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Research Article

Learning-Related Emotions in First-Year International Students: Investigating Affective, Cognitive, Motivational, and Physiological Components

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Abstract: The component process model of achievement emotions views learning emotions as interconnected psychological processes comprising affective, cognitive, motivational, and physiological components. Based on this framework, the Achievement Emotion Questionnaire (AEQ) was developed as a key self-report tool for measuring specific achievement emotions in educational settings. Despite widespread use of the AEQ in empirical research, only a few studies have explicitly validated its component structure. This study aims to address that gap by examining the component structure of learning emotions measured with the AEQ. We applied both confirmatory and exploratory factor analyses to a large dataset of responses to evaluate the robustness of the component structure. Our sample included 14,456 first-year students enrolled at a Dutch business and economics school across the academic years 2010/2011 to 2023/2024. Most importantly, findings reveal a significant issue: the multi-component model does not hold for at least one crucial aspect—the physiological component of the positive learning emotion, enjoyment. This component does not align well with the others and fails to adhere to a fundamental assumption of the control-value theory of achievement emotions, which posits that academic control, along with intrinsic and extrinsic value, serves as a proximal antecedent for both emotions and their components. Additionally, hierarchical regression models were used to examine the predictive strength of proximal antecedents across components, with a specific focus on gender effects and their interactions with emotion components. Gender effects uncover that while female students generally experience higher anxiety and hopelessness and lower boredom compared to male students, their emotional patterns in relation to the proximal antecedents are largely similar to those of male students in comparable situations.

***Keywords*:** achievement emotions, international classroom, first-year students, emotion components

1. Introduction

Affect—encompassing learning-related emotions and self-efficacy beliefs—remains one of the most underexplored dimensions in mathematics education, particularly during the first year of university. Research suggests that these affective factors significantly influence student performance and persistence. For instance, Niculescu (2015) reported that heightened anxiety was linked to exam absenteeism, while feelings of hopelessness were related with lower exam scores. Similarly, Daker et al. (2021) demonstrated that math anxiety negatively predicted both the number of STEM

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courses pursued and math achievement, even when controlling for mathematical ability. A growing body of research has also shown that strong self-efficacy beliefs are associated with greater retention in STEM and engineering fields (Besterfield-Sacre et al., 1997; Lent et al., 2003; Schaefers et al., 1997). More recently, Geisler et al. (2023) found that declines in students' mathematical self-concept during the first year were predictive of dropout. These findings suggest that students' adjustment during the transition to university may be influenced by affective, social, and cognitive factors, all of which are closely tied to academic success (Di Martino et al., 2023). Mathematics anxiety has also been shown to exhibit a gendered pattern, with numerous studies highlighting an association between gender and anxiety levels in mathematics (e.g., Hart & Ganley, 2019; Vos et al., 2023). However, the so-called 'gender mathematics gap' should not be accepted as inevitable. In fact, in several neighboring European countries such as Sweden, Norway, and Iceland, girls outperform boys in mathematics (Givord & Mostafa, 2019, pp. 25-26). These disparities are not rooted in biological differences but are instead shaped by enduring cultural stereotypes and educational practices that influence gendered expectations and experiences in mathematics (Givord & Mostafa, 2019). The issue is thus sociocultural rather than innate. Although it is widely recognized that women have historically been underrepresented in Science, Technology, Engineering, and Mathematics (STEM) fields (Takahira et al., 1998), the specific vulnerability of this group during introductory university courses—where negative experiences can deter continued participation—is often overlooked. This underscores the importance of exploring how students of different genders emotionally experience their first year in university mathematics, as these affective dimensions may significantly influence their academic trajectory.

Learning-related emotions are one crucial factor that plays a role in the academic success or failure of first year students. Achievement learning emotions are emotions that arise in performance settings—environments where learners are expected to demonstrate their abilities. Performance in these contexts depends on various individual and environmental factors. What sets these emotions apart is the deeply personal nature of their experience. At the same time, their expression and impact are shaped by contextual factors, as emotions are influenced by situational dimensions (Mesquita et al., 2010). This paper aims to explore which emotional dimensions most effectively characterize learning experiences in achievement contexts.

"Self-report is not well suited to assess the physiological and behavioural components of emotions, such as physiological arousal and facial expressions (Pekrun, 2024, p. 83)." Despite this insight from one of the creators of the Achievement Emotion Questionnaire (Pekrun et al., 2011a; 2011b), the AEQ remains the leading tool for measuring discrete emotions in educational contexts. However, few empirical studies critically examine the AEQ's component structure. Those that do generally use confirmatory approaches and report that their factor or structural equation models, based on the control-value theory, achieve adequate fit. Yet, merely achieving adequate fit does not necessarily confirm which theoretical framework best aligns with observed emotional data.

Given these limitations, a more thorough examination of the AEQ's component structure is crucial for refining our understanding of how discrete emotions operate within educational contexts. Specifically, an exploration beyond confirmatory approaches—incorporating exploratory analyses—can shed light on potential inconsistencies and reveal whether the current framework fully captures the complexity of these emotions.

The present study addresses exactly this gap and proposes a more comprehensive method to investigate the issue. We do this by using a large sample over more than a decade of data collection. To the best of our knowledge, this is the first study with such an approach.

The following section will explain the construct of achievement emotion and the roles played by its various components. This will be achieved by first offering a broad definition of emotions, then identifying achievement emotions, and finally explaining the taxonomy of achievement emotions along with the different types of emotions that arise from it.

2. The construct of emotions

2.1 *Definition*

Emotions, broadly defined, are complex processes characterized by a set of changes triggered by the appraisal of an event or situation as relevant. Consistent with contemporary emotion theories (Scherer & Moors, 2019), these changes—and their corresponding components—are affective, cognitive, motivational, physiological, and expressivebehavioural in nature. While emotional expressions can vary significantly between individuals, within individuals, and across cultures (Barrett et al., 2019), they are shaped by specific patterns that represent responses to particular events (Pekrun et al., 2023). These patterns give rise to prototypical emotions, which are conceptually distinct from other emotions and can be assessed, for example, through verbal reports. This distinction is crucial, as groups of prototypical emotions share similar properties, such as the achievement emotions and their various categories (Pekrun et al., 2023).

