognitive and self-regulatory processes (e.g., motivation, uses of learning strategies, attention) that are considered critical for success in academic settings (Loderer et al., 2018; Tze, Daniels, & Klassen, 2016). This motivated my exploration of whether individual differences in achievement emotions, understood as emotions experienced by students in achievement learning situations such as attending classes, studying, completing tasks, or taking exams (Pekrun, 2006), would be linked to students' results in CPS.

One possibility was that positive emotions like enjoyment were linked to a more significant motivation to invest effort and would be associated with better performance in the cognitive domain of CPS. In contrast, the experience of negative emotions such as boredom and

anger would be negatively linked to CPS (cognitive) as they tend to undermine motivation and effort. A third possibility was that enjoyment, boredom, and anger would be directly associated with CPS (social), as they may affect the quality of interaction and communication between groups. The results provide support for all these perspectives and show that emotions are significant factors associated with complex students' abilities such as the critical skills for 21st-century modern curricula, namely, communication, critical thinking, collaboration, and creativity, grouped within CPS (Camacho- Morles, Slemp, Oades, Morrish, et al., 2019).

Having validated the model postulating that achievement emotions predict students' CPS performance, I was then interested in investigating the emotional arousal process of adolescents in this new subject domain. It was essential to determine whether students' experience of discrete achievement emotions in CPS settings would be associated with two factor appraisals, namely, academic control, meaning the students' beliefs about various external and personal factors such as perceived ability, experience, aptitude, among others that could influence their academic performance (Perry, Hladkyj, Pekrun, & Pelletier, 2001); and task value, which relates to the importance and value attributed by students to achievement activities (Eccles & Wigfield, 1995). First, it was possible that students who found the tasks more valuable and sufficiently controllable would experience enjoyment. For anger, it was hypothesized that it would show a negative relationship with both academic control and task value, given the obstacles and impasses that CPS tasks could present to students. A final possibility was that boredom would be experienced by students when their perceived academic control was low, coupled with a lack of task value. Findings from this dissertation offer support for all of these predictions, and build connections between the emerging CPS subject and ongoing theories in the educational psychology field such as the control-value theory of achievement emotions (Pekrun, 2006) by

showing that the arousal of discrete achievement emotions in CPS scenarios is associated with students' perceived academic control and task value appraisals to a significant extent (Camacho-Morles, Slemp, Oades, Pekrun, et al., 2019).

Another contribution of this research relates to testing the domain-specificity of achievement emotions proposed by Goetz et al. (2006, 2007, 2011). This principle states that achievement emotions are dependent on the context in which they are elicited. Given that CPS is a new subject domain, I investigated the set of emotions students may experience during CPS activities, which remained unknown and could not be accurately predicted. Findings from this research indicate that adolescents experience a more intense pattern of positive activating emotions such as enjoyment, in contrast to less harmful activating (i.e., anger) and deactivating emotions like (i.e., boredom) in CPS settings (Camacho-Morles, Slemp, Oades, Pekrun, et al., 2019).

Finally, results from the meta-analytical review of the literature on activity-related emotions and academic achievement presented in chapter four contribute to clarify the existing discrepancies in the literature and corroborate the positive link between positive activating emotions such as enjoyment and student performance. These results also provide further evidence suggesting that the experience of both boredom and anger during achievement activities had a moderate to strong correlation with students' final performance and achievement. Taken together, these findings suggest that discrete activity-related emotions are important factors related to academic success. Particularly for young populations (e.g., secondary students), correlations between emotions and achievement are stronger.

Implications

This research extends the existing literature conducted primarily with adult samples by contributing to the understanding of the affective process of school-attending youth in CPS settings. Given the global implementation of CPS skills in pedagogy practices, this research may contribute to understanding how to teach these skills in schools taking into account the influence of achievement emotions in adolescents' final performance. Based on these considerations, students need to make use of their ability to regulate the emotions elicited by both the cognitive and social challenges of the CPS situation (Ivcevic & Brackett, 2014). These emotion regulation skills may help students to identify, manage and modify their emotional experiences (Thompson, 1994) minimizing, therefore, the impact of negative emotions such as boredom and anger, and promoting the occurrence of favourable emotions like enjoyment in order to achieve the shared goal of the CPS activity.