2.2 *Achievement emotions*

Achievement emotions have traditionally been defined as emotional reactions to success and failure, or outcomes, within achievement contexts (Pekrun, 2006). More recently, this definition has been broadened to include emotional responses to ongoing activities appraised based on competence—that is, emotions arising from actions judged as competently performed, even if they ultimately lead to success or failure (Pekrun et al., 2023). This distinction between outcome-related and activity-related emotions is fundamental to the taxonomy of achievement emotions.

2.3 *Taxonomy of achievement emotions*

According to Pekrun's (2006) taxonomy, achievement emotions can be classified along three key dimensions: valence, activation, and focus. The valence dimension refers to the emotional experience's perceived pleasantness, distinguishing positive emotions from negative ones. For example, experiencing anxiety during an exam is generally unpleasant and thus categorized as a negative achievement emotion. The activation dimension relates to the physiological arousal associated with an emotion. Emotional experiences characterized by parameters such as an increased heart or respiratory rate are considered highly arousing and activating, as in the case of anxiety. Finally, the focus dimension differentiates emotions based on their object, which can pertain to an activity or an outcome, or their temporal relationship with the object, experienced as ongoing, anticipatory, or retrospective achievement emotions (Pekrun et al., 2023).

These dimensions are essential for understanding the emergence of emotions and their functions in appraising situations and influencing action. For instance, the focus dimension explains how achievement emotions arise and how they contribute to subsequent outcomes, such as success or failure. Importantly, the dimensions of valence, activation, and focus do not operate independently but instead interact to form distinct groups of achievement emotions. This integration is captured in the three-dimensional taxonomy of achievement emotions (Pekrun et al., 2023), which categorizes emotions into activity-focused, outcome-prospective, and retrospective emotions (by focus). Each of these can be further classified as positive or negative (by valence) and activating or deactivating (by arousal or activation).

In the Control-Value Theory of Achievement Emotions (Pekrun, 2006), emotional experiences are context-dependent, meaning they can occur in various academic settings within a course: 1) attending class, 2) taking tests and exams, and 3) studying outside of class, such as during homework preparation or independent learning. Consequently, these settings are used to assess distinct types of emotions: class-related, test-related, and learning-related emotions. Among these, learning-related emotions are particularly noteworthy, given their association with achievement outcomes, yet remain underexplored in higher education contexts (Niculescu, 2015).

2.4 *Learning-related emotions and their antecedents*

Learning-Related Emotions (LREs), according to the Three-dimensional Taxonomy, are categorized as activity emotions. Within the framework of the Control-Value Theory of Achievement Emotions (CVTAE), specific Learning-Related Emotions (LREs) arise from the appraisal of achievement-related activities and outcomes, indirectly shaping achievement outcomes. Two key dimensions of appraisal underlie these emotions: control and value. Control appraisals reflect a student's belief in their ability to influence learning activities or outcomes, whereas value appraisals signify the subjective importance assigned to these activities or outcomes. Both types of appraisals are regarded as direct antecedents of LREs and are typically shaped at the course level (Pekrun, 2006). Empirical evidence has consistently shown that both control and value appraisals are significant predictors of enjoyment (e.g., Buff et al., 2011; Putwain et al., 2018). Moreover, anxiety tends to increase when individuals perceive a negative outcome value combined with a moderate level of control (e.g., Hall et al., 2016; Lohbeck et al., 2016). Finally, boredom is associated with a lack of perceived value and either very high or very low control—when tasks are perceived as too easy or too difficult (e.g., Bieg et al., 2013; Shao et al., 2020).

Control appraisals, in particular, display perceptions of one's competency in achieving outcomes. Generally, high and low levels of control appraisal are associated with emotions in different ways. For example, higher levels of control tend to enhance positive emotional experiences, such as enjoyment of learning (Pekrun, 2000). LREs, which often arise during ongoing activities like homework or studying, are especially relevant as they represent autonomous learning processes during a course.

With respect to gender differences in mathematics, existing research has identified notable disparities in achievement emotions and their underlying antecedents. Specifically, studies have shown that girls tend to report significantly lower levels of enjoyment and higher levels of anxiety, hopelessness, and shame compared to boys. These emotional differences are primarily attributed to girls' lower competence beliefs, coupled with higher subjective valuation of success in mathematics (Frenzel et al., 2007a; 2007b; Hill et al., 2016). Given the focus on autonomous learning, a central aspect of the course examined in this study, the validity and reliability of existing self-report instruments, such as the Achievement Emotions Questionnaire (AEQ), in capturing LREs in university settings become a critical question. Concerns have been raised regarding the adequacy of certain emotion components for learning situations. For instance, the relevance of the physiological component for capturing learning enjoyment has been questioned (Niculescu et al., 2015). Furthermore, the AEQ has recently been updated to better address the unique challenges specific to mathematics classes, which set them apart from other academic domains (Bieleke et al., 2023). Meanwhile, some researchers have chosen to use shortened versions of the AEQ to reduce the length of questionnaires (Bieleke et al., 2021). However, these abbreviated versions do not differentiate between the affective, cognitive, motivational, and physiological components.

In utilizing the full questionnaire, our study seeks to perform a comprehensive exploratory analysis of AEQ data, with a particular emphasis on the multi-component structure of learning emotions. By doing so, we seek to provide empirical evidence to support the updated CVTAE framework (Pekrun, 2024).

2.5 *Research questions and objectives*

This study aims to bridge this gap by conducting an in-depth, exploratory analysis of AEQ data, focusing on the multi-component structure of learning emotions. By doing so, we seek to answer three key questions: (1) Does the physiological component align with the other three components (affective, cognitive, and motivational) across various learning emotions? (2) How well does the control-value theory explain the variation in emotion scales and their components, particularly the physiological dimension? and (3) What gender-related differences can be observed in relation to these two aspects?

Three research objectives are central to addressing these questions. The first involves analysing component alignment by investigating the consistency of the physiological component across different emotions. The second aims to achieve theoretical validation by assessing the explanatory power of academic control, intrinsic value, and extrinsic value for each component, with a particular emphasis on discrepancies between the physiological component and other components. Finally, the third objective focuses on addressing methodological implications, specifically by discussing how the findings inform the continued use of the AEQ self-report instrument.

Our methodology involves applying both confirmatory and exploratory factor analyses to a large dataset of AEQ responses to evaluate the robustness of the component structure. Additionally, hierarchical regression models will be used to examine the predictive strength of proximal antecedents across components, with a specific focus on gender effects and their interactions with emotion components.

3. Methods

3.1 *Research design*

The present study is an observational, cross-sectional study involving first-year international students. Data were collected from fourteen student cohorts using survey instruments featuring Likert-scale items, yielding quantitative scale data.

3.2 *Participants and educational context*

This study focuses on first-year students at a Dutch business and economics school from the 2010/2011 to 2023/2024 academic years (fourteen cohorts). The school is renowned for its student-centred Problem-Based Learning (PBL) approach and strong international focus, offering primarily English-taught programs that attract a predominantly international student body. It holds the prestigious Triple Crown accreditation, a rare distinction among global business schools. The study includes 14,456 freshmen, of whom 40% are female and 60% male; 21% are domestic students, while 79% are international. Most students enrol immediately after completing secondary education, typically aged between 18 and 20 (mean age = 19.20, SD = 0.40). Data were collected during their first course, an introductory mathematics and statistics module.

The institution primarily employs PBL in small tutorial groups of 15 students each. To address varying levels of proficiency, particularly in mathematics and statistics, traditional methods are supplemented with online resources, creating a blended learning environment. Students use e-learning tools to prepare individually for tutorials, followed by collaborative problem-solving in small groups—an approach aligned with the "flipped classroom" model (Non & Tempelaar, 2016). To further enhance student learning in this module, Dispositional Learning Analytics (DLA) is utilized. Learning Analytics (Buckingham Shum & Crick, 2012) delivers feedback to students about their learning progress using trace data gathered from their interactions with digital learning platforms. DLA extends this by incorporating data from self-report surveys that assess learning dispositions (Buckingham Shum & Crick, 2012; Tempelaar et al., 2015; 2018). These surveys, grounded in social-cognitive learning theories, serve two purposes: offering personalized feedback and providing individual datasets for statistical projects, thereby improving students' data analysis skills. The Achievement Emotions Questionnaire (Pekrun et al. 2011a; 2011b) is one survey instrument that effectively serves this dual purpose.

3.3 *Instruments*

Achievement emotions. The Control-Value Theory of Achievement Emotions (CVTAE) (Pekrun, 2006) suggests that achievement emotions vary in terms of valence, focus, and activation. Using the Achievement Emotions Questionnaire (Pekrun et al., 2011a; 2011b)—which is grounded in CVTAE—we selected four scales most closely linked to academic performance: the positive-activating emotion of Learning Enjoyment (LJO), the negative-activating emotion of Learning Anxiety (LAX), and the negative-deactivating emotions of Learning Boredom (LBO) and Learning Hopelessness (LHL). Considering the focus on independent, self-regulated learning within the PBL system, we utilized the learning-related versions of these scales instead of the class- or test-related versions.

Academic control (Acad. Control), assessed using the Perceived Academic Control scale by Perry et al. (2001), is incorporated as a first proximal antecedent of learning activity emotions.

Attitudes towards learning. To complement the control antecedent with a value component, we used an extended version of the Survey of Attitudes Toward Statistics (SATS; Tempelaar et al., 2007). Grounded in expectancy-value theory (Wigfield & Eccles, 2000), this instrument measures six attitudes related to learning mathematics and statistics. For this study, we focused on two scales representing extrinsic and intrinsic value dimensions in learning maths and stats: Extrinsic Value (Value Extrinsic), which reflects students' perceptions of usefulness, relevance, and personal significance, and Intrinsic Value (Value Intrinsic), which captures their individual interest and enjoyment.

3.4 *Data collection*

During the first eight weeks of their initial academic semester, students completed two mandatory modules: one integrating organizational theory and marketing, and the other combining maths and stats. In the first and fourth weeks, they completed self-report questionnaires on learning dispositions for use in a data analysis project, both in and outside class. To ensure students were familiar with the learning environment and assessment structure, the learning emotions and learning attitudes questionnaires were administered midway through the term, at the end of the fourth week of the eight-week module.

The study received ethics approval from the Ethical Review Committee Inner City faculties (ERCIC) of Maastricht University under file ERCIC_044_14_07_2017. All individuals gave their informed consent for the utilization of anonymized student data in educational research prior to participation.

3.5 *Data analysis*

Students completed self-report questionnaires on their learning dispositions during the early weeks of the module, reflecting habits developed in high school. Additional surveys—such as the learning emotions instrument, which required familiarity with specific learning activities and graded assessments—were administered at the module's midpoint. These surveys served a dual purpose: they provided personalized feedback to both students and tutors, and they generated data for use in student-led statistical projects during the final week of the module. Completing these surveys was part of a regular module assignment required of all students; as such, no data were missing unless a student withdrew from the module, in which case their data were excluded from the study.

Scale data for all instruments were initially calculated in MS Excel and shared with students and tutors. Subsequent analyses were conducted using MPlus (version 8.7) for Confirmatory Factor Analysis (CFA), while Exploratory Factor Analysis (EFA) and hierarchical regression analyses were performed using SPSS (version 27).

4. Results

4.1 *Descriptive analysis of scales*

Table 1 presents the descriptive statistics for learning activity emotions, including means, standard deviations, skewness, kurtosis, sample reliability (Cronbach's alpha), and correlations, categorized by gender. All measures meet the standard criteria for univariate analysis (Kline, 2016). The descriptive analysis reveals some noteworthy gender differences. Using a Likert scale where 4 is the neutral point, we find that the mean Learning Anxiety (LAX) score for male students is below neutral, whereas it is above neutral for female students. Both male and female students report mean Learning Boredom (LBO) scores below neutral, though female students exhibit lower boredom levels than males. Conversely, mean Learning Hopelessness (LHL) scores for both genders are below neutral, but females score higher than males. Mean Learning Enjoyment (LJO) scores for both genders hover slightly above the neutral point. Figure 1 visually illustrates these gender differences.