Teachers can put findings from this research into action by incorporating strategies into their pedagogy practice, to assist students in regulating their emotions in CPS scenarios appropriately. These emotion regulation skills are teachable via a range of social and emotional literacy interventions (Osher et al., 2016). Among these, mindfulness, acceptance-based, or other exercises to stem from the contemplative traditions (Slemp, Jach, Chia, Loton, & Kern, 2019), which target executive control may be particularly beneficial in managing harmful emotions, such as boredom and anger (Broderick & Jennings, 2012; Chambers, Gullone, & Allen, 2009; Karbach & Unger, 2014), while the enhancement of positive emotions including enjoyment can be achieved by a variety of evidence-based interventions (e.g., increase emotion regulation capacity through education about emotions, communication skills, and stress management) (Morrish et al., 2017).

Consistent with the literature, this research found that positive emotions promote social bonds and intellectual resources (Fredrickson, 2009). In joint problem-solving activities such as CPS, the experience of enjoyment was found to enhance students' ability to effectively engage with their problem-solving partner and adopt a more flexible cognitive approach to the task at hand, leading to more successful performance outcomes (Camacho- Morles, Slemp, Oades, Morrish, et al., 2019). Policymakers and educational stakeholders are encouraged, therefore, to promote positive emotional environments within classrooms in order to facilitate favourable relationships between students (e.g., perspective-taking) and beneficial achievement-related emotions (e.g., interest). This could be achieved through structural changes that affect intrinsic motivation in schools, which are closely linked with enjoyment such as autonomy support training and interventions (Slemp, Kern, Patrick, & Ryan, 2018; Su & Reeve, 2011) and positive education interventions (Slemp et al., 2017). In addition, a focus on emotion regulation interventions is also necessary to address the impact of disturbing emotions (e.g., boredom, and anger) and related students' self-beliefs (e.g., low self-efficacy), as well as to enhance students' engagement and concentration during joined problem-solving tasks.

Aligned with previous findings, our results highlight the importance of effort regulation skills for the academic achievement of adolescents (Richardson, Abraham, & Bond, 2012; Robbins et al., 2004). Importantly, activity emotions are closely associated with the effort regulation capabilities of students in CPS activities. Teachers, therefore, should promote the experience of positive emotions such as enjoyment as they can lead students to persist completing joint problem-solving classroom tasks, even when such activities are perceived as difficult or uninteresting.

Findings from this research about the origins and domain-specificity of achievement emotions in CPS activities have several implications for the ongoing refinement of the computer-based tasks used in this study, and for the design and development of advanced learning technologies (ALTs) that can detect and react to students' emotions in computer-assisted CPS settings. For instance, game designers, programmers and software engineers from the human-interaction field could use this evidence to develop affective-sensitive learning material such as problem-solving tasks or games, which can first detect the emotional state of students and then react to it in an effort to reduce the incidence of harmful emotions (e.g., boredom, and anger) on CPS performance (Calvo, D'Mello, Gratch, & Kappas, 2015; Picard, 1997). A student with high ability, for instance, may experience boredom because she/he finds the task at hand to be too easy; ALTs should be capable of detecting this situation and increase the difficulty of the problem to a point where it matches the student ability to potentially reduce boredom, increase engagement and create a state of flow which is ideal for learning to occur (Griffin, 2007). Findings from this dissertation may also contribute to the current design and development of ALTs in other learning contexts beyond CPS, such as supporting teaching practices (e.g., teacher noticing) (Lee, Tan, & Tan, 2019), learner-centered pedagogy (e.g., doubt identification from student reflections) (Lo, Tan, & Ouh, 2019), and analysis of learning behaviours patterns in technology-assisted environments (Shih, 2019).

Limitations and Recommendations for Future Research

Only a limited number of emotions were examined as predictors of CPS performance in this dissertation. The links between CPS and other emotions or affective states such as confusion, frustration, and curiosity deserve future research attention given the evidence

suggesting they affect student learning and performance in computer-based scenarios (Muis et al., 2015).

The expressive component of emotions was not measured in this thesis due to resource limitations: they require facial expression analysis. To assess all the sub-components of emotions suggested by Scherer (1982) in his multi-component process definition of emotions, a measure of students' facial expressions, gestures, postures, or analysis of the written text is needed. As problem-solving partners need to communicate through a chat box in order to complete the CPS tasks, it will be possible to gather information about the intensity and dynamics of the emotions expressed by students and complement it with their self-report measures. It could also be possible to collect this data by recording the student faces as they complete the CPS tasks and then examine how it correlates with self-reported data. This as an exciting avenue for future research that would provide a holistic measure of students' emotions in CPS.