Table 1. Means, standard deviations and correlations of AEQ scales, by gender

		Mean	SD	Skew	Kurtosis	Reliability	Correlations		
							LAX	LBO	LHL
Males (N = 8,763)	LAX	3.69	1.13	-0.051	-0.466	0.913			
	LBO	3.07	1.13	0.456	-0.200	0.934	0.452		
	LHL	2.90	1.16	0.505	-0.240	0.941	0.818	0.599	
	LJO	4.21	0.92	-0.184	0.165	0.853	-0.271	-0.540	-0.416
Females (N = 5,693)	LAX	4.26	1.18	-0.282	-0.253	0.918			
	LBO	2.77	1.10	0.682	0.263	0.935	0.391		
	LHL	3.29	1.27	0.307	-0.442	0.945	0.827	0.537	
	LJO	4.25	0.90	-0.205	0.061	0.848	-0.358	-0.469	-0.499

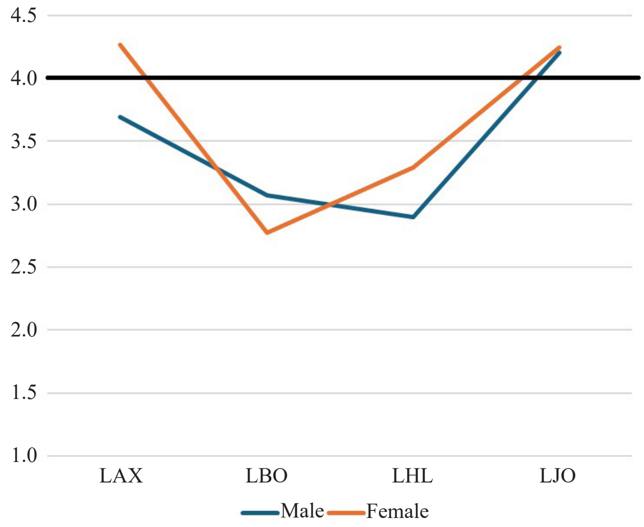

Figure 1. Gender differences in AEQ scale means

All scales exhibit high reliability, with particularly strong scores for LAX, LBO, and LHL. In contrast, the reliability score for LJO is also high but slightly lower.

4.2 *Descriptive analysis of scale components*

When breaking down the learning activity emotion scale scores into four components—Affective (A), Cognitive (C), Motivational (M), and Physiological (P)—two distinct patterns emerge, as shown in Table 2 and Figure 2. LBO and LHL scores remain relatively stable across all four components, with male students consistently scoring higher on LBO and lower on LHL compared to female students. In contrast, LAX and LJO component scores display much more variation. Cognitive learning anxiety scores are the highest, exceeding the neutral point for both genders, whereas motivational anxiety scores remain below neutral. The slightly lower reliability of the LJO scale is primarily due to the high physiological component scores, which are significantly higher than those of the other three components for both genders.

Table 2. AEQ scale component means, by gender

	A	C	M	P
LAXmale	3.66	4.11	3.01	3.77
LAXfemale	4.27	4.75	3.39	4.35
LBOmale	3.17	3.11	3.08	2.92
LBOfemale	2.74	2.96	2.78	2.61
LHLmale	3.03	2.92	2.70	2.86
LHLfemale	3.46	3.36	2.91	3.28
LJOmale	4.49	4.13	3.52	4.89
LJOfemale	4.45	4.17	3.50	5.14

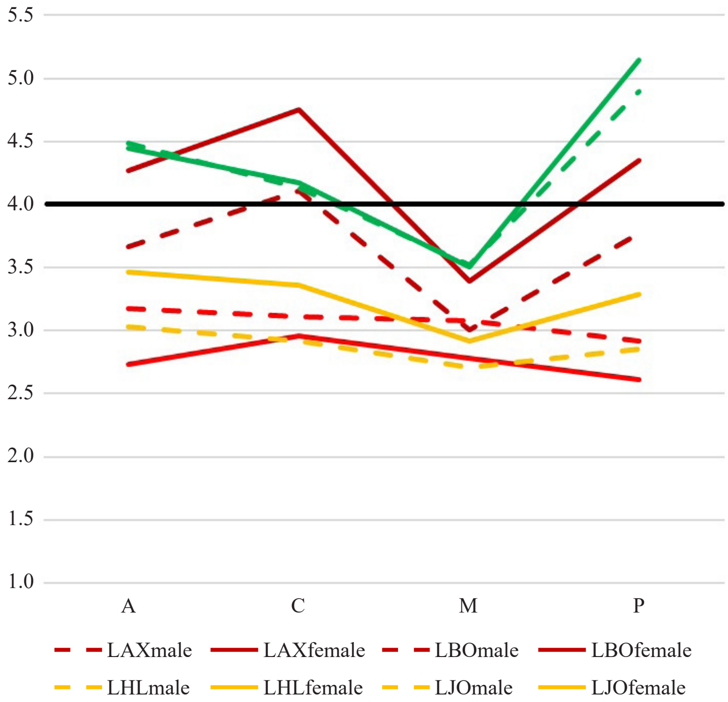

Figure 2. Gender differences in AEQ scale component means

The distinct nature of the LBOM component compared to the other learning boredom components is particularly evident in the correlation matrix in Table 3 (based on the full sample). While the other components within each emotion exhibit strong correlations that support combining them into a composite scale, the correlations between LBOM and the other LBO components range only from 0.2 to 0.3, indicating a different underlying characteristic.

Table 3. AEQ scale component correlations

Anxiety	LAXA	LAXC	LAXM	Boredom	LBOA	LBOC	LBOM
LAXA				LBOA			
LAXC	0.779			LBOC	0.749		
LAXM	0.708	0.602		LBOM	0.704	0.685	
LAXP	0.793	0.709	0.647	LBOP	0.818	0.790	0.755
Hopeless	LHLA	LHLC	LHLM	Enjoyment	LJOA	LJOC	LJOM
LHLA				LJOA			
LHLC	0.828			LJOC	0.730		
LHLM	0.801	0.759		LJOM	0.681	0.703	
LHLP	0.771	0.714	0.726	LJOP	0.297	0.275	0.225

4.3 *Confirmatory and exploratory factor analysis of AEQ items*

Consistent with previous studies examining the component structure of learning activity emotions (Pekrun et al., 2011a; 2011b), Confirmatory Factor Analysis (CFA) on the full sample yields an adequately fitting factor model. The fit statistics are as follows: Root Mean Square Error of Approximation (RMSEA) = 0.045, 95% CI [0.044, 0.045], Probability of RMSEA < 0.05 = 1, Comparative Fit Index (CFI) = 0.949, Tucker-Lewis Index (TLI) = 0.937, and Standardized Root Mean Square Residual (SRMR) = 0.059. To address the first research objective—examining the consistency of the physiological component across different emotions—we conducted an Exploratory Factor Analysis (EFA). The results of this EFA indicate that alternative models may provide a better fit. When conducting EFA at the item level with four factors specified, the first factor captures all learning anxiety and learning hopelessness items, the second factor includes all learning boredom items, and the learning enjoyment items are split according to the correlation structure noted earlier: Affective (A), Cognitive (C), and Motivational (M) items load onto the third factor, while Physiological (P) items load onto the fourth factor. Running the EFA using scale components instead of individual items produces an identical pattern of factor loadings. Table 4 presents the rotated component matrix for the scale component analysis; Figure 3 provides a visualisation of the factor solution.

Repeating both analyses—using AEQ items or component subscales as inputs for exploratory factor analysis—on the male and female subsamples again yields the same factor structure and loadings. This consistency indicates that the A, C, and M components of LBO are more distinct from the P component compared to the components of LAX and LHL, which form a more cohesive group.

Table 4. Factor loadings of rotated components for AEQ scale components

	components			
	1	2	3	4
LAXA	0.874	0.094	-0.152	0.161
LAXC	0.816	0.035	-0.247	0.187
LAXM	0.785	0.325	-0.075	-0.053
LAXP	0.832	0.058	-0.056	0.220
LBOA	0.149	0.847	-0.299	-0.053
LBOC	0.316	0.817	-0.170	-0.037
LBOM	0.188	0.825	-0.194	-0.071
LBOP	0.219	0.900	-0.134	-0.046
LHLA	0.841	0.262	-0.242	-0.052
LHLC	0.819	0.213	-0.211	-0.086
LHLM	0.740	0.378	-0.228	-0.127
LHLP	0.822	0.300	-0.063	-0.093
LJOA	-0.234	-0.318	0.780	0.171
LJOC	-0.252	-0.223	0.823	0.138
LJOM	-0.145	-0.174	0.879	0.009
LJOP	0.129	-0.120	0.212	0.926

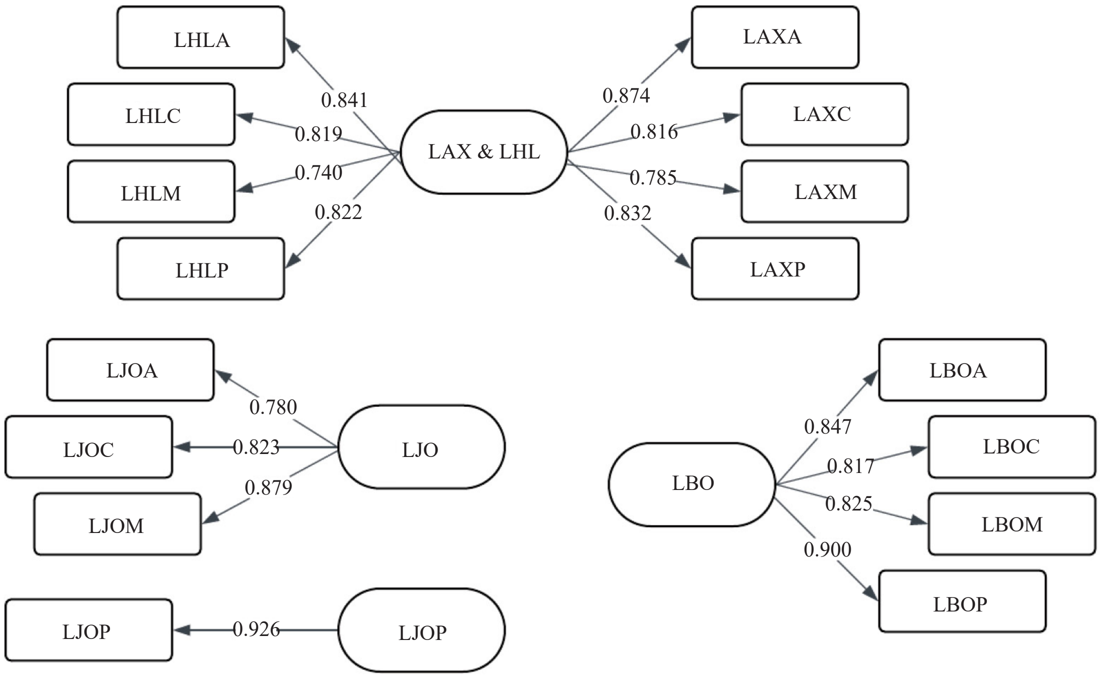

Figure 3. Exploratory factor analysis results showing factor loadings greater than 0.4

4.4 *Antecedent relations of AEQ scales and scale components*

The final step in the analysis addresses our second research objective: examining the antecedent relationships of learning activity emotions and their affective, cognitive, motivational, and physiological components. According to control-value theory, there are three proximal antecedents: academic control, extrinsic value, and intrinsic value. Given the pronounced gender differences observed across all learning emotions, hierarchical regression models also include gender and interaction terms between gender and each of these three antecedents as predictors.

4.4.1 *Learning anxiety*

Academic control emerges as the strongest predictor of learning anxiety: the more students perceive control over their learning, the lower their anxiety levels. Extrinsic value also contributes to reducing anxiety. A significant gender effect is present, with female students exhibiting higher anxiety levels across all components. However, this gender difference diminishes among female students with high intrinsic value, as indicated by the negative beta coefficient of the interaction term. Interestingly, the relationship between intrinsic value and the Physiological component of Learning Anxiety (LAXP) shows a reversed pattern: higher intrinsic value is associated with increased physiological anxiety, contrary to the CVTAE framework's expectation that intrinsic value reduces anxiety. Detailed regression coefficients are provided in Table 5.

Table 5. Hierarchical regression models for antecedent relationships of learning anxiety scale and scale components

	LAX	LAXA	LAXC	LAXM	LAXP
Acad. Control	-0.517***	-0.475***	-0.480***	-0.461***	-0.419***
Value Extrinsic	-0.044***	-0.036***	-0.036***	-0.049***	-0.037***
Value Intrinsic	-0.004	-0.005	-0.022*	-0.046***	0.047***
Gender	0.182***	0.173***	0.185***	0.089***	0.176***
AcadContrXGender	0.004	0.009	0.021*	-0.013	-0.009
ValueExtXGender	0.009	0.003	0.012	0.001	0.012
ValueIntXGender	-0.032**	-0.032**	-0.016	-0.025*	-0.041***
R^2	0.339	0.286	0.288	0.274	0.233

Note: *: p < 0.05; **: p < 0.01; ***: p < 0.001.