Regarding the origins of emotions in CPS, I focused only on self-elicited emotions as they have been recognized as the primary source of emotions in collaborative learning (Jarvenoja & Jarvela, 2005). Future research should explore alternative sources such as emotions towards the problem-solving partner (e.g., anger because of a lack of participation of a partner), towards the technology (e.g., frustration due to a poor internet connection or towards a slow processing computer), and emotions directed at the settings (e.g., anxiety elicited because of lab contexts). These findings can produce further insights into the emotion arousal process of students working in groups to solve problems collaboratively.

There exist two different perspectives regarding the links between perceived academic control and the arousal of enjoyment. A body of literature suggests a moderate to strong

relationship between these constructs (Buff, 2014; Frenzel, Pekrun, et al., 2007; Luo, Ng, Lee, & Aye, 2016; Pekrun et al., 2002; Ruthig et al., 2008) whereas more recent studies, including findings from this research, report rather weak or non-significant correlations between them (Buil, Catalan, & Martinez, 2016; Butz, Stupnisky, Pekrun, Jensen, & Harsell, 2016; Garn, Simonton, Dasingert, & Simonton, 2017; Muis et al., 2015). A synthesis of empirical findings examining these connections may help to identify an overall pattern and strength of these relationships.

I have emphasised the technology-enhanced aspect of CPS due to the nature of our research which used computer-based tasks to assess student competence on this topic. However, I think findings from my research work are a good initial step to better understand student performance on CPS more generally (e.g., face-to-face CPS activities). More research is certainly warranted. Similarly, our research focused exclusively on students working in pairs to solve problems collaboratively. An interesting avenue for future research would be to explore the influence of emotions in the CPS performance of groups with more than two students. According to Cen, Ruta, Powell, Hirsch, and Ng (2016), the learning behaviour of students in groups tend to be more complex due to several factors such as the quality of contributions from members and group composition. Therefore, even though the same set of CPS skills would apply (e.g., social and cognitive) (Hesse et al., 2012), it is possible that emotions may have a more significant impact in group performance as they may negatively influence the quality of the interaction between group members and generate conflicts (e.g., frustration) (Ayoko, Callan, & Härtel, 2008), and may also be detrimental to the harmony within the group leading students to lower their task engagement (e.g., anger) (Naykki et al., 2014).

This research refers to the common challenge of ecological validity, understood as the extent to whether a behaviour observed in laboratory settings reflects the natural behaviour in real-world scenarios (Schmuckler, 2001). Although there were benefits for conducting this research in lab contexts such as control of test environment and stimuli, and reduce distractions, results may be different when students complete CPS activities in their classrooms. Future research should explore this possibility and investigate the arousal process of achievement emotions in natural learning environments.

A final limitation of this research relates to its reliance on self-report questionnaires and the ordinal data they produce, which can violate assumptions of normality causing subsequent analysis problems (e.g., ceiling and flooring effects). Future research should consider this potential issue and take it into account when estimating SEM models. A possible solution is to use the weighted least squares (WLSMV) estimator that is considered an excellent alternative for modelling ordinal or categorical data that is not normally distributed (Brown, 2015). Future studies may also consider complementing the information gather from self-reports with additional measures of emotions such as analysis of expressive cues (e.g., speech, gestures, facial expressions), and interpretation of neurophysiological responses (e.g., electrodermal and brain activity).

Conclusions

While research on achievement emotions has increased substantially over the last two decades, there remain questions within the field that have not received much research attention, including (a) the origins and impact of discrete achievement emotions in collaborative learning scenarios, (b) the antecedents and outcomes of discrete achievement emotions in young populations (e.g., secondary school children), and (c) the study of activity-related discrete

emotions (e.g., enjoyment, anger, frustration, and boredom) as opposed to outcome-related emotions, such as test anxiety. This dissertation was conducted with the aim of addressing these gaps to bring new insights into these specific domains.

This dissertation contributes to the literature in several ways. First, it presents the first attempt to systematically locate and statistically aggregate the available studies investigating the role of enjoyment, anger, frustration, and boredom activity-related achievement emotions in academic performance, as well as moderators of those effects. The meta-analysis that was conducted resolved the inconsistencies that were identified in the literature and yields insight about the aggregate strength and direction of the relationships between these emotions and academic performance. The results are consistent with the premise that insofar as students are able to regulate their emotional experiences in activity-achievement situations (e.g., attending classes, studying, doing homework), their academic performance may be impacted. Results point to the critical role of enjoyment, anger, and boredom in academic performance. In particular, while emotions matter across all age groups and participant demographics, it was found they are particularly important for secondary school students, where the effects were stronger across the literature.