4.4.2 *Learning boredom*

Learning boredom is primarily influenced by two key factors: academic control and intrinsic value. Higher levels of both antecedents are associated with lower boredom. These effects are more pronounced for male students, as the positive beta coefficients for the interaction terms between gender and both academic control and intrinsic value reduce the beneficial impact of these factors for female students. Nonetheless, the overall gender effect is significant, with female students generally reporting lower boredom levels. Refer to Table 6 for detailed results.

Table 6. Hierarchical regression models for antecedent relationships of learning boredom scale and scale components

	LBO	LBOA	LBOC	LBOM	LBOP
Acad. Control	-0.311***	-0.254***	-0.321***	-0.231***	-0.306***
Value Extrinsic	-0.059***	-0.065***	-0.051***	-0.044***	-0.049***
Value Intrinsic	-0.298***	-0.323***	-0.231***	-0.277***	-0.247***
Gender	-0.151***	-0.184***	-0.087***	-0.129***	-0.140***
AcadContrXGender	0.034***	0.015	0.037***	0.024*	0.047***
ValueExtXGender	-0.008	-0.004	-0.007	-0.011	-0.010
ValueIntXGender	0.033**	0.038***	0.022	0.031**	0.028*
R^2	0.250	0.249	0.196	0.176	0.200

Note: *: p < 0.05; **: p < 0.01; ***: p < 0.001.

4.4.3 *Learning hopelessness*

The similarity between learning hopelessness and anxiety, highlighted by the exploratory factor analysis, is further confirmed by the hierarchical regression results. Once again, academic control emerges as the primary explanatory factor, with intrinsic and extrinsic values playing a lesser role. The negative beta coefficients for these values align with the predictions of the CVTAE framework. The positive beta for the gender variable indicates higher hopelessness levels among female students. However, the negative interaction betas for academic control suggest that a sense of control reduces hopelessness more effectively for female students than for male students. Table 7 provides a complete overview of these results.

Table 7. Hierarchical regression models for antecedent relationships of learning hopelessness scale and scale components

	LJO	LJOA	LJOC	LJOM	LJOP
Acad. Control	-0.629***	-0.586***	-0.605***	-0.551***	-0.525***
Value Extrinsic	-0.056***	-0.047***	-0.058***	-0.067***	-0.032**
Value Intrinsic	-0.083***	-0.083***	-0.068***	-0.112***	-0.046***
Gender	0.091***	0.094***	0.101***	0.021***	0.093***
AcadContrXGender	-0.028***	-0.036***	-0.031***	-0.014	-0.013
ValueExtXGender	-0.005	0.001	-0.005	-0.002	-0.015
ValueIntXGender	-0.007	-0.007	0.000	-0.014	-0.008
R^2	0.507	0.449	0.471	0.401	0.337

Note: *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$.

4.4.4 *Learning enjoyment*

The dominant role of academic control in explaining negative emotions diminishes when considering the positive emotion of learning enjoyment. Here, intrinsic value becomes the primary explanatory factor, while academic control plays a secondary role. For the Physiological Component of Enjoyment (LJOP), the impact of academic control is minimal, resulting in an exceptionally low explained variance—only about 5% is accounted for by proximal antecedents. Positive gender effects and a positive beta for the gender-control interaction suggest that female students generally experience higher enjoyment levels, particularly in the physiological component, and benefit more from a sense of control. In contrast, the negative betas for the gender-intrinsic value interaction indicate that female students derive less benefit from high intrinsic value compared to male students. Table 8 provides a detailed summary of these results.

Table 8. Hierarchical regression models for antecedent relationships of learning enjoyment scale and scale components

	LJO	LJOA	LJOC	LJOM	LJOP
Acad. Control	0.237***	0.274***	0.282***	0.143***	0.029***
Value Extrinsic	-0.022	-0.019	-0.016	-0.008	-0.028*
Value Intrinsic	0.445***	0.456***	0.343***	0.348***	0.225***
Gender	0.036***	-0.001	0.039***	0.002	0.103***
AcadContrXGender	0.046***	0.028**	0.046***	0.053***	0.017
ValueExtXGender	0.009	0.017	0.001	0.011	-0.009
ValueIntXGender	-0.040***	-0.041***	-0.023*	-0.036***	-0.023
R^2	0.291	0.324	0.245	0.165	0.054

Note: *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$.

5. Discussion

Since the introduction of the control-value theory of learning emotions and the development of related measurement tools such as the AEQ, empirical research on achievement emotions has flourished. However, limited research has focused on the multi-component structure underlying the AEQ, which conceptualizes achievement emotions as interconnected affective, cognitive, motivational, and physiological processes. Studies using the AEQ typically follow a confirmatory approach, which tends to validate the presence of discrete achievement emotions and their decomposition into these four components, as demonstrated by our confirmatory factor analysis.

Our exploratory and correlational analyses at the component level revealed different results. Within the enjoyment scale, the physiological component does not align well with the other components and forms its own distinct factor. This separation comes at the expense of grouping anxiety and hopelessness items onto a single factor, when forcing the factor analysis into a 4-factor solution. It is unsurprising that the physiological component stands out, given the limitations of surveys highlighted in the literature (Pekrun, 2024). The more surprising finding is that, for negative emotions, the Physiological component (P) aligned well with the Affective (A), Cognitive (C), and Motivational (M) components.

With regard to our third research objective, the finding that the Physiological (P) component of enjoyment does not align with the multi-component structure of learning achievement emotions is further underscored by its inconsistency with the Control-Value Theory of Achievement Emotions (CVTAE). According to CVTAE, academic control, along with intrinsic and extrinsic value, are proposed as proximal antecedents for all achievement emotions and their respective components. However, these factors, even when combined with gender and interaction terms, explain only about 5% of the variation in the P-component of enjoyment. This is in stark contrast to the significantly higher explanatory power observed for all other components and emotions.

There are notable gender differences in AEQ scale scores, particularly evident in the three negative learning emotions: female students tend to score higher on anxiety and hopelessness, while male students score higher on boredom. In the hierarchical regression analysis, gender effects also emerge through statistically significant beta values for the interaction terms between gender and the three proximal antecedents. However, a reassuring outcome is that these interaction terms contribute less than the proximal antecedents themselves, which consistently have a dominant influence. In other words, while female students generally experience higher anxiety and hopelessness and lower boredom compared to male students, their emotional patterns in relation to the proximal antecedents are largely similar to those of male students in comparable situations.

6. Conclusions

The multi-component structure of learning achievement emotions has been central to the emotion framework introduced at the start of this millennium (Pekrun et al., 2004), which continues to shape empirical research on learning emotions today. However, few studies have explicitly validated this component structure, and those that have primarily used confirmatory approaches. Our exploratory analysis suggests that we should exercise caution when applying the four components—Affective (A), Cognitive (C), Motivational (M), and Physiological (P). Specifically, for at least one positive learning emotion, enjoyment, the physiological component consistently shows a different pattern compared to the other components. More concerningly, this physiological component diverges from the predictions of the CVTAE framework: while the other components for all emotions studied were well explained by proximal antecedents academic control and intrinsic & extrinsic value, the physiological component of enjoyment was not. Therefore, researchers should consider excluding this component from empirical studies that rely on self-reported emotion measures.

The primary limitation of this study—and of any research examining the component structure of learning emotions—is the extensive length of the instrument. To differentiate among the affective, cognitive, motivational, and physiological components across eight learning emotions, the AEQ employs 75 items. When combined with additional surveys targeting antecedents of learning emotions, such as academic control, the resulting battery becomes so extensive that its administration is rarely feasible in authentic educational settings. This practical constraint likely contributes to the limited number of empirical studies on the component structure of learning emotions.

At the same time, our findings underscore the importance of further investigating this component structure. To reduce student response burden, the present study focused on four of the eight learning emotions. Future research may adopt a similar strategy—selecting a subset of learning emotions while ensuring that all four components are represented. Given the clear gender effects observed in this study, it would be valuable for future research to include the potential to further explore gender-related differences.

Conflict of interest

Both authors do not have any conflicts of interest to disclose.

References

Barrett, L. F., Adolphs, R., Marsella, S., Martinez, A. M., & Pollak, S. D. (2019). Emotional expressions reconsidered: challenges to inferring emotion from human facial movements. *Psychological Science in the Public Interest*, *20*(1), 168. https://doi.org/10.1177/1529100619832930

Besterfield-Sacre, M., Atman, C. J., & Shuman, L. J. (1997). Characteristics of freshman engineering students: models for determining student attrition in engineering. *Journal of Engineering Education*, *86*(2), 139-149. https://doi.org/10.1002/j.2168-9830.1997.tb00277.x

Bieleke, M., Goetz, T., Yanagida, T., Botes, E., Frenzel, A. C., & Pekrun, R. (2023). Measuring emotions in mathematics: The Achievement Emotions Questionnaire-Mathematics (AEQ-M). *ZDM-Mathematics Education*, *55*(2), 269-284. https://doi.org/10.1007/s11858-022-01425-8

Bieleke, M., Gogol, K., Goetz, T., Daniels, L., & Pekrun, R. (2021). The AEQ-S: A short version of the achievement emotions questionnaire. *Contemporary Educational Psychology*, *65*(101), 940. https://doi.org/10.1016/j.cedpsych.2020.101940

Bieg, M., Goetz, T., & Hubbard, K. (2013). Can I master it and does it matter? An intraindividual analysis on control-value antecedents of trait and state academic emotions. *Learning and Individual Differences*, *28*, 102-108. https://doi.org/10.1016/j.lindif.2013.09.006

Buff, A., Reusser, K., Rakoczy, K., & Pauli, C. (2011). Activating positive affective experiences in the classroom: "Nice to have" or something more? *Learning and Instruction*, *21*(3), 452-466. https://doi.org/10.1016/j.learninstruc.2010.07.008

Buckingham Shum, S., & Crick, R. D. (2012). Learning dispositions and transferable competencies: Pedagogy, modelling and learning analytics. In S. Buckingham Shum, D. Gasevic, & R. Ferguson (Eds.), *Proceedings of the 2nd International Conference on Learning Analytics and Knowledge* (pp. 92-101). New York, NY, USA: ACM.

Daker, R. J., Gattas, S. U., Sokolowski, H. M., Green, A. E., & Lyons, I. M. (2021). First-year students' math anxiety predicts STEM avoidance and underperformance throughout university, independently of math ability. *Npj Science of Learning*, *6*(1), 1-13. https://doi.org/10.1038/s41539-021-00095-7

Di Martino, P., Gregorio, F., & Iannone, P. (2023). The transition from school to university in mathematics education research: New trends and ideas from a systematic literature review. *Educational Studies in Mathematics*, *113*(1), 7-34. https://doi.org/10.1007/s10649-022-10194-w

Frenzel, A. C., Pekrun, R., & Goetz, T. (2007a). Girls and mathematics—A "hopeless" issue? A control-value approach to gender differences in emotions towards mathematics. *European Journal of Psychology of Education*, *22*(4), 497-514. https://doi.org/10.1007/BF03173468

Frenzel, A. C., Pekrun, R., & Goetz, T. (2007b). Perceived learning environment and students' emotional experiences: A multilevel analysis of mathematics classrooms. *Learning and Instruction*, *17*(5), 478-493.

Geisler, S., Rolka, K., & Rach, S. (2023). Development of affect at the transition to university mathematics and its relation to dropout—Identifying related learning situations and deriving possible support measures. *Educational Studies in Mathematics*, *113*(1), 35-56. https://doi.org/10.1007/s10649-022-10200-1

Givord, P., & Mostafa, T. (2019). *PISA 2018 Results (Volume II): Where All Students Can Succeed*. (PISA). OECD. https://doi.org/10.1787/b5fd1b8f-en

Hall, N. C., Sampasivam, L., Muis, K. R., & Ranellucci, J. (2016). Achievement goals and emotions: The mediational roles of perceived progress, control, and value. *British Journal of Educational Psychology*, *86*(2), 313-330. https://doi.org/10.1111/bjep.12108

Hart, S. A., & Ganley, C. M. (2019). The nature of math anxiety in adults: Prevalence and correlates. *Journal of Numerical Cognition*, *5*(2), 122-139. https://doi.org/10.5964/jnc.v5i2.195

Hill, F., Mammarella, I. C., Devine, A., Caviola, S., Passolunghi, M. C., & Szűcs, D. (2016). Maths anxiety in primary and secondary school students: Gender differences, developmental changes and anxiety specificity. *Learning and Individual Differences*, *48*, 45-53. http://dx.doi.org/10.1016/j.lindif.2016.02.006

Kline, R. B. (2016). *Principles and practice of structural equation modeling* (4th ed.). The Guilford Press.