Second, this thesis comprises some of the first empirical inquiries into student-related factors affecting the performance of adolescents working on the newly created and globally recognized subject domain of Collaborative problem-solving (CPS). Results provide evidence supporting that students' discrete achievement emotions such as enjoyment, boredom, and anger influence various aspects of group functioning, including effort regulation, participation, perspective taking and actual group outcomes in collaborative problem-solving activities. Finally, this research offers evidence about the antecedents of achievement emotions in CPS

settings by determining their relationship with perceived academic control and task value appraisals. By being able to model how the emotions of young learners affect their collaborative problem-solving outcomes, it is possible to design and implement interventions to help ensure their later success in the 21st century workplace.

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APPENDIX A

Interrater Agreement Statistics

Variable	ICC	Kappa
r	.97	
N	.99	
r_{xx}	.99	
r_{yy}	.99	
Age	1.00	
Publication status		.99
Achievement emotion measure		.94
Subject domain		.68
Educational context		.99
Nationality of participants		.94

Note: *r* = effect size, *N* = study sample size, r_{xx} = reliability of the achievement emotion variable, r_{yy} = reliability of the performance criterion variable; publication status = coded as "Published" or "Unpublished"; Achievement emotions measure = coded as "AEQ", "AEQ-M", "AEQ-S", "AEQ-PA", "AEQ-ES", "EES", or "Other". Subject domain = coded as "Mathematics", "Literacy", "Sciences", "Psychology", or "Other". Educational context = coded as "Primary", "Secondary", or "Undergraduate".

APPENDIX B

Reliability distribution descriptive statistics for the relations between activity achievement emotions and academic achievement

Variable	R_{xx}			R_{yy}		
	N	*M*	*SD*	*N*	*M*	*SD*
Enjoyment	52	.85	.07	7	.91	.03
Boredom	57	.87	.07	6	.91	.03
Anger	22	.84	.09	1	.85	--
Frustration	6	.80	.06	--	--	--

Note: *N* = Number of reliability coefficients reported; *M* = Mean; *SD* = Standard Deviation; R_{xx} = Reliability coefficient for activity achievement emotions; R_{yy} = Reliability coefficient for performance.

APPENDIX C

List of sources eligible for inclusion in the meta-analysis

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APPENDIX D

Example of social or cognitive skills and indicative behaviors for exemplary tasks in Laughing Clowns

CPS elements/Skills	Indicative behavior	An example of data captured (Evidence of data)
Interaction	Interacting with partner	Presence of chat before allowing the partner to make a move
Audience Awareness	Adapts contributions to increase understanding for the partner	Number of ball moves attempted before stopping and waiting for the partner to move or respond
Responsibility initiative	Takes responsibility for progress for the group task	Number of times communicated with the partner before the first half of the shared balls was used up
Resource Management	Manages resources	Realizes that balls are meant to be shared and uses only allotted half
Systematicity	Implements possible solutions to a problem	Uses the allotted half of the balls to cover the positions in a sequential order
Relationships	Identifies connections and patterns between elements of knowledge	The two students come to an agreement on how their machine works
Solution	Arrives at the correct answer	Selection of the correct option by A and B on how their machine works

Adapted with permission from Care, Griffin, Scoular, Awwal, & Zoanetti, (2015, p.92)

APPENDIX E

Indirect and total effects

	β			*B*				
Model	Jo	Bo	Ag	Jo	Bo	Ag	*SE*	R^2
Direct								
Effort regulation	0.38	-0.21	-0.15	0.56	-0.22	-0.26	0.066	0.40
CPS Social	0.21	-0.04	-0.16	0.24	-0.03	-0.20		
Indirect (through ER)								
CPS Social	0.02	-0.01	-0.01	0.02	-0.01	-0.01		
CPS Cognitive	0.10	-0.05	-0.04	0.14	-0.06	-0.07		
Total								
CPS Social	0.23	-0.05	-0.17	0.26	-0.04	-0.21	0.039	0.14
CPS Cognitive	0.14	-0.11	-0.13	0.14	-0.06	-0.07	0.060	0.27

Notes: Jo = Enjoyment; Bo = Boredom; Ag = Anger; ER = Effort regulation; β = Standardized estimates; B = Unstandardized estimates; *SE* = Standardized error; R^2 = Variance explained