Lent, R. W., Brown, S. D., Schmidt, J., Brenner, B., Lyons, H., & Treistman, D. (2003). Relation of contextual supports and barriers to choice behavior in engineering majors: Test of alternative social cognitive models. *Journal of Counseling Psychology*, *50*(4), 458-465. https://doi.org/10.1037/0022-0167.50.4.458

Lohbeck, A., Nitkowski, D., & Petermann, F. (2016). A control-value theory approach: Relationships between academic self-concept, interest, and test anxiety in elementary school children. *Child & Youth Care Forum*, *45*, 887-904. https://doi.org/10.1007/s10566-016-9362-1

Mesquita, B., Feldman Barrett, L., & Smi, E. R. (2010). *The mind in context*. The Guilford Press.

Niculescu, A. C. (2015). *Hidden in plain sight: Capturing freshmen emotional experiences and their effects on performance at university*. Maastricht University. https://doi.org/10.26481/dis.20151016an

Niculescu, A. C., Tempelaar, D., Leppink, J., Dailey, A., Segers, M., & Gijselaers, W. (2015). Feelings and performance in the first year at university: Learning-related emotions as predictors of achievement outcomes in mathematics and statistics. *Electronic Journal of Research in Educational Psychology*, *13*(3), 432 462. https://doi.org/10.14204/ejrep.37.15012

Non, A., & Tempelaar, D. (2016). Time preferences, study effort, and academic performance. *Economics of Education Review*, *54*, 36-61. https://doi:10.1016/j.econedurev.2016.06.003

Pekrun, R. (2000). A social-cognitive, control-value theory of achievement emotions. In J. Heckhausen (Ed.), *Motivational psychology of human development: Developing motivation and motivating development* (pp. 143-163). Elsevier Science. https://doi.org/10.1016/S0166-4115(00)80010-2

Pekrun, R. (2006). The control-value theory of achievement emotions: assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Review*, *18*(4), 315-341. https://doi.org/10.1007/s10648-006-9029-9

Pekrun, R. (2024). Control-value theory: from achievement emotion to a general theory of human emotions. *Educational Psychology Review*, *36*, 83. https://doi.org/10.1007/s10648-024-09909-7

Pekrun, R., Goetz, T., Frenzel, A. C., Barchfeld, P., & Perry, R. P. (2011a). Measuring emotions in students' learning and performance: The Achievement Emotions Questionnaire (AEQ). *Contemporary Educational Psychology*, *36*(1), 36-48. https://doi.org/10.1016/j.cedpsych.2010.10.002

Pekrun, R., Goetz, T., Frenzel, A. C., & Perry, R. P. (2011b). *Academic Emotions Questionnaire (AEQ). User's manual* (2nd ed.). Munich, Germany: Department of Psychology, University of Munich.

Pekrun, R., Goetz, T., Perry, R. P., Kramer, K., Hochstadt, M., & Molfenter, S. (2004). Beyond test anxiety: Development and validation of the test emotions questionnaire (TEQ). *Anxiety*, *Stress & Coping*, *17*(3), 287-316. https://doi:10.1080/10615800412331303847

Pekrun, R., Marsh, H. W., Elliot, A. J., Stockinger, K., Perry, R. P., Vogl, E., Goetz, T., van Tilburg, W. A. P., Lüdtke, O., & Vispoel, W. P. (2023). A three-dimensional taxonomy of achievement emotions. *Journal of Personality and Social Psychology*, *124*(1), 145-178. https://doi.org/10.1037/pspp0000448

Perry, R. P., Hladkyj, S., Pekrun, R. H., & Pelletier, S. T. (2001). Academic control and action control in the achievement of college students: A longitudinal field study. *Journal of Educational Psychology*, *93*(4), 776-789. https://doi.org/10.1037/0022-0663.93.4.776

Putwain, D. W., Pekrun, R., Nicholson, L. J., Symes, W., Becker, S., & Marsh, H. W. (2018). Control-value appraisals, enjoyment, and boredom in mathematics: A longitudinal latent interaction analysis. *American Educational Research Journal*, *55*(6), 1339-1368. https://doi.org/10.3102/0002831218786689

Schaefers, K. G., Epperson, D. L., & Nauta, M. M. (1997). Women's career development: Can theoretically derived variables predict persistence in engineering majors? *Journal of Counseling Psychology*, *44*(2), 173-183. https://doi.org/10.1037/0022-0167.44.2.173

Scherer, K. R., & Moors, A. (2019). The emotion process: event appraisal and component differentiation. *Annual Review of Psychology*, *70*, 719745. https://doi.org/10.1146/annurev-psych-122216-011854

Shao, K., Pekrun, R., Marsh, H. W., & Loderer, K. (2020). Control-value appraisals, achievement emotions, and foreign language performance: A latent interaction analysis. *Learning and Instruction*, *69*, 1-12. https://doi.org/10.1016/j.learninstruc.2020.101356

Takahira, S., Goodings, D. J., & Byrnes, J. P. (1998). Retention and performance of male and female engineering students: An examination of academic and environmental variables. *Journal of Engineering Education*, *87*(3), 297-304.

Tempelaar, D. T., Gijselaers, W. H., van der Loeff, S. S., & Nijhuis, J. F. H. (2007). A structural equation model analyzing the relationship of student achievement motivations and personality factors in a range of academic subject-matter areas. *Contemporary Educational Psychology*, *32*(1), 105-131. https://doi.org/10.1016/j.cedpsych.2006.10.004

Tempelaar, D., Rienties, B., & Giesbers, B. (2015). In search for the most informative data for feedback generation: Learning analytics in a data-rich context. *Computers in Human Behavior*, *47*, 157-167. https://doi.org/10.1016/j.chb.2014.05.038

Tempelaar, D., Rienties, B., Mittelmeier, J., & Nguyen, Q. (2018). Student profiling in a dispositional learning analytics application using formative assessment. *Computers in Human Behavior*, *78*, 408-420. https://doi.org/10.1016/j.chb.2017.08.010

Vos, H., Marinova, M., De Léon, S. C., Sasanguie, D., & Reynvoet, B. (2023). Gender differences in young adults' mathematical performance: Examining the contribution of working memory, math anxiety and gender-related stereotypes. *Learning and Individual Differences*, *102*, 102255. https://doi.org/10.1016/j.lindif.2022.102255

Wigfield, A., & Eccles, J. S. (2000). Expectancy-value theory of achievement motivation. *Contemporary Educational Psychology*, *25*, 68-81. https://doi.org/10.1006/ceps.1999.1